

Buck Hill Road

ND NP THRO 204(1)

Final Hydraulics Report

In Partnership With:

Theodore Roosevelt National Park
National Park Service

Federal Highway Administration
Central Federal Lands Highway Division



February 2025

Signature Sheet

Report prepared by:

MARY KATHLEEN
KELEHAN

Digitally signed by MARY
KATHLEEN KELEHAN
Date: 2025.02.19 15:40:29
-07'00'

Katie Kelehan, Hydraulic Engineer

Report reviewed by:

AARON ESTEP, PE

Digitally signed by AARON ESTEP, PE
Date: 2025.02.19 16:13:14 -07'00'

Aaron Estep, Hydraulic Engineer

Approved for distribution by:

LUIS GERARDO
CALDERON

Digitally signed by LUIS GERARDO
CALDERON
Date: 2025.02.19 18:17:56 -07'00'

Luis Calderón, Lead Hydraulic Engineer

Distribution

Electronic: N:\ND\thro204(01)\Hydraulics\9_Final-Report

Toni Pankau, *Project Management*
Stacy Dicciccio, *Lead Designer*
Wilmari Valentin-Medina, *Designer*
Catherine Henry, *Environment*
Dominic Monarco, *Geotech*
Ron Andresen, *Pavements*
Vaughn Marshall, *Construction*

Executive Summary

Project Description:

Hydrologic and hydraulic analyses were conducted for the ND NP THRO 204(1) Buck Hill Road project located in Billings County, North Dakota. Buck Hill Trail Road, also known as Route 204, is in the Southeast portion of the South Unit of Theodore Roosevelt National Park. The route begins at the intersection of Buck Hill Trail Road and Scenic Loop Road. The route then proceeds southeasterly for approximately $\frac{3}{4}$ of a mile and ascends approximately 300 feet vertically to the Buck Hill Overlook parking area. The Buck Hill Overlook is a very popular location in the park, with approximately 32% of the park visitors visiting this overlook. This project proposes to rehabilitate the existing pavement, address subsurface issues observed along the route (including a previously identified slide area), and reconstruct the Buck Hill Overlook parking area at the end of the route. Along the project route, 8 existing culverts are slated for replacement or removal. An active landslide exists from approximate station 113+00 to station 122+50. Ditch reconditioning and additional inlets are recommended to reduce standing water at the base of this slide.

Design Criteria:

The Federal Lands Highway Project Development and Design Manual (PDDM) establishes the hydraulic design criteria for Buck Hill Road. With an average daily traffic (ADT) of 150 vehicles and a design speed of 15 mph, Buck Hill Road is classified as a low-standard road for hydraulic design.

Hydrologic Analysis:

The design flows recommended for use in hydraulic design were derived using the Rational Method.

Hydraulics Analysis:

The hydraulic performance of each of the existing culverts was analyzed. An inlet control analysis was performed for all crossings to determine required structure size.

Recommendations:

For this project, one existing culvert was not analyzed as part of this project – C08. This culvert will be removed as part of the proposed parking lot configuration thus it was not evaluated. An additional existing culvert, C04, was identified at the 30% field review. This pipe was mostly blocked by sediment and assumed to have been left behind from a previous road realignment. This pipe is recommended to be cleaned-in-place as it may provide additional drainage for the existing slide area.

All other existing structures will be replaced to accommodate roadway widening and to bring all structures up to the same service life. At the request of project partners, all replacement and new culverts will be HDPE to better withstand the corrosive properties of the soils within the park. Inlet and outlet end treatments are specified in Table 1.

At the base of the existing slide area is a wide, flattened slope. Currently, runoff from the surrounding terrain ponds in this area. In addition to the paved ditches discussed in this report, superelevation of the road surface to the outboard side of this slide area is recommended with additional inlets installed to capture drainage along this reach.

With the addition of curb and gutter along much of the project reach, regular maintenance of inlets and ditches will be necessary to retain hydraulic efficiency as the erosive potential of the surrounding soils is high. Recommendations for each crossing can be found in Table 1 following this section.

Outlet Protection:

Outlet protection for single barrel pipe culverts with diameters less than or equal to 48 in. and pipe slopes up to 10% may be sized in accordance with Standard Detail C251-50, Placed Riprap at Culverts. This is applicable for culvert C01. A Standard Riprap Aprons is also recommended for C03 once the pipe is run down to a flatter slope. Rundowns adhering to Special Detail C602-A are recommended for culverts C02, C07, and PR04 due to pipe slopes exceeding 10% and limited surface cover. Standard riprap aprons at these outlets are recommended for if slopes allow.

The proposed location of PR05 is largely driven by grading of the proposed parking lot and results in the pipe outletting onto a fill slope. Due to sediment concerns from the surrounding hillsides which have the potential to drain to this inlet, the alignment of the pipe should remain perpendicular to the inlet. A riprap apron adhering to Standard Detail C251-51, Placed Riprap Between Cut and Fill, should be installed at the outlet.

Class 1, Type E, non-woven geotextile is recommended for all aprons.

Ditches:

This project proposes to install paved ditch along much of the effected reach to help convey pavement drainage and reduce erosive sheet flow. Along the project reach, a minimum of 1-ft deep (below the structural section) triangular ditch is recommended. This is assuming a foreslope of 1V:6H and a maximum backslope of 1V:1.0H. In addition, a minimum 6-inch concrete curb is recommended.

A ditch lined with articulated concrete block (ACB) adhering to Special Detail 253-A is proposed to provide flow conveyance to an existing culvert at the base of the slide area. Typical details and cross sections for this ditch have been included in the project plans as a parabolic ditch with approximate maximum side slopes of 1V:2H, minimum depth of 9 inches, and a minimum width of 3 ft. This ditch should be lined with non-woven, Class 1, Type E geotextile.

To protect the guardrail aggregate pad from erosion, vegetated ditches are recommended throughout the project reach. These vegetated ditches should be triangular with an assumed foreslope of 1:4 and backslope of 1:3. In addition, these ditches should accommodate a minimum 6-inch flow depth. Before permanent vegetation is established, the ditches should be lined with rolled erosion control product Type 2C.

Location-specific ditch recommendations are included in Table 3 and additional details for the ditches lined with ACB are included in section 6.1 of this report.

Parking Lot Drainage:

Reconfiguration of the parking at the end of the existing project reach (to replace the loop) is proposed. A detailed layout for the new parking lot has been included in the project plans. A new storm drain with curb-opening inlet and grate is proposed near the southeast corner of the parking lot to convey drainage. NDDOT Detail D-722-2 for Inlet – Type 2 will be adapted for this project and included in the plans. The location of this inlet will be reassessed as needed to account for potential changes in the parking lot grading.

Table 1: Hydraulic Recommendations

Crossing Identifier	Crossing ¹ Station	Existing Structure							Hydraulic Adequacy of Existing Structure	Recommended Action	Proposed Replacement Structure								
		Box		Arch or Elliptical		Circular	Number of Barrels	Structure Type			Box		Arch or Elliptical		Circular	Number of Barrels	Structure Type	Inlet ² Configuration	Outlet ² Configuration
		Span (ft)	Rise (ft)	Span (in)	Rise (in)						Diameter (in)	Span (ft)	Rise (ft)	Span (in)					
C01	100+38	----	----	----	----	18	1	CMP	Adequate	Replace with Recommended Structure	----	----	----	----	24	1	HDPE	Other	Other
C02	105+95	----	----	----	----	12	1	CMP	Upsize Needed	Replace with Recommended Structure					24	1	HDPE	FES	Special Rundown with outlet mitered to slope
C03	114+45	----	----	----	----	24	1	CMP	Adequate	Replace with Recommended Structure	----	----	----	----	24	1	HDPE	Other	
C04	118+92	----	----	----	----	Unk	1	Unk	Unknown	Clean in Place	----	----	----	----	----	----	----	----	Other
C05	131+70	----	----	----	----	24	1	CMP	Adequate	Replace with Recommended Structure	----	----	----	----	24	1	HDPE	Drop Inlet	Other
C06	136+82					12	1	CMP	Adequate	Replace with Recommended Structure					24	1	HDPE	Drop Inlet	Other
C07	138+15	----	----	----	----	12	1	CMP	Adequate	Replace with Recommended Structure	----	----	----	----	24	1	HDPE	FES	Special Rundown with outlet mitered to slope
C08	N/A	----	----	----	----	24	1	CMP	Not Evaluated	Remove	----	----	----	----	----	----	----	----	
PR01	107+60	----	----	----	----	----	----	----	N/A (New Pipe)	No Work Proposed	----	----	----	----	24	----	----	----	----
PR02	117+95	----	----	----	----	----	----	----	N/A (New Pipe)	No Work Proposed	----	----	----	----	24	----	----	Other	Other
PR03	121+19	----	----	----	----	----	----	----	N/A (New Pipe)	Install New Pipe	----	----	----	----	24	1	HDPE	Drop Inlet	Other
PR04	125+17	----	----	----	----	----	----	----	N/A (New Pipe)	Install New Pipe	----	----	----	----	24	1	HDPE	FES	Special Rundown with outlet mitered to slope
PR05	See Report	----	----	----	----	----	----	----	N/A (New Pipe)	Install New Pipe	----	----	----	----	24	1	HDPE	Curb-Opening Inlet	

1 - Crossing Station not provided for C08 as it's recommended for removal. Location of PR05 is given by approximate coordinates within the body of the report.

2 - FES: Flared End Section; Other: Pipes should be mitered to slope with a concrete toe wall added for stability as requested by project partners. A detail for this end treatment is included in the project plans.

Table 2: Outlet Protection Recommendations

Crossing Identifier	Crossing ¹ Station	Recommended Outlet Protection	Custom Apron Dimensions ²					Pipe Anchors ³ Recommended?	Comments
			Riprap Class	Length (ft)	Width at Outlet (ft)	Width at Apron End (ft)	Thickness (ft)		
C01	100+38	Standard Riprap Apron (C251-50)	----	----	----	----	----	No	
C02	105+95	Standard Riprap Apron (C251-50)	----	----	----	----	----	Yes	Install after rundown (Special Detail C602-A)
C03	114+45	Standard Riprap Apron (C251-50)	----	----	----	----	----	Yes	Install after pipe rundown
C04	118+92	None or Not Applicable	----	----	----	----	----	N/A	
C05	131+70	None or Not Applicable	----	----	----	----	----	Yes	Slope is well vegetated and stable
C06	136+82	None or Not Applicable	----	----	----	----	----	Yes	Slope is well vegetated and stable
C07	138+15	Standard Riprap Apron (C251-50)	----	----	----	----	----	Yes	Install after rundown (Special Detail C602-A)
C08	N/A	None or Not Applicable	----	----	----	----	----	N/A	
PR01	107+60	None or Not Applicable	----	----	----	----	----	N/A	
PR02	117+95	None or Not Applicable	----	----	----	----	----	N/A	
PR03	121+19	None or Not Applicable	----	----	----	----	----	Yes	
PR04	125+17	Standard Riprap Apron (C251-50)	----	----	----	----	----	Yes	Install after rundown (Special Detail C602-A)
PR05	See Report	Energy Dissipator	----	----	----	----	----	Yes	Standard Detail C251-51, Placed Riprap between Cut and Fill. Install after pipe rundown

1 - Crossing Station not provided for C08 as it's recommended for removal. Location of PR05 is given by approximate coordinates within the body of the report.

2 - Refer to C251-50 for apron shape and dimensions.

3 - Pipe Anchors required for any exposed pipes. The PDDM recommends pipes anchors on concrete pipes exceeding 10% or corrugated metal pipes exceeding 25%.

Table 3: Ditch Hydraulics

Ditch	Start Station	End Station	Location	Type	Drainage Area (ac)	10-yr Flow	Slope	Flow Depth (ft.)	Spread ² (ft)	Avg Velocity (fps)	Recommendation
D01	100+52	101+75	RT	Paved	0.3	0.4	7.6%	0.09	0.0	4.0	Paved with minimum 6 in. Concrete Curb
D02	106+00	113+80	LT	Paved	1.5	1.7	8.3%	0.17	0.0	6.5	Paved with minimum 6 in. Concrete Curb
D03	108+10	119+63	RT	Paved	2.2	2.4	5.1%	0.23	0.0	6.1	Paved with minimum 6 in. Concrete Curb
D04	119+64	124+00	RT	Paved	1.5	1.7	10.7 %	0.16	0.0	7.1	Paved with minimum 6 in. Concrete Curb
D05	114+50	117+04	LT	Lined	1.9	2.1	4.2%	0.15	N/A	5.8	Parabolic with minimum 0.75 ft. depth and 3 ft. width (ACB lining)
D06	117+95	125+00	LT	Paved	0.8	0.9	1.0%	0.21	0.0	2.6	Paved with minimum 6 in. Concrete Curb
D07	127+50	129+75	RT	Paved	0.5	0.5	9.0%	0.11	0.0	4.5	Paved with minimum 6 in. Concrete Curb
D08	131+16	131+70	LT	Vegetated	1.3 ¹	1.4	7.8%	0.30	N/A	4.5	Triangular Ditch assuming max foreslope of 1V:4H and max backslope of 1V:3H
D09	131+70	136+82	LT	Paved	1.3	1.4	8.7%	0.16	0.0	6.2	Paved with minimum 6 in. Concrete Curb
D10	136+82	138+15	LT	Paved	1.2	1.3	9.3%	0.15	0.0	6.2	Paved with minimum 6 in. Concrete Curb

1 – D08 is proposed to provide erosion protection to the aggregate base layer of the guardrail terminal. Total drainage area to C05 used to provide conservative discharge estimate for the applicability of vegetated lining at these ditches along the project reach.

