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Grand Canyon Unified School District
Master Drainage Plan

Sulaiman Alhabashi, Ahmed Alsahili, Sean Heckmann, Jason MacDonald

Seniors in Civil and Environmental Engineering

Department of Civil and Environmental Engineering

Northern Arizona University

MILE HIGH ENGINEERING
2112 S HUFFER LN, FLAGSTAFF, AZ 86001

TABLE OF CONTENTS

1.0 Project Description 1
1.1 Introduction 1
1.2 Project Location 1
1.3 Constraints and Limitations 3
2.0 Field Work 4
2.1 Existing Conditions 4
2.2 Robotic Total Station Survey 4
2.3 Topographic Map 5
3.0 Hydrological Analysis 6
3.1 Delineation of Pertinent Watersheds 6
3.2 Runoff Coefficient Analysis 7
3.3 Discharge Analysis through Modified Rational Method 8
4.0 Hydraulic Analysis of Existing Infrastructure 10
4.1 Existing Culvert Analysis 10
4.2 Existing Channel Analysis 12
5.0 Area A Proposed Improvements 13
5.1 Preliminary Design 13
5.2 Hydraulic Analysis 13
5.3 Cost to Implement 13
6.0 Area B Proposed Improvements 14
6.1 Preliminary Design 14
6.2 Hydraulic Analysis 14
6.3 Cost to Implement 14
7.0 Area C Proposed Improvements 15
7.1 Preliminary Design 15
7.2 Hydraulic Analysis 15
7.3 Cost to Implement 15
8.0 Area D Proposed Improvements 16
8.1 Preliminary Design 16
8.2 Hydraulic Analysis 16
8.3 Cost to Implement 16

9.0 Area E Proposed Improvements 17
9.1 Preliminary Design 17
9.2 Hydraulic Analysis 17
9.3 Cost to Implement 17
10.0 Proposed Phasing 18
10.1 Implementation Plan 18
10.2 Phased Costs 19
11.0 Summary of Engineering Work 20
12.0 Summary of Engineering Costs 22
References 24
Appendix A: Existing Infrastructure Site Photos 25
Appendix B: Total Station Raw Point Data 28
Appendix C-1: Topographic Map of Area A 29
Appendix C-2: Topographic Map of Area B 30
Appendix C-3: Topographic Map of Area C 31
Appendix D: Raw Data Table for Weighted C 34
APPENDIX E: CULVERT MASTER RESULTS 35
CULVERT 3 REPORT 35
CULVERT 5 REPORT 41
CULVERT 6 REPORT 46
CULVERT 8 REPORT 51
CULVERT 9 REPORT 56
CULVERT 10 REPORT 61
CULVERT 11 REPORT 66
CULVERT 12 REPORT 68
CULVERT 13 REPORT 70
CULVERT 15 REPORT 72
CULVERT 16 REPORT 77
CULVERT 17 REPORT 82
CULVERT 18 REPORT 87
CULVERT 19 REPORT 92
CULVERT 20 REPORT 99
CULVERT 21 REPORT 104
CULVERT 22 REPORT 108

CULVERT 23 REPORT 112
CULVERT 24 REPORT 115
Appendix F: Flow Master Results 118
Appendix F-1: Area A problem for 25 years [7] 119

List of Figures

Figure 1: Geographical location of Grand Canyon village within Arizona [1]. 1
Figure 2: Completed topographic map of GCUSD campus with problem areas highlighted. 5
Figure 3: GCUSD campus watersheds delineated. 6
Figure 4: Inventory and location summary of existing culverts on GCUSD campus. 10
Figure 5: Example of Culvert on Site 25
Figure 6: Example of surface flow causing erosion 25
Figure 7: Example of channel on site (a) 26
Figure 8: Example of drainage area (a) 26
Figure 9: Example of drainage area (b) 27
Figure 10: Topographic map of Problem Area A with the proposed alternatives, construction notes, details, and additional information. 29
Figure 11: Topographic map of Problem Area B with the proposed alternatives, construction notes, details, and additional information. 30
Figure 12: Topographic map of Problem Area C with the proposed alternatives, construction notes, details, and additional information. 31
Figure 13: Topographic map of Problem Area D with the proposed alternatives, construction notes, details, and additional information. 32
Figure 14: Topographic map of Problem Area E with the proposed alternatives, construction notes, details, and additional information. 33

List of Equations

Equation 1: Modified Rational Equation.....8

List of Tables

Table 1: Measured Area of Delineated Sub-Basins for GCUSD Master Drainage Study 7
Table 2: Runoff Coefficients 7
Table 3: Summary of hydrological data and factors. 8
Table 4: Results of weighted runoff coefficient determination 8
Table 5: Results of discharge analysis for 10-minute duration with 25-year average recurrence. 9
Table 6: Results of discharge analysis for 10-minute duration with 50-year average recurrence. 9
Table 7: Results of discharge analysis of each problem area for 25 and 50 years average recurrence 10
Table 8: Summary Table of CulvertMaster results for existing culverts 11
Table 9: Summary table of proposed culvert design for GCUSD campus 11
Table 10: This table shows the complete construction and implementation costs for the proposed alternatives within problem area A 13
Table 11: This table shows the complete construction and implementation costs for the proposed alternatives within problem area B 14
Table 12: This table shows the complete construction and implementation costs for the proposed alternatives within problem area C 15
Table 13: This table shows the complete construction and implementation costs for the proposed alternatives within problem area D 16
Table 14: This table shows the complete construction and implementation costs for the proposed alternatives within problem area E 17
Table 15: Cost Summary for Phase 1 19
Table 16: Cost Summary for Phase 2 19
Table 17: Cost Summary for Phase 3 19
Table 18: Cost Summary for Phase 4 19
Table 19: Cost Summary for Phase 5 20
Table 20: Proposed (CENE476) and Completed (CENE486) schedule 21
Table 21: Major Tasks and staff hours 22
Table 22: Material and installation cost [8] [9] 22
Table 23: Staff Member Rates and Hours 23
Table 24: COST OF ENGINEERING SERVICES 23
Table 25: Summary of Expenses 23
Table 26: Raw data table for weighted runoff coefficients 34

Nomenclature

GCUSD: Grand Canyon Unified School District

EPA: Environmental Protection Agency

GCHS: Grand Canyon Historical Society

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We would like to express appreciation to Ivan Landry for his time and availability regarding visitation to GCUSD campus as well as illuminating details of current infrastructure. Mr. Landry's first hand experience with the current infrastructure provided incalculable assistance.

Special thanks to Mark Lamer, P.E. for guidance provided throughout this project as well as accomadating access to the resources needed for completion of site survey. Without Professor Lamer's valuable time, professional supervision and technical support, this project would not have been successful.

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We would also like to thank the Staff and Faculty of GCUSD for their understanding and allowing the team to access campus grounds during operations.

Finally, we would like to thank our fellow NAU Capstone team working on the GCUSD Retaining Wall for sharing additional, pertinent survey data.

1.0 Project Description

1.1 Introduction

Grand Canyon Unified School District has storm drainage issues due to inadequate infrastructure. A master drainage study will analyze the existing conditions, flow capacities, and propose improvements. The primary objective of this project is to provide hydraulic analysis of the current infrastructure, plan, and develop a comprehensive stormwater design.

1.2 Project Location

Grand Canyon Unified School District campus is located at 100 Boulder St, Grand Canyon Village, AZ 86023. The geographical location of Grand Canyon Village is showing in Figure 1.

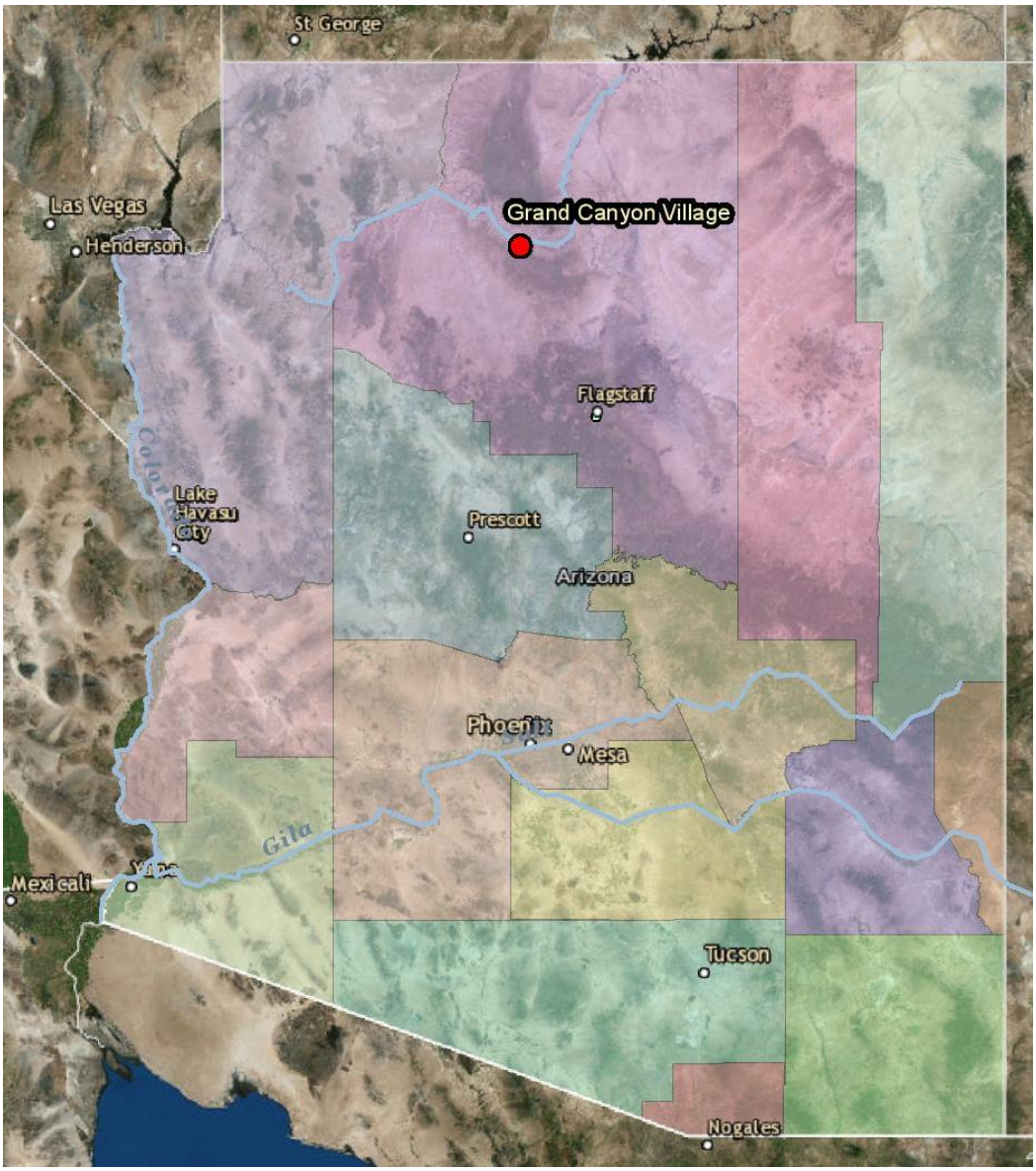

Figure 1: Geographical location of Grand Canyon village within Arizona [1].

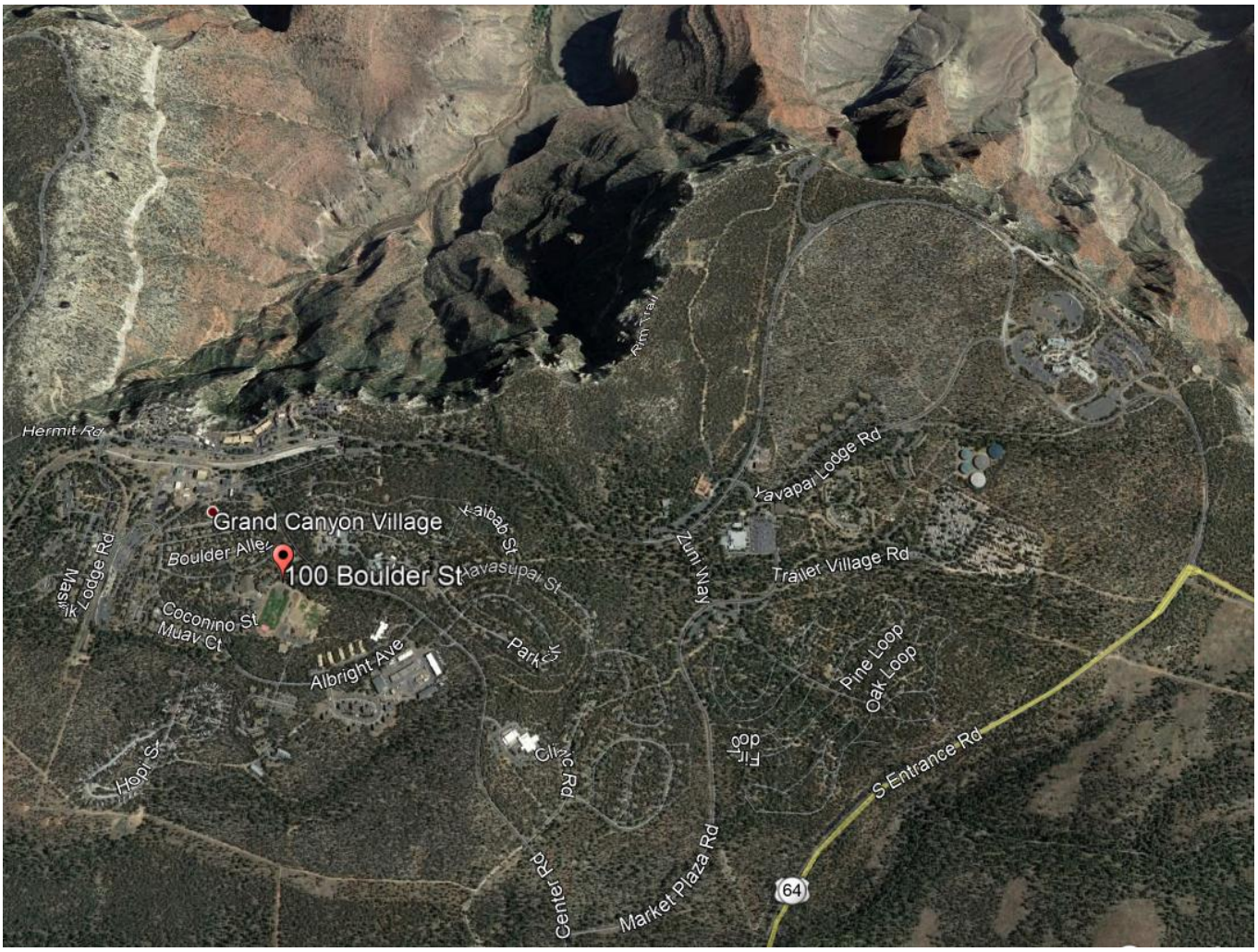

Figure 2: Regional map of GCUSD site [6]

Figure 3 shows an aerial view of the GCS campus. This includes all buildings currently affected by drainage issues as well as the watershed area, which is being analyzed. Problem areas A-E are highlighted.

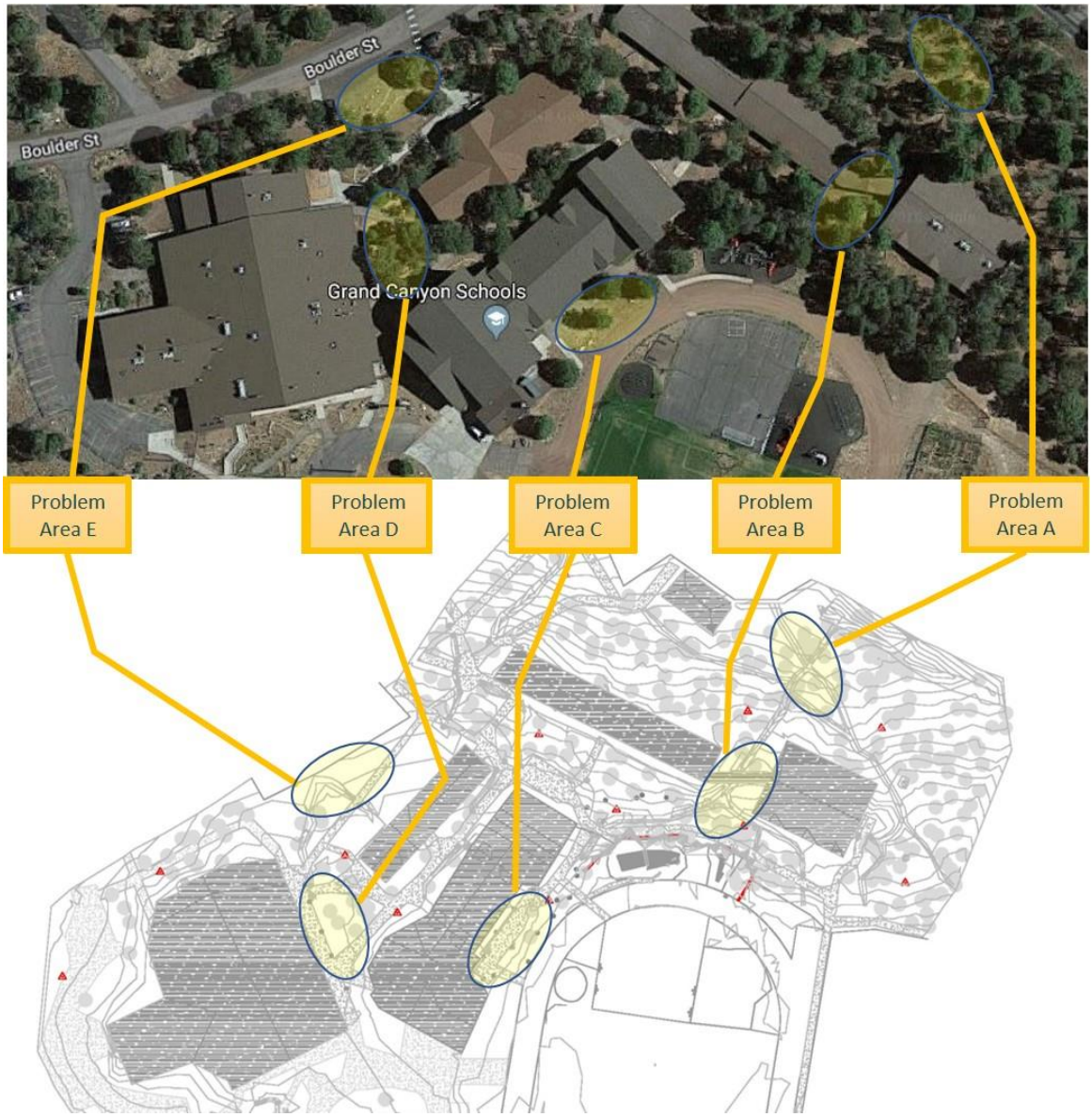

Figure 3: Aerial view of GCS Campus [1]

1.3 Constraints and Limitations

The project is located within Grand Canyon National Park, and therefore, the Grand Canyon Historical Society (GCHS) must approve all new construction. Proposed drainage improvements will be limited to material that matches the local environment, as per GCHS recommendations.

Drainage design must meet all federal regulations set forth by the US Environmental Protection Agency (EPA) as well as Coconino County regulations. Coconino County meets the minimum federal requirements for designation by the EPA as a Small Municipal Separate Storm Sewer

System Operator [4]. The proposed drainage improvements provided within are designed to follow all pertinent Title 49 subsections as well as the Coconino County Engineering and Construction Criteria Manual. [2, 3]

2.0 Field Work

2.1 Existing Conditions

The client, Ivan Landry, GCUSD maintenance supervisor, provided a walking tour and description of current infrastructure during the site visit. The current infrastructure has evolved piecewise as the campus grew through its history. As a result, no master drainage plan exists. Presently, there are several small channels and culverts across the campus. There are signs of sedimentation decreasing the ability of current hydraulic structures to convey water off the premises. Figure 3 shows an example of the sedimentation disrupting a culvert's carrying capacity on site. Additional photos of the infrastructure are provided in Appendix A.

Figure 4: Example of current conditions of infrastructure and culvert carrying capacity [4]

During the site visit, the client commented on high velocity and overtopping in Area A and Area B. Area A deposits sediment across the parking lot to the north. Area B is the coalescence of two channels below an elevated walkway. The intersection tends to meander westward, eroding foundation of the building.

Additionally, the client expressed a need to address ponding in Area C and Area D. In both locations, impervious surface area associated with rooftop and surrounding walkway contributes to collection and concentration of rainfall. Lack of proper grading has caused flooding of entryways at these locations.

The overland flow in Area E is unrestrained and heavy storm occurrences typically result in overtopping of the road into neighboring residencies.

2.2 Robotic Total Station Survey

A survey of the four problem areas and surrounding landscape was performed using a robotic total station for precision and convenience. A total of 3400 surveying points was recorded. The point data is provided in Table 1 of Appendix B.

2.3 Topographic Map

Data collected from the robotic Total Station was imported to AutoCAD. Surfaces and hatching were applied accordingly. The complete topographic map is shown in Figure 4 on the following page. Additional topographic maps of problem areas A through E are provided in Appendix C.