2 – Total width of paved ditch and gutter section is 3.5 ft. All flow for paved ditches contained within this section.

Table of Contents

1	Project Background Information	4
1.1	Project Information	4
1.2	Flood Insurance Study	4
2	Hydraulic Design Criteria	5
3	Hydrology	5
3.1	Hydrologic Setting and Topographic Data	5
3.2	Available Hydrologic Data.....	6
3.3	Rational Method Estimates	6
3.4	Regression Equation Estimates	6
3.5	Recommended Design Flows.....	7
4	Culvert Capacity Design	7
4.1	Inlet Control Analysis.....	7
4.2	Culvert Capacity Design Results	8
5	Culvert Stability Design.....	8
5.1	Entrance Treatment.....	8
5.2	Outlet Protection.....	8
5.3	Inlet Protection.....	9
6	Additional Considerations	9
6.1	Hydraulic ditches	9
6.2	Parking Lot Drainage.....	10
7	References	11

Tables

Table 1: Hydraulic Recommendations.....	2
Table 2: Outlet Protection Recommendations.....	2
Table 3: Ditch Hydraulics	2
Table 4: PDDM Hydraulic Design Criteria	5
Table 5: Maximum Peak Flows Based on Inlet Control Conditions.....	8

Figures

Figure 1: Project Location Map	4
--------------------------------------	---

Appendices

Appendix A: Existing Site Information
Appendix B: Hydrology
Appendix C: Hydraulic Analyses
Appendix D: Details

1 PROJECT BACKGROUND INFORMATION

1.1 PROJECT INFORMATION

Buck Hill Road, also known as Route 204, is in the southeast portion of the South Unit of Theodore Roosevelt National Park which falls within Billings County, ND. The route begins at the intersection of Buck Hill Road and the South Unit Loop Road. The route then proceeds southeasterly for approximately $\frac{3}{4}$ of a mile and ascends approximately 300 feet vertically to the Buck Hill Overlook parking area. The Buck Hill Overlook is a very popular location in the park with approximately 32% of visitors visiting this overlook.

The present-day condition of the road is poor; the surface is rough with broken pavement, deep cracks, and rutted to where it is marginally safe to use. One steep segment of the road has gravel surfacing; consequently, the road is subject to wash board type roughness soon after road maintenance takes place. This portion is also susceptible to severe erosion after rain events, as the deep rutting forces water to run directly down the roadway washing away much of the surface gravel. In recent years the road has been closed on occasion due to underlying drainage structures failing, resulting in large and deep sink holes in the road surface. This project proposes to rehabilitate the existing pavement, address subsurface issues observed along the route (including a previously identified slide area), and rehabilitate or reconstruct the Buck Hill Overlook parking area at the end of the route. Hydraulically, the project route has 8 existing culverts as well as stormwater inlets – all slated for replacement or removal. The project location is depicted in Figure 1 below. The existing crossings were evaluated for capacity and recommendations are provided for each structure. Existing crossing information can be found in Appendix A.



Figure 1: Project Location Map

1.2 FLOOD INSURANCE STUDY

The Federal Emergency Management Agency (FEMA) provides Flood Insurance Rate Maps (FIRMs) that detail special flood hazard areas. Lands inundated by the base flood (100-year) are subject to National Flood Insurance

Program (NFIP) floodplain management regulations. This project falls outside of all special flood hazard areas. As such, the project will not be subject to NFIP floodplain management regulations for backwater and for unregulated floodplain zones, the PDDM allows a maximum of 1-foot rise in proposed condition base flood elevations. The FEMA FIRM for this area has been included in Appendix A.

2 HYDRAULIC DESIGN CRITERIA

One existing culvert was not analyzed as part of this project – C08. This culvert will be removed as part of the proposed parking lot configuration. An additional existing culvert, C04, was identified at the 30% field review. This pipe was mostly blocked by sediment and assumed to have been left behind from a previous road realignment. This pipe is recommended to be cleaned-in-place as it may provide additional drainage for the existing slide area.

For all other culverts, the Federal Lands Highway Project Development and Design Manual (PDDM) (Federal Lands Highway 2012) establishes the hydraulic design criteria for Buck Hill Road. Based on the project scoping documents, Buck Hill Road will have a design speed of 15 mph and has an average daily traffic (ADT) of 150 vehicles. Per the PDDM, Buck Hill Road is classified as a low-standard road and will have a design frequency of 25 years for culverts. Therefore, hydraulic analysis will conform to the FLH design criteria listed in Table 4. The PDDM also recommends a HW/D of 1.5 for all minor culverts with reductions made in the case of sediment or debris load concerns. Due the sandy nature of the soil along the Buck Hill project reach, a HW/D of 1.0 has been used.

Table 4: PDDM Hydraulic Design Criteria

<i>High-Standard Roadway</i>	Design Frequency	Check Frequency	Design Criteria
Roadway Culverts	25-year	Overtopping	New: AHW $\leq$ bottom of aggregate base layer
			Where $D \leq 48"$, HW/D ≤ 1.5 & Where $D > 48"$, HW/D ≤ 1.2
			Heavy debris or sediment load concerns: $0.8 \leq \text{HW/D} \leq 1.0$
			Crossing is stable at the design flood
			Minimum pipe size: 24 in. or equivalent
Roadside Ditches	10-year	N/A	New: WSEL $\leq$ bottom of aggregate base layer
			Minimum longitudinal slope = 0.5%
			Permanent Ditch Linings: Stable at the 10-year flood
Pavement Drainage	10-year, 50-year in sumps	N/A	Allowable Spread = Half of one travel lane
			Depth in Sumps and Parking Areas = 6" (150 mm)
			Inlet Clogging Factor = 50% for grate inlets in sag or sumps

3 HYDROLOGY

3.1 HYDROLOGIC SETTING AND TOPOGRAPHIC DATA

The project is in the Missouri Plateau hydrographic region of southwestern North Dakota. The contributing drainage basins for each crossing selected for evaluation were delineated in the Watershed Modeling System version 11.1 using 1-meter Digital Elevation Model information obtained from the USGS National Map (U.S. Geological Survey 2023). Point precipitation depths were determined from NOAA Atlas 14 (National Oceanic and Atmospheric Administration 2023) using the approximate centroid of the project area. Drainage basin delineations have been included in Appendix B.

3.2 AVAILABLE HYDROLOGIC DATA

There are no active USGS streamflow stations within the project limits. The closest stations are located on Sheep Creek Tributary and Sheep Creek Tributary 2, both near Medora, ND. Information from these gages was not used in the hydrologic analysis for this project as the gages are both hydrologically disconnected from the project area and have drainage areas much larger than any of the basins analyzed for this project.

3.3 RATIONAL METHOD ESTIMATES

Per the PDDM, the Rational Method is applicable for basins up to 200 acres. All basins within the Buck Hill Road project fell below this 200-ac limit.

Values for the dimensionless runoff coefficient (C) were chosen based on the land use identified from available aerial imagery. The basins are represented with a value of 0.2 per HDS-2 (FHWA 2002). These values are associated with unimproved area surrounding the project area.

The Hydraulic Toolbox (FHWA 2022) was used to develop IDF curve equations from NOAA Atlas 14 rainfall data. A single location was selected in NOAA Atlas 14 (approximate centroid of project) and was taken to represent all basins evaluated using the Rational Method. Times of concentration were initially computed for each basin through WMS using the Kirpich Method for overland flow on bare earth. Each basin produced a T_c less than 5 minutes so 5 minutes was used corresponding to the minimum storm duration specified by NOAA Atlas 14. Rainfall intensities were derived using this duration and computed IDF equations and the resulting Rational Method peak flows are provided in Appendix B.

3.4 REGRESSION EQUATION ESTIMATES

The U.S. Geological Survey (USGS) provides information for estimating peak flows via regional regression equations for North Dakota in Report 2015-5096. For these equations, the basins delineated for the Buck Hill Road project fall within Hydrologic Zone B. The equations developed for this zone consider drainage area, a ruggedness number, and a compactness number.

For these equations, the ruggedness number is defined as the stream density times basin relief, where stream density is the stream length divided by the drainage area, and the basin relief is the maximum basin elevation minus the minimum basin elevation. The NDDOT Drainage Design Manual requires the total of all flowlines represented by the USGS National Hydrography Dataset (NHD) to be used when calculating the ruggedness number. For small drainage areas which do not contain any NHD stream lines, the length of a single stream line representing the longest flow path in the drainage area may be used. For Buck Hill Road, all drainage areas derived contained no NHD streamlines so the longest flow paths developed in WMS were used to compute the ruggedness numbers.

These equations also define the compactness ratio as a measure of basin shape related to basin perimeter and drainage area. It is computed as the basin perimeter length divided by two times the square root of pi times the drainage area.

For Zone B, the range of applicable drainage areas is from 0.110 to 8,342.4 mi², the range of the ruggedness number is 68.02 and 7819.7 ft/mi, and the range of the dimensionless compaction number is 1.41 to 3.48. Additionally, the Zone B regression equations have an average standard error of prediction of 58.8% for the 25-yr event and 63.5% for the 100-yr event.

For this analysis, the parameters determined for each crossing were developed using WMS. Variables calculated for each basin are provided in Appendix B.

3.5 RECOMMENDED DESIGN FLOWS

The selected design flows recommended for use in hydraulic design were computed using PDDM requirements for the Rational Method. Although regional regression equations are preferred by the North Dakota Department of Transportation (NDDOT) for rural basins (NDDOT 2023), the drainage areas and computed compactness numbers for each basin along Buck Hill Road were well outside the ranges typically used for the Zone B regression equations. Because of this, regional regression analysis for the existing culverts resulted in unusable peak flow estimates. Computing approximate culvert replacement sizes using the Rational Method peak flow rates resulted in most of the existing culverts (cross and side drainages) being adequately sized for the 25-year design flow.

4 CULVERT CAPACITY DESIGN

Using the selected design flows described in Section 3, the hydraulic performance of each of the project crossings was evaluated. An inlet control analysis was initially performed for all crossings to determine required structure size.

4.1 INLET CONTROL ANALYSIS

As a rapid evaluation of hydraulic capacity, an inlet control analysis was first performed for each of the identified project culverts. This analysis is based on the inlet control equations documented in HDS-5, Appendix A (FHWA 2012). Section A.5 of HDS-5 describes how the inlet control equations were developed into polynomial equations for use in the HY-8 software. The standard inlet control polynomial equation is provided in HDS-5, Section A.5 and Section 5.2.1.1 of the HY-8 version 7.8 user manual. This equation was simplified as shown below for use with round pipes (barrel span equal to rise).

$$\frac{HW}{D} = a + b \left[\frac{Q}{D^{2.5}} \right] + c \left[\frac{Q}{D^{2.5}} \right]^2 + d \left[\frac{Q}{D^{2.5}} \right]^3 + e \left[\frac{Q}{D^{2.5}} \right]^4 + f \left[\frac{Q}{D^{2.5}} \right]^5 + K_s S$$

Where:

HW	Headwater depth above inlet invert, ft
D	Interior height of culvert barrel, ft
Q	Discharge, ft ³ /s
K _s	Slope correction, 0.7 for mitered to slope inlet configurations
S	Culvert barrel slope, ft/ft, assumed to be 0.1 for this analysis

The coefficients *a*, *b*, *c*, *d*, *e*, and *f* are provided for various culvert shapes, materials, and inlet edge configurations in Appendix A of the HY-8 version 7.7 user manual. The calculations for each crossing using the above equation were carried out using Microsoft Excel.

For this analysis, it is assumed that all minor culverts (diameter of 48-in or less) will be replaced with pipe sizes as determined by the inlet control analysis only. In addition, project partners requested mitered to slope end treatments for aiding in culvert maintenance. For this reason, it is assumed that the replacement structures will be mitered with concrete toe walls for added stability. Coefficients corresponding to a Mitered to Slope inlet configuration (K_e = 0.7) were used. Maximum flow rates for various pipe sizes based on the above assumptions are provided in Table 5 below.

Table 5: Maximum Peak Flows Based on Inlet Control Conditions

Pipe Diameter	WWA	Maximum Flow (cfs)			
(in)	(sq ft)	HW/D = 0.8	HW/D = 1.0	HW/D = 1.2	HW/D = 1.5
18	1.8	3.5	5.4	6.9	8.7
24	3.1	7.7	11.2	14.3	17.9
30	4.9	13.4	19.7	24.9	31.3
36	7.1	21.2	31.1	39.4	49.3
42	9.6	31.3	45.7	57.9	72.5
48	12.6	43.7	63.8	80.9	101.3

4.2 CULVERT CAPACITY DESIGN RESULTS

The results from the inlet control analysis indicate that all the crossings are considered minor drainages (requiring less than or equal to a single 48-in barrel). Of the 7 existing culverts analyzed, 6 were determined to be adequately sized while 1, the existing rundown, C02, required upsizing. All culverts are proposed for replacement to accommodate the road improvements as well as to update the service life of all drainages within the project section. Additionally, the adequately sized culverts are recommended to be upsized to meet the minimum required pipe size recommended by the PDDM (24-in for cross culvert). No culverts will be downsized.