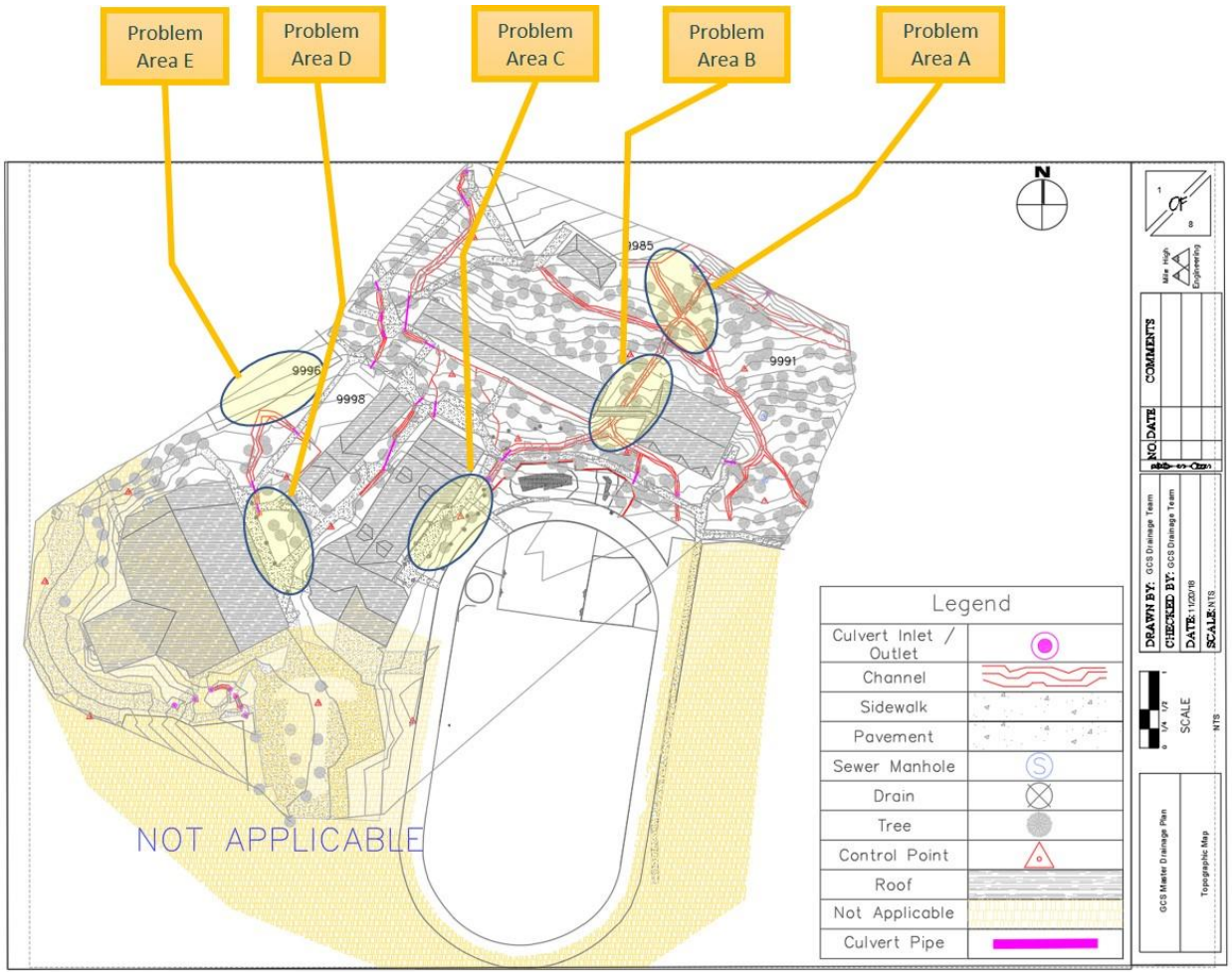

Figure 2: Completed topographic map of GCUSD campus with problem areas highlighted.

3.0 Hydrological Analysis

3.1 Delineation of Pertinent Watersheds

Points of concentration were chosen according to the problem areas identified. Delineated watersheds are provided in Figure 5 below.

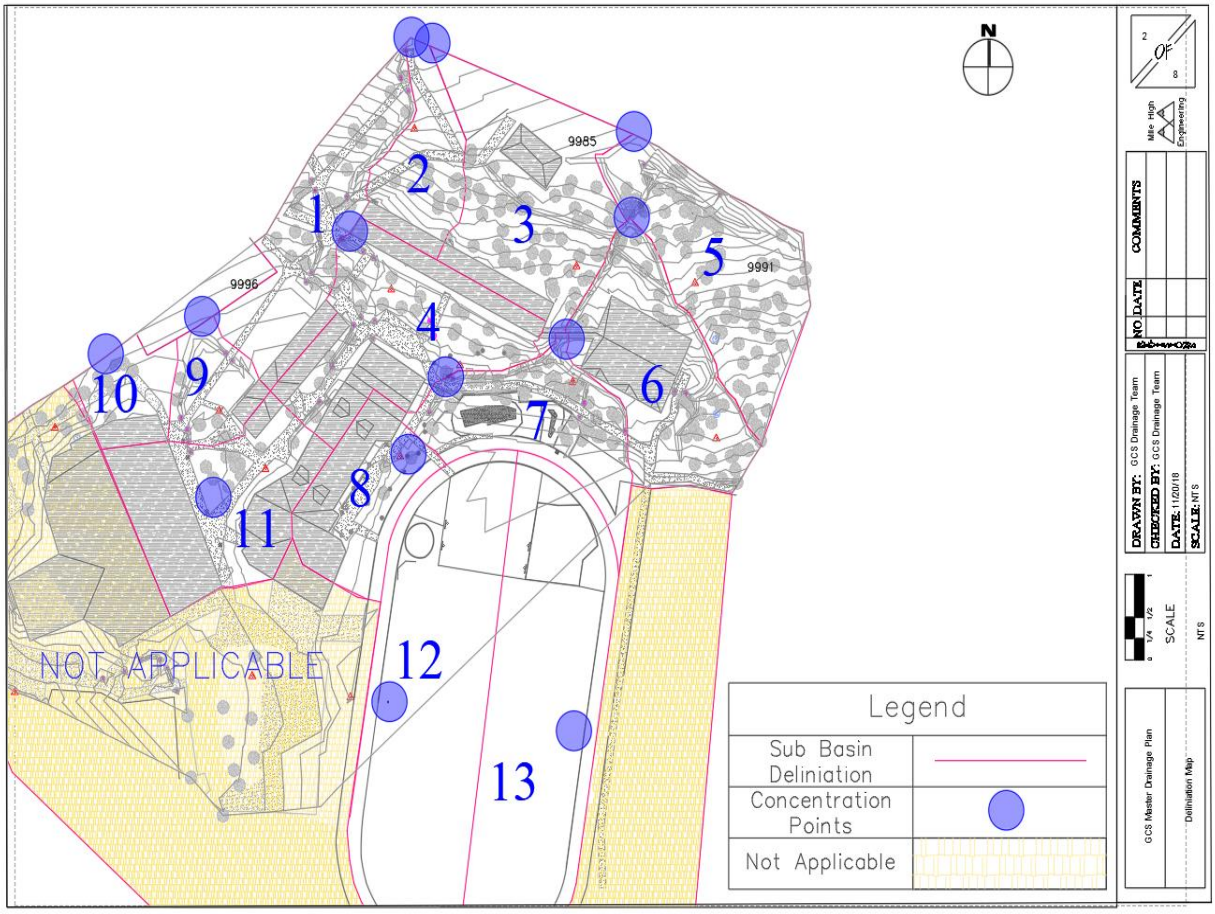

Figure 3: GCUSD campus watersheds delineated.

The area to the southwest was deemed Not Applicable, as it drains off the property, away from identified problem areas. Table 1 below shows the area of each watershed, as measured with AutoCAD.

Table 1: Measured Area of Delineated Sub-Basins for GCUSD Master Drainage Study

Grand Canyon School Sub Basin Delineation Information		
	Area (Sq Ft)	**Area (Acres)**
Sub Basin #1	20872.3	0.5
Sub Basin #2	11590.6	0.3
Sub Basin #3	22974.8	0.5
Sub Basin #4	27568.2	0.6
Sub Basin #5	26793.6	0.6
Sub Basin #6	25263.2	0.6
Sub Basin #7	19199.7	0.4
Sub Basin #8	15385.3	0.4
Sub Basin #9	7915.2	0.2
Sub Basin #10	7864.6	0.2
Sub Basin #11	25224.3	0.6
Sub Basin #12	51416.1	1.2
Sub Basin #13	47502.3	1.1
Total area	309570.1	7.1

3.2 Runoff Coefficient Analysis

The runoff coefficient for each sub-basin was determined using a weighted value dependent on the area within each sub-basin corresponding to terrain type. Table 2 shows the runoff coefficients used for each area type.

Table 2: Runoff Coefficients

Runoff Coefficients for GCUSD	
Terrain	Coefficient (C)
Woods, Gravelly Clay, Steep	0.17
Woods, Gravelly Clay, Average	0.12
Landscaping, Flat	0.1
Sidewalks	0.95
Parking Lot	0.95
Dense Vegetation, Clay Soils, Flat	0.15
Roof	0.95

Precipitation intensities for Average Recurrence Intervals of 25 and 50 years were, as per Coconino County Engineering and Construction Criteria Manual [3]. Antecedent Precipitation Factor of 1.1 and 1.2 are used for the 25 year and 50 year storm, respectively [3]. Table 3 summarizes data used for analysis.

Table 3: Summary of hydrological data and factors.

Hydrological Data and Factors		
Factor	**Average Recurrence Interval**	
	25 Years	**50 Years**
Precipitation Intensity (10 min)	1.16 in	1.43 in
Antecedent Precipitation Factor	1.1	1.2

Results for weighted runoff coefficients of each sub basin are shown in Table 4, below. Raw data tables for calculation of weighted runoff coefficients are provided in Appendix D.

Table 4: Results of weighted runoff coefficient determination

Weighted Runoff Coefficients for GCUSD Campus Sub-Basins	
Sub-Basin	Weighted C
1	0.345
2	0.364
3	0.338
4	0.574
5	0.145
6	0.444
7	0.302
8	0.618
9	0.339
10	0.401
11	0.760
12	0.113
13	0.112

3.3 Discharge Analysis through Modified Rational Method

The volumetric discharge of each sub-basin was calculated using the modified rational method, as per Coconino County Title 13. Equation 1 shows the modified rational method.

Equation 1: Modified Rational Equation

$$\boldsymbol{Q = C_f * C_w * I * A}$$

Where Q = volumetric discharge (cfs)
Cf = Antecedent Precipitation Factor
Cw = Weighted Runoff Coefficient
I = Rainfall Intensity (in/hr)
A = Sub-Basin Area (acres)

Results of discharge analysis for the 25 years flood are provided in Table 5.

Table 5: Results of discharge analysis for 10-minute duration with 25-year average recurrence.

Volumetric Discharge for 10 min duration for 25 years frequency					
Sub-Basin	**Cf**	**Cw**	**i (in/hr)**	**A (acres)**	**Q (cfs)**
1	1.1	0.35	4.16	0.5	0.8
2	1.1	0.36	4.16	0.3	0.4
3	1.1	0.34	4.16	0.5	0.8
4	1.1	0.57	4.16	0.6	1.7
5	1.1	0.15	4.16	0.6	0.4
6	1.1	0.44	4.16	0.6	1.2
7	1.1	0.30	4.16	0.4	0.6
8	1.1	0.62	4.16	0.4	1.0
9	1.1	0.34	4.16	0.2	0.3
10	1.1	0.40	4.16	0.2	0.3
11	1.1	0.76	4.16	0.6	2.0
12	1.1	0.35	4.16	1.2	1.9
13	1.1	0.38	4.16	1.1	1.9

Results of discharge analysis for the 50 years flood are provided in Table 6.

Table 6: Results of discharge analysis for 10-minute duration with 50-year average recurrence.

Volumetric Discharge for 10 min duration for 50 years frequency					
Sub-Basin	**Cf**	**Cw**	**i (in/hr)**	**A (acres)**	**Q (cfs)**
1	1.2	0.3	5.12	0.5	1.0
2	1.2	0.4	5.12	0.3	0.6
3	1.2	0.3	5.12	0.5	1.1
4	1.2	0.6	5.12	0.6	2.2
5	1.2	0.1	5.12	0.6	0.5
6	1.2	0.4	5.12	0.6	1.6
7	1.2	0.3	5.12	0.4	0.8
8	1.2	0.6	5.12	0.4	1.3
9	1.2	0.3	5.12	0.2	0.4
10	1.2	0.4	5.12	0.2	0.4
11	1.2	0.8	5.12	0.6	2.7
12	1.2	0.3	5.12	1.2	2.5
13	1.2	0.4	5.12	1.1	2.5

Results of discharge analysis of each problem area for the 25 and 50 years flood provided in Table 7

Table 7: Results of discharge analysis of each problem area for 25 and 50 years average recurrence

Problem Area	Total Q for 25 yr	Total Q for 50 yr
	(cfs)	
A	6.6	8.8
B	5.4	7.2
C	2.9	3.9
D	2.0	2.7
E	2.6	3.5

4.0 Hydraulic Analysis of Existing Infrastructure

The following sections provide the results of hydraulic analysis for existing infrastructure including channels in Problem Area A and B as well as all culverts on the property.

4.1 Existing Culvert Analysis

An inventory of existing culverts is shown in Figure 6 below.

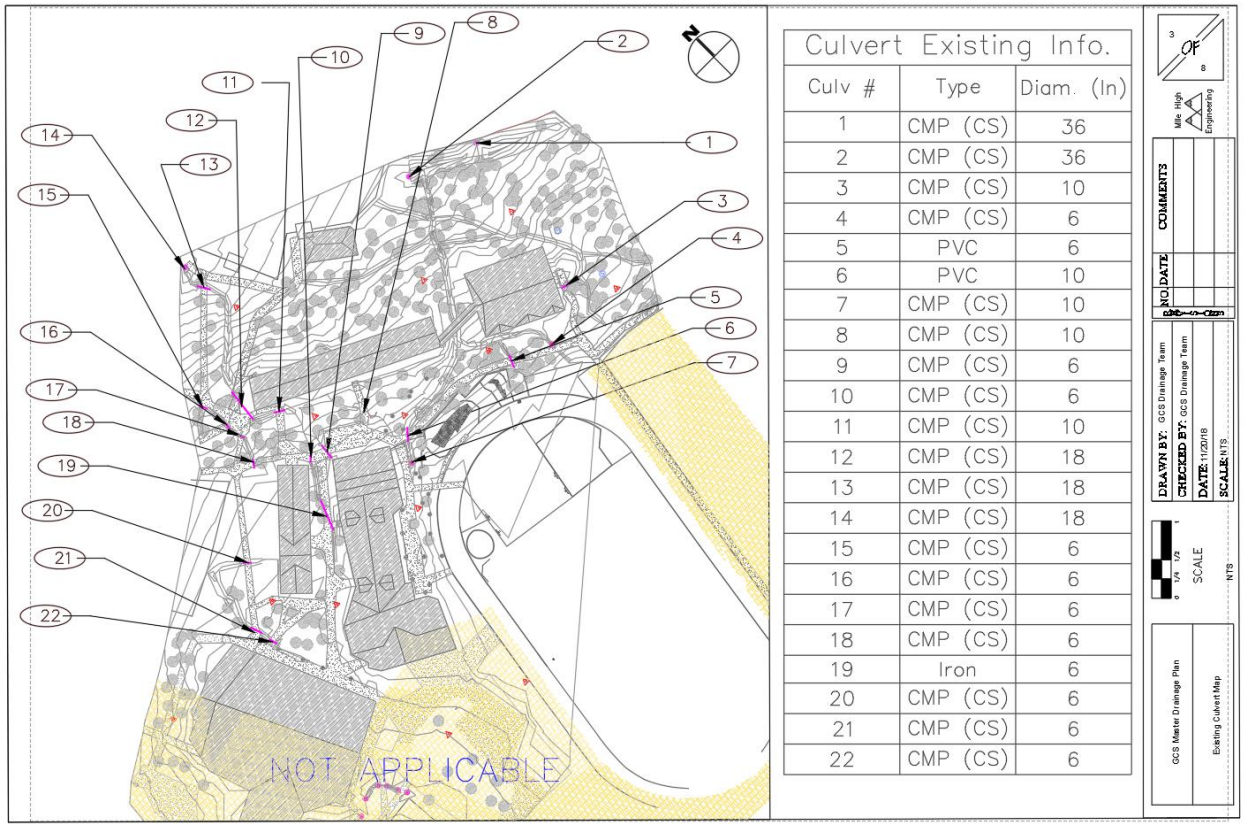

Figure 4: Inventory and location summary of existing culverts on GCUSD campus.

CulvertMaster was used to analyze all existing culverts. The parameters used to determine pass/fail during CulvertMaster analysis are as follows

- Maximum Headwater Elevation: 1 foot above Upstream Invert Elevation
- Maximum Height of Culvert: 2 feet
- Velocity Range in Culvert: 3-15 feet/sec
- Allowable Velocity in Channel: 5 feet/sec

A summary table of results of analysis is provided in Table 8 below.

Table 8: Summary Table of CulvertMaster results for existing culverts

Existing Condition Analysis				
Culvert	Elevation Above Crown	Downstream velocity	Notes	Pass/Fail
(#)	*(ft)*	*(ft/s)*		
1				n/a
2				n/a
3	2.56	8.43		FAIL
4				n/a
5	2.1	9.22		FAIL
6	1.17	7.05		FAIL
7				n/a
8	1.80	7.05		FAIL
9	0.61	5.2	**Actual diameter 6 inches	FAIL
10	0.13	4.51	**Actual diameter 6 inches	FAIL
11	-0.14	3.84	**Actual diameter 10 inches	PASS
12	-0.16	4.80		PASS
13	-0.17	4.80		PASS
14				n/a
15	0.13	4.51	**Actual diameter 6 inches	FAIL
16	0.13	4.51	**Actual diameter 6 inches	FAIL
17	0.27	4.51	**Actual diameter 6 inches	FAIL
18	0.07	5.09	**Actual diameter 6 inches	FAIL
19	0.07	5.28	**Actual diameter 6 inches	FAIL
20	0.71	5.2	**Actual diameter 6 inches	FAIL
21	0.05	4.04	**Actual diameter 6 inches	FAIL
22	0.05	4.04	**Actual diameter 6 inches	FAIL

As seen in Table 8, Culverts 3, 5, 6, 8-10, and 15-22 are failing to convey runoff for both 25 and 50 year storm. Culverts 1, 2, 4, 7, 14 had inlets or outlets outside the range of this study and were therefore not analyzed. Culverts 11, 12, 13 were found to be acceptable. Note, several culverts were inventoried with a diameter of 6 inches. CulvertMaster will only analyze a minimum 12 inch diameter pipe. However, analyzed at 12 inch diameter, the culverts still failed; constituting a fail for the actual existing culvert.

After existing culvert analysis was performed, CulvertMaster was used to solve for the size of culvert needed to convey both 25 and 50 year flood intervals. Differing shapes of culverts were analyzed as well as entrance type and number of culverts in parallel. A slope % of 1 was used to simplify analysis. Results of CulvertMaster Analysis is provided in Appendix E. Table 9 below shows a summary of proposed culvert design.

Table 9: Summary table of proposed culvert design for GCUSD campus

Proposed Culvert Design							
Culvert ID	Entrance	Slope (%)	Shape	Material	Size	Number	Length (Ft)
1	Insufficient field data.						
2	Insufficient field data.						
3	Beveled ring, 33.7° (1.5:1)bevels	1	Circular	CMP	18 inch	2	12
4	Insufficient field data.						
5	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	22x34 inch	1	14
6	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	22x34 inch	1	20
7	Insufficient field data.						
8	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	22x34 inch	1	14
9	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	14x23 inch	1	15
10	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	14x23 inch	1	10
11	No Improvement Required						
12	No Improvement Required						
13	No Improvement Required						
14	Insufficient field data.						
15	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	14x23 inch	1	10
16	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	14x23 inch	1	10
17	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	14x23 inch	1	10
18	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	14x23 inch	1	10
19	Beveled ring, 33.7° bevels	1	Circular	Corrugated HDPE (Smooth Interior)	12 inch	2	35
20	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	14x23 inch	1	10
21	Beveled ring, 33.7° bevels	1	Circular	Corrugated HDPE (Smooth Interior)	15 inch	1	12
22	Beveled ring, 33.7° bevels	1	Circular	Corrugated HDPE (Smooth Interior)	15 inch	1	12
23	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	19x30 inch	3	6
24	45° wingwall flares – offset	1	Box	Concrete	4x4 feet	1	10
25	Groove end projecting (horizontal ellipse)	1	Horizontal Ellipse	Concrete	14x23 inch	1	10

4.2 Existing Channel Analysis

FlowMaster was used for the analysis in problem area A and B to compute velocity, flow type, elevation difference, and depth to floodplain. All the results of the analysis are showing in the appendix section E. All the types of the flow is Supercritical as it shown in the reports in the appendix section E. Figure 16 in appendix E is showing the location of all the cross sections for problems A and B. There are three cross sections on each right and left upstream in problem area A and one on right and left downstream in this area. For problem area B, there are two on the right and left upstream and one downstream. The analysis were for 25 years and 50 years for each cross section on these problem areas. Appendix E-1 shows the results of the 25-year analysis for problem area A and appendix E-2 is showing the results of the 50-year analysis in problem area A also. Appendix E-3 is the beginning of the results and analysis of area problem B for 25 years, this section shows that the cross section RUR cs 1 is over flowing. Appendix E-4 is the results and analysis of area problem B analysis for 50 years, in this section it shows that the cross section RUR cs 1 is over flowing for 50 years analysis also.

5.0 Area A Proposed Improvements

5.1 Preliminary Design

The preliminary design and proposed alternatives for problem area A consists of the installation of check dams, culverts, and a mix of cut and fill. This problem area in particular was recommended for the following:

- Install 2 18 inch diameter Corrugated metal pipe culvert with a 10 foot length
- Insert a 4 foot by 4 foot box concrete culvert with a 10 foot length
- Install 3 19 inch by 30 inch horizontal ellipse concrete culverts with a 6 foot length
- Approximate cut and fill where culverts need installation and channels need widening

Alternatives were proposed to ensure prevention of constant blowout from two channels colliding and erosion of the foundation for the buildings elevated walkway. Please see appendix figure 11 for the complete construction plans with notes and additional details. This will also show the exact location of the proposed installations and modifications.

5.2 Hydraulic Analysis

A complete hydraulic analysis was utilized for all problem areas. After the analysis of their current existing infrastructure, proposed alternatives were explored. Different cross sections were ran through Bentley Flow master to ensure capacity, flow type, velocity, elevation difference, as well as flood plain elevation. Proposed culverts for each existing culvert that failed were then analyzed to ensure that water would be carried off the property in a fashion without ponding, erosion, and degradation. Per each problem area, the grading, installation, cut and fill, and options differ due to existing conditions and needs.

5.3 Cost to Implement

Table 8 below shows the proposed alternatives and their costs with respect to labor, linear feet, and installation [8,9].

Table 10: This table shows the complete construction and implementation costs for the proposed alternatives within problem area A

Material and Installation Cost for Problem area A								
Type	**# of Units**	**Material**	**Length**	**Cost ($)/linear ft**	**Labor ($) / Hour**	**# of Hours**	**Installation ($)**	**Cost ($)**
18" Dia. CMP Culv.	2	CMP	10 Ft	27	30	10	1550	3670
4'x4' Concrete Box Culv.	1	Concrete	10 Ft	63.2	30	10	2445	5822
19"x30" Horiz. Concrete Ellipse Culv.	3	Concrete	6 Ft	51.7	30	10	1830	4477

Cut	9 CY	Soil	N/A	N/A	30	10	N/A	300
Fill	2 CY	Soil	N/A	N/A	30	10	N/A	300
								$14569

6.0 Area B Proposed Improvements

6.1 Preliminary Design

The preliminary design and proposed alternatives for problem area B consists of the installation of culverts, channel widening and a mix of cut and fill. This problem area in particular was recommended for the following:

Install 1 22 inch by 34 inch horizontal ellipse concrete culvert with a 14 foot length

Install 1 22 inch by 34 inch horizontal ellipse concrete culvert with a 20 foot length

Insert a 4 foot by 4 foot box concrete culvert with a 10 foot length

Approximate cut and fill where culverts need installation and channels need widening

Alternatives were proposed to ensure prevention of ponding and erosion of the foundation for the buildings elevated walkway. Please see appendix Figure 12 for the complete construction plans with notes and additional details. This will also show the exact location of the proposed installations and modifications.

6.2 Hydraulic Analysis

A complete hydraulic analysis was utilized for all problem areas. After the analysis of their current existing infrastructure, proposed alternatives were explored. Different cross sections were ran through Bentley Flow master to ensure capacity, flow type, velocity, elevation difference, as well as flood plain elevation. Proposed culverts for each existing culvert that failed were then analyzed to ensure that water would be carried off the property in a fashion without ponding, erosion, and degradation. Per each problem area, the grading, installation, cut and fill, and options differ due to existing conditions and needs.

6.3 Cost to Implement

Table 11 below shows the proposed alternatives and their costs with respect to labor, linear feet, and installation [8,9].

Table 11: This table shows the complete construction and implementation costs for the proposed alternatives within problem area B

Material and Installation Cost for Problem area B								
Type	**# of Units**	**Material**	**Length**	**Cost ($)/linear ft**	**Labor ($) / Hour**	**# of Hours**	**Installation ($)**	**Cost ($)**
22"x34" Horiz.	1	Concrete	10 Ft	27	30	10	1550	2120

Concrete Ellipse Culv.								
22"x34" Horiz. Concrete Ellipse Culv.	1	Concrete	10 Ft	63.2	30	10	2445	3377
4'x4' Concrete Box Culv.	1	Concrete	10 Ft	63.2	30	10	2445	5822
Cut	5 CY	Soil	N/A	N/A	30	10	N/A	300
Fill	3 CY	Soil	N/A	N/A	30	10	N/A	300
								$11919

7.0 Area C Proposed Improvements

7.1 Preliminary Design

The preliminary design and proposed alternatives for problem area C consists of the installation of culverts, channel widening and a mix of cut and fill. This problem area in particular was recommended for the following:

Install 1 14 inch by 23 inch horizontal ellipse concrete culvert with a 10 foot length

Approximate cut and fill where culverts need installation and channels need widening

Alternatives were proposed to ensure prevention of ponding and backflow of water runoff into the building. Please see appendix figure 13 for the complete construction plans with notes and additional details. This will also show the exact location of the proposed installations and modifications.

7.2 Hydraulic Analysis

A complete hydraulic analysis was utilized for all problem areas. After the analysis of their current existing infrastructure, proposed alternatives were explored. Different cross sections were ran through Bentley Flow master to ensure capacity, flow type, velocity, elevation difference, as well as flood plain elevation. Proposed culverts for each existing culvert that failed were then analyzed to ensure that water would be carried off the property in a fashion without ponding, erosion, and degradation. Per each problem area, the grading, installation, cut and fill, and options differ due to existing conditions and needs.

7.3 Cost to Implement

Table 12 below shows the proposed alternatives and their costs with respect to labor, linear feet, and installation [8,9].

Table 12: This table shows the complete construction and implementation costs for the proposed alternatives within problem area C

Material and Installation Cost for Problem area C

Type	# of Units	Material	Length	Cost ($)/linear ft	Labor ($) / Hour	# of Hours	Installation ($)	Cost ($)
14"x23" Horiz. Concrete Ellipse Culv.	1	Concrete	10 Ft	27	30	10	1550	2120
Cut	15 CY	Soil	N/A	N/A	30	10	N/A	600
Fill	1 CY	Soil	N/A	N/A	30	10	N/A	300
								$3020

8.0 Area D Proposed Improvements

8.1 Preliminary Design

The preliminary design and proposed alternatives for problem area D consists of the installation of culverts, channel widening and a mix of cut and fill. This problem area in particular was recommended for the following:

Install 1 15 inch HDPE (smooth interior) culvert with a 12 foot length

Install 1 15 inch HDPE (smooth interior) culvert with a 24 foot length

Approximate cut and fill where culverts need installation and channels need widening

Alternatives were proposed to ensure prevention of ponding and backflow of runoff water into the existing buildings. Please see appendix figure 14 for the complete construction plans with notes and additional details. This will also show the exact location of the proposed installations and modifications.

8.2 Hydraulic Analysis

A complete hydraulic analysis was utilized for all problem areas. After the analysis of their current existing infrastructure, proposed alternatives were explored. Different cross sections were ran through Bentley Flow master to ensure capacity, flow type, velocity, elevation difference, as well as flood plain elevation. Proposed culverts for each existing culvert that failed were then analyzed to ensure that water would be carried off the property in a fashion without ponding, erosion, and degradation. Per each problem area, the grading, installation, cut and fill, and options differ due to existing conditions and needs.

8.3 Cost to Implement

Table 13 below shows the proposed alternatives and their costs with respect to labor, linear feet, and installation [8,9].

Table 13: This table shows the complete construction and implementation costs for the proposed alternatives within problem area D

Material and Installation Cost for Problem area D

Type	# of Units	Material	Length	Cost ($)/linear ft	Labor ($) / Hour	# of Hours	Installation ($)	Cost ($)
15" Dia. HDPE Culv.	1	HDPE	12 Ft	15	30	10	1390	1870
15" Dia. HDPE Culv.	1	HDPE	24 Ft	15	30	10	1390	2050
Cut	1 CY	Soil	N/A	N/A	30	10	N/A	300
Fill	3 CY	Soil	N/A	N/A	30	10	N/A	300
								$4520

9.0 Area E Proposed Improvements

9.1 Preliminary Design

The preliminary design and proposed alternatives for problem area D consists of the installation of culverts, channel widening and a mix of cut and fill. This problem area in particular was recommended for the following:

Install 1 15 inch HDPE (smooth interior) culvert with a 12 foot length

Install 1 14 inch by 23 inch horizontal ellipse concrete culvert with a 10 foot length

Approximate cut and fill where culverts need installation and channels need widening

Alternatives were proposed to ensure prevention of ponding and sheet flow of runoff water into the existing buildings and neighboring properties. Please see appendix Figure 15 for the complete construction plans with notes and additional details. This will also show the exact location of the proposed installations and modifications.

9.2 Hydraulic Analysis

A complete hydraulic analysis was utilized for all problem areas. After the analysis of their current existing infrastructure, proposed alternatives were explored. Different cross sections were ran through Bentley Flow master to ensure capacity, flow type, velocity, elevation difference, as well as flood plain elevation. Proposed culverts for each existing culvert that failed were then analyzed to ensure that water would be carried off the property in a fashion without ponding, erosion, and degradation. Per each problem area, the grading, installation, cut and fill, and options differ due to existing conditions and needs.

9.3 Cost to Implement

Table 14 below shows the proposed alternatives and their costs with respect to labor, linear feet, and installation [8,9].

Table 14: This table shows the complete construction and implementation costs for the proposed alternatives within problem area E

Material and Installation Cost for Problem area E

Type	# of Units	Material	Length	Cost ($)/linear ft	Labor ($) / Hour	# of Hours	Installation ($)	Cost ($)
15" Dia. HDPE Culv.	1	CMP	12 Ft	15	30	10	1390	1870
14"x23" Horiz. Concrete Ellipse Culv.	1	Concrete	10 Ft	27	30	10	1550	2120
Cut	1 CY	Soil	N/A	N/A	30	10	N/A	300
Fill	3 CY	Soil	N/A	N/A	30	10	N/A	300
								$4590

10.0 Proposed Phasing

The following sections propose an implementation plan in three phases and provide the cost for each phase.

10.1 Implementation Plan

Phase 1 will focus on Problem Areas D and E to prioritize the safety of students and faculty as well as terminate contribution to flood damage of neighboring properties. Phase 1 begins with regrading of Problem Area D to convey runoff toward Culvert 22. Additional regrading will be performed in Problem Area E, east of parking lot, to create a berm and channelize runoff toward Culvert 18. The addition of Culvert 25 under walkway will allow flow from berm to Culvert 18. Finally, Culverts 21 and 22 will be upgraded as seen in Table ??.

Phase 2 will focus on Problem Areas A and B to improve channel performance and minimize maintenance requirements. Phase 2 will begin with the installation of Culvert 23, a Y-Culvert assembly of 3 horizontal ellipse culverts within the channel at intersection in Problem Area A. Additionally, the installation of Culvert 24 underneath walkway in Problem Area B will be completed.

Phase 3 will include the upgrade of culverts which showed extreme poor performance. This includes Culvert 3, 5, 8, 9, and 20. These culverts showed overtopping greater than 6 inches above crown and will be upgraded as seen in Table ??

Phase 4 will include the upgrade of all additional culverts, with the exception of Culvert 6 to improve overall water conveyance. This includes Culverts 10, 15, 16, 17, 18, and 19. These culverts will be upgraded as seen in Table ??

Phase 5 should only be performed after construction and addition of impervious surface in Problem Area C is complete. An updated hydrologic and hydraulic analysis should be completed

prior to improvements suggested in Phase 5. At this stage, regrading can be performed as needed as well as the installation of Culvert 6.

10.2 Phased Costs

Tables 15-19 below show the costs for each proposed phase of implementation.

Table 15: Cost Summary for Phase 1

Phase 1 Cost Summary			
Item	Material Cost	Labor Cost	Total Cost
Culvert 21	180	1390	1570
Culvert 22	180	1390	1570
Culvert 25	517	1550	2067
Cut/Fill		600	600
Total Cost of Phase1	877	4930	5807

Table 16: Cost Summary for Phase 2

Phase 2 Cost Summary			
Item	Material Cost	Labor Cost	Total Cost
Culvert 23	1093	1830	2923
Culvert 24	418	2475	2893
Cut/Fill		600	600
Total Cost of Phase1	1511	4905	6416

Table 17: Cost Summary for Phase 3

Phase 3 Cost Summary			
Item	Material Cost	Labor Cost	Total Cost
Culvert 3	324	1550	1874
Culvert 5	885	2445	3330
Culvert 8	885	2445	3330
Culvert 9	776	1550	2326
Culvert 20	517	1550	2067
Cut/Fill		900	
Total Cost of Phase1	3387	10440	13827

Table 18: Cost Summary for Phase 4

Phase 4 Cost Summary			
Item	Material Cost	Labor Cost	Total Cost
Culvert 10	517	1550	2067
Culvert 15	517	1550	2067
Culvert 16	517	1550	2067
Culvert 17	517	1550	2067
Culvert 18	517	1550	2067

Culvert 19	420	1550	1970
Cut/Fill		600	600
Total Cost of Phase1	3005	9900	12905

Table 19: Cost Summary for Phase 5

Phase 5 Cost Summary			
Item	Material Cost	Labor Cost	Total Cost
Culvert 6	1264	2445	3709
Cut/Fill		600	600
Total Cost of Phase1	1264	3045	4309

11.0 Summary of Engineering Work

Table 20 below shows the proposed and actual project schedule. The highlighted tasks those in which start and end dates and/or duration were significantly different from proposed to actual.

Table 20: Proposed (CENE476) and Completed (CENE486) schedule

Task	Proposed			Computed		
	Duration	Start	End	Duration	Start	End
1.0 Field Work	7 days	Wed 8/1/18	Wed 8/8/18	3 days	Mon 8/13/18	Wed 8/15/18
1.1 Complete Nau Safety forms	2 days	Wed 8/1/18	Thu 8/2/18	2 days	Mon 8/13/18	Tue 8/14/18
1.2 Field Investigation	3 days	Mon 8/6/18	Wed 8/8/18	1 day	Wed 8/15/18	Wed 8/15/18
2.0 Survey With GPS	8 days	Thu 8/9/18	Fri 8/17/18	13 days	Wed 8/15/18	Fri 8/31/18
2.1 Inventory of Existing Infrastructure	5 days	Thu 8/9/18	Tue 8/14/18	8 days	Wed 8/15/18	Fri 8/24/18
2.2 Record data points in Excel and create topo map with AutoCAD	4 days	Tue 8/14/18	Fri 8/17/18	5 days	Tue 8/14/18	Mon 8/20/18
3.0 Calculate Discharge From Hydrological Data	8 days	Mon 8/20/18	Wed 8/29/18	12 days	Tue 8/21/18	Wed 9/5/18
3.1 Watershed Delineation	5 days	Mon 8/20/18	Fri 8/24/18	7 days	Tue 8/21/18	Wed 8/29/18
3.2 Weighted Runoff Coefficient Determination	3 days	Mon 8/27/18	Wed 8/29/18	5 days	Thu 8/30/18	Wed 9/5/18
4.0 Evaluate Hydraulics	20 days	Mon 9/3/18	Fri 9/28/18	35 days	Thu 9/6/18	Wed 10/24/18
4.1 Existing Culvert Analysis	5 days	Mon 9/3/18	Fri 9/7/18	20 days	Thu 9/6/18	Wed 10/3/18
4.2 Develop Alternative Culvert Designs	5 days	Mon 9/10/18	Fri 9/14/18	5 days	Thu 10/4/18	Wed 10/10/18
4.3 Existing Channel Analysis	5 days	Mon 9/17/18	Fri 9/21/18	5 days	Thu 10/11/18	Wed 10/17/18
4.4 Develop Alternative Channel Designs	5 days	Mon 9/24/18	Fri 9/28/18	5 days	Thu 10/18/18	Wed 10/24/18
5.0 Generate Conceptual Design Plans	15 days	Mon 10/1/18	Fri 10/19/18	28 days	Thu 10/25/18	Mon 12/3/18
5.1 Overlay Existing Maps	5 days	Mon 10/1/18	Fri 10/5/18	15 days	Mon 10/1/18	Fri 10/19/18
5.2 Draft Alternatives	8 days	Mon 10/8/18	Wed 10/17/18	5 days	Mon 10/8/18	Fri 10/12/18
5.3 Determine Material Quantities	8 days	Mon 10/8/18	Wed 10/17/18	8 days	Mon 10/8/18	Wed 10/17/18
6.0 Project Management	104 days	Wed 8/1/18	Thu 12/20/18	90 days	Mon 8/13/18	Fri 12/14/18
6.1 Meetings	9 days	Tue 8/21/18	Fri 8/31/18	9 days	Tue 8/21/18	Fri 8/31/18
6.2 Minutes and Notes	8 days	Sat 8/11/18	Tue 8/21/18	8 days	Sat 8/11/18	Tue 8/21/18
6.3 Task assignment and feedback	3 days	Wed 9/5/18	Fri 9/7/18	3 days	Wed 9/5/18	Fri 9/7/18
6.4 Deliverable Items	80 days	Fri 8/31/18	Thu 12/20/18	76 days	Fri 8/31/18	Fri 12/14/18
6.4.1Status Updates	5 days	Mon 8/27/18	Fri 8/31/18	5 days	Fri 8/31/18	Thu 9/6/18
6.4.2 30% design	5 days	Mon 9/24/18	Fri 9/28/18	3 days	Mon 9/24/18	Wed 9/26/18
6.4.3 60% design	10 days	Thu 11/1/18	Wed 11/14/18	10 days	Thu 11/1/18	Wed 11/14/18
6.4.4 90% website	10 days	Sat 11/17/18	Thu 11/29/18	10 days	Sat 11/17/18	Thu 11/29/18
6.4.5 Final Presentation	10 days	Sun 12/9/18	Thu 12/20/18	8 days	Wed 11/28/18	Fri 12/7/18
6.4.6 Final Report	13 days	Tue 12/4/18	Thu 12/20/18	9 days	Tue 12/4/18	Fri 12/14/18

Table 21 below shows proposed and actual hours for each staff in all the tasks. The total proposed hours for the project was 701 hours and the actual total hours worked is 819 hours.

Table 21: Major Tasks and staff hours

Major Tasks and Staff Proposed & Actual (Hrs)									
#	**Task Description**	**Principle**	**Manager**	**PE**	**EIT**	**Tech**	**Admin**	**Proposed hours**	**Actual Hours**
1	Field Work	1	1	3	8	0	1	32	14
2	Surveying with GPS	0	0	4	90	0	0	53	94
3	Hydrology	1	1	2	20	20	0	30	44
4	Evaluate Hydraulics	0	0	4	20	10	0	120	34
5	Generate Conceptual Design Plans	1	8	8	24	24	24	54	89
6	Provide Documentation	0	0	8	24	24	8	14	64
7	Project Management	40	80	40	120	120	80	400	480
Total Staff Hours		43	90	69	306	198	113	**703**	**819**

12.0 Summary of Engineering Costs

Material cost was measured based on the proposed solution, where the costs were measured from the RS means book [8]. The installation cost was measured based on the cost of the material and the type of the material as provided on table 10 [9]. These costs were determined based on the proposed solutions for the problematic areas.

Table 22: Material and installation cost [8] [9]

Material and Installation Cost						
Culvert (Name)	**Material**	**Equivalent diameter**	**Length**	**Cost ($)/linear ft**	**Installation ($)**	**Cost ($)**
3	CMP	18”	12	27	1,550	2,198.0
5	Concrete	27”	14	63.2	2,445	3,330.2
6	Concrete	27”	20	63.2	2,445	3,709.6
8	Concrete	27”	14	63.2	2,445	3,330.2
9	Concrete	18”	15	51.7	1,550	2,325.4
10	Concrete	18”	10	51.7	1,550	2,066.9
15	Concrete	18”	10	51.7	1,550	2,066.9
16	Concrete	18”	10	51.7	1,550	2,066.9
17	Concrete	18”	10	51.7	1,550	2,066.9
18	Concrete	18”	10	51.7	1,550	2,066.9
19	Corrugated HDPE (Smooth Interior)	15”	35	12	1,390	2,230.0
20	Concrete	18”	10	51.7	1,550	2,066.9
21	Corrugated HDPE (Smooth Interior)	15”	12	15	1,390	1,570.0
22	Corrugated HDPE (Smooth Interior)	15”	12	15	1,390	1,570.0
23	Concrete	24”	6	60.7	1,830	2,923.0

24	Concrete	4x4 ft	10	41.8	2,475	2,893.2
25	Concrete	18”	10	51.7	1,550	2,066.9
TOTAL Cost ($)						40,548

Results of the staff members’ rates and hours are provided in Table 23, including the proposed hours and rates and the actual hours and rates.

Table 23: Staff Member Rates and Hours

Staff Member Rates and Hours					
Position	**Rate ($/hr)**	**Proposed**		**Actual**	
		(hrs)	**(USD)**	**(hrs)**	**(USD)**
Principal Engineer	200	57	11,400	43	8,600
Manager	125	45	5,625	90	11,250
Project Engineer	142	96	13,632	69	9798
EIT	105	201	21,105	306	32,130
Tech	80	208	16,640	198	15,840
Administration	50	96	4,800	113	5,650
TOTAL HOURS		703		819	
TOTAL USD $		73,202		83,268	

Results of engineering services are provided in Table 24, including the cost of travel and equipment rental based on 5 days.

Table 24: COST OF ENGINEERING SERVICES

COST OF ENGINEERING SERVICES	
Cost of Travel	
Mileage Cost	$300
Car Rental ($/day)	$55
Total Travel Cost for 5 days	$575
Cost of Equipment	
Surveying Equipment ($/day)	$250
Total Equipment Rental for 5 days	$1,250

Finally, the summary of expenses results are provided in Table 25, including the total cost of the project.

Table 25: Summary of Expenses

Summary of Expenses	
Total Cost of Engineering Services	$1,825
Total Staffing Cost	$83,268

Cost of Materials and Labor [8,9]	$40,548
Total Cost of Project	$125,641

REFERENCES

[1] "ArcGIS.com," 2018. [Online]. Available: https://www.arcgis.com/features/index.html. [Accessed 20 October 2018].

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[3] "Coconino County Engineering Construction Criteria Manual," Coconino.AZ.gov, 2018. [Online]. Available:http://coconino.az.gov/DocumentCenter/View/1788. [Accessed 14 August 2018].

[4] M. Lamer, Site photographs of Grand Canyon Unified School District, Grand Canyon Village, 2018.

[5] AutoCAD. (2018). AutoDesk.

[6] Google Earth. (2018). Google.

[7] FlowMaster. (2018). Bentley Systems.

[8] M. Mossman, "Means Facilities Construction Cost Data," Kingstone, MA, R.S. Means, Co, 2005.

[9] "CULVERT PRICE LIST," townofwaukesha.us, Waukesha, WI, 2009.

Appendix A: Existing Infrastructure Site Photos

Figure 5: Example of Culvert on Site

Figure 6: Example of surface flow causing erosion

Figure 7: Example of channel on site (a)

Figure 8: Example of drainage area (a)

Figure 9: Example of drainage area (b)

Appendix B: Total Station Raw Point Data

See attached excel file.