Of the 5 culverts originally proposed, PR01 and PR02 were removed from the final scope. Reconditioning of the existing ditch at PR01 was determined to be more beneficial at the 30% field review than installing a new inlet. In addition, daylighting of the outlet for PR02 would be hindered without extensive grading of an earthen embankment across the road. Instead, an existing ditch at the base of the slide area will be reconditioned and lined to better convey flow from the proposed paved ditch along the right up station of the slide area.

Results and additional details of the inlet control analysis are provided in Appendix C. Final recommendations are provided in Table 1 of the Executive Summary of the report.

5 CULVERT STABILITY DESIGN

In addition to culvert capacity, the stability at each structure was evaluated to ensure long term success. The following suggestions discuss culvert stability considerations throughout the project.

5.1 ENTRANCE TREATMENT

At the request of project partners, C01, PR02, and C03 are recommended to have inlet end sections mitered to slope for ease of maintenance. These end sections should be anchored with a concrete toe wall for stability. C02, PR04, and C07 should be equipped with flared end sections at the inlets. Also, at the request of partners, the proposed concrete curb should be tied into these flared end sections and for C02 and C07, the asphalt paving should extend 3 inches into the inlet to provide a continuous surface such that no vegetation may grow. A Special of CFL Standard Detail 602-5 has been included in the project plans for these culverts. Standard drop inlets with catch basins are recommended for C05, C06, and PR03. Analysis of these inlets has been included in Appendix C.

5.2 OUTLET PROTECTION

Outlet protection for single barrel pipe culverts with diameters less than or equal to 48 inches and pipe slopes up to 10% may be sized in accordance with Standard Detail C251-50, Placed Riprap at Culverts. This is applicable for culvert C01. A Standard Riprap Apron is also recommended at C03 once the pipe is run down to a flatter slope.

Rundowns adhering to Special Detail C602-A are recommended for culverts C02, C07, and PR04 due to limited surface cover. These rundowns have been successful in other areas of Theodore Roosevelt National Park. Additional testing requirements for these rundowns will be included in the SCRs. Standard riprap aprons should be installed at the outlets if the final outlet slope allows.

PR03, C05, and C06 would require lengthening in excess of 200 feet to outlet onto flatter, more stable slopes. These pipes should be extended away from the road surface a minimum of one pipe length to protect the road from erosion. As observed at the 30% site visit, C05 and C06 both outlet onto a slope that is well vegetated and stable.

The proposed location of PR05 is largely driven by grading of the proposed parking lot and results in the pipe outletting onto a fill slope. Due to sediment concerns from the surrounding hillsides which have the potential to drain to this inlet, the alignment of the pipe should remain perpendicular to the inlet. A riprap apron adhering to Standard Detail C251-51, Placed Riprap Between Cut and Fill, should be installed at the outlet. The location of this inlet may be re-evaluated in subsequent project phases if the proposed parking lot grading allows for a different configuration.

Class 1, Type E, non-woven geotextile is recommended for all aprons.

5.3 INLET PROTECTION

No inlet scour concerns were identified during project scoping. No additional inlet protections are proposed currently aside from entrance treatments specified in section 5.1.

6 ADDITIONAL CONSIDERATIONS

6.1 HYDRAULIC DITCHES

Paved Ditches

Proposed ditches along the project reach were analyzed to ensure they meet flow capacity requirements and convey flow to drainage structures along the corridor. Using the Hydraulic Toolbox, a capacity analysis was completed for locations throughout the project.

To compute ditch design flows, subbasins draining to each of the outlets were delineated. In addition, longitudinal slope for each section was provided by Design. For this project, curb and gutter dimensions were adopted from NDDOT standards to create CFL Special Detail 609-A. For these ditches, a 2-ft wide paved section (at a 1V:6H foreslope) was used along with a 1.5-ft wide concrete gutter and a 1-inch relief along the gutter section.

To conform with other areas throughout the park, a 6-inch-tall concrete curb is recommended. Ditch typical detail and cross sections are available in the project plans. Site-specific results of the ditch capacity analysis can be found in Table 3 included in the Recommendation Summary. The capacity analysis including a representative cross section used in the analysis can be found in Appendix C.

Lined Ditches

Lined ditches are proposed in key locations throughout the project site specifically to protect the guardrail aggregate pad from erosion. In addition, two existing ditches (one along the base of the slide area (approximate station 114+42 to 117+55) and the second behind the RT guardrail (starting at approximate station 107+56) should be reconditioned and lined to provide better flow conveyance. Like other ditches in Theodore Roosevelt National Park, these ditches should be lined with Articulated Concrete Block adhering to Central Federal Lands Special

Detail 253-A. To accommodate the use of the ACB, these ditches should be parabolic in shape with a maximum side slope of 2:1, a depth of 0.75 ft., and maximum width of 3 ft. A detail for this ditch can found in Appendix D and the project plans and analysis for these ditches has been included in Appendix C.

Vegetated Ditches

Vegetated ditches are proposed in key locations throughout the project site specifically to protect the guardrail aggregate pad from erosion. Analysis for these ditches was first completed using the Hydraulic Toolbox however, results from this analysis indicates the need for a more robust lining. From observations made in the field, many of the existing ditch reaches are well vegetated with little evidence of significant erosion. In addition, flow depths and velocities through these ditches is expected to be low.

Based on these observations, these ditches are recommended to be lined with a temporary Rolled Erosion Control Product Type 2C until permanent vegetation is established. The capacity analysis completed for these ditches assumed a triangular section with a foreslope of 1:4 and backslope of 1:3. The ditches should accommodate a minimum flow depth of 0.5 ft. Additional details for these ditches have been included in the project plan set. Full ditch analysis for these ditches has been included in Appendix C.

6.2 PARKING LOT DRAINAGE

A 24" HDPE with rundown and riprap adhering to Standard Detail C251-51, Placed Riprap Between Cut and Fill, should be installed in the southeast corner of the proposed parking lot (approximately 46.92661667 N, 103.39034722 W). The inlet for PR05 was sized using Hydraulic Toolbox. A 50% clogging factor was used for grates located in sump. The inlet should have a curb opening height of 6" with a minimum grate length of 12 ft. to maintain flow depths less than the curb height. The design discharge for this inlet was determined using the Rational Method and the 50-year design event as well as a composite runoff coefficient which was derived considering the proposed increase in impervious area.

A detail for this inlet adapted from NDDOT Detail D-722-02 for Inlet – Type 2 – Double has been included in the project plans. In addition, grate style "D" is recommended per NDDOT guidance as it is specifically designed for use in a sag. Analysis for this inlet has been included in Appendix C.

7 REFERENCES

- Aquaveo. 2023. *Watershed Modeling System (WMS)*. Provo, UT: Software version 11.1.12.
- Federal Lands Highway. 2012. "Project Development and Design Manual, Chapter 7 Hydrology and Hydraulics." <https://flh.fhwa.dot.gov/resources/design/pddm/>.
- FHWA. 2002. "Highway Design Series No. 2, Second Edition, FHWA NHI-02-001."
- FHWA. 2008. "Hydraulic Design Series No. 4: Introduction to Highway Hydraulics."
- FHWA. 2012. "Hydraulic Design Series No. 5, Third Edition, Hydraulic Design of Highway Culverts."
- FHWA. 2006. "Hydraulic Engineering Circular No. 14, Third Edition."
- FHWA. 2022. *Hydraulic Toolbox*. Software Version 5.2, Federal Highway Administration, Aquaveo.
- Multi-Resolution Land Characteristics Consortium. 2011. *National Land Cover Database 2011 (NLCD 2011)*. Multi-Resolution Land Characteristics Consortium (MRLC). <https://www.mrlc.gov/data/references/national-land-cover-database-2019-landcover-imperviousness-nlcd2019>.
- National Oceanic and Atmospheric Administration. 2023. *NOAA Atlas 14 Precipitation Frequency Data Server (PFDS)*. Accessed November 2023. https://hdsc.nws.noaa.gov/pfds/pfds_map_cont.html.
- Natural Resources Conservation Service. 2015. *Soil Survey Geographic (SSURGO) database*. Fort Worth, TX. Accessed April 2019. <http://websoilsurvey.nrcs.usda.gov>.
- NDDOT. 2023. *NDDOT Design Manual Chapter V: Hydraulic Studies and Drainage Design*. North Dakota Department of Transportation.
- U.S. Geological Survey. 2015. *Regional Regression Equations to Estimate Peak-Flow Frequency at Sites in North Dakota Using Data through 2009*. USGS.
- U.S. Geological Survey. 2023. *The National Map Viewer*. Accessed Nov 2023. <https://apps.nationalmap.gov/viewer/>.