Appendix C-1: Topographic Map of Area A

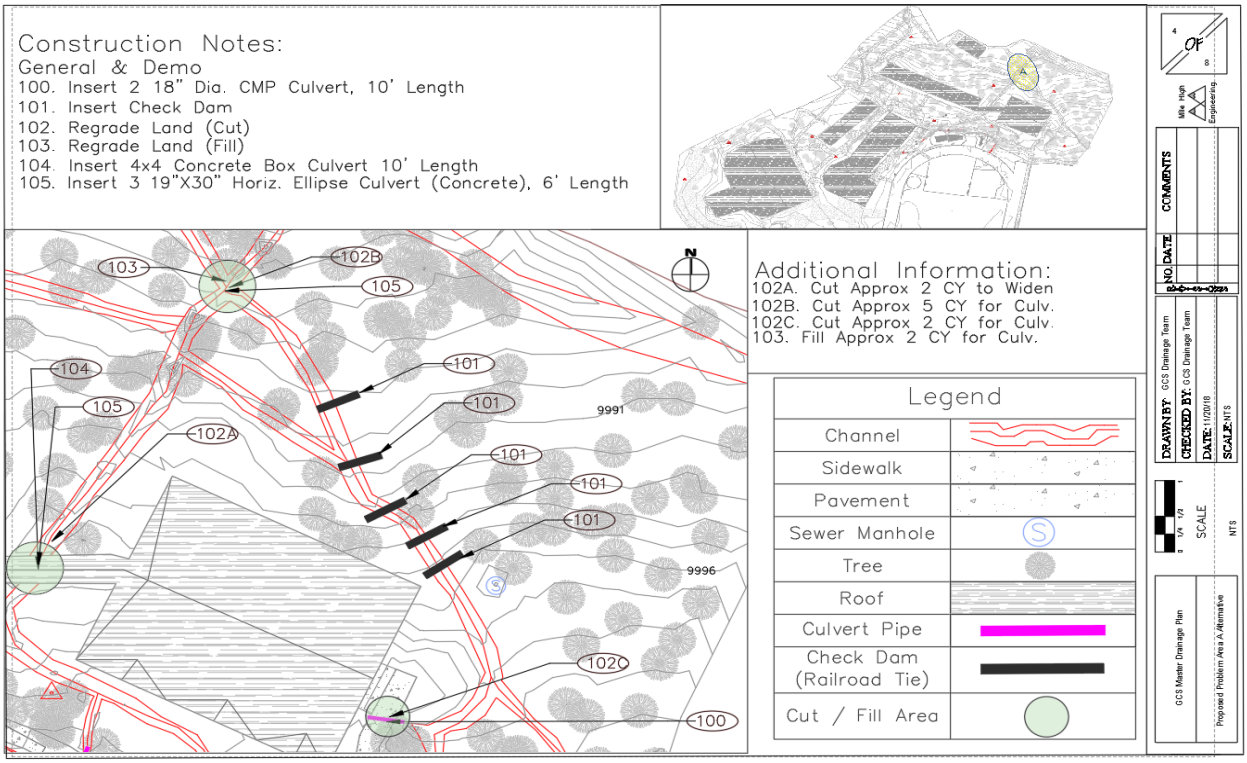

Figure 10: Topographic map of Problem Area A with the proposed alternatives, construction notes, details, and additional information.

Appendix C-2: Topographic Map of Area B

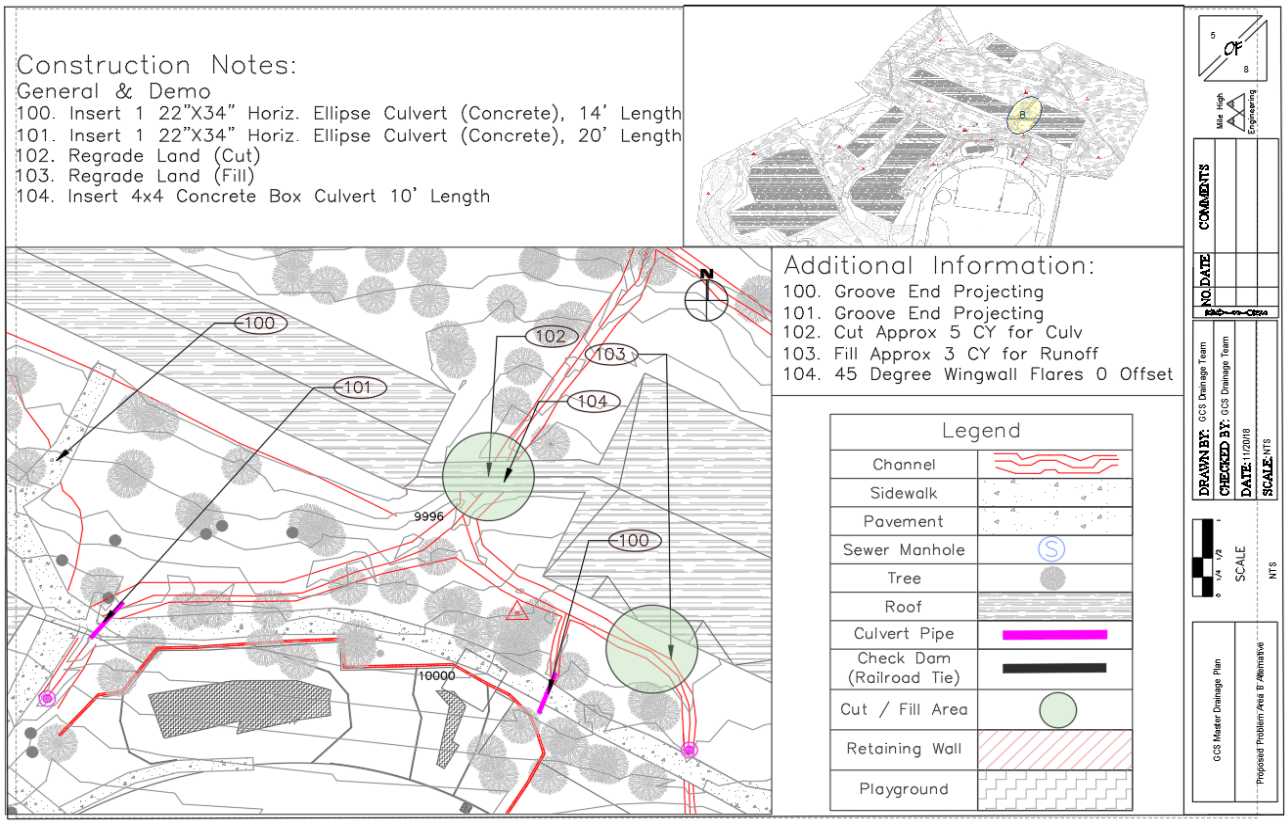

Figure 11: Topographic map of Problem Area B with the proposed alternatives, construction notes, details, and additional information.

Appendix C-3: Topographic Map of Area C

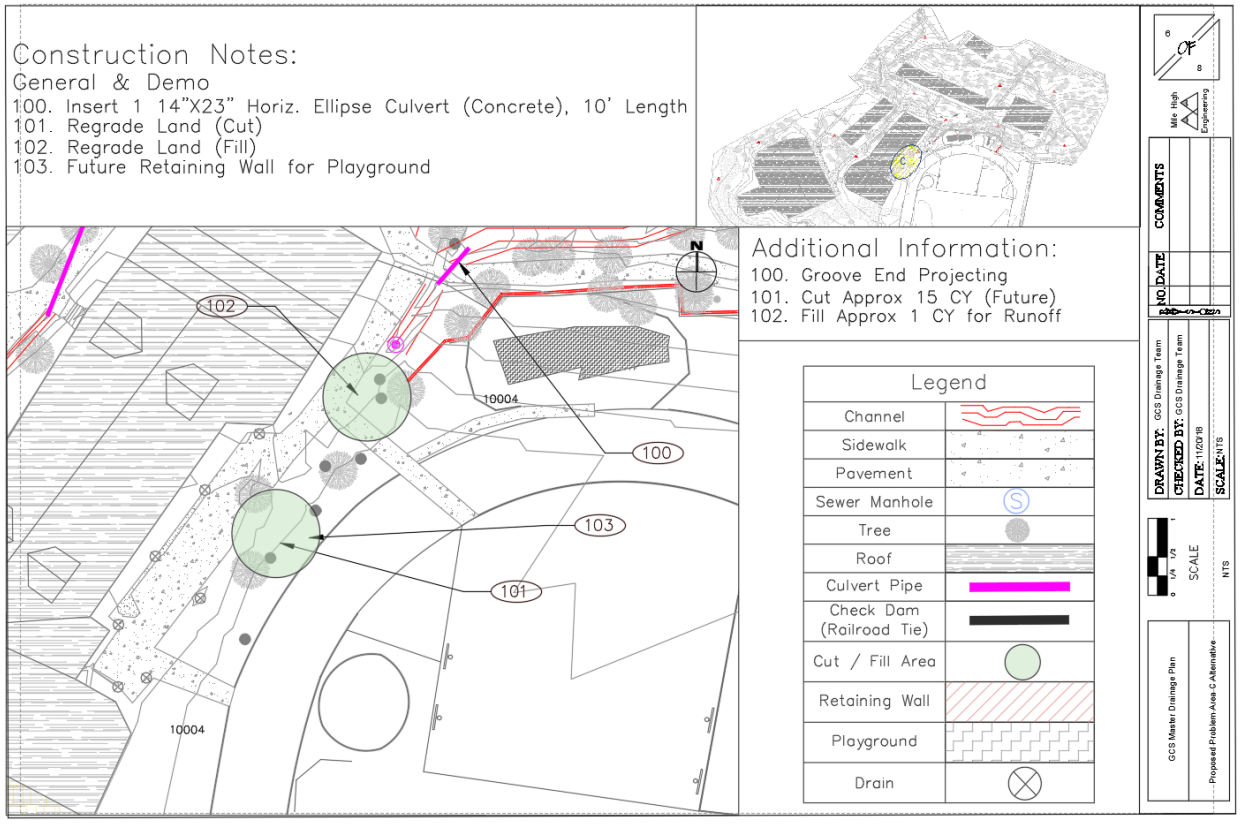

Figure 12: Topographic map of Problem Area C with the proposed alternatives, construction notes, details, and additional information.

APPENDIX C-4: TOPOGRAPHIC MAP OF AREA D

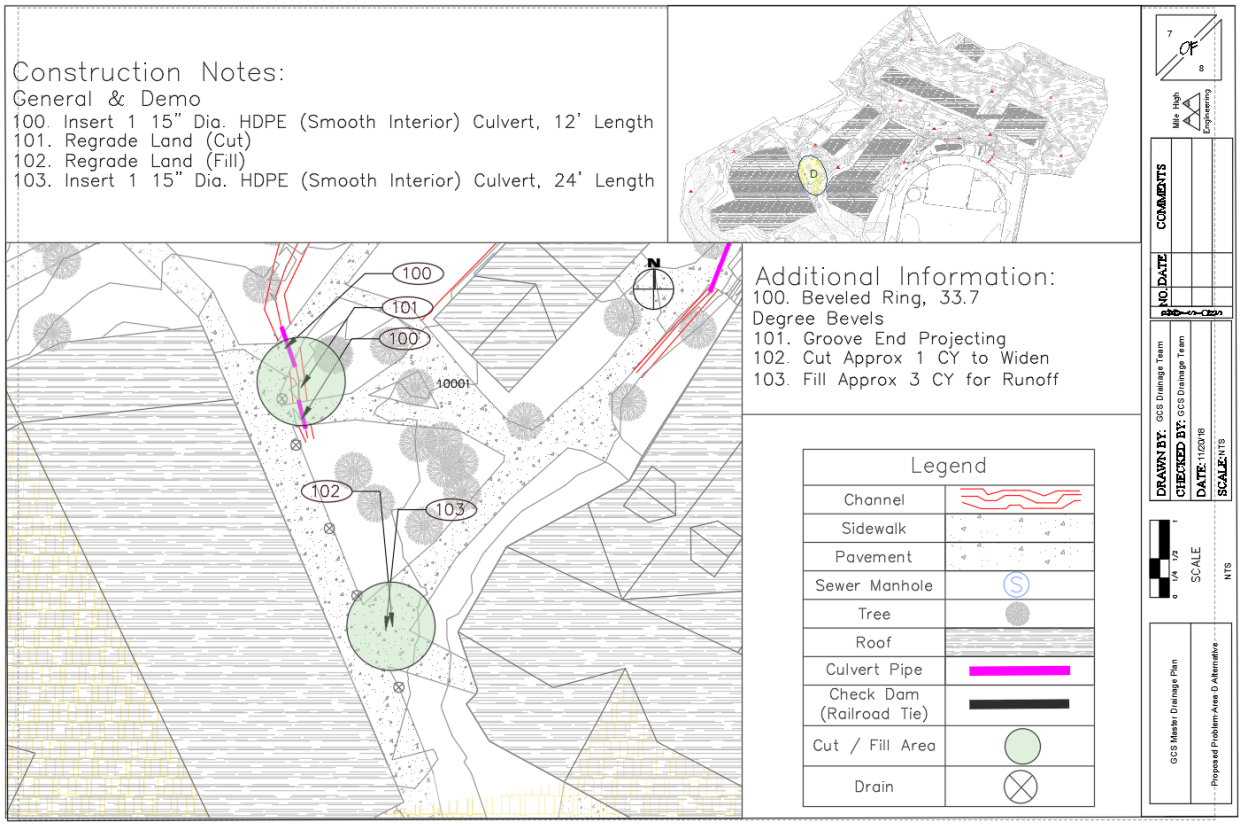

Figure 13: Topographic map of Problem Area D with the proposed alternatives, construction notes, details, and additional information.

APPENDIX C-5: TOPOGRAPHIC MAPS OF AREA E

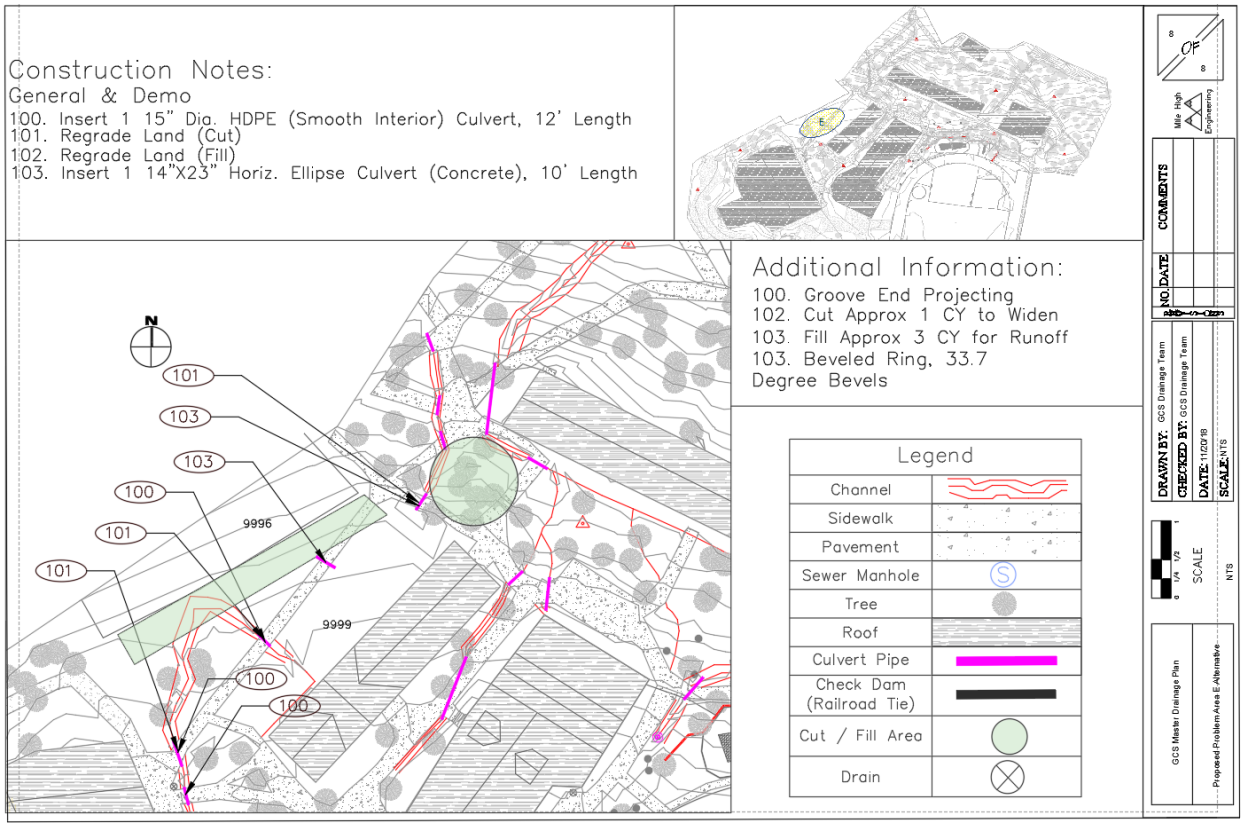

Figure 14: Topographic map of Problem Area E with the proposed alternatives, construction notes, details, and additional information.

Appendix D: Raw Data Table for Weighted C

Table 26: Raw data table for weighted runoff coefficients

Raw Data for Calculation of Weighted Runoff Coefficients									
Sub Basin	Woods, Gravelly Steep	Woods, Gravelly Average	Landscaping Flat	Sidewalk	Parking Lot	Dense Vegitation	Roof	Total Area (Acres)	Weighted C
1	27.00%	35.20%	11.90%	18.40%	0.00%	0.00%	7.40%	0.48	0.345
2	48.10%	25.80%	0.00%	16.50%	0.00%	0.00%	9.90%	0.27	0.364
3	79.00%	0.00%	0.00%	2.80%	0.00%	0.00%	18.60%	0.53	0.338
4	0.00%	45.30%	0.00%	20.60%	0.00%	0.00%	34.10%	0.63	0.574
5	51.70%	48.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.62	0.145
6	48.90%	15.30%	0.00%	6.90%	0.00%	0.00%	29.20%	0.58	0.444
7	51.20%	14.20%	14.90%	12.30%	0.00%	0.00%	7.00%	0.44	0.302
8	0.00%	26.10%	13.50%	15.30%	0.00%	0.00%	45.00%	0.35	0.618
9	0.00%	0.00%	59.66%	19.10%	0.00%	12.60%	8.32%	0.18	0.339
10	0.00%	65.99%	0.00%	13.19%	0.00%	0.00%	20.65%	0.18	0.401
11	0.00%	0.00%	22.19%	19.02%	0.00%	0.00%	58.62%	0.58	0.760
12	0.00%	0.00%	73.25%	0.00%	0.00%	26.43%	0.00%	0.91	0.113
13	0.00%	0.00%	74.62%	0.00%	0.00%	25.24%	0.00%	0.95	0.112
	0.17	0.12	0.1	0.95	0.95	0.15	0.95		

APPENDIX E: CULVERT MASTER RESULTS

CULVERT 3 REPORT

Culvert Designer/Analyzer Report
Culvert 03

Comments: Actual diameter of existing is 10 inches.
Entrance conditions are best fit.

Peak Discharge Method: User-Specified					
Design Discharge	6.56	cfs	Check Discharge	8.80	cfs

Grades Model: Inverts					
Invert Upstream	9,999.75	ft	Invert Downstream	9,999.63	ft
Length	12.00	ft	Slope	0.010000	ft/ft
Drop	0.12	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	10,000.75	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-12 inch Circular	6.56 cfs	10,003.31 ft	8.43 ft/s
	Trial-2	1-60 inch Circular	6.56 cfs	10,000.73 ft	3.93 ft/s
	Trial-3	2-21 inch Circular	6.56 cfs	10,000.71 ft	3.96 ft/s
	Trial-4	3-15 inch Circular	6.56 cfs	10,000.63 ft	3.83 ft/s
	Trial-5	2-18 inch Circular	8.80 cfs	10,000.96 ft	4.56 ft/s

Culvert Designer/Analyzer Report
Culvert 03

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,000.75	ft	Storm Event	Design	
Computed Headwater Elev	10,003.31	ft	Discharge	6.56	cfs
Headwater Depth/Height	3.56		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,002.58	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,003.31	ft			

Grades					
Upstream Invert	9,999.75	ft	Downstream Invert	9,999.63	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	0.97	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.97	ft
Velocity Downstream	8.43	ft/s	Critical Slope	0.101479	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,003.31	ft	Upstream Velocity Head	1.08	ft
Ke	0.20		Entrance Loss	0.22	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,002.58	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 45° (1:1) bevels		Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	A	
C	0.03000		Equation Form	1	
Y	0.74000				

Culvert Designer/Analyzer Report
Culvert 03

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.75	ft	Storm Event	Design	
Computed Headwater Elev	10,000.73	ft	Discharge	6.56	cfs
Headwater Depth/Height	0.20		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.66	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,000.73	ft			

Grades					
Upstream Invert	9,999.75	ft	Downstream Invert	9,999.63	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.70	ft
Slope Type	Mild		Normal Depth	0.73	ft
Flow Regime	Subcritical		Critical Depth	0.70	ft
Velocity Downstream	3.93	ft/s	Critical Slope	0.012241	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	5.00	ft
Section Size	60 inch		Rise	5.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.73	ft	Upstream Velocity Head	0.21	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.66	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	19.6	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 03

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.75	ft	Storm Event	Design	
Computed Headwater Elev	10,000.71	ft	Discharge	6.56	cfs
Headwater Depth/Height	0.55		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.65	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,000.71	ft			

Grades					
Upstream Invert	9,999.75	ft	Downstream Invert	9,999.63	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.66	ft
Slope Type	Mild		Normal Depth	0.75	ft
Flow Regime	Subcritical		Critical Depth	0.66	ft
Velocity Downstream	3.96	ft/s	Critical Slope	0.016110	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.75	ft
Section Size	21 inch		Rise	1.75	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.71	ft	Upstream Velocity Head	0.18	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.65	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	4.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 03

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.75	ft	Storm Event	Design	
Computed Headwater Elev	10,000.63	ft	Discharge	6.56	cfs
Headwater Depth/Height	0.70		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.57	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,000.63	ft			

Grades					
Upstream Invert	9,999.75	ft	Downstream Invert	9,999.63	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.59	ft
Slope Type	Mild		Normal Depth	0.72	ft
Flow Regime	Subcritical		Critical Depth	0.59	ft
Velocity Downstream	3.83	ft/s	Critical Slope	0.018995	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.25	ft
Section Size	15 inch		Rise	1.25	ft
Number Sections	3				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.63	ft	Upstream Velocity Head	0.15	ft
Ke	0.20		Entrance Loss	0.03	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.57	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	3.7	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 03