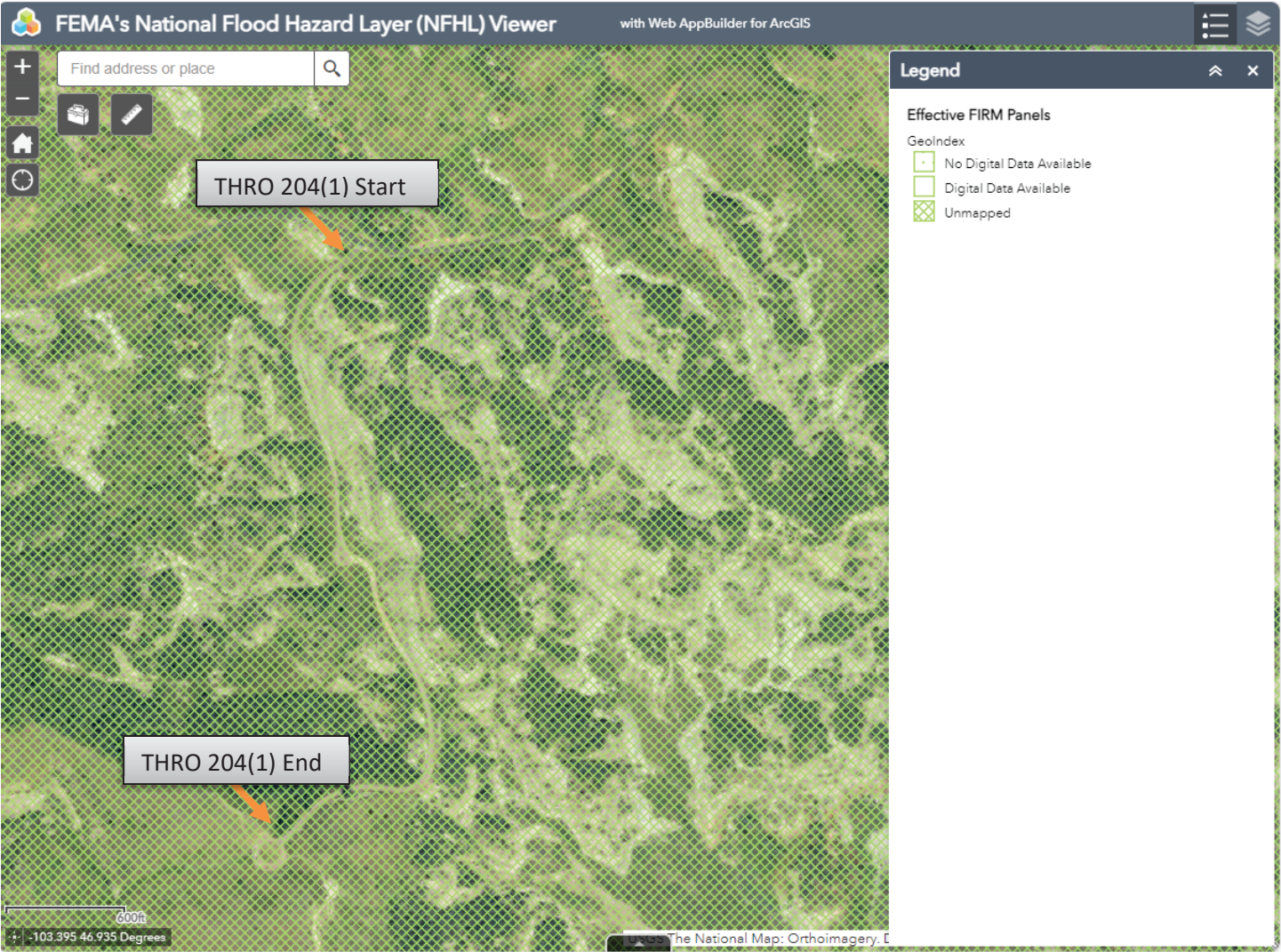
Appendix A

Existing Site Information

Existing Structure Information

Crossing Identifier	Crossing Station	Ex. Structure Size						Existing Structure Type	Existing Structure Orientation	Inlet Invert Elevation (ft)	Outlet Invert Elevation (ft)	Length (ft)	Slope (ft/ft)	Cover at Inlet Shoulder (ft)	Comments/Notes
		Box		Arch or Elliptical		Circular	Number of Barrels								
		Span (ft)	Rise (ft)	Span (in)	Rise (in)	Diameter (in)									
C01		----	----	----	----	18	1	CMP	Cross	2484.9	2484.3	48.0	0.012		Cross culvert at BHR entrance - may extend based on proposed
C02		----	----	----	----	12	1	CMP	Other	2535.0	2525.6	25.0	0.376		Culvert discharges down steep slope
C03		----	----	----	----	24	1	CMP	Cross						Leave to provide drainage from Slide area - add ditch to direct flow into
C04		----	----	----	----	Unk	1	Unk	Other	2598.2	2591.7	91.0	0.071	Unk	Located at 30% field review - not surveyed. Inlet clear but outlet is nearly completely buried. Pipe no longer functioning and maybe drained old road alignment - clean in place for additional slide drainage. Labeled C10 in 30% field notes.
C05		----	----	----	----	24	1	CMP	Cross						Drop Inlet - 40"x30" - discharge down steep slope
C06						12	1	CMP	Other	2777.2	2771.8	13.0	0.410	Unk	Discharge down steep slope
C07		----	----	----	----	12	1	CMP	Cross	2789.1	2776.6	46.0	0.272		Discharge down steep slope
C08		----	----	----	----	24	1	CMP	Cross						Drop Inlet - 3.4'x2.4' - discharge down steep slope - will be removed/replaced for new parking lot drainage
PR01		----	----	----	----	----	----	----	0				----	----	At 30% - slope and vegetation not allowing water to flow and is continuing down road. Labeled C08 in 30% field notes. Clear vegation and replace riprap ditch from 30% with rundown to reduce roughness and increase conveyance.
PR02		----	----	----	----	----	----	----	0				----	----	Add culvert DI w/ extended inlet grate and vault to capture flow - steep drainage from PR ditch before it falls into flat area at base of slide
PR03		----	----	----	----	----	----	----	0				----	----	Recommend superelevate road to drain to outboard side of landslide. Add additional culvert rundowns to drain. Labeled C11 in 30% field notes.
PR04		----	----	----	----	----	----	----	0				----	----	Recommend superelevate road to drain to outboard side of landslide. Add additional culvert rundowns to drain. Labeled C11 in 30% field notes.
PR05		----	----	----	----	----	----	----	0				----	----	Proposed DI for drainage of proposed parking lot

FEMA Effective FIRM



Appendix B

Hydrology

Hydrology Output Tables

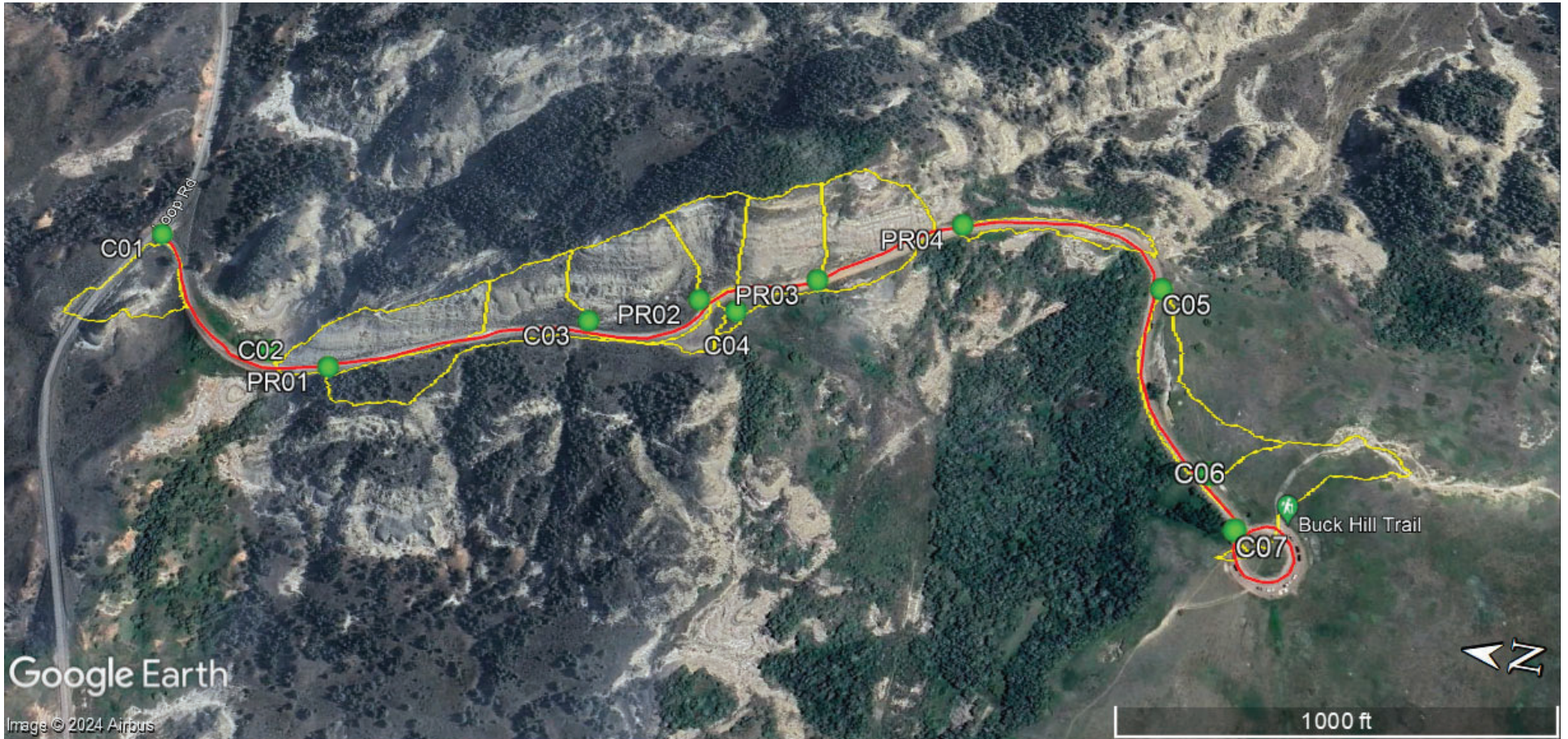
Crossing Data		Rational Method														
Crossing Identifier	Crossing ¹ Station	Drainage Area (ac)	Runoff Coefficient	Tc (min)	Rainfall Intensities						Flow Rates					
					2YR (in/hr)	5YR (in/hr)	10YR (in/hr)	25YR (in/hr)	50YR (in/hr)	100YR (in/hr)	2YR (cfs)	5YR (cfs)	10YR (cfs)	25YR (cfs)	50YR (cfs)	100YR (cfs)
C01	100+38	1.1	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	0.7	0.9	1.2	1.5	1.8	2.1
C02	105+95	1.5	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	1.0	1.4	1.7	2.1	2.6	3.0
C03	114+45	1.9	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	1.3	1.7	2.1	2.6	3.1	3.7
C04	118+92	1.4	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	0.9	1.2	1.5	1.9	2.3	2.7
C05	131+70	1.3	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	0.9	1.2	1.4	1.8	2.2	2.6
C06	136+82	1.2	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	0.8	1.1	1.3	1.7	2.0	2.3
C07	138+15	0.0	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	0.0	0.0	0.0	0.0	0.1	0.1
C08	N/A	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PR01	107+60	2.2	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	1.5	1.9	2.3	3.0	3.6	4.2
PR02	117+95	0.8	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	0.6	0.7	0.9	1.1	1.4	1.6
PR03	121+19	1.5	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	1.0	1.4	1.7	2.1	2.6	3.0
PR04	125+17	0.5	0.20	6.0	3.4	4.5	5.5	7.0	8.4	9.9	0.3	0.4	0.5	0.7	0.8	1.0
PR05	See Report	2.3	0.36	---	---	---	---	7.0	---	---	---	---	---	---	---	---

1 - Location for PR05 identified in report with approximate coordinates.

Crossing Data		USGS Regression Equation												Selected Hydrologic Method	Selected Design Storm	Selected Design Flow (cfs)
Crossing Identifier	Crossing ¹ Station	Drainage Area (sqmi)	Stream Length (mi)	Min Basin Elev. (ft)	Ruggedness Number (ft/mi) (units)	Basin Perimeter Length (mi)	Compactness Number	Flow Rates								
								2YR (cfs)	5YR (cfs)	10YR (cfs)	25YR (cfs)	50YR (cfs)	100YR (cfs)			
C01	100+38	0.00166	0.073	2485.48	2546.567	0.24	40.88	-5.1	-7.1	---	-8.1	---	-8.5	Rational Method	25YR	1.5
C02	105+95	0.00239	0.151	2536.79	9108.298	0.35	41.30	-4.7	-6.8	---	-7.8	---	-8.1	Rational Method	25YR	2.1
C03	114+45	0.00294	0.114	2599.30	5152.403	0.29	27.85	-3.0	-4.1	---	-4.7	---	-4.9	Rational Method	25YR	2.6
C04	118+92	0.00216	0.110	2610.48	7093.167	0.29	37.94	-4.3	-6.2	---	-7.1	---	-7.4	Rational Method	25YR	1.9
C05	131+70	0.00206	0.149	2731.76	6635.623	0.36	49.24	-5.9	-8.5	---	-9.8	---	-10.3	Rational Method	25YR	1.8
C06	136+82	0.00186	0.112	2777.97	4752.630	0.29	44.00	-5.3	-7.5	---	-8.6	---	-9.1	Rational Method	25YR	1.7
C07	138+15	0.00005	0.021	2791.01	4498.316	0.05	300.90	-41.9	-60.3	---	-70.6	---	-74.9	Rational Method	25YR	0.0
C08	N/A	---	---	---	---	---	---	---	---	---	---	---	---	Select Method	Select Storm	---
PR01	107+60	0.00336	0.262	2551.77	10850.559	0.66	55.42	-6.6	-9.5	---	-11.0	---	-11.6	Rational Method	25YR	3.0
PR02	117+95	0.00127	0.072	2611.29	7419.593	0.21	46.81	-5.7	-8.1	---	-9.3	---	-9.7	Rational Method	25YR	1.1
PR03	121+19	0.00239	0.118	2635.04	5901.126	0.26	30.68	-3.4	-4.7	---	-5.4	---	-5.6	Rational Method	25YR	2.1
PR04	125+17	0.00078	0.110	2675.23	6711.392	0.26	93.88	-12.4	-17.7	---	-20.6	---	-21.8	Rational Method	25YR	0.7
PR05	See Report	---	---	---	---	---	---	---	---	---	---	---	---	Rational Method	50YR	7.0

1 - Location for PR05 identified in report with approximate coordinates.

Culvert Basin Delineations



Basin Delineation for Proposed Parking Lot Inlet



Note: Proposed Parking Lot layout shown in blue, proposed curb and gutter shown in yellow.

Precipitation Frequency Data Server Information



NOAA Atlas 14, Volume 8, Version 2
Location name: Medora, North Dakota, USA*
Latitude: 46.9284°, Longitude: -103.3909°
Elevation: 2688 ft**
* source: ESRI Maps
** source: USGS



POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypala, Dale Unruh, Michael Yelka, Geoffrey Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

[PF tabular](#) | [PF graphical](#) | [Maps & arials](#)

PF tabular

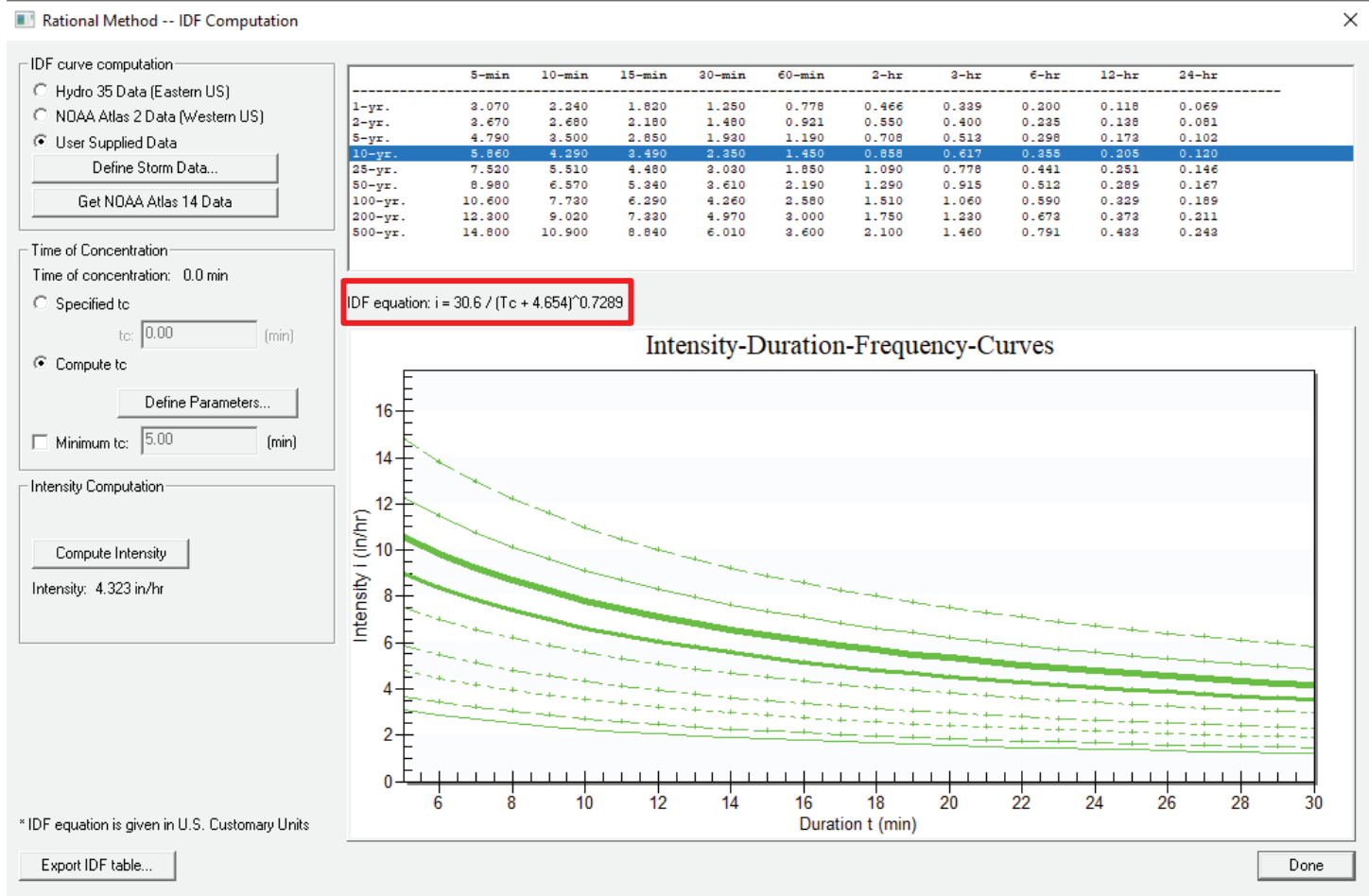
PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour) ¹										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	3.07 (2.38-3.98)	3.67 (2.83-4.78)	4.79 (3.68-6.25)	5.86 (4.49-7.67)	7.52 (5.68-10.4)	8.98 (6.56-12.4)	10.6 (7.48-14.9)	12.3 (8.36-17.8)	14.8 (9.71-21.9)	16.9 (10.7-25.0)
10-min	2.24 (1.73-2.92)	2.68 (2.07-3.49)	3.50 (2.70-4.57)	4.29 (3.28-5.62)	5.51 (4.15-7.61)	6.57 (4.81-9.11)	7.73 (5.47-10.9)	9.02 (6.13-13.0)	10.9 (7.10-16.0)	12.4 (7.84-18.3)
15-min	1.82 (1.41-2.38)	2.18 (1.68-2.84)	2.85 (2.19-3.72)	3.49 (2.67-4.56)	4.48 (3.38-6.18)	5.34 (3.91-7.41)	6.29 (4.45-8.89)	7.33 (4.98-10.6)	8.84 (5.78-13.0)	10.1 (6.38-14.9)
30-min	1.25 (0.964-1.62)	1.48 (1.14-1.93)	1.93 (1.48-2.51)	2.35 (1.80-3.08)	3.03 (2.28-4.18)	3.61 (2.65-5.02)	4.26 (3.01-6.03)	4.97 (3.38-7.19)	6.01 (3.93-8.87)	6.87 (4.35-10.1)
60-min	0.778 (0.601-1.01)	0.921 (0.711-1.20)	1.19 (0.916-1.55)	1.45 (1.11-1.89)	1.85 (1.39-2.55)	2.19 (1.61-3.04)	2.58 (1.82-3.64)	3.00 (2.03-4.32)	3.60 (2.36-5.31)	4.10 (2.60-6.06)
2-hr	0.466 (0.364-0.598)	0.550 (0.430-0.707)	0.708 (0.551-0.912)	0.858 (0.664-1.11)	1.09 (0.830-1.48)	1.29 (0.955-1.76)	1.51 (1.08-2.10)	1.75 (1.20-2.49)	2.10 (1.39-3.05)	2.38 (1.53-3.47)
3-hr	0.339 (0.267-0.433)	0.400 (0.315-0.511)	0.513 (0.401-0.656)	0.617 (0.481-0.792)	0.778 (0.595-1.05)	0.915 (0.681-1.24)	1.06 (0.766-1.47)	1.23 (0.848-1.73)	1.46 (0.972-2.10)	1.65 (1.07-2.38)
6-hr	0.200 (0.159-0.252)	0.235 (0.187-0.296)	0.298 (0.236-0.376)	0.355 (0.279-0.449)	0.441 (0.340-0.581)	0.512 (0.385-0.681)	0.590 (0.429-0.799)	0.673 (0.470-0.931)	0.791 (0.532-1.12)	0.886 (0.579-1.26)
12-hr	0.118 (0.095-0.146)	0.138 (0.111-0.172)	0.173 (0.139-0.216)	0.205 (0.163-0.256)	0.251 (0.195-0.325)	0.289 (0.219-0.378)	0.329 (0.242-0.439)	0.373 (0.263-0.507)	0.433 (0.295-0.602)	0.481 (0.319-0.673)
24-hr	0.069 (0.056-0.084)	0.081 (0.066-0.099)	0.102 (0.083-0.125)	0.120 (0.097-0.148)	0.146 (0.114-0.186)	0.167 (0.128-0.214)	0.189 (0.140-0.247)	0.211 (0.151-0.282)	0.243 (0.167-0.331)	0.267 (0.179-0.368)
2-day	0.039 (0.032-0.047)	0.046 (0.038-0.056)	0.059 (0.048-0.071)	0.069 (0.056-0.084)	0.084 (0.066-0.105)	0.095 (0.074-0.120)	0.107 (0.080-0.137)	0.119 (0.086-0.156)	0.135 (0.094-0.181)	0.147 (0.100-0.200)
3-day	0.028 (0.023-0.034)	0.033 (0.028-0.040)	0.042 (0.035-0.051)	0.049 (0.040-0.059)	0.059 (0.047-0.073)	0.067 (0.052-0.084)	0.075 (0.057-0.096)	0.083 (0.061-0.108)	0.095 (0.066-0.126)	0.103 (0.070-0.138)
4-day	0.023 (0.019-0.027)	0.027 (0.022-0.032)	0.033 (0.027-0.040)	0.039 (0.032-0.046)	0.046 (0.037-0.057)	0.052 (0.041-0.065)	0.059 (0.044-0.074)	0.065 (0.047-0.084)	0.074 (0.052-0.097)	0.080 (0.055-0.107)
7-day	0.015 (0.013-0.018)	0.017 (0.015-0.021)	0.022 (0.018-0.026)	0.025 (0.021-0.030)	0.030 (0.024-0.036)	0.034 (0.027-0.041)	0.037 (0.029-0.047)	0.041 (0.031-0.053)	0.047 (0.033-0.061)	0.051 (0.035-0.067)
10-day	0.012 (0.010-0.014)	0.014 (0.012-0.016)	0.017 (0.014-0.020)	0.019 (0.016-0.023)	0.023 (0.019-0.028)	0.026 (0.021-0.032)	0.029 (0.022-0.036)	0.032 (0.023-0.040)	0.036 (0.025-0.046)	0.039 (0.027-0.051)
20-day	0.008 (0.007-0.009)	0.009 (0.008-0.010)	0.011 (0.009-0.013)	0.013 (0.011-0.015)	0.015 (0.012-0.017)	0.016 (0.013-0.020)	0.018 (0.014-0.022)	0.020 (0.015-0.024)	0.022 (0.016-0.027)	0.023 (0.016-0.030)
30-day	0.006 (0.005-0.007)	0.007 (0.006-0.008)	0.009 (0.007-0.010)	0.010 (0.008-0.011)	0.011 (0.009-0.014)	0.013 (0.010-0.015)	0.014 (0.011-0.017)	0.015 (0.011-0.018)	0.016 (0.012-0.021)	0.017 (0.012-0.022)
45-day	0.005 (0.004-0.006)	0.006 (0.005-0.007)	0.007 (0.006-0.008)	0.008 (0.007-0.009)	0.009 (0.007-0.011)	0.010 (0.008-0.012)	0.011 (0.008-0.013)	0.012 (0.009-0.014)	0.013 (0.009-0.016)	0.013 (0.009-0.017)
60-day	0.004 (0.004-0.005)	0.005 (0.004-0.006)	0.006 (0.005-0.007)	0.007 (0.006-0.008)	0.008 (0.006-0.009)	0.008 (0.007-0.010)	0.009 (0.007-0.011)	0.010 (0.007-0.012)	0.010 (0.008-0.013)	0.011 (0.008-0.014)

¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values. Please refer to NOAA Atlas 14 document for more information.

[Back to Top](#)

IDF Equations (Rational Method)

10-Year:



25-Year:

Rational Method -- IDF Computation

IDF curve computation

- ☐ Hydro 35 Data (Eastern US)
☐ NOAA Atlas 2 Data (Western US)
☒ User Supplied Data

Define Storm Data...

Get NOAA Atlas 14 Data

Time of Concentration

Time of concentration: 0.0 min

- ☐ Specified to

to: 0.00 (min)

- ☒ Compute to

Define Parameters...

☐ Minimum to: 5.00 (min)

Intensity Computation

Compute Intensity

Intensity: 4.323 in/hr

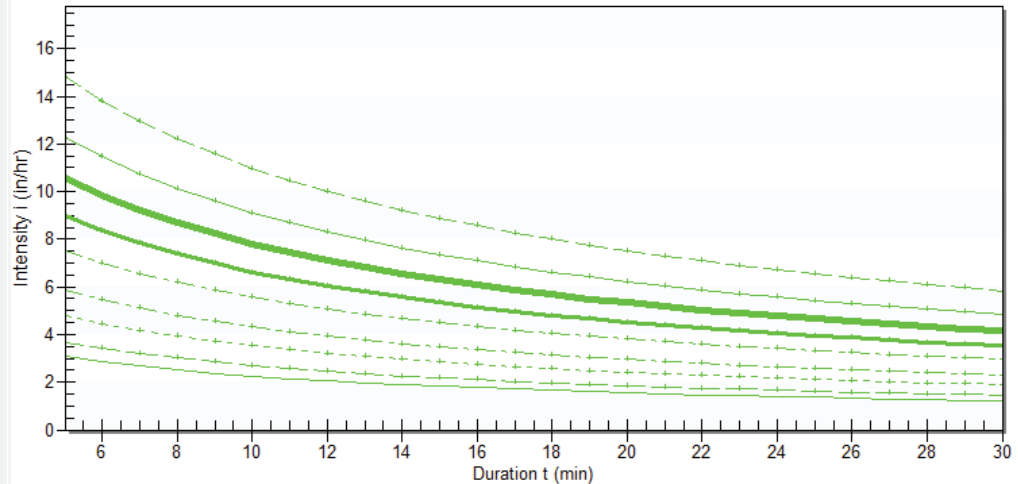
* IDF equation is given in U.S. Customary Units

Export IDF table...

	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
1-yr.	3.070	2.240	1.820	1.250	0.778	0.466	0.339	0.200	0.118	0.069
2-yr.	3.670	2.680	2.180	1.480	0.921	0.550	0.400	0.235	0.138	0.081
5-yr.	4.790	3.500	2.850	1.930	1.190	0.708	0.513	0.298	0.173	0.102
10-yr.	5.860	4.290	3.490	2.350	1.450	0.858	0.617	0.355	0.205	0.120
25-yr.	7.520	5.510	4.480	3.030	1.850	1.090	0.778	0.441	0.251	0.146
50-yr.	8.980	6.570	5.340	3.610	2.190	1.290	0.915	0.512	0.289	0.167
100-yr.	10.600	7.730	6.290	4.260	2.580	1.510	1.060	0.590	0.329	0.189
200-yr.	12.300	9.020	7.320	4.970	3.000	1.750	1.230	0.673	0.373	0.211
500-yr.	14.800	10.900	8.840	6.010	3.600	2.100	1.460	0.791	0.433	0.243