Design:Trial-5

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,000.75	ft	Storm Event	Check	
Computed Headwater Elev	10,000.96	ft	Discharge	8.80	cfs
Headwater Depth/Height	0.81		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.89	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,000.96	ft			

Grades					
Upstream Invert	9,999.75	ft	Downstream Invert	9,999.63	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.80	ft
Slope Type	Mild		Normal Depth	0.99	ft
Flow Regime	Subcritical		Critical Depth	0.80	ft
Velocity Downstream	4.56	ft/s	Critical Slope	0.018909	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.96	ft	Upstream Velocity Head	0.22	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.89	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	3.5	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 5 REPORT

Culvert Designer/Analyzer Report
Culvert 05

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	5.38	cfs	Check Discharge	7.20	cfs

Grades Model: Inverts					
Invert Upstream	9,999.75	ft	Invert Downstream	9,999.61	ft
Length	14.00	ft	Slope	0.010000	ft/ft
Drop	0.14	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	10,001.00	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	7.20 cfs	10,003.10 ft	9.22 ft/s
x	Trial-2	1-22x34 inch Horiz Ellipse	7.20 cfs	10,000.88 ft	5.49 ft/s
	Trial-3	1-36 inch Circular	7.20 cfs	10,000.96 ft	5.70 ft/s
	Trial-4	1-26.0 x 15.5 inch Arch	7.20 cfs	10,000.97 ft	5.80 ft/s

Culvert Designer/Analyzer Report
Culvert 05

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Elev	10,003.10	ft	Discharge	7.20	cfs
Headwater Depth/Height	3.35		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,003.10	ft	Control Type	Inlet Control	
Outlet Control HW Elev.	10,002.66	ft			

Grades					
Upstream Invert	9,999.75	ft	Downstream Invert	9,999.61	ft
Length	14.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	0.98	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.98	ft
Velocity Downstream	9.22	ft/s	Critical Slope	0.031008	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,002.66	ft	Upstream Velocity Head	1.31	ft
Ke	0.20		Entrance Loss	0.26	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,003.10	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	0.8	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 05

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Elev	10,000.88	ft	Discharge	7.20	cfs
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.83	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.88	ft			

Grades					
Upstream Invert	9,999.75	ft	Downstream Invert	9,999.61	ft
Length	14.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.65	ft
Slope Type	Steep		Normal Depth	0.61	ft
Flow Regime	Supercritical		Critical Depth	0.78	ft
Velocity Downstream	5.49	ft/s	Critical Slope	0.003903	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.83	ft
Section Size	22x34 inch		Rise	1.79	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.88	ft	Upstream Velocity Head	0.29	ft
Ke	0.20		Entrance Loss	0.06	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.83	ft	Flow Control	N/A	
Inlet Type	Grooved projecting (horizontal ellipse)		Area Full	4.0	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 05

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Elev	10,000.96	ft	Discharge	7.20	cfs
Headwater Depth/Height	0.40		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.88	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.96	ft			

Grades					
Upstream Invert	9,999.75	ft	Downstream Invert	9,999.61	ft
Length	14.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.70	ft
Slope Type	Steep		Normal Depth	0.64	ft
Flow Regime	Supercritical		Critical Depth	0.84	ft
Velocity Downstream	5.70	ft/s	Critical Slope	0.003320	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	3.00	ft
Section Size	36 inch		Rise	3.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.96	ft	Upstream Velocity Head	0.30	ft
Ke	0.20		Entrance Loss	0.06	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.88	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° bevels		Area Full	7.1	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 05

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Elev	10,000.97	ft	Discharge	7.20	cfs
Headwater Depth/Height	0.94		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.93	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.97	ft			

Grades					
Upstream Invert	9,999.75	ft	Downstream Invert	9,999.61	ft
Length	14.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.66	ft
Slope Type	Steep		Normal Depth	0.62	ft
Flow Regime	Supercritical		Critical Depth	0.77	ft
Velocity Downstream	5.80	ft/s	Critical Slope	0.005112	ft/ft

Section					
Section Shape	Arch		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.17	ft
Section Size	26.0 x 15.5 inch		Rise	1.29	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.97	ft	Upstream Velocity Head	0.37	ft
Ke	0.20		Entrance Loss	0.07	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.93	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (arch)		Area Full	2.2	ft²
K	0.00450		HDS 5 Chart	0	
M	2.00000		HDS 5 Scale	0	
C	0.03170		Equation Form	1	
Y	0.69000				

CULVERT 6 REPORT

Culvert Designer/Analyzer Report
Culvert 06

Comments: Actual diameter of existing is 10 inches.

Peak Discharge Method: User-Specified					
Design Discharge	5.38	cfs	Check Discharge	7.20	cfs

Grades Model: Inverts					
Invert Upstream	9,999.00	ft	Invert Downstream	9,998.80	ft
Length	20.00	ft	Slope	0.010000	ft/ft
Drop	0.20	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	10,000.00	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	5.38 cfs	10,001.17 ft	7.05 ft/s
x	Trial-2	1-22x34 inch Horiz Ellipse	5.38 cfs	9,999.96 ft	5.21 ft/s
	Trial-3	1-32x50 inch Horiz Ellipse	7.20 cfs	9,999.99 ft	5.32 ft/s
	Trial-4	1-72 inch Circular	7.20 cfs	9,999.98 ft	3.92 ft/s

Culvert Designer/Analyzer Report
Culvert 06

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,000.00	ft	Storm Event	Design	
Computed Headwater Elev	10,001.17	ft	Discharge	5.38	cfs
Headwater Depth/Height	2.17		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,001.17	ft	Control Type	Inlet Control	
Outlet Control HW Elev.	10,001.04	ft			

Grades					
Upstream Invert	9,999.00	ft	Downstream Invert	9,998.80	ft
Length	20.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	0.93	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.93	ft
Velocity Downstream	7.05	ft/s	Critical Slope	0.016796	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,001.04	ft	Upstream Velocity Head	0.73	ft
Ke	0.20		Entrance Loss	0.15	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,001.17	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	0.8	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 06

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,000.00	ft	Storm Event	Design	
Computed Headwater Elev	9,999.96	ft	Discharge	5.38	cfs
Headwater Depth/Height	0.54		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,999.91	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,999.96	ft			

Grades					
Upstream Invert	9,999.00	ft	Downstream Invert	9,998.80	ft
Length	20.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.55	ft
Slope Type	Steep		Normal Depth	0.53	ft
Flow Regime	Supercritical		Critical Depth	0.67	ft
Velocity Downstream	5.21	ft/s	Critical Slope	0.003941	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.83	ft
Section Size	22x34 inch		Rise	1.79	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,999.96	ft	Upstream Velocity Head	0.25	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,999.91	ft	Flow Control	N/A	
Inlet Type	Grooved projecting (horizontal ellipse)		Area Full	4.0	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 06

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.00	ft	Storm Event	Check	
Computed Headwater Elev	9,999.99	ft	Discharge	7.20	cfs
Headwater Depth/Height	0.38		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,999.93	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,999.99	ft			

Grades					
Upstream Invert	9,999.00	ft	Downstream Invert	9,998.80	ft
Length	20.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.57	ft
Slope Type	Steep		Normal Depth	0.54	ft
Flow Regime	Supercritical		Critical Depth	0.70	ft
Velocity Downstream	5.32	ft/s	Critical Slope	0.003630	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	4.13	ft
Section Size	32x50 inch		Rise	2.63	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,999.99	ft	Upstream Velocity Head	0.25	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,999.93	ft	Flow Control	N/A	
Inlet Type	Grooved projecting (horizontal ellipse)		Area Full	8.5	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 06

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.00	ft	Storm Event	Check	
Computed Headwater Elev	9,999.98	ft	Discharge	7.20	cfs
Headwater Depth/Height	0.16		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,999.91	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,999.98	ft			

Grades					
Upstream Invert	9,999.00	ft	Downstream Invert	9,998.80	ft
Length	20.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.70	ft
Slope Type	Mild		Normal Depth	0.73	ft
Flow Regime	Subcritical		Critical Depth	0.70	ft
Velocity Downstream	3.92	ft/s	Critical Slope	0.011976	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	6.00	ft
Section Size	72 inch		Rise	6.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,999.98	ft	Upstream Velocity Head	0.21	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,999.91	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	28.3	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 8 REPORT

Culvert Designer/Analyzer Report
Culvert 08

Comments: Actual diameter of existing is 10 inches.

Peak Discharge Method: User-Specified					
Design Discharge	5.38	cfs	Check Discharge	7.20	cfs

Grades Model: Inverts					
Invert Upstream	9,996.75	ft	Invert Downstream	9,996.61	ft
Length	14.00	ft	Slope	0.010000	ft/ft
Drop	0.14	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,997.75	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	5.38 cfs	9,999.55 ft	7.05 ft/s
x	Trial-2	1-22x34 inch Horiz Ellipse	5.38 cfs	9,997.71 ft	5.09 ft/s
	Trial-3	1-32x50 inch Horiz Ellipse	7.20 cfs	9,997.74 ft	5.18 ft/s
	Trial-4	1-72 inch Circular	7.20 cfs	9,997.73 ft	3.92 ft/s

Culvert Designer/Analyzer Report
Culvert 08

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,997.75	ft	Storm Event	Design	
Computed Headwater Elev	9,999.55	ft	Discharge	5.38	cfs
Headwater Depth/Height	2.80		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,998.72	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,999.55	ft			

Grades					
Upstream Invert	9,996.75	ft	Downstream Invert	9,996.61	ft
Length	14.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	0.93	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.93	ft
Velocity Downstream	7.05	ft/s	Critical Slope	0.067183	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,999.55	ft	Upstream Velocity Head	0.73	ft
Ke	0.20		Entrance Loss	0.15	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,998.72	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 08

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,997.75	ft	Storm Event	Design	
Computed Headwater Elev	9,997.71	ft	Discharge	5.38	cfs
Headwater Depth/Height	0.54		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,997.66	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,997.71	ft			

Grades					
Upstream Invert	9,996.75	ft	Downstream Invert	9,996.61	ft
Length	14.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.56	ft
Slope Type	Steep		Normal Depth	0.53	ft
Flow Regime	Supercritical		Critical Depth	0.67	ft
Velocity Downstream	5.09	ft/s	Critical Slope	0.003941	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.83	ft
Section Size	22x34 inch		Rise	1.79	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,997.71	ft	Upstream Velocity Head	0.25	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,997.66	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	4.0	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 08

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,997.75	ft	Storm Event	Check	
Computed Headwater Elev	9,997.74	ft	Discharge	7.20	cfs
Headwater Depth/Height	0.38		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,997.68	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,997.74	ft			

Grades					
Upstream Invert	9,996.75	ft	Downstream Invert	9,996.61	ft
Length	14.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.58	ft
Slope Type	Steep		Normal Depth	0.54	ft
Flow Regime	Supercritical		Critical Depth	0.70	ft
Velocity Downstream	5.18	ft/s	Critical Slope	0.003630	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	4.13	ft
Section Size	32x50 inch		Rise	2.63	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,997.74	ft	Upstream Velocity Head	0.25	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,997.68	ft	Flow Control	Unsubmerged	
Inlet Type	Grate projecting (horizontal ellipse)		Area Full	8.5	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 08

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,997.75	ft	Storm Event	Check	
Computed Headwater Elev	9,997.73	ft	Discharge	7.20	cfs
Headwater Depth/Height	0.16		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,997.66	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,997.73	ft			

Grades					
Upstream Invert	9,996.75	ft	Downstream Invert	9,996.61	ft
Length	14.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.70	ft
Slope Type	Mild		Normal Depth	0.73	ft
Flow Regime	Subcritical		Critical Depth	0.70	ft
Velocity Downstream	3.92	ft/s	Critical Slope	0.011976	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	6.00	ft
Section Size	72 inch		Rise	6.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,997.73	ft	Upstream Velocity Head	0.21	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,997.66	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	28.3	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 9 REPORT

Culvert Designer/Analyzer Report
Culvert 09

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,998.00	ft	Invert Downstream	9,997.85	ft
Length	15.00	ft	Slope	0.010000	ft/ft
Drop	0.15	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,999.00	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	3.50 cfs	9,999.61 ft	5.20 ft/s
x	Trial-2	1-14x23 inch Horiz Ellipse	2.63 cfs	9,998.75 ft	4.51 ft/s
	Trial-3	1-14x23 inch Horiz Ellipse	3.50 cfs	9,998.89 ft	4.89 ft/s
	Trial-4	1-21 inch Circular	3.50 cfs	9,998.99 ft	4.04 ft/s

Culvert Designer/Analyzer Report
Culvert 09

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,999.00	ft	Storm Event	Check	
Computed Headwater Elev	9,999.61	ft	Discharge	3.50	cfs
Headwater Depth/Height	1.61		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,999.31	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,999.61	ft			

Grades					
Upstream Invert	9,998.00	ft	Downstream Invert	9,997.85	ft
Length	15.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	0.80	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.80	ft
Velocity Downstream	5.20	ft/s	Critical Slope	0.034479	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,999.61	ft	Upstream Velocity Head	0.31	ft
Ke	0.20		Entrance Loss	0.06	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,999.31	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 09

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.00	ft	Storm Event	Design	
Computed Headwater Elev	9,998.75	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,998.72	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,998.75	ft			

Grades					
Upstream Invert	9,998.00	ft	Downstream Invert	9,997.85	ft
Length	15.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.43	ft
Slope Type	Steep		Normal Depth	0.42	ft
Flow Regime	Supercritical		Critical Depth	0.52	ft
Velocity Downstream	4.51	ft/s	Critical Slope	0.004463	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,998.75	ft	Upstream Velocity Head	0.20	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,998.72	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 09

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.00	ft	Storm Event	Check	
Computed Headwater Elev	9,998.89	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.75		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,998.85	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,998.89	ft			

Grades					
Upstream Invert	9,998.00	ft	Downstream Invert	9,997.85	ft
Length	15.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.50	ft
Slope Type	Steep		Normal Depth	0.49	ft
Flow Regime	Supercritical		Critical Depth	0.59	ft
Velocity Downstream	4.89	ft/s	Critical Slope	0.004692	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,998.89	ft	Upstream Velocity Head	0.24	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,998.85	ft	Flow Control	N/A	
Inlet Type	Grooved projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 09

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.00	ft	Storm Event	Check	
Computed Headwater Elev	9,998.99	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.57		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,998.93	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,998.99	ft			

Grades					
Upstream Invert	9,998.00	ft	Downstream Invert	9,997.85	ft
Length	15.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.68	ft
Slope Type	Mild		Normal Depth	0.78	ft
Flow Regime	Subcritical		Critical Depth	0.68	ft
Velocity Downstream	4.04	ft/s	Critical Slope	0.016193	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.75	ft
Section Size	21 inch		Rise	1.75	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,998.99	ft	Upstream Velocity Head	0.18	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,998.93	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	2.4	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 10 REPORT

Culvert Designer/Analyzer Report
Culvert 10

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,997.50	ft	Invert Downstream	9,997.40	ft
Length	10.00	ft	Slope	0.010000	ft/ft
Drop	0.10	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,998.50	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	2.63 cfs	9,998.63 ft	4.51 ft/s
x	Trial-2	1-14x23 inch Horiz Ellipse	2.63 cfs	9,998.25 ft	4.41 ft/s
	Trial-3	1-14x23 inch Horiz Ellipse	3.50 cfs	9,998.39 ft	4.77 ft/s
	Trial-4	1-21 inch Circular	3.50 cfs	9,998.49 ft	4.04 ft/s

Culvert Designer/Analyzer Report
Culvert 10

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,998.50	ft	Storm Event	Design	
Computed Headwater Elev	9,998.63	ft	Discharge	2.63	cfs
Headwater Depth/Height	1.13		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,998.54	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,998.63	ft			

Grades					
Upstream Invert	9,997.50	ft	Downstream Invert	9,997.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.70	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.70	ft
Velocity Downstream	4.51	ft/s	Critical Slope	0.026986	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,998.63	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,998.54	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 10

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,998.50	ft	Storm Event	Design	
Computed Headwater Elev	9,998.25	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,998.22	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,998.25	ft			

Grades					
Upstream Invert	9,997.50	ft	Downstream Invert	9,997.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.44	ft
Slope Type	Steep		Normal Depth	0.42	ft
Flow Regime	Supercritical		Critical Depth	0.52	ft
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,998.25	ft	Upstream Velocity Head	0.20	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,998.22	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 10

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,998.50	ft	Storm Event	Check	
Computed Headwater Elev	9,998.39	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.75		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,998.35	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,998.39	ft			

Grades					
Upstream Invert	9,997.50	ft	Downstream Invert	9,997.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.51	ft
Slope Type	Steep		Normal Depth	0.49	ft
Flow Regime	Supercritical		Critical Depth	0.59	ft
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,998.39	ft	Upstream Velocity Head	0.24	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,998.35	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 10

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,998.50	ft	Storm Event	Check	
Computed Headwater Elev	9,998.49	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.57		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,998.43	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,998.49	ft			

Grades					
Upstream Invert	9,997.50	ft	Downstream Invert	9,997.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.68	ft
Slope Type	Mild		Normal Depth	0.78	ft
Flow Regime	Subcritical		Critical Depth	0.68	ft
Velocity Downstream	4.04	ft/s	Critical Slope	0.016193	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.75	ft
Section Size	21 inch		Rise	1.75	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,998.49	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,998.43	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	2.4	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 11 REPORT

Culvert Designer/Analyzer Report
Culvert 11

Comments: Actual diameter of existing is 10 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,993.25	ft	Invert Downstream	9,993.14	ft
Length	11.00	ft	Slope	0.010000	ft/ft
Drop	0.11	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,994.25	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	2-12 inch Circular	3.50 cfs	9,994.11 ft	3.84 ft/s

Culvert Designer/Analyzer Report
Culvert 11

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,994.25	ft	Storm Event	Check	
Computed Headwater Elev	9,994.11	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.86		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,994.05	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,994.11	ft			

Grades					
Upstream Invert	9,993.25	ft	Downstream Invert	9,993.14	ft
Length	11.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.56	ft
Slope Type	Mild		Normal Depth	0.75	ft
Flow Regime	Subcritical		Critical Depth	0.56	ft
Velocity Downstream	3.84	ft/s	Critical Slope	0.022257	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	9,994.11	ft	Upstream Velocity Head	0.14	ft
Ke	0.20		Entrance Loss	0.03	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,994.05	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	1.6	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 12 REPORT

Culvert Designer/Analyzer Report
Culvert 12

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,992.75	ft	Invert Downstream	9,992.38	ft
Length	37.00	ft	Slope	0.010000	ft/ft
Drop	0.37	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,994.25	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-18 inch Circular	3.50 cfs	9,993.81 ft	4.22 ft/s

Culvert Designer/Analyzer Report
Culvert 12

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,994.25	ft	Storm Event	Check	
Computed Headwater Elev	9,993.81	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.71		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,993.74	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,993.81	ft			

Grades					
Upstream Invert	9,992.75	ft	Downstream Invert	9,992.38	ft
Length	37.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.71	ft
Slope Type	Mild		Normal Depth	0.85	ft
Flow Regime	Subcritical		Critical Depth	0.71	ft
Velocity Downstream	4.22	ft/s	Critical Slope	0.017931	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,993.81	ft	Upstream Velocity Head	0.18	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,993.74	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	1.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 13 REPORT

Culvert Designer/Analyzer Report
Culvert 13

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,980.75	ft	Invert Downstream	9,980.60	ft
Length	15.00	ft	Slope	0.010000	ft/ft
Drop	0.15	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,982.25	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-18 inch Circular	2.63 cfs	9,981.65 ft	3.86 ft/s

Culvert Designer/Analyzer Report
Culvert 13

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,982.25	ft	Storm Event	Design	
Computed Headwater Elev	9,981.65	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.60		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,981.59	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,981.65	ft			

Grades					
Upstream Invert	9,980.75	ft	Downstream Invert	9,980.60	ft
Length	15.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.61	ft
Slope Type	Mild		Normal Depth	0.72	ft
Flow Regime	Subcritical		Critical Depth	0.61	ft
Velocity Downstream	3.86	ft/s	Critical Slope	0.017209	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,981.65	ft	Upstream Velocity Head	0.16	ft
Ke	0.20		Entrance Loss	0.03	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,981.59	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	1.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 15 REPORT

Culvert Designer/Analyzer Report
Culvert 15

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,990.25	ft	Invert Downstream	9,990.15	ft
Length	10.00	ft	Slope	0.010000	ft/ft
Drop	0.10	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,991.25	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	2.63 cfs	9,991.38 ft	4.51 ft/s
x	Trial-2	1-14x23 inch Horiz Ellipse	2.63 cfs	9,991.00 ft	4.41 ft/s
	Trial-3	1-14x23 inch Horiz Ellipse	3.50 cfs	9,991.14 ft	4.77 ft/s
	Trial-4	1-21 inch Circular	3.50 cfs	9,991.24 ft	4.04 ft/s

Culvert Designer/Analyzer Report
Culvert 15

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,991.25	ft	Storm Event	Design	
Computed Headwater Elev	9,991.38	ft	Discharge	2.63	cfs
Headwater Depth/Height	1.13		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,991.29	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,991.38	ft			

Grades					
Upstream Invert	9,990.25	ft	Downstream Invert	9,990.15	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.70	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.70	ft
Velocity Downstream	4.51	ft/s	Critical Slope	0.026986	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,991.38	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,991.29	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 15

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,991.25	ft	Storm Event	Design	
Computed Headwater Elev	9,991.00	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,990.97	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,991.00	ft			

Grades					
Upstream Invert	9,990.25	ft	Downstream Invert	9,990.15	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.44	ft
Slope Type	Steep		Normal Depth	0.42	ft
Flow Regime	Supercritical		Critical Depth	0.52	ft
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,991.00	ft	Upstream Velocity Head	0.20	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,990.97	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 15

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,991.25	ft	Storm Event	Check	
Computed Headwater Elev	9,991.14	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.75		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,991.10	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,991.14	ft			

Grades					
Upstream Invert	9,990.25	ft	Downstream Invert	9,990.15	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.51	ft
Slope Type	Steep		Normal Depth	0.49	ft
Flow Regime	Supercritical		Critical Depth	0.59	ft
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,991.14	ft	Upstream Velocity Head	0.24	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,991.10	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 15

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,991.25	ft	Storm Event	Check	
Computed Headwater Elev	9,991.24	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.57		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,991.18	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,991.24	ft			