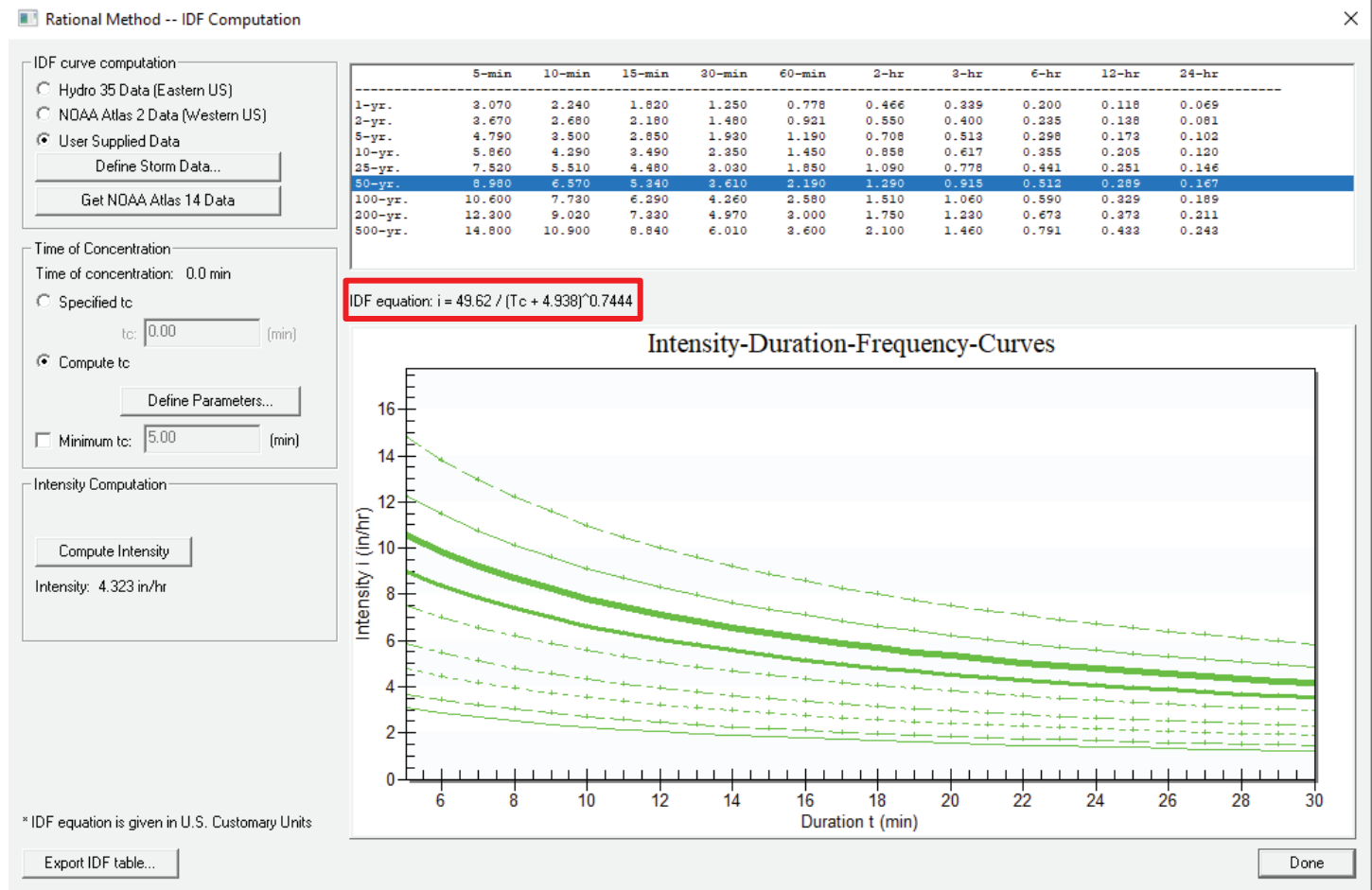
IDF equation: $i = 40.67 / (T_c + 4.858)^{0.7376}$

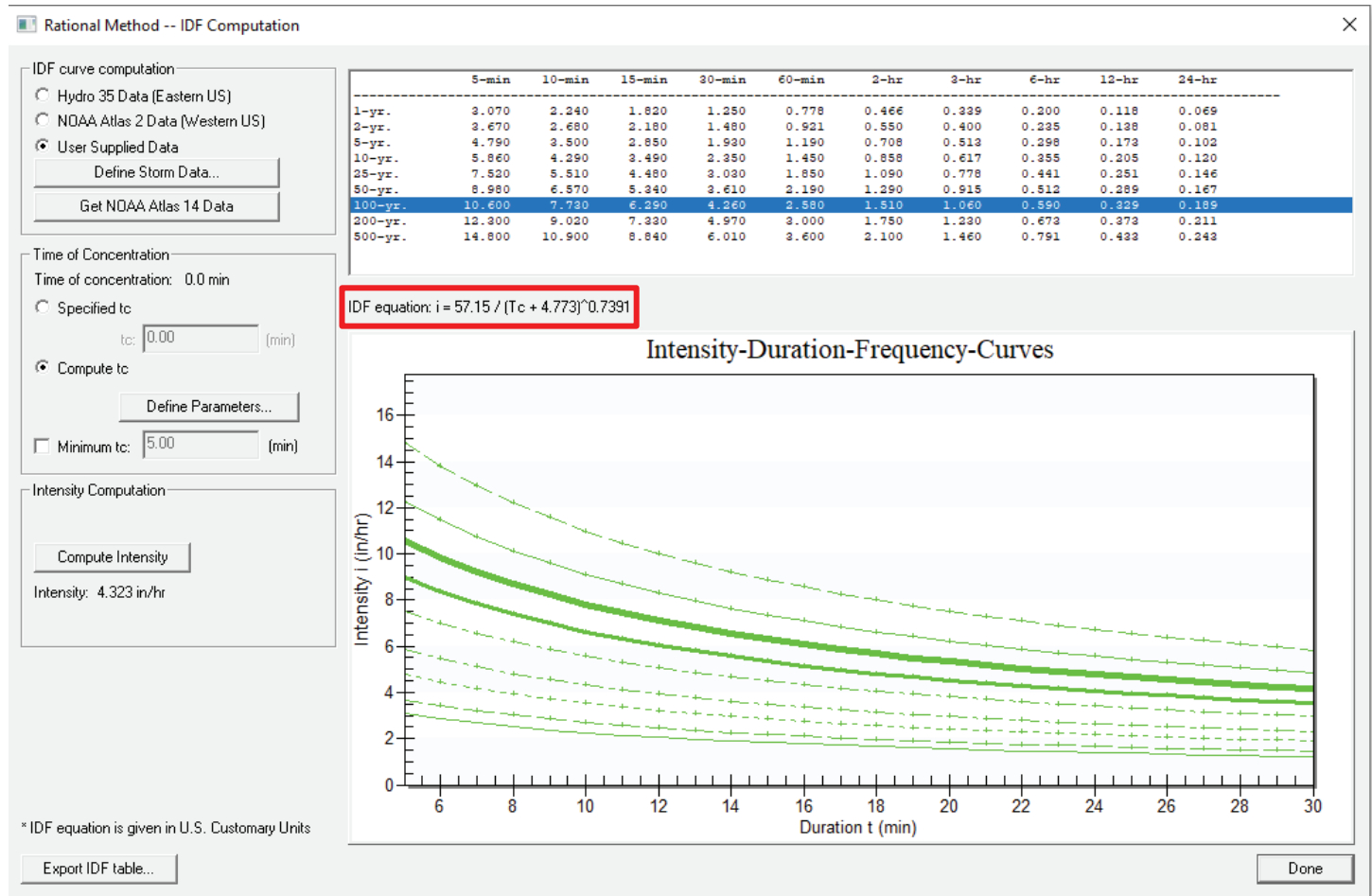
Intensity-Duration-Frequency-Curves



Done

50-Year:





Appendix C

Hydraulic Analyses

Inlet Control Capacity Analysis

Crossing Data			Target HW/D Ratio	Existing Structure Opening							Minimum Required Opening (per Inlet Control Equations)		Comments
Crossing Identifier	Crossing Station	Design Flow ¹ (cfs)		Box		Arch or Elliptical		Circular	Number of Barrels	WWA ² (sqft)	Diameter (in)	WWA ² (sqft)	
				Span (ft)	Rise (ft)	Span (in)	Rise (in)	Diameter (in)					
C01	100+38	1.5	1.0	----	----	----	----	18	1	1.8	12	0.8	Existing structure size is adequate.
C02	105+95	2.1	1.0	----	----	----	----	12	1	0.8	18	1.8	Larger structure required.
C03	114+45	2.6	1.0	----	----	----	----	24	1	3.1	18	1.8	Existing structure size is adequate.
C04	118+92	1.9	1.0	----	----	----	----	Unk	1	Unk	12	0.8	Existing structure size is unknown.
C05	131+70	1.8	1.0	----	----	----	----	24	1	3.1	12	0.8	Existing structure size is adequate.
C06	136+82	1.7	1.0					12	1	Missing Data	12	0.8	
C07	138+15	0.0	1.0	----	----	----	----	12	1	0.8	8	0.3	Existing structure size is adequate.
C08	N/A	----	1.0	----	----	----	----	24	1	3.1			Not Evaluated
PR01	107+60	3.0	1.0	----	----	----	----	----	----	----	18	1.8	No existing structure.
PR02	117+95	1.1	1.0	----	----	----	----	----	----	----	12	0.8	No existing structure.
PR03	121+19	2.1	1.0	----	----	----	----	----	----	----	18	1.8	No existing structure.
PR04	125+17	0.7	1.0	----	----	----	----	----	----	----	8	0.3	No existing structure.
PR05	See Report	7.0	1.0	----	----	----	----	----	----	----	24	3.1	No existing structure.

1 - Design flow is the 25-year storm for all roadway culverts and the 50-year storm for PR05 located in the proposed parking lot.

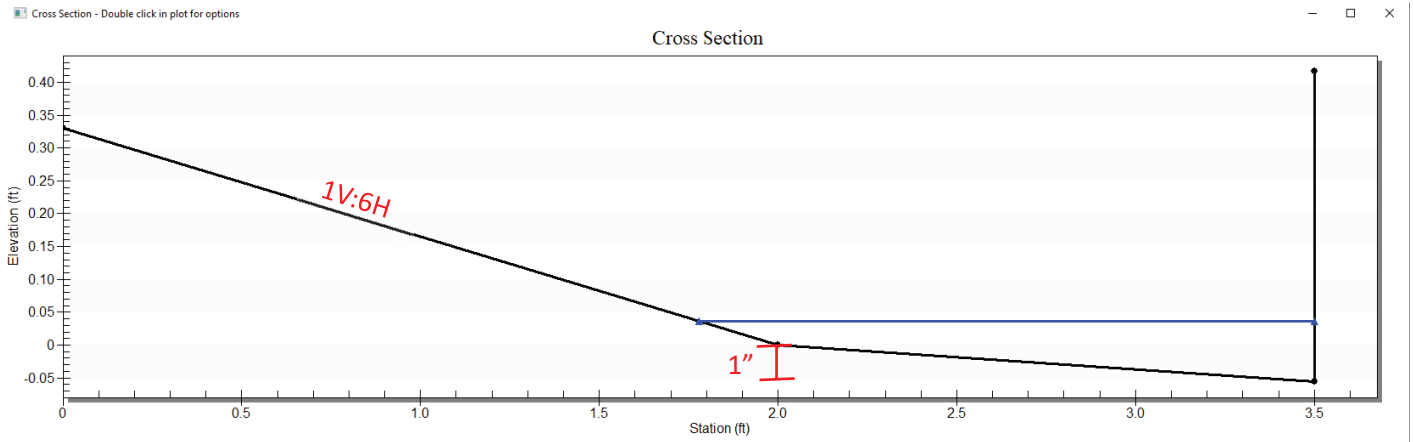
2 - Waterway opening area in square feet.

Ditch Analysis Summary:

Ditch Sample Locations	Drainage Area ¹ (ac)	Drainage Area (sqmi)	Rational Method					Slope Calculator					Ditch Sample Locations	10YR Design Flow (cfs)	Ditch Slope (ft/ft)	Typical paved ditch, curb, and gutter from NDDOT Standard. See Appendix C		Comments
			Drainage Area (ac)	Runoff Coefficient	Tc (min)	10YR Rainfall Intensity (in/hr)	10YR Design Flow (cfs)	X1	Y1	X2	Y2	Ditch Slope (ft/ft)				Flow Depth (ft)	Lining Requirement	
D01	0.3	0.0005	0.3	0.20	6.0	5.46	0.4	0.0	2488.0	117.8	2497.0	0.08	D01	0.4	0.076	0.16	Stone Lining N/A - Proposed ditch will be paved	Paved ditch with minimum 6-inch curb to conform with other areas of the Park.
D02	1.5	0.0024	1.5	0.20	6.0	5.46	1.7	0.0	2537.0	776.3	2601.4	0.08	D02	1.7	0.083	0.26	Stone Lining N/A - Proposed ditch will be paved	Paved ditch with minimum 6-inch curb to conform with other areas of the Park.
D03	2.2	0.0034	2.2	0.20	6.0	5.46	2.4	0.0	2557.5	1077.8	2612.7	0.05	D03	2.4	0.051	0.33	Stone Lining N/A - Proposed ditch will be paved	Paved ditch with minimum 6-inch curb to conform with other areas of the Park.
D04	1.5	0.0024	1.5	0.20	6.0	5.46	1.7	0.0	2634.0	298.6	2666.0	0.11	D04	1.7	0.107	0.25	Stone Lining N/A - Proposed ditch will be paved	Paved ditch with minimum 6-inch curb to conform with other areas of the Park.
D05	1.9	0.0029	1.9	0.20	6.0	5.46	2.1	0.0	2598.2	285.0	2610.1	0.04	D05	2.1	0.042	0.15	Articulated Concrete Block - Special Detail 253-A	Recondition Hyd. Ditch at base of slide - line with Articulated Concrete Block
D06	0.8	0.0013	0.8	0.20	6.0	5.46	0.9	0.0	2611.5	119.1	2612.7	0.01	D06	0.9	0.010	0.62	Stone Lining N/A - Proposed ditch will be paved	Paved ditch with minimum 6-inch curb to conform with other areas of the Park.
D07	0.5	0.0008	0.5	0.20	6.0	5.46	0.5	0.0	2696.0	217.8	2715.5	0.09	D07	0.5	0.090	0.16	Stone Lining N/A - Proposed ditch will be paved	Paved ditch with minimum 6-inch curb to conform with other areas of the Park.
D08	1.3	0.0021	1.3	0.20	6.0	5.46	1.4	0.0	2734.2	512.6	2779.0	0.09	D08	1.4	0.078	0.30	Temporary RECP Type 2C - vegetated	Assumed triangular section with max. 6-inch flow depth and foreslope of 1:4 and backslope of 1:3.
D09	1.3	0.0021	1.3	0.20	6.0	5.46	1.4	0.0	2734.2	512.6	2779.0	0.09	D09	1.4	0.087	0.24	Stone Lining N/A - Proposed ditch will be paved	Paved ditch with minimum 6-inch curb to conform with other areas of the Park.
D10	1.2	0.0019	1.2	0.20	6.0	5.46	1.3	0.0	2779.0	118.3	2790.0	0.09	D10	1.3	0.093	0.23	Stone Lining N/A - Proposed ditch will be paved	Paved ditch with minimum 6-inch curb to conform with other areas of the Park.

Paved and Vegetated Ditch Analysis:

Typical Paved Ditch with Concrete Curb and Gutter adopted from NDDOT (CFL Special Detail 609-A):



Paved_D1_RT_100+52

Type: Cross Section Define...

Side Slope 1 (Z1): 6.0 H : 1V
Side Slope 2 (Z2): 1.0 H : 1V
Channel Width (B): 0.0 (ft)
Pipe Diameter (D): 0.0 (ft)
Longitudinal Slope: 0.076 (ft/ft)
Manning's Roughness: 0.0150

☒ Enter Flow: 0.400 (cfs)
☐ Enter Depth: 0.092 (ft)

Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	0.400	cfs
Depth	0.092	ft
Area of Flow	0.101	sq ft
Wetted Perimeter	1.818	ft
Hydraulic Radius	0.055	ft
Average Velocity	3.970	fps
Top Width (T)	1.721	ft
Froude Number	2.892	
Critical Depth	0.154	ft
Critical Velocity	1.832	fps
Critical Slope	0.00771	ft/ft
Critical Top Width	2.095	ft
Max Shear Stress	0.439	lb/ft ²
Avg Shear Stress	0.263	lb/ft ²
Composite Manning's n Equ...	Lotter ...	
Manning's Roughness	0.0150	

OK Cancel

Paved_D2_LT_106+00

Type: Cross Section Define...

Side Slope 1 (Z1): 6.0 H : 1V
Side Slope 2 (Z2): 1.0 H : 1V
Channel Width (B): 0.0 (ft)
Pipe Diameter (D): 0.0 (ft)
Longitudinal Slope: 0.083 (ft/ft)
Manning's Roughness: 0.0150

☒ Enter Flow: 1.700 (cfs)
☐ Enter Depth: 0.174 (ft)

Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	1.700	cfs
Depth	0.174	ft
Area of Flow	0.261	sq ft
Wetted Perimeter	2.400	ft
Hydraulic Radius	0.109	ft
Average Velocity	6.507	fps
Top Width (T)	2.215	ft
Froude Number	3.339	
Critical Depth	0.321	ft
Critical Velocity	2.602	fps
Critical Slope	0.00635	ft/ft
Critical Top Width	3.108	ft
Max Shear Stress	0.901	lb/ft ²
Avg Shear Stress	0.564	lb/ft ²
Composite Manning's n Equ...	Lotter ...	
Manning's Roughness	0.0150	

OK Cancel

Paved_D3_RT_108+10

Type: Cross Section Define...

Side Slope 1 (Z1): 6.0 H : 1V

Side Slope 2 (Z2): 1.0 H : 1V

Channel Width (B): 0.0 (ft)

Pipe Diameter (D): 0.0 (ft)

Longitudinal Slope: 0.051 (ft/ft)

Manning's Roughness: 0.0150

☒ Enter Flow: 2.400 (cfs)

☐ Enter Depth: 0.230 (ft)

Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	2.400	cfs
Depth	0.230	ft
Area of Flow	0.396	sq ft
Wetted Perimeter	2.802	ft
Hydraulic Radius	0.141	ft
Average Velocity	6.066	fps
Top Width (T)	2.557	ft
Froude Number	2.717	
Critical Depth	0.382	ft
Critical Velocity	2.812	fps
Critical Slope	0.00608	ft/ft
Critical Top Width	3.477	ft
Max Shear Stress	0.733	lb/ft ²
Avg Shear Stress	0.449	lb/ft ²
Composite Manning's n Equ...	Lotter ...	
Manning's Roughness	0.0150	

OK Cancel

Paved_D4_RT_119+64_ToPR03

Type: Cross Section Define...

Side Slope 1 (Z1): 6.0 H : 1V

Side Slope 2 (Z2): 1.0 H : 1V

Channel Width (B): 0.0 (ft)

Pipe Diameter (D): 0.0 (ft)

Longitudinal Slope: 0.107 (ft/ft)

Manning's Roughness: 0.0150

☒ Enter Flow: 1.700 (cfs)

☐ Enter Depth: 0.164 (ft)

Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	1.700	cfs
Depth	0.164	ft
Area of Flow	0.239	sq ft
Wetted Perimeter	2.328	ft
Hydraulic Radius	0.103	ft
Average Velocity	7.108	fps
Top Width (T)	2.154	ft
Froude Number	3.759	
Critical Depth	0.321	ft
Critical Velocity	2.602	fps
Critical Slope	0.00635	ft/ft
Critical Top Width	3.108	ft
Max Shear Stress	1.094	lb/ft ²
Avg Shear Stress	0.686	lb/ft ²
Composite Manning's n Equ...	Lotter ...	
Manning's Roughness	0.0150	

OK Cancel

Paved_D6_LT_117+95_ToPR02

Type: Cross Section Define...

Side Slope 1 (Z1): 3.0 H : 1V

Side Slope 2 (Z2): 1.5 H : 1V

Channel Width (B): 0.0 (ft)

Pipe Diameter (D): 0.0 (ft)

Longitudinal Slope: 0.01 (ft/ft)

Manning's Roughness: 0.0150

☒ Enter Flow: 0.900 (cfs)

☐ Enter Depth: 0.213 (ft)

Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	0.900	cfs
Depth	0.213	ft
Area of Flow	0.352	sq ft
Wetted Perimeter	2.677	ft
Hydraulic Radius	0.131	ft
Average Velocity	2.560	fps
Top Width (T)	2.450	ft
Froude Number	1.191	
Critical Depth	0.233	ft
Critical Velocity	2.242	fps
Critical Slope	0.00689	ft/ft
Critical Top Width	2.570	ft
Max Shear Stress	0.133	lb/ft ²
Avg Shear Stress	0.082	lb/ft ²
Composite Manning's n Equ...	Lotter ...	
Manning's Roughness	0.0150	

OK Cancel

Paved_D7_RT_127+50_ToPR04

Type: Cross Section Define...

Side Slope 1 (Z1): 6.0 H : 1V

Side Slope 2 (Z2): 1.0 H : 1V

Channel Width (B): 0.0 (ft)

Pipe Diameter (D): 0.0 (ft)

Longitudinal Slope: 0.09 (ft/ft)

Manning's Roughness: 0.0150

☒ Enter Flow: 0.500 (cfs)

☐ Enter Depth: 0.098 (ft)

Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	0.500	cfs
Depth	0.098	ft
Area of Flow	0.110	sq ft
Wetted Perimeter	1.857	ft
Hydraulic Radius	0.059	ft
Average Velocity	4.527	fps
Top Width (T)	1.755	ft
Froude Number	3.180	
Critical Depth	0.172	ft
Critical Velocity	1.940	fps
Critical Slope	0.00746	ft/ft
Critical Top Width	2.206	ft
Max Shear Stress	0.551	lb/ft ²
Avg Shear Stress	0.334	lb/ft ²
Composite Manning's n Equ...	Lotter ...	
Manning's Roughness	0.0150	

OK Cancel

Paved_D9_LT_131+70_ToC05

Type: **Cross Section** Define...

Side Slope 1 (Z1): 6.0 H : 1V
 Side Slope 2 (Z2): 1.0 H : 1V
 Channel Width (B): 0.0 (ft)
 Pipe Diameter (D): 0.0 (ft)
 Longitudinal Slope: 0.087 (ft/ft)
 Manning's Roughness: 0.0150

☒ Enter Flow: 1.400 (cfs)
☐ Enter Depth: 0.157 (ft)

Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	1.400	cfs
Depth	0.157	ft
Area of Flow	0.225	sq ft
Wetted Perimeter	2.279	ft
Hydraulic Radius	0.099	ft
Average Velocity	6.234	fps
Top Width (T)	2.113	ft
Froude Number	3.369	
Critical Depth	0.291	ft
Critical Velocity	2.488	fps
Critical Slope	0.00651	ft/ft
Critical Top Width	2.926	ft
Max Shear Stress	0.853	lb/ft ²
Avg Shear Stress	0.535	lb/ft ²
Composite Manning's n Equ...	Lotter ...	
Manning's Roughness	0.0150	

OK Cancel

Paved_D10_LT_136+82_ToC06

Type: **Cross Section** Define...

Side Slope 1 (Z1): 6.0 H : 1V
 Side Slope 2 (Z2): 1.0 H : 1V
 Channel Width (B): 0.0 (ft)
 Pipe Diameter (D): 0.0 (ft)
 Longitudinal Slope: 0.093 (ft/ft)
 Manning's Roughness: 0.0150

☒ Enter Flow: 1.300 (cfs)
☐ Enter Depth: 0.149 (ft)

Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	1.300	cfs
Depth	0.149	ft
Area of Flow	0.209	sq ft
Wetted Perimeter	2.224	ft
Hydraulic Radius	0.094	ft
Average Velocity	6.235	fps
Top Width (T)	2.066	ft
Froude Number	3.459	
Critical Depth	0.281	ft
Critical Velocity	2.446	fps
Critical Slope	0.00657	ft/ft
Critical Top Width	2.861	ft
Max Shear Stress	0.867	lb/ft ²
Avg Shear Stress	0.544	lb/ft ²
Composite Manning's n Equ...	Lotter ...	
Manning's Roughness	0.0150	

OK Cancel

Vegetated_D8_LT_131+16_ForGuardrail

Type: **Triangular** Define...

Side Slope 1 (Z1): 4.0 H : 1V
 Side Slope 2 (Z2): 3.0 H : 1V
 Channel Width (B): 2.0 (ft)
 Pipe Diameter (D): 0.0 (ft)
 Longitudinal Slope: 0.078 (ft/ft)
 Manning's Roughness: 0.0250

☒ Enter Flow: 1.400 (cfs)
☐ Enter Depth: 0.297 (ft)

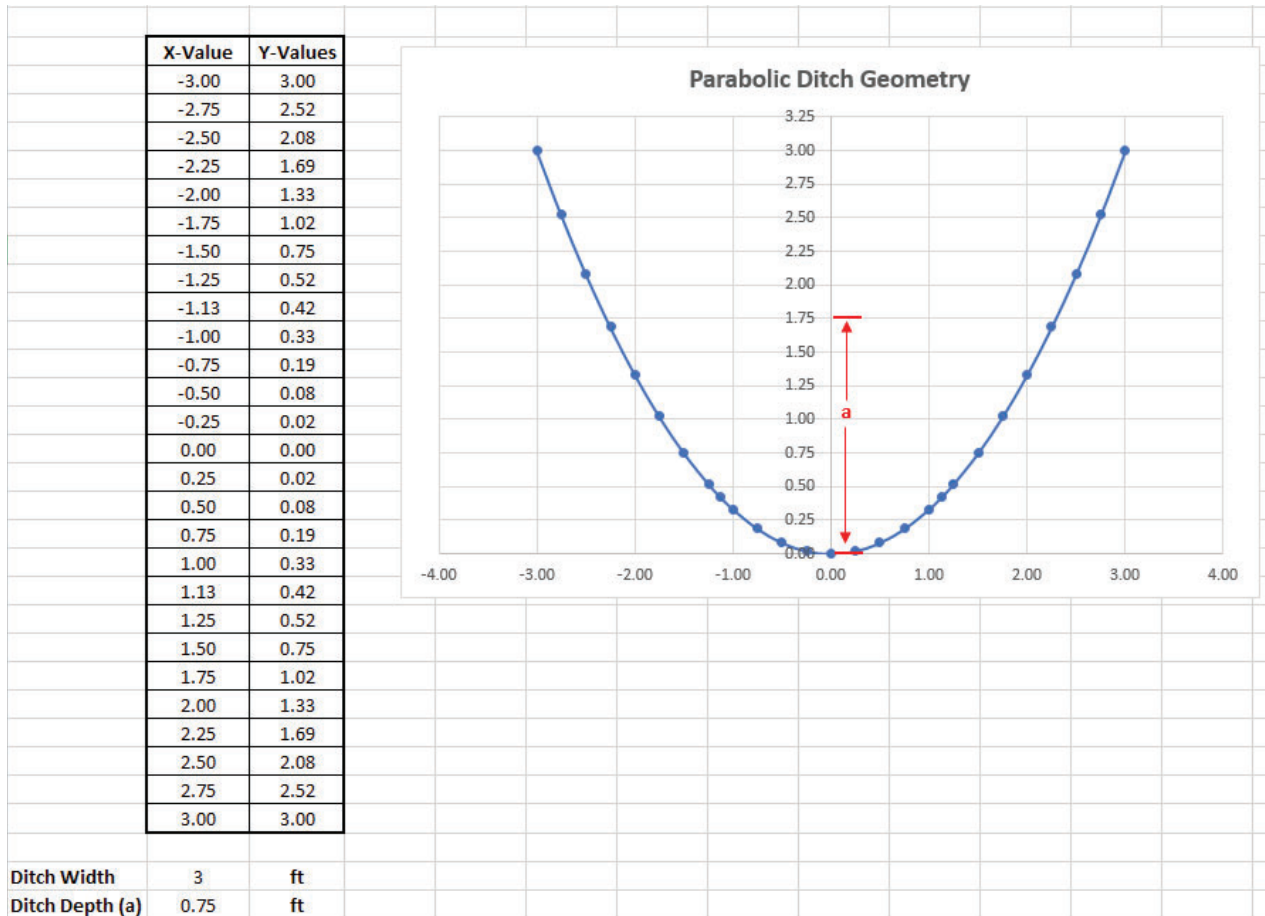
Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	1.400	cfs
Depth	0.297	ft
Area of Flow	0.309	sq ft
Wetted Perimeter	2.164	ft
Hydraulic Radius	0.143	ft
Average Velocity	4.533	fps
Top Width (T)	2.079	ft
Froude Number	2.073	
Critical Depth	0.399	ft
Critical Velocity	2.509	fps
Critical Slope	0.01611	ft/ft
Critical Top Width	2.853	ft
Max Shear Stress	1.446	lb/ft ²
Avg Shear Stress	0.695	lb/ft ²