Grades					
Upstream Invert	9,990.25	ft	Downstream Invert	9,990.15	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.68	ft
Slope Type	Mild		Normal Depth	0.78	ft
Flow Regime	Subcritical		Critical Depth	0.68	ft
Velocity Downstream	4.04	ft/s	Critical Slope	0.016193	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.75	ft
Section Size	21 inch		Rise	1.75	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,991.24	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,991.18	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	2.4	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 16 REPORT

Culvert Designer/Analyzer Report
Culvert 16

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,992.25	ft	Invert Downstream	9,992.15	ft
Length	10.00	ft	Slope	0.010000	ft/ft
Drop	0.10	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,993.25	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	2.63 cfs	9,993.38 ft	4.51 ft/s
x	Trial-2	1-14x23 inch Horiz Ellipse	2.63 cfs	9,993.00 ft	4.41 ft/s
	Trial-3	1-14x23 inch Horiz Ellipse	3.50 cfs	9,993.14 ft	4.77 ft/s
	Trial-4	1-21 inch Circular	3.50 cfs	9,993.24 ft	4.04 ft/s

Culvert Designer/Analyzer Report
Culvert 16

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,993.25	ft	Storm Event	Design	
Computed Headwater Elev	9,993.38	ft	Discharge	2.63	cfs
Headwater Depth/Height	1.13		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,993.29	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,993.38	ft			

Grades					
Upstream Invert	9,992.25	ft	Downstream Invert	9,992.15	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.70	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.70	ft
Velocity Downstream	4.51	ft/s	Critical Slope	0.026986	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,993.38	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,993.29	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 16

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,993.25	ft	Storm Event	Design	
Computed Headwater Elev	9,993.00	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,992.97	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,993.00	ft			

Grades					
Upstream Invert	9,992.25	ft	Downstream Invert	9,992.15	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.44	ft
Slope Type	Steep		Normal Depth	0.42	ft
Flow Regime	Supercritical		Critical Depth	0.52	ft
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,993.00	ft	Upstream Velocity Head	0.20	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,992.97	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 16

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,993.25	ft	Storm Event	Check	
Computed Headwater Elev	9,993.14	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.75		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,993.10	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,993.14	ft			

Grades					
Upstream Invert	9,992.25	ft	Downstream Invert	9,992.15	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.51	ft
Slope Type	Steep		Normal Depth	0.49	ft
Flow Regime	Supercritical		Critical Depth	0.59	ft
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,993.14	ft	Upstream Velocity Head	0.24	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,993.10	ft	Flow Control	N/A	
Inlet Type	Grooved projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 16

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,993.25	ft	Storm Event	Check	
Computed Headwater Elev	9,993.24	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.57		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,993.18	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,993.24	ft			

Grades					
Upstream Invert	9,992.25	ft	Downstream Invert	9,992.15	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.68	ft
Slope Type	Mild		Normal Depth	0.78	ft
Flow Regime	Subcritical		Critical Depth	0.68	ft
Velocity Downstream	4.04	ft/s	Critical Slope	0.016193	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.75	ft
Section Size	21 inch		Rise	1.75	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,993.24	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,993.18	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	2.4	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 17 REPORT

Culvert Designer/Analyzer Report
Culvert 17

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,993.50	ft	Invert Downstream	9,993.40	ft
Length	10.00	ft	Slope	0.010000	ft/ft
Drop	0.10	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,994.50	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	2.63 cfs	9,994.77 ft	4.51 ft/s
x	Trial-2	1-14x23 inch Horiz Ellipse	2.63 cfs	9,994.25 ft	4.41 ft/s
	Trial-3	1-14x23 inch Horiz Ellipse	3.50 cfs	9,994.39 ft	4.77 ft/s
	Trial-4	1-21 inch Circular	3.50 cfs	9,994.49 ft	4.04 ft/s

Culvert Designer/Analyzer Report
Culvert 17

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,994.50	ft	Storm Event	Design	
Computed Headwater Elev	9,994.77	ft	Discharge	2.63	cfs
Headwater Depth/Height	1.27		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,994.71	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,994.77	ft			

Grades					
Upstream Invert	9,993.50	ft	Downstream Invert	9,993.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.70	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.70	ft
Velocity Downstream	4.51	ft/s	Critical Slope	0.026986	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,994.77	ft	Upstream Velocity Head	0.19	ft
Ke	0.90		Entrance Loss	0.17	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,994.71	ft	Flow Control	N/A	
Inlet Type	Projecting		Area Full	0.8	ft²
K	0.03400		HDS 5 Chart	2	
M	1.50000		HDS 5 Scale	3	
C	0.05530		Equation Form	1	
Y	0.54000				

Culvert Designer/Analyzer Report
Culvert 17

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,994.50	ft	Storm Event	Design	
Computed Headwater Elev	9,994.25	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,994.22	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,994.25	ft			

Grades					
Upstream Invert	9,993.50	ft	Downstream Invert	9,993.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.44	ft
Slope Type	Steep		Normal Depth	0.42	ft
Flow Regime	Supercritical		Critical Depth	0.52	ft
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,994.25	ft	Upstream Velocity Head	0.20	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,994.22	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 17

Design:Trial-3

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,994.50	ft	Storm Event	Check	
Computed Headwater Elev	9,994.39	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.75		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,994.35	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,994.39	ft			

Grades					
Upstream Invert	9,993.50	ft	Downstream Invert	9,993.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.51	ft
Slope Type	Steep		Normal Depth	0.49	ft
Flow Regime	Supercritical		Critical Depth	0.59	ft
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,994.39	ft	Upstream Velocity Head	0.24	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,994.35	ft	Flow Control	N/A	
Inlet Type	Grate projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 17

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,994.50	ft	Storm Event	Check	
Computed Headwater Elev	9,994.49	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.57		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,994.43	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,994.49	ft			

Grades					
Upstream Invert	9,993.50	ft	Downstream Invert	9,993.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.68	ft
Slope Type	Mild		Normal Depth	0.78	ft
Flow Regime	Subcritical		Critical Depth	0.68	ft
Velocity Downstream	4.04	ft/s	Critical Slope	0.016193	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.75	ft
Section Size	21 inch		Rise	1.75	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,994.49	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,994.43	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	2.4	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 18 REPORT

Culvert Designer/Analyzer Report
Culvert 18

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,995.75	ft	Invert Downstream	9,995.65	ft
Length	10.00	ft	Slope	0.010000	ft/ft
Drop	0.10	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,996.75	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	2.63 cfs	9,996.82 ft	5.09 ft/s
x	Trial-2	1-14x23 inch Horiz Ellipse	2.63 cfs	9,996.50 ft	4.41 ft/s
	Trial-3	1-14x23 inch Horiz Ellipse	3.50 cfs	9,996.64 ft	4.77 ft/s
	Trial-4	1-21 inch Circular	3.50 cfs	9,996.74 ft	4.04 ft/s

Culvert Designer/Analyzer Report
Culvert 18

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,996.75	ft	Storm Event	Design	
Computed Headwater Elev	9,996.82	ft	Discharge	2.63	cfs
Headwater Depth/Height	1.07		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,996.81	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,996.82	ft			

Grades					
Upstream Invert	9,995.75	ft	Downstream Invert	9,995.65	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.63	ft
Slope Type	Steep		Normal Depth	0.61	ft
Flow Regime	Supercritical		Critical Depth	0.70	ft
Velocity Downstream	5.09	ft/s	Critical Slope	0.006746	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,996.82	ft	Upstream Velocity Head	0.32	ft
Ke	0.20		Entrance Loss	0.06	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,996.81	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	0.8	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 18

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,996.75	ft	Storm Event	Design	
Computed Headwater Elev	9,996.50	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,996.47	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,996.50	ft			

Grades					
Upstream Invert	9,995.75	ft	Downstream Invert	9,995.65	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.44	ft
Slope Type	Steep		Normal Depth	0.42	ft
Flow Regime	Supercritical		Critical Depth	0.52	ft
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,996.50	ft	Upstream Velocity Head	0.20	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,996.47	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 18

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,996.75	ft	Storm Event	Check	
Computed Headwater Elev	9,996.64	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.75		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,996.60	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,996.64	ft			

Grades					
Upstream Invert	9,995.75	ft	Downstream Invert	9,995.65	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.51	ft
Slope Type	Steep		Normal Depth	0.49	ft
Flow Regime	Supercritical		Critical Depth	0.59	ft
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,996.64	ft	Upstream Velocity Head	0.24	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,996.60	ft	Flow Control	N/A	
Inlet Type	Grooved projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 18

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,996.75	ft	Storm Event	Check	
Computed Headwater Elev	9,996.74	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.57		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,996.68	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	9,996.74	ft			

Grades					
Upstream Invert	9,995.75	ft	Downstream Invert	9,995.65	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.68	ft
Slope Type	Mild		Normal Depth	0.78	ft
Flow Regime	Subcritical		Critical Depth	0.68	ft
Velocity Downstream	4.04	ft/s	Critical Slope	0.016193	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.75	ft
Section Size	21 inch		Rise	1.75	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,996.74	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,996.68	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	2.4	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 19 REPORT

Culvert Designer/Analyzer Report
Culvert 19

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	10,000.00	ft	Invert Downstream	9,999.65	ft
Length	35.00	ft	Slope	0.010000	ft/ft
Drop	0.35	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	10,001.00	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	2.63 cfs	10,001.07 ft	5.28 ft/s
x	Trial-2	1-14x23 inch Horiz Ellipse	2.63 cfs	10,000.75 ft	4.69 ft/s
	Trial-3	1-14x23 inch Horiz Ellipse	3.50 cfs	10,000.89 ft	5.09 ft/s
	Trial-4	1-21 inch Circular	3.50 cfs	10,000.99 ft	4.04 ft/s
	Trial-5	2-12 inch Circular	2.63 cfs	10,000.71 ft	4.45 ft/s
	Trial-6	2-12 inch Circular	3.50 cfs	10,000.84 ft	4.79 ft/s

Culvert Designer/Analyzer Report
Culvert 19

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Design	
Computed Headwater Elev	10,001.07	ft	Discharge	2.63	cfs
Headwater Depth/Height	1.07		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,001.06	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,001.07	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,999.65	ft
Length	35.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.61	ft
Slope Type	Steep		Normal Depth	0.61	ft
Flow Regime	Supercritical		Critical Depth	0.70	ft
Velocity Downstream	5.28	ft/s	Critical Slope	0.006746	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,001.07	ft	Upstream Velocity Head	0.32	ft
Ke	0.20		Entrance Loss	0.06	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,001.06	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	0.8	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 19

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Design	
Computed Headwater Elev	10,000.75	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.72	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.75	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,999.65	ft
Length	35.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.42	ft
Slope Type	Steep		Normal Depth	0.42	ft
Flow Regime	Supercritical		Critical Depth	0.52	ft
Velocity Downstream	4.69	ft/s	Critical Slope	0.004463	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.75	ft	Upstream Velocity Head	0.20	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.72	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 19

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Elev	10,000.89	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.75		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.85	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.89	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,999.65	ft
Length	35.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.49	ft
Slope Type	Steep		Normal Depth	0.49	ft
Flow Regime	Supercritical		Critical Depth	0.59	ft
Velocity Downstream	5.09	ft/s	Critical Slope	0.004692	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.89	ft	Upstream Velocity Head	0.24	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.85	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 19

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Elev	10,000.99	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.57		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.93	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,000.99	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,999.65	ft
Length	35.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.68	ft
Slope Type	Mild		Normal Depth	0.78	ft
Flow Regime	Subcritical		Critical Depth	0.68	ft
Velocity Downstream	4.04	ft/s	Critical Slope	0.016193	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.75	ft
Section Size	21 inch		Rise	1.75	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.99	ft	Upstream Velocity Head	0.18	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.93	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels		Area Full	2.4	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 19

Design:Trial-5

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Design	
Computed Headwater Elev	10,000.71	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.71		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.67	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.71	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,999.65	ft
Length	35.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.40	ft
Slope Type	Steep		Normal Depth	0.40	ft
Flow Regime	Supercritical		Critical Depth	0.48	ft
Velocity Downstream	4.45	ft/s	Critical Slope	0.005164	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.71	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.67	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° bevels		Area Full	1.6	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 19

Design:Trial-6

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Elev	10,000.84	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.84		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.80	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.84	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,999.65	ft
Length	35.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.47	ft
Slope Type	Steep		Normal Depth	0.47	ft
Flow Regime	Supercritical		Critical Depth	0.56	ft
Velocity Downstream	4.79	ft/s	Critical Slope	0.005564	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.84	ft	Upstream Velocity Head	0.23	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.80	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° bevels		Area Full	1.6	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 20 REPORT

Culvert Designer/Analyzer Report
Culvert 20

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.63	cfs	Check Discharge	3.50	cfs

Grades Model: Inverts					
Invert Upstream	9,998.50	ft	Invert Downstream	9,998.40	ft
Length	10.00	ft	Slope	0.010000	ft/ft
Drop	0.10	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	9,999.50	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	3.50 cfs	10,000.21 ft	5.20 ft/s
x	Trial-2	1-14x23 inch Horiz Ellipse	2.63 cfs	9,999.25 ft	4.41 ft/s
	Trial-3	1-14x23 inch Horiz Ellipse	3.50 cfs	9,999.39 ft	4.77 ft/s
	Trial-4	1-21 inch Circular	3.50 cfs	9,999.49 ft	4.91 ft/s

Culvert Designer/Analyzer Report
Culvert 20

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,999.50	ft	Storm Event	Check	
Computed Headwater Elev	10,000.21	ft	Discharge	3.50	cfs
Headwater Depth/Height	1.71		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.13	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,000.21	ft			

Grades					
Upstream Invert	9,998.50	ft	Downstream Invert	9,998.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	0.80	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	0.80	ft
Velocity Downstream	5.20	ft/s	Critical Slope	0.034479	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.21	ft	Upstream Velocity Head	0.31	ft
Ke	0.90		Entrance Loss	0.28	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.13	ft	Flow Control	N/A	
Inlet Type	Projecting		Area Full	0.8	ft²
K	0.03400		HDS 5 Chart	2	
M	1.50000		HDS 5 Scale	3	
C	0.05530		Equation Form	1	
Y	0.54000				

Culvert Designer/Analyzer Report
Culvert 20

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.50	ft	Storm Event	Design	
Computed Headwater Elev	9,999.25	ft	Discharge	2.63	cfs
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,999.22	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,999.25	ft			

Grades					
Upstream Invert	9,998.50	ft	Downstream Invert	9,998.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.44	ft
Slope Type	Steep		Normal Depth	0.42	ft
Flow Regime	Supercritical		Critical Depth	0.52	ft
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,999.25	ft	Upstream Velocity Head	0.20	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,999.22	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 20

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.50	ft	Storm Event	Check	
Computed Headwater Elev	9,999.39	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.75		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,999.35	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,999.39	ft			

Grades					
Upstream Invert	9,998.50	ft	Downstream Invert	9,998.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.51	ft
Slope Type	Steep		Normal Depth	0.49	ft
Flow Regime	Supercritical		Critical Depth	0.59	ft
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,999.39	ft	Upstream Velocity Head	0.24	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,999.35	ft	Flow Control	N/A	
Inlet Type	Groove end projecting (horizontal ellipse)		Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Designer/Analyzer Report
Culvert 20

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.50	ft	Storm Event	Check	
Computed Headwater Elev	9,999.49	ft	Discharge	3.50	cfs
Headwater Depth/Height	0.56		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,999.43	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	9,999.49	ft			

Grades					
Upstream Invert	9,998.50	ft	Downstream Invert	9,998.40	ft
Length	10.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.59	ft
Slope Type	Steep		Normal Depth	0.56	ft
Flow Regime	Supercritical		Critical Depth	0.68	ft
Velocity Downstream	4.91	ft/s	Critical Slope	0.004751	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.75	ft
Section Size	21 inch		Rise	1.75	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	9,999.49	ft	Upstream Velocity Head	0.25	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	9,999.43	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° bevels		Area Full	2.4	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 21 REPORT

Culvert Designer/Analyzer Report
Culvert 21

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified					
Design Discharge	2.00	cfs	Check Discharge	2.70	cfs

Grades Model: Inverts					
Invert Upstream	9,999.50	ft	Invert Downstream	9,999.38	ft
Length	12.00	ft	Slope	0.010000	ft/ft
Drop	0.12	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	10,000.50	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	2.00 cfs	10,000.55 ft	4.04 ft/s
	Trial-2	1-12 inch Circular	2.00 cfs	10,000.41 ft	4.77 ft/s
x	Trial-3	1-15 inch Circular	2.70 cfs	10,000.47 ft	5.00 ft/s

Culvert Designer/Analyzer Report
Culvert 21

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,000.50	ft	Storm Event	Design	
Computed Headwater Elev	10,000.55	ft	Discharge	2.00	cfs
Headwater Depth/Height	1.05		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.49	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,000.55	ft			

Grades					
Upstream Invert	9,999.50	ft	Downstream Invert	9,999.38	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.60	ft
Slope Type	Mild		Normal Depth	0.86	ft
Flow Regime	Subcritical		Critical Depth	0.60	ft
Velocity Downstream	4.04	ft/s	Critical Slope	0.023390	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.55	ft	Upstream Velocity Head	0.15	ft
Ke	0.90		Entrance Loss	0.14	ft

Inlet Control Properties				
Inlet Control HW Elev.	10,000.49	ft	Flow Control	N/A
Inlet Type	Projecting		Area Full	0.8 ft²
K	0.03400		HDS 5 Chart	2
M	1.50000		HDS 5 Scale	3
C	0.05530		Equation Form	1
Y	0.54000			

Culvert Designer/Analyzer Report
Culvert 21

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.50	ft	Storm Event	Design	
Computed Headwater Elev	10,000.41	ft	Discharge	2.00	cfs
Headwater Depth/Height	0.91		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.37	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.41	ft			

Grades					
Upstream Invert	9,999.50	ft	Downstream Invert	9,999.38	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.53	ft
Slope Type	Steep		Normal Depth	0.51	ft
Flow Regime	Supercritical		Critical Depth	0.60	ft
Velocity Downstream	4.77	ft/s	Critical Slope	0.005848	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.41	ft	Upstream Velocity Head	0.25	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.37	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° bevels		Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 21

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.50	ft	Storm Event	Check	
Computed Headwater Elev	10,000.47	ft	Discharge	2.70	cfs
Headwater Depth/Height	0.78		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.43	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.47	ft			

Grades					
Upstream Invert	9,999.50	ft	Downstream Invert	9,999.38	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.57	ft
Slope Type	Steep		Normal Depth	0.54	ft
Flow Regime	Supercritical		Critical Depth	0.66	ft
Velocity Downstream	5.00	ft/s	Critical Slope	0.004980	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.25	ft
Section Size	15 inch		Rise	1.25	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.47	ft	Upstream Velocity Head	0.26	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.43	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° bevels		Area Full	1.2	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 22 REPORT

Culvert Designer/Analyzer Report
Culvert 22

Comments: Actual diameter of existing is 6 inches.

Peak Discharge Method: User-Specified			
Design Discharge	2.00 cfs	Check Discharge	2.70 cfs

Grades Model: Inverts			
Invert Upstream	10,000.25 ft	Invert Downstream	10,000.13 ft
Length	12.00 ft	Slope	0.010000 ft/ft
Drop	0.12 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	10,001.25 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	N/A ft

	Name	Description	Discharge	HW Elev.	Velocity
	Trial-1	1-12 inch Circular	2.00 cfs	10,001.30 ft	4.04 ft/s
	Trial-2	1-12 inch Circular	2.00 cfs	10,001.16 ft	4.77 ft/s
x	Trial-3	1-15 inch Circular	2.70 cfs	10,001.22 ft	5.00 ft/s

Culvert Designer/Analyzer Report
Culvert 22

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,001.25	ft	Storm Event	Design	
Computed Headwater Elev	10,001.30	ft	Discharge	2.00	cfs
Headwater Depth/Height	1.05		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,001.24	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,001.30	ft			

Grades					
Upstream Invert	10,000.25	ft	Downstream Invert	10,000.13	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.60	ft
Slope Type	Mild		Normal Depth	0.86	ft
Flow Regime	Subcritical		Critical Depth	0.60	ft
Velocity Downstream	4.04	ft/s	Critical Slope	0.023390	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,001.30	ft	Upstream Velocity Head	0.15	ft
Ke	0.90		Entrance Loss	0.14	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,001.24	ft	Flow Control	Unsubmerged	
Inlet Type	Projecting		Area Full	0.8	ft²
K	0.03400		HDS 5 Chart	2	
M	1.50000		HDS 5 Scale	3	
C	0.05530		Equation Form	1	
Y	0.54000				

Culvert Designer/Analyzer Report
Culvert 22

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.25	ft	Storm Event	Design	
Computed Headwater Elev	10,001.16	ft	Discharge	2.00	cfs
Headwater Depth/Height	0.91		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,001.12	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,001.16	ft			

Grades					
Upstream Invert	10,000.25	ft	Downstream Invert	10,000.13	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.53	ft
Slope Type	Steep		Normal Depth	0.51	ft
Flow Regime	Supercritical		Critical Depth	0.60	ft
Velocity Downstream	4.77	ft/s	Critical Slope	0.005848	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.00	ft
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,001.16	ft	Upstream Velocity Head	0.25	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,001.12	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° bevels		Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Culvert Designer/Analyzer Report
Culvert 22

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.25	ft	Storm Event	Check	
Computed Headwater Elev	10,001.22	ft	Discharge	2.70	cfs
Headwater Depth/Height	0.78		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,001.18	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,001.22	ft			

Grades					
Upstream Invert	10,000.25	ft	Downstream Invert	10,000.13	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.57	ft
Slope Type	Steep		Normal Depth	0.54	ft
Flow Regime	Supercritical		Critical Depth	0.66	ft
Velocity Downstream	5.00	ft/s	Critical Slope	0.004980	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	1.25	ft
Section Size	15 inch		Rise	1.25	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	10,001.22	ft	Upstream Velocity Head	0.26	ft
Ke	0.20		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,001.18	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° bevels		Area Full	1.2	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 23 REPORT

Culvert Designer/Analyzer Report
Problem Area A Culvert

Peak Discharge Method: User-Specified					
Design Discharge	6.60	cfs	Check Discharge	8.80	cfs

Grades Model: Inverts					
Invert Upstream	10,000.00	ft	Invert Downstream	9,998.00	ft
Length	12.00	ft	Slope	0.166667	ft/ft
Drop	2.00	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	10,001.00	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	2-14x23 inch Horiz Ellipse	6.60 cfs	10,000.92 ft	11.00 ft/s
	Trial-2	2-19x30 inch Horiz Ellipse	8.80 cfs	10,000.97 ft	11.25 ft/s

Culvert Designer/Analyzer Report
Problem Area A Culvert

Design:Trial-1

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Design	
Computed Headwater Elev	10,000.92	ft	Discharge	6.60	cfs
Headwater Depth/Height	0.78		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.74	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.92	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,998.00	ft
Length	12.00	ft	Constructed Slope	0.166667	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.27	ft
Slope Type	Steep		Normal Depth	0.23	ft
Flow Regime	Supercritical		Critical Depth	0.58	ft
Velocity Downstream	11.00	ft/s	Critical Slope	0.004463	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	ft
Section Size	14x23 inch		Rise	1.19	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.92	ft	Upstream Velocity Head	0.23	ft
Ke	0.50		Entrance Loss	0.11	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.74	ft	Flow Control	N/A	
Inlet Type	Square edge with headwall (horizontal ellipse)		Area Full	3.6	ft²
K	0.01000		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Designer/Analyzer Report
Problem Area A Culvert

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Elev	10,000.97	ft	Discharge	8.80	cfs
Headwater Depth/Height	0.60		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.74	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.97	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,998.00	ft
Length	12.00	ft	Constructed Slope	0.166667	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.29	ft
Slope Type	Steep		Normal Depth	0.25	ft
Flow Regime	Supercritical		Critical Depth	0.62	ft
Velocity Downstream	11.25	ft/s	Critical Slope	0.004081	ft/ft

Section					
Section Shape	Horizontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.52	ft
Section Size	19x30 inch		Rise	1.60	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.97	ft	Upstream Velocity Head	0.23	ft
Ke	0.50		Entrance Loss	0.12	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.74	ft	Flow Control	N/A	
Inlet Type	Square edge with headwall (horizontal ellipse)		Area Full	6.6	ft²
K	0.01000		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

CULVERT 24 REPORT

Culvert Designer/Analyzer Report
Problem Area B Culvert

Peak Discharge Method: User-Specified					
Design Discharge	5.40	cfs	Check Discharge	7.20	cfs

Grades Model: Inverts					
Invert Upstream	10,000.00	ft	Invert Downstream	9,999.88	ft
Length	12.00	ft	Slope	0.010000	ft/ft
Drop	0.12	ft			

Headwater Model: Maximum Allowable HW		
Headwater Elevation	100,001.00	ft

Tailwater Conditions: Constant Tailwater		
Tailwater Elevation	N/A	ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	2-2 x 2 ft Box	5.40 cfs	10,000.67 ft	4.25 ft/s
	Trial-2	2-2 x 2 ft Box	7.20 cfs	10,000.81 ft	4.64 ft/s

Culvert Designer/Analyzer Report
Problem Area B Culvert

Design:Trial-1

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	100,001.00	ft	Storm Event	Design	
Computed Headwater Elev	10,000.67	ft	Discharge	5.40	cfs
Headwater Depth/Height	0.34		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.61	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.67	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,999.88	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.32	ft
Slope Type	Steep		Normal Depth	0.31	ft
Flow Regime	Supercritical		Critical Depth	0.38	ft
Velocity Downstream	4.25	ft/s	Critical Slope	0.005226	ft/ft

Section					
Section Shape	Box		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	ft
Section Size	2 x 2 ft		Rise	2.00	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.67	ft	Upstream Velocity Head	0.19	ft
Ke	0.50		Entrance Loss	0.10	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.61	ft	Flow Control	N/A	
Inlet Type	45° wingwall flares - offset		Area Full	8.0	ft²
K	0.49700		HDS 5 Chart	13	
M	0.66700		HDS 5 Scale	1	
C	0.03020		Equation Form	2	
Y	0.83500				

Culvert Designer/Analyzer Report
Problem Area B Culvert

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	100,001.00	ft	Storm Event	Check	
Computed Headwater Elev	10,000.81	ft	Discharge	7.20	cfs
Headwater Depth/Height	0.41		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	10,000.74	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	10,000.81	ft			

Grades					
Upstream Invert	10,000.00	ft	Downstream Invert	9,999.88	ft
Length	12.00	ft	Constructed Slope	0.010000	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.39	ft
Slope Type	Steep		Normal Depth	0.37	ft
Flow Regime	Supercritical		Critical Depth	0.47	ft
Velocity Downstream	4.64	ft/s	Critical Slope	0.005289	ft/ft

Section					
Section Shape	Box		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	ft
Section Size	2 x 2 ft		Rise	2.00	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	10,000.81	ft	Upstream Velocity Head	0.23	ft
Ke	0.50		Entrance Loss	0.12	ft

Inlet Control Properties					
Inlet Control HW Elev.	10,000.74	ft	Flow Control	N/A	
Inlet Type	45° wingwall flares - offset		Area Full	8.0	ft²
K	0.49700		HDS 5 Chart	13	
M	0.66700		HDS 5 Scale	1	
C	0.03020		Equation Form	2	
Y	0.83500				

APPENDIX F: FLOW MASTER RESULTS

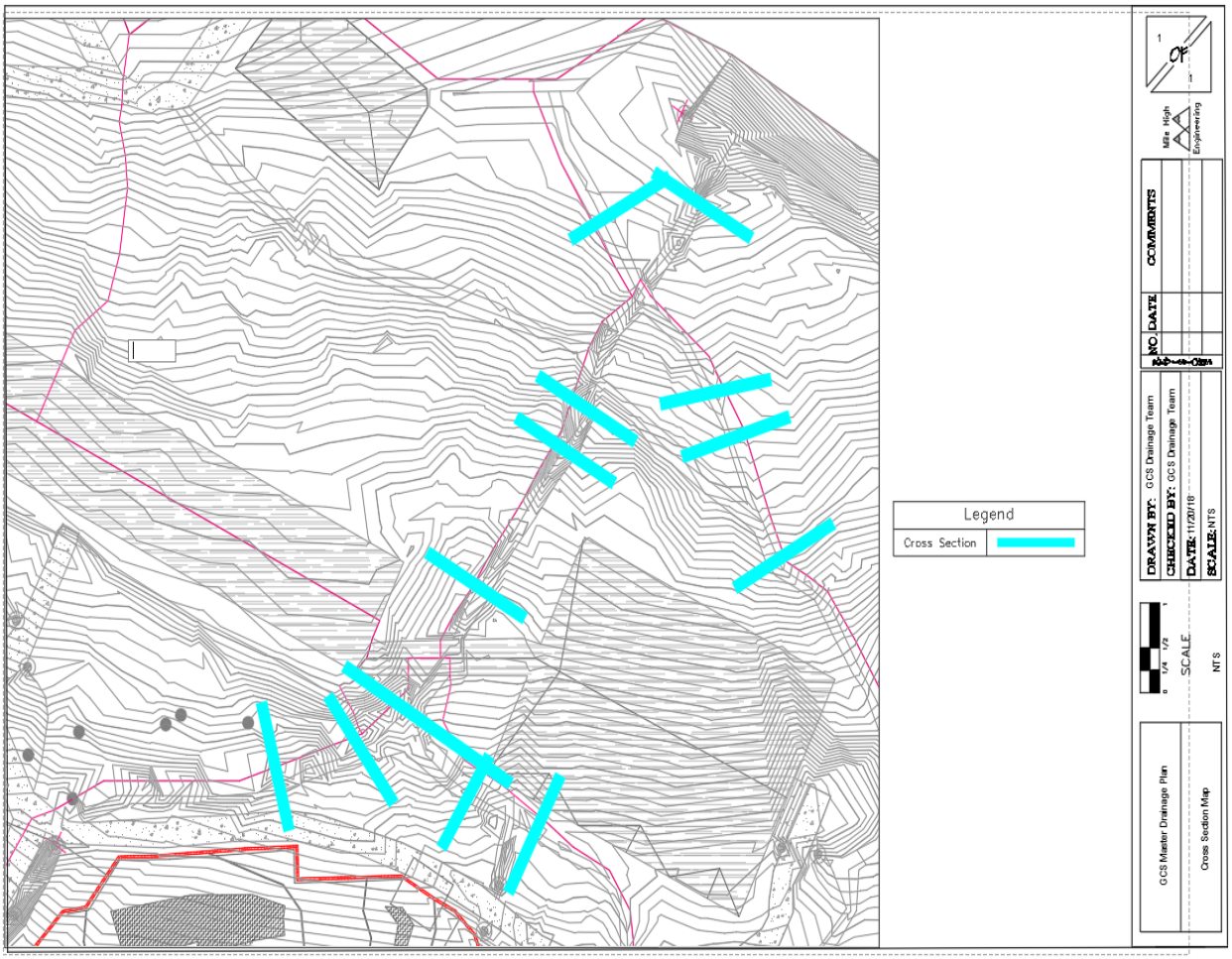

Figure 16: Location of cross sections for Problem Area A and B. [5]

Appendix F-1: Area A problem for 25 years [7]

Worksheet for LDR_CS0_25YR

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Discharge	7.00

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,984.75
0+01	9,984.75
0+16	9,984.50
0+17	9,984.25
0+18	9,984.00
0+19	9,983.75
0+19	9,983.75
0+20	9,984.00
0+22	9,984.25
0+24	9,984.50
0+25	9,984.75
0+26	9,985.00
0+31	9,985.25
0+36	9,985.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,984.75)	(0+16, 9,984.50)	0.060
(0+16, 9,984.50)	(0+26, 9,985.00)	0.020
(0+26, 9,985.00)	(0+36, 9,985.50)	0.060

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	5.8
Elevation Range	9,983.8 to 9,985.5 ft
Flow Area	1.0
Wetted Perimeter	5.1
Hydraulic Radius	2.3
Top Width	4.90
Normal Depth	5.8

Worksheet for LDR_CS0_25YR
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Results	
Critical Depth	8.3
Critical Slope	0.009
Velocity	7.08
Velocity Head	0.78
Specific Energy	1.26
Froude Number	2.778
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	5.8
Critical Depth	8.3
Channel Slope	0.081
Critical Slope	0.009

Cross Section for LDR_CS0_25YR
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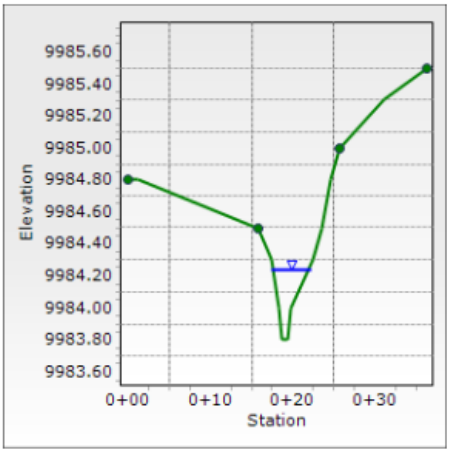
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	5.8
Discharge	7.00



Worksheet for LDR_CS1_25YR

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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.081
Discharge	6.60

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,988.00
0+02	9,988.00
0+11	9,988.00
0+12	9,987.75
0+12	9,987.75
0+13	9,987.25
0+14	9,987.50
0+15	9,987.75
0+17	9,988.00
0+18	9,988.25

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,988.00)	(0+11, 9,988.00)	0.060
(0+11, 9,988.00)	(0+15, 9,987.75)	0.020
(0+15, 9,987.75)	(0+18, 9,988.25)	0.060

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	7.5
Elevation Range	9,987.3 to 9,988.3 ft
Flow Area	1.2
Wetted Perimeter	4.9
Hydraulic Radius	3.0
Top Width	4.60
Normal Depth	7.5
Critical Depth	9.7
Critical Slope	0.027
Velocity	5.35
Velocity Head	0.44

Worksheet for LDR_CS1_25YR
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Results	
Specific Energy	1.07
Froude Number	1.820
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	7.5
Critical Depth	9.7
Channel Slope	0.081
Critical Slope	0.027

Cross Section for LDR_CS1_25YR
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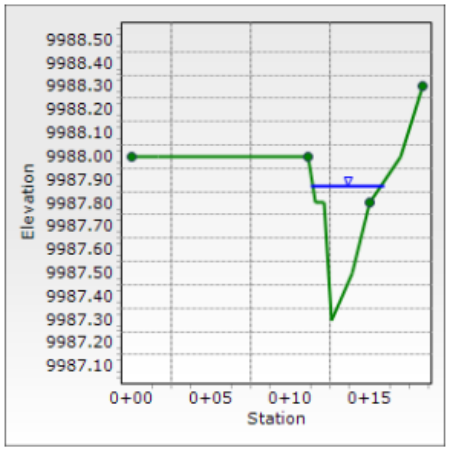
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	7.5
Discharge	6.60



Worksheet for LDR_CS2_25YR

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Discharge	6.60

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,989.50
0+00	9,989.50
0+04	9,989.75
0+07	9,990.00
0+10	9,990.30
0+12	9,990.00
0+12	9,989.80
0+13	9,989.75
0+14	9,989.50
0+15	9,989.25
0+15	9,989.00
0+16	9,989.00
0+17	9,989.25
0+18	9,989.50
0+20	9,990.00
0+20	9,990.25
0+30	9,990.30

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,989.50)	(0+10, 9,990.30)	0.060
(0+10, 9,990.30)	(0+20, 9,990.00)	0.020
(0+20, 9,990.00)	(0+30, 9,990.30)	0.060

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	4.7
Elevation Range	9,989.0 to 9,990.3 ft
Flow Area	0.8
Wetted Perimeter	3.4

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Results	
Hydraulic Radius	2.9
Top Width	3.26
Normal Depth	4.7
Critical Depth	8.0
Critical Slope	0.009
Velocity	8.15
Velocity Head	1.03
Specific Energy	1.43
Froude Number	2.885
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	4.7
Critical Depth	8.0
Channel Slope	0.081
Critical Slope	0.009

Cross Section for LDR_CS2_25YR
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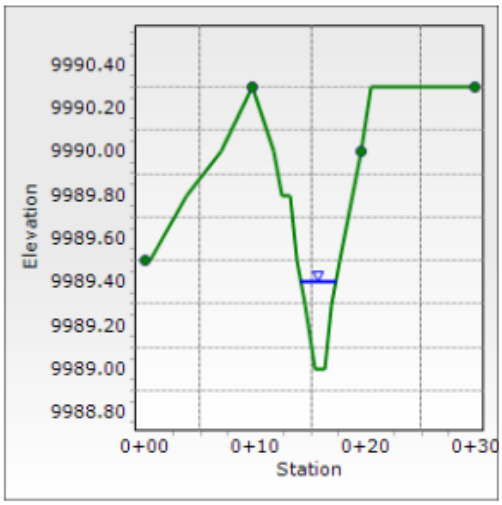
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	4.7
Discharge	6.60



Worksheet for LDR_CS3_25YR

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Discharge	6.60

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,991.50
0+00	9,991.50
0+07	9,991.75
0+16	9,991.75
0+17	9,991.50
0+17	9,991.25
0+18	9,991.00
0+19	9,990.75
0+20	9,990.75
0+22	9,991.00
0+23	9,991.25
0+23	9,991.50
0+28	9,991.75
0+32	9,992.00
0+36	9,992.25

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,991.50)	(0+16, 9,991.75)	0.060
(0+16, 9,991.75)	(0+23, 9,991.50)	0.020
(0+23, 9,991.50)	(0+36, 9,992.25)	0.060

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	3.7
Elevation Range	9,990.8 to 9,992.3 ft
Flow Area	0.9
Wetted Perimeter	4.1
Hydraulic Radius	2.5
Top Width	4.04

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Results	
Normal Depth	3.7
Critical Depth	6.4
Critical Slope	0.009
Velocity	7.53
Velocity Head	0.88
Specific Energy	1.19
Froude Number	2.852
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	3.7
Critical Depth	6.4
Channel Slope	0.081
Critical Slope	0.009

Cross Section for LDR_CS3_25YR
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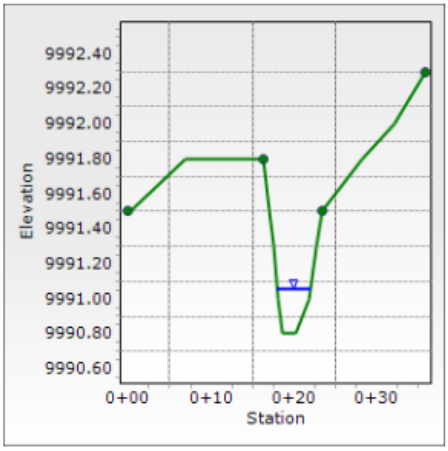
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	3.7
Discharge	6.60



Worksheet for RDR_CS1_25 years

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Discharge	6.60

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,993.00
0+03	9,992.75
0+06	9,992.50
0+09	9,992.25
0+13	9,992.00
0+16	9,991.75
0+18	9,991.75
0+27	9,992.00
0+34	9,992.25
0+37	9,993.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,993.00)	(0+03, 9,992.75)	0.020
(0+03, 9,992.75)	(0+06, 9,992.50)	0.020
(0+06, 9,992.50)	(0+09, 9,992.25)	0.020
(0+09, 9,992.25)	(0+13, 9,992.00)	0.020
(0+13, 9,992.00)	(0+16, 9,991.75)	0.020
(0+16, 9,991.75)	(0+18, 9,991.75)	0.020
(0+18, 9,991.75)	(0+27, 9,992.00)	0.020
(0+27, 9,992.00)	(0+34, 9,992.25)	0.020
(0+34, 9,992.25)	(0+37, 9,993.50)	0.020

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	2.6
Elevation Range	9,991.8 to 9,993.5 ft
Flow Area	1.6
Wetted Perimeter	13.0
Hydraulic Radius	1.5

Worksheet for RDR_CS1_25 years
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Results	
Top Width	12.99
Normal Depth	2.6
Critical Depth	3.6
Critical Slope	0.011
Velocity	4.12
Velocity Head	0.26
Specific Energy	0.48
Froude Number	2.067
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	2.6
Critical Depth	3.6
Channel Slope	0.050
Critical Slope	0.011

Cross Section for RDR_CS1_25 years
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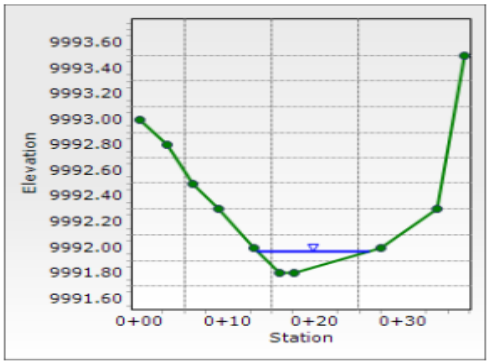
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	2.6
Discharge	6.60



Worksheet for RDR_CS2_25 years

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Discharge	6.60

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,990.00
0+02	9,989.75
0+06	9,989.50
0+11	9,989.25
0+39	9,989.25
0+44	9,989.50
0+49	9,989.75

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,990.00)	(0+02, 9,989.75)	0.020
(0+02, 9,989.75)	(0+06, 9,989.50)	0.020
(0+06, 9,989.50)	(0+11, 9,989.25)	0.020
(0+11, 9,989.25)	(0+39, 9,989.25)	0.020
(0+39, 9,989.25)	(0+44, 9,989.50)	0.020
(0+44, 9,989.50)	(0+49, 9,989.75)	0.020

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	0.9
Elevation Range	9,989.3 to 9,990.0 ft
Flow Area	2.3
Wetted Perimeter	31.0
Hydraulic Radius	0.9
Top Width	31.01
Normal Depth	0.9
Critical Depth	1.4
Critical Slope	0.012
Velocity	2.91
Velocity Head	0.13

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Results	
Specific Energy	0.21
Froude Number	1.895
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	0.9
Critical Depth	1.4
Channel Slope	0.050
Critical Slope	0.012

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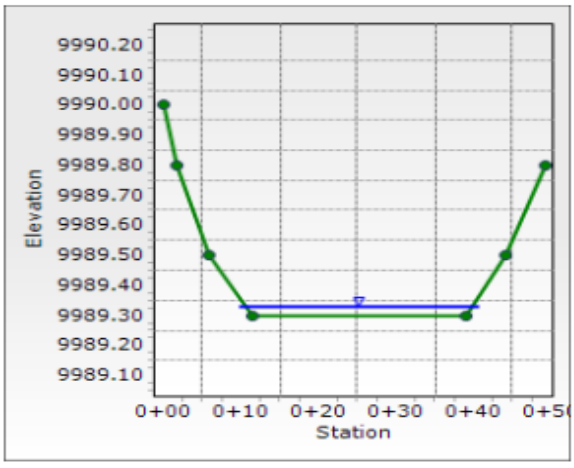
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	0.9
Discharge	6.60



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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	6.60

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,989.00
0+07	9,988.75
0+13	9,988.50
0+17	9,988.50
0+19	9,988.75
0+24	9,988.75

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,989.00)	(0+07, 9,988.75)	0.020
(0+07, 9,988.75)	(0+13, 9,988.50)	0.020
(0+13, 9,988.50)	(0+17, 9,988.50)	0.020
(0+17, 9,988.50)	(0+19, 9,988.75)	0.020
(0+19, 9,988.75)	(0+24, 9,988.75)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	2.4
Elevation Range	9,988.5 to 9,989.0 ft
Flow Area	1.5
Wetted Perimeter	10.6
Hydraulic Radius	1.7
Top Width	10.59
Normal Depth	2.4
Critical Depth	3.6
Critical Slope	0.011
Velocity	4.46
Velocity Head	0.31
Specific Energy	0.51
Froude Number	2.104

Worksheet for RDR_CS3_25 years
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Results	
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	2.4
Critical Depth	3.6
Channel Slope	0.050
Critical Slope	0.011