OK Cancel

Lined Ditch Analysis:



Lined_D5_LT_114+50_ToC03_BaseofSlide

Type: **Cross Section** Define...

Side Slope 1 (Z1): 3.0 H : 1V
Side Slope 2 (Z2): 3.0 H : 1V
Channel Width (B): 2.0 (ft)
Pipe Diameter (D): 0.0 (ft)
Longitudinal Slope: 0.042 (ft/ft)
Manning's Roughness: 0.0130

☒ Enter Flow: 2.100 (cfs)
☐ Enter Depth: 0.260 (ft)

Calculate

Plot... Compute Curves...

Parameter	Value	Units
Flow	2.100	cfs
Depth	0.260	ft
Area of Flow	0.301	sq ft
Wetted Perimeter	1.848	ft
Hydraulic Radius	0.163	ft
Average Velocity	6.983	fps
Top Width (T)	1.750	ft
Froude Number	2.968	
Critical Depth	0.446	ft
Critical Velocity	3.081	fps
Critical Slope	0.00416	ft/ft
Critical Top Width	2.312	ft
Max Shear Stress	0.683	lb/ft ²
Avg Shear Stress	0.426	lb/ft ²
Composite Manning's n Equ...	Lotter ...	
Manning's Roughness	0.0130	

OK Cancel

Curb and Gutter Analysis:

Note: Gutter width represented by total width of gutter and paved ditch section.

Curb and Gutter Analysis - PR03

Gutter

Longitudinal Slope of Road: 0.140 (ft/ft)

Cross-slope of Pavement: 0.026 (ft/ft)

☒ Define Cross-slope of Gutter: 0.167 (ft/ft)

Manning's Roughness: 0.015

Gutter Width: 3.500 (ft)

Enter one of the following:

☒ Design Flow: 1.700 (cfs)

☐ Width of Spread: 1.391 (ft)

Compute unknown

Gutter Depression: 5.909 (in)

Area of Flow: 0.887 (ft²)

Eo (Gutter Flow to Total Flow): 1.000

Depth at Curb: 2.782 (in)

Inlet

Inlet Location: Inlet on grade

Percent Clogging: 50.000 (%)

Inlet Types: Grate

Grate Types: P - 1-7/8

Grate Width: 2.500 (ft)

Grate Length: 3.250 (ft)

Length of Inlet: 10.000 (ft)

Curb Opening Height: 6.000 (in)

Local Depression: 0.000 (in)

Compute Inlet Data

Parameter	Value	Units
Eo'	0.784	
Intercepted Flow	1.497	cfs
Bypass Flow	0.203	cfs
Approach Velocity	1.917	fps
Splash-over Velocity	10.371	fps
Efficiency	0.881	

OK Cancel

Curb and Gutter Analysis - C05

Gutter

Longitudinal Slope of Road: 0.074 (ft/ft)

Cross-slope of Pavement: 0.043 (ft/ft)

☒ Define Cross-slope of Gutter: 0.167 (ft/ft)

Manning's Roughness: 0.015

Gutter Width: 3.500 (ft)

Enter one of the following:

☒ Design Flow: 1.400 (cfs)

☐ Width of Spread: 1.457 (ft)

Compute unknown

Gutter Depression: 5.174 (in)

Area of Flow: 0.801 (ft²)

Eo (Gutter Flow to Total Flow): 1.000

Depth at Curb: 2.915 (in)

Inlet

Inlet Location: Inlet on grade

Percent Clogging: 50.000 (%)

Inlet Types: Grate

Grate Types: P - 1-7/8

Grate Width: 2.500 (ft)

Grate Length: 3.250 (ft)

Length of Inlet: 10.000 (ft)

Curb Opening Height: 6.000 (in)

Local Depression: 0.000 (in)

Compute Inlet Data

Parameter	Value	Units
Eo'	0.701	
Intercepted Flow	1.239	cfs
Bypass Flow	0.161	cfs
Approach Velocity	1.748	fps
Splash-over Velocity	10.371	fps
Efficiency	0.885	

OK Cancel

Curb and Gutter Analysis - C06

Gutter

Longitudinal Slope of Road: 0.090 (ft/ft)

Cross-slope of Pavement: 0.021 (ft/ft)

☒ Define Cross-slope of Gutter: 0.167 (ft/ft)

Manning's Roughness: 0.015

Gutter Width: 3.500 (ft)

Enter one of the following:

☒ Design Flow: 1.300 (cfs)

☐ Width of Spread: 1.366 (ft)

Compute unknown

Gutter Depression: 6.119 (in)

Area of Flow: 0.912 (ft²)

E_o (Gutter Flow to Total Flow): 1.000

Depth at Curb: 2.733 (in)

Inlet

Inlet Location: Inlet on grade

Percent Clogging: 50.000 (%)

Inlet Types: Grate

Grate Types: P - 1-7/8

Grate Width: 2.500 (ft)

Grate Length: 3.250 (ft)

Length of Inlet: 10.000 (ft)

Curb Opening Height: 6.000 (in)

Local Depression: 0.000 (in)

Compute Inlet Data

Parameter	Value	Units
E _o	0.809	
Intercepted Flow	1.182	cfs
Bypass Flow	0.118	cfs
Approach Velocity	1.425	fps
Splash-over Velocity	10.371	fps
Efficiency	0.909	

OK Cancel

Curb and Gutter Analysis - PR05

Gutter

Longitudinal Slope of Road: 0.129 (ft/ft)

Cross-slope of Pavement: 0.029 (ft/ft)

☒ Define Cross-slope of Gutter: 0.056 (ft/ft)

Manning's Roughness: 0.015

Gutter Width: 1.500 (ft)

Enter one of the following:

☒ Design Flow: 7.000 (cfs)

☐ Width of Spread: 6.924 (ft)

Compute unknown

Gutter Depression: 0.479 (in)

Area of Flow: 0.725 (ft²)

E_o (Gutter Flow to Total Flow): 0.524

Depth at Curb: 2.888 (in)

Inlet

Inlet Location: Inlet in sag

Percent Clogging: 50.000 (%)

Inlet Types: Equal-length combo

Grate Types: P - 1-7/8

Grate Width: 1.000 (ft)

Grate Length: 12.000 (ft)

Length of Inlet: 12.000 (ft)

Curb Opening Height: 6.000 (in)

Local Depression: 0.000 (in)

Compute Inlet Data

Parameter	Value	Units
Perimeter	14.000	ft
Effective Perimeter	7.000	ft
Area	16.800	ft ²
Effective Area	8.400	ft ²
Depth at center of grate	0.481	ft
Computed Width of Spread at Sag	16.160	ft
Flow type	Weir Flow	
Efficiency	1.000	

OK Cancel

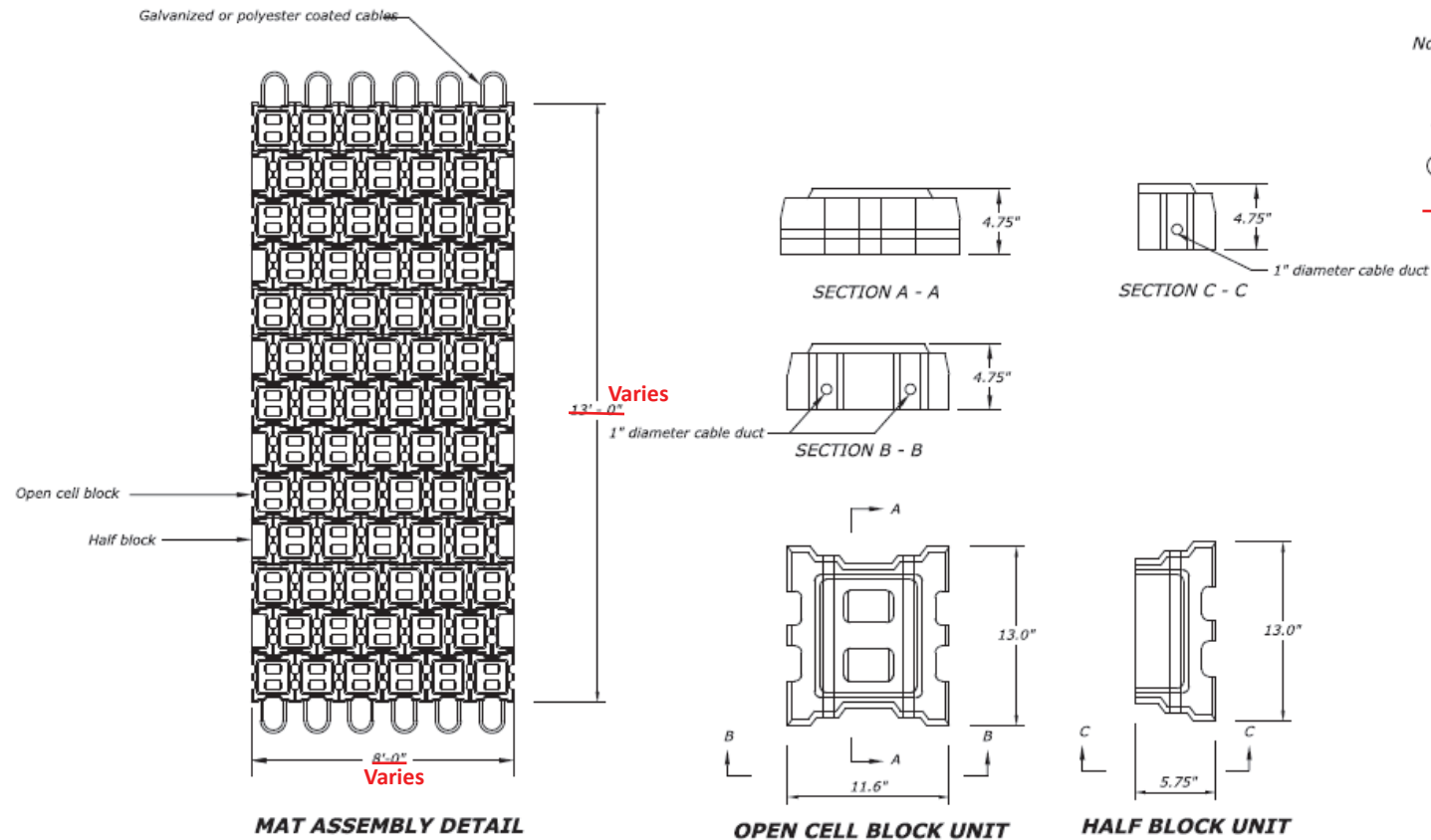
Appendix D

Details

STATE	PROJECT	SHEET NUMBER
ND	FTNP THRO 11(7) SOUTH UNIT LOOP ROAD	G2

Note:

1. Furnish geotextile conforming to subsection 714.01(a).
2. Excavation and backfill for placement of blocks will not be measured for payment.
- ③ Match the ~~existing paved~~ waterway's centerline alignment and profile.
- ~~4. Removal of the existing paved waterway is subsidiary to 25306-1000 Revetment Mat Articulated Concrete Block~~



No Scale

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

U.S. CUSTOMARY SPECIAL

**REVTMENT MAT
ARTICULATED CONCRETE
BLOCK**

SPECIAL
253-A