Cross Section for RDR_CS3_25 years
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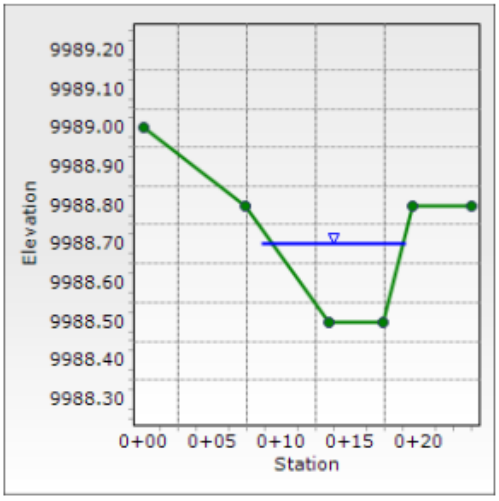
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	2.4
Discharge	6.60



Worksheet for RDR_CS4_25 years

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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	7.00

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,986.00
0+07	9,985.75
0+13	9,985.50
0+18	9,985.50
0+22	9,985.75
0+24	9,985.75

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,986.00)	(0+07, 9,985.75)	0.020
(0+07, 9,985.75)	(0+13, 9,985.50)	0.020
(0+13, 9,985.50)	(0+18, 9,985.50)	0.020
(0+18, 9,985.50)	(0+22, 9,985.75)	0.020
(0+22, 9,985.75)	(0+24, 9,985.75)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	2.3
Elevation Range	9,985.5 to 9,986.0 ft
Flow Area	1.6
Wetted Perimeter	12.2
Hydraulic Radius	1.6
Top Width	12.20
Normal Depth	2.3
Critical Depth	3.4
Critical Slope	0.011
Velocity	4.33
Velocity Head	0.29
Specific Energy	0.48
Froude Number	2.095

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Results	
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	2.3
Critical Depth	3.4
Channel Slope	0.050
Critical Slope	0.011

Cross Section for RDR_CS4_25 years
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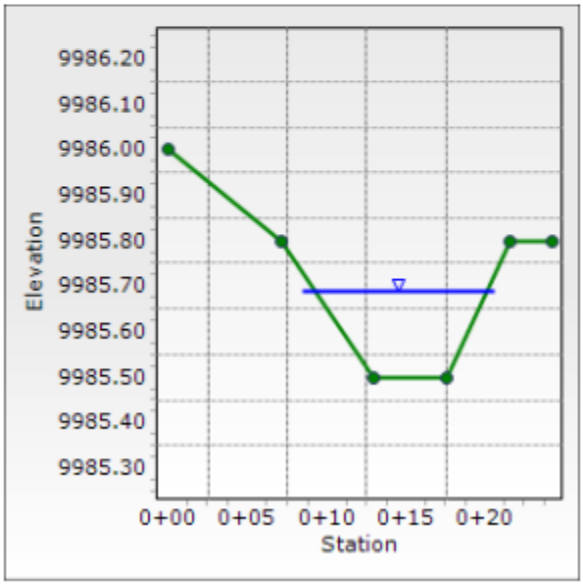
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	2.3
Discharge	7.00



Appendix E-2: Area A problem for 50 years [7]

Worksheet for LDR_CS0_50YR

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Discharge	9.40

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,984.75
0+01	9,984.75
0+16	9,984.50
0+17	9,984.25
0+18	9,984.00
0+19	9,983.75
0+19	9,983.75
0+20	9,984.00
0+22	9,984.25
0+24	9,984.50
0+25	9,984.75
0+26	9,985.00
0+31	9,985.25
0+36	9,985.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,984.75)	(0+16, 9,984.50)	0.060
(0+16, 9,984.50)	(0+26, 9,985.00)	0.020
(0+26, 9,985.00)	(0+36, 9,985.50)	0.060

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	6.4
Elevation Range	9,983.8 to 9,985.5 ft
Flow Area	1.2
Wetted Perimeter	5.7
Hydraulic Radius	2.6
Top Width	5.46
Normal Depth	6.4

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Results	
Critical Depth	9.5
Critical Slope	0.009
Velocity	7.63
Velocity Head	0.91
Specific Energy	1.44
Froude Number	2.833
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	6.4
Critical Depth	9.5
Channel Slope	0.081
Critical Slope	0.009

Cross Section for LDR_CS0_50YR
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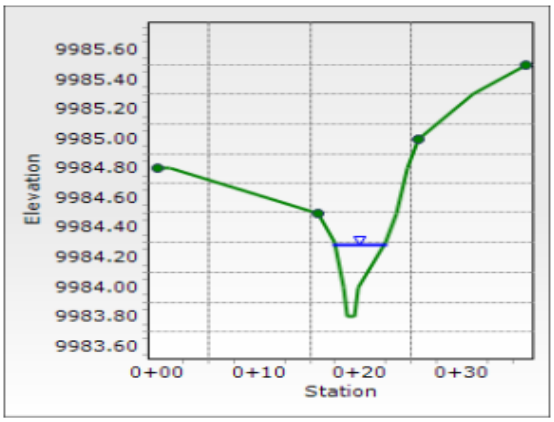
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	6.4
Discharge	9.40



Worksheet for LDR_CS1_50YR

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Discharge	8.80

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,988.00
0+02	9,988.00
0+11	9,988.00
0+12	9,987.75
0+12	9,987.75
0+13	9,987.25
0+14	9,987.50
0+15	9,987.75
0+17	9,988.00
0+18	9,988.25

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,988.00)	(0+11, 9,988.00)	0.060
(0+11, 9,988.00)	(0+15, 9,987.75)	0.020
(0+15, 9,987.75)	(0+18, 9,988.25)	0.060

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	8.5
Elevation Range	9,987.3 to 9,988.3 ft
Flow Area	1.7
Wetted Perimeter	5.8
Hydraulic Radius	3.5
Top Width	5.46
Normal Depth	8.5
Critical Depth	10.1
Critical Slope	0.033
Velocity	5.20
Velocity Head	0.42

Worksheet for LDR_CS1_50YR
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Results	
Specific Energy	1.13
Froude Number	1.648
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	8.5
Critical Depth	10.1
Channel Slope	0.081
Critical Slope	0.033

Cross Section for LDR_CS1_50YR
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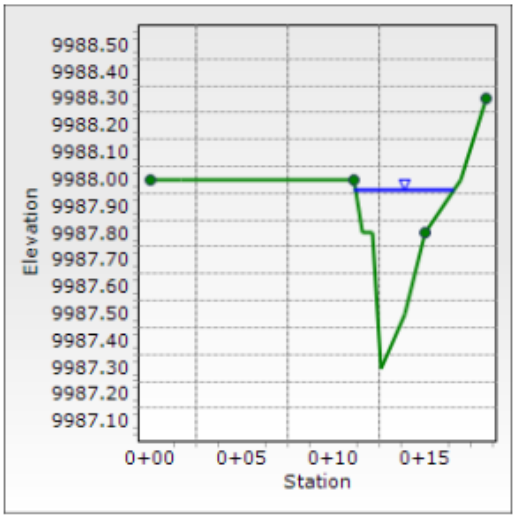
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	8.5
Discharge	8.80



Worksheet for LDR_CS2_50YR

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Discharge	8.80

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,989.50
0+00	9,989.50
0+04	9,989.75
0+07	9,990.00
0+10	9,990.30
0+12	9,990.00
0+12	9,989.80
0+13	9,989.75
0+14	9,989.50
0+15	9,989.25
0+15	9,989.00
0+16	9,989.00
0+17	9,989.25
0+18	9,989.50
0+20	9,990.00
0+20	9,990.25
0+30	9,990.30

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,989.50)	(0+10, 9,990.30)	0.060
(0+10, 9,990.30)	(0+20, 9,990.00)	0.020
(0+20, 9,990.00)	(0+30, 9,990.30)	0.060

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	5.4
Elevation Range	9,989.0 to 9,990.3 ft
Flow Area	1.0
Wetted Perimeter	3.8

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Results	
Hydraulic Radius	3.2
Top Width	3.62
Normal Depth	5.4
Critical Depth	8.9
Critical Slope	0.009
Velocity	8.77
Velocity Head	1.19
Specific Energy	1.65
Froude Number	2.936
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	5.4
Critical Depth	8.9
Channel Slope	0.081
Critical Slope	0.009

Cross Section for LDR_CS2_50YR
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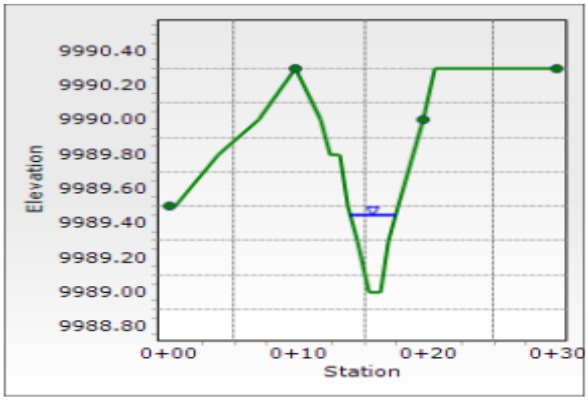
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	5.4
Discharge	8.80



Worksheet for LDR_CS3_50YR

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Discharge	8.80

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,991.50
0+00	9,991.50
0+07	9,991.75
0+16	9,991.75
0+17	9,991.50
0+17	9,991.25
0+18	9,991.00
0+19	9,990.75
0+20	9,990.75
0+22	9,991.00
0+23	9,991.25
0+23	9,991.50
0+28	9,991.75
0+32	9,992.00
0+36	9,992.25

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,991.50)	(0+16, 9,991.75)	0.060
(0+16, 9,991.75)	(0+23, 9,991.50)	0.020
(0+23, 9,991.50)	(0+36, 9,992.25)	0.060

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	4.3
Elevation Range	9,990.8 to 9,992.3 ft
Flow Area	1.1
Wetted Perimeter	4.4
Hydraulic Radius	2.9
Top Width	4.31

Worksheet for LDR_CS3_50YR
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Results	
Normal Depth	4.3
Critical Depth	7.4
Critical Slope	0.008
Velocity	8.23
Velocity Head	1.05
Specific Energy	1.41
Froude Number	2.913
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	4.3
Critical Depth	7.4
Channel Slope	0.081
Critical Slope	0.008

Cross Section for LDR_CS3_50YR
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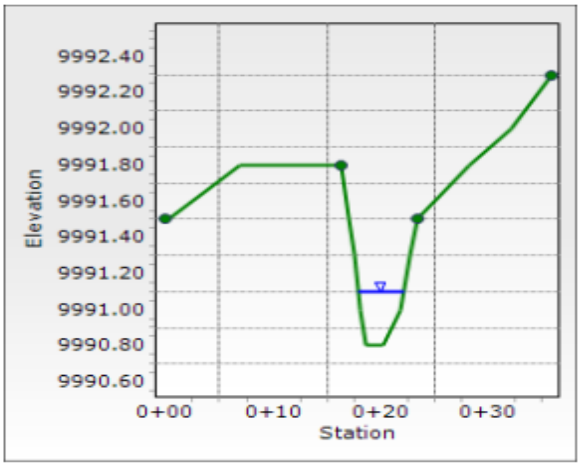
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	4.3
Discharge	8.80



Worksheet for RDR_CS1_50 years
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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	8.80

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,993.00
0+03	9,992.75
0+06	9,992.50
0+09	9,992.25
0+13	9,992.00
0+16	9,991.75
0+18	9,991.75
0+27	9,992.00
0+34	9,992.25
0+37	9,993.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,993.00)	(0+03, 9,992.75)	0.020
(0+03, 9,992.75)	(0+06, 9,992.50)	0.020
(0+06, 9,992.50)	(0+09, 9,992.25)	0.020
(0+09, 9,992.25)	(0+13, 9,992.00)	0.020
(0+13, 9,992.00)	(0+16, 9,991.75)	0.020
(0+16, 9,991.75)	(0+18, 9,991.75)	0.020
(0+18, 9,991.75)	(0+27, 9,992.00)	0.020
(0+27, 9,992.00)	(0+34, 9,992.25)	0.020
(0+34, 9,992.25)	(0+37, 9,993.50)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	3.0
Elevation Range	9,991.8 to 9,993.5 ft
Flow Area	2.0
Wetted Perimeter	14.5
Hydraulic Radius	1.6

Worksheet for RDR_CS1_50 years
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Results	
Top Width	14.45
Normal Depth	3.0
Critical Depth	4.1
Critical Slope	0.010
Velocity	4.43
Velocity Head	0.30
Specific Energy	0.55
Froude Number	2.104
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	3.0
Critical Depth	4.1
Channel Slope	0.050
Critical Slope	0.010

Cross Section for RDR_CS1_50 years
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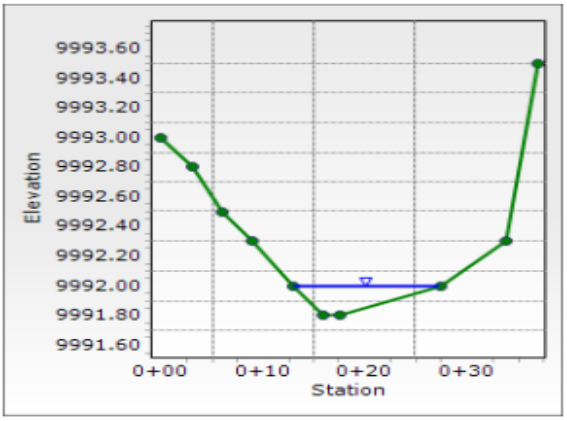
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	3.0
Discharge	8.80



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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	8.80

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,990.00
0+02	9,989.75
0+06	9,989.50
0+11	9,989.25
0+39	9,989.25
0+44	9,989.50
0+49	9,989.75

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,990.00)	(0+02, 9,989.75)	0.020
(0+02, 9,989.75)	(0+06, 9,989.50)	0.020
(0+06, 9,989.50)	(0+11, 9,989.25)	0.020
(0+11, 9,989.25)	(0+39, 9,989.25)	0.020
(0+39, 9,989.25)	(0+44, 9,989.50)	0.020
(0+44, 9,989.50)	(0+49, 9,989.75)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	1.1
Elevation Range	9,989.3 to 9,990.0 ft
Flow Area	2.7
Wetted Perimeter	31.6
Hydraulic Radius	1.0
Top Width	31.61
Normal Depth	1.1
Critical Depth	1.7
Critical Slope	0.012
Velocity	3.25
Velocity Head	0.16

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Results	
Specific Energy	0.26
Froude Number	1.954
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	1.1
Critical Depth	1.7
Channel Slope	0.050
Critical Slope	0.012

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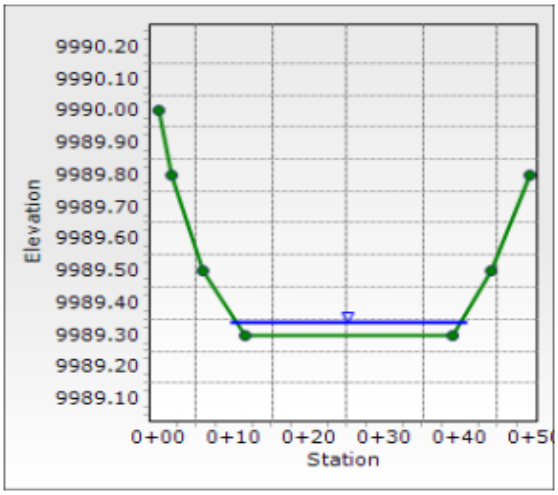
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	1.1
Discharge	8.80



Worksheet for RDR_CS3_50 years
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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	8.80

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,989.00
0+07	9,988.75
0+13	9,988.50
0+17	9,988.50
0+19	9,988.75
0+24	9,988.75

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coeffident
(0+00, 9,989.00)	(0+07, 9,988.75)	0.020
(0+07, 9,988.75)	(0+13, 9,988.50)	0.020
(0+13, 9,988.50)	(0+17, 9,988.50)	0.020
(0+17, 9,988.50)	(0+19, 9,988.75)	0.020
(0+19, 9,988.75)	(0+24, 9,988.75)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	2.8
Elevation Range	9,988.5 to 9,989.0 ft
Flow Area	1.8
Wetted Perimeter	11.6
Hydraulic Radius	1.9
Top Width	11.59
Normal Depth	2.8
Critical Depth	4.1
Critical Slope	0.010
Velocity	4.83
Velocity Head	0.36
Specific Energy	0.60
Froude Number	2.149

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Results	
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	2.8
Critical Depth	4.1
Channel Slope	0.050
Critical Slope	0.010

Cross Section for RDR_CS3_50 years
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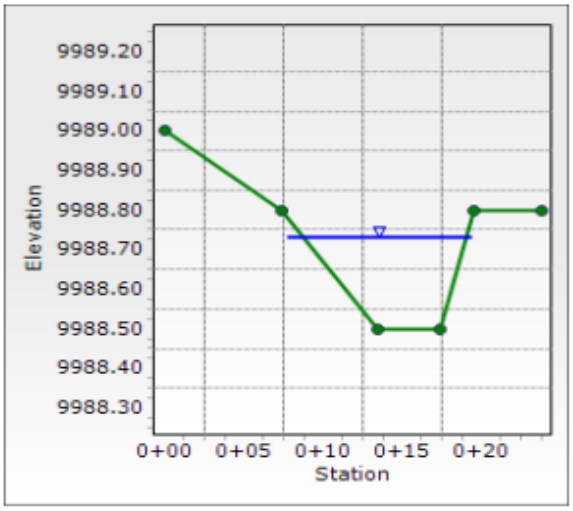
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	2.8
Discharge	8.80



Worksheet for RDR_CS4_50 years

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Discharge	9.40

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,986.00
0+07	9,985.75
0+13	9,985.50
0+18	9,985.50
0+22	9,985.75
0+24	9,985.75

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coeffident
(0+00, 9,986.00)	(0+07, 9,985.75)	0.020
(0+07, 9,985.75)	(0+13, 9,985.50)	0.020
(0+13, 9,985.50)	(0+18, 9,985.50)	0.020
(0+18, 9,985.50)	(0+22, 9,985.75)	0.020
(0+22, 9,985.75)	(0+24, 9,985.75)	0.020

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	2.7
Elevation Range	9,985.5 to 9,986.0 ft
Flow Area	2.0
Wetted Perimeter	13.4
Hydraulic Radius	1.8
Top Width	13.41
Normal Depth	2.7
Critical Depth	3.9
Critical Slope	0.010
Velocity	4.68
Velocity Head	0.34
Specific Energy	0.56
Froude Number	2.132

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Results	
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	2.7
Critical Depth	3.9
Channel Slope	0.050
Critical Slope	0.010

Cross Section for RDR_CS4_50 years
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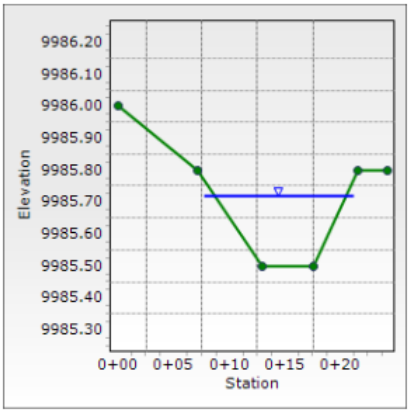
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	2.7
Discharge	9.40



Appendix E-3: Area B problem for 25 years [7]

Worksheet for LDR_CS4_25YR

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Discharge	6.60

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,994.50
0+00	9,994.50
0+02	9,994.75
0+06	9,994.75
0+08	9,994.50
0+09	9,994.25
0+11	9,994.00
0+14	9,994.00
0+16	9,994.25
0+17	9,994.50
0+18	9,994.75

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,994.50)	(0+06, 9,994.75)	0.060
(0+06, 9,994.75)	(0+16, 9,994.25)	0.020
(0+16, 9,994.25)	(0+18, 9,994.75)	0.060

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	2.6
Elevation Range	9,994.0 to 9,994.8 ft
Flow Area	1.0
Wetted Perimeter	6.3
Hydraulic Radius	2.0
Top Width	6.29
Normal Depth	2.6
Critical Depth	4.6
Critical Slope	0.009
Velocity	6.36

Worksheet for LDR_CS4_25YR
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Results	
Velocity Head	0.63
Specific Energy	0.85
Froude Number	2.759
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	2.6
Critical Depth	4.6
Channel Slope	0.081
Critical Slope	0.009

Cross Section for LDR_CS4_25YR
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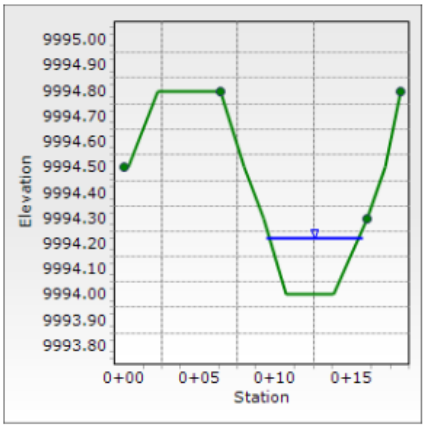
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	2.6
Discharge	6.60



Worksheet for RUR_CS1_25 years

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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	5.40

Section Definitions

Station (ft)	Elevation (ft)
0+00	10,000.25
0+05	10,000.00
0+10	9,999.75
0+16	9,999.50
0+17	9,999.25
0+18	9,999.00
0+19	9,999.00
0+21	9,999.25
0+24	9,999.25

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 10,000.25)	(0+05, 10,000.00)	0.020
(0+05, 10,000.00)	(0+10, 9,999.75)	0.020
(0+10, 9,999.75)	(0+16, 9,999.50)	0.020
(0+16, 9,999.50)	(0+17, 9,999.25)	0.020
(0+17, 9,999.25)	(0+18, 9,999.00)	0.020
(0+18, 9,999.00)	(0+19, 9,999.00)	0.020
(0+19, 9,999.00)	(0+21, 9,999.25)	0.020
(0+21, 9,999.25)	(0+24, 9,999.25)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	4.0
Elevation Range	9,999.0 to 10,000.3 ft
Flow Area	1.1
Wetted Perimeter	7.1
Hydraulic Radius	1.9
Top Width	6.94
Normal Depth	4.0

Worksheet for RUR_CS1_25 years
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Results	
Critical Depth	5.3
Critical Slope	0.010
Velocity	4.84
Velocity Head	0.36
Specific Energy	0.70
Froude Number	2.126
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	4.0
Critical Depth	5.3
Channel Slope	0.050
Critical Slope	0.010

Cross Section for RUR_CS1_25 years
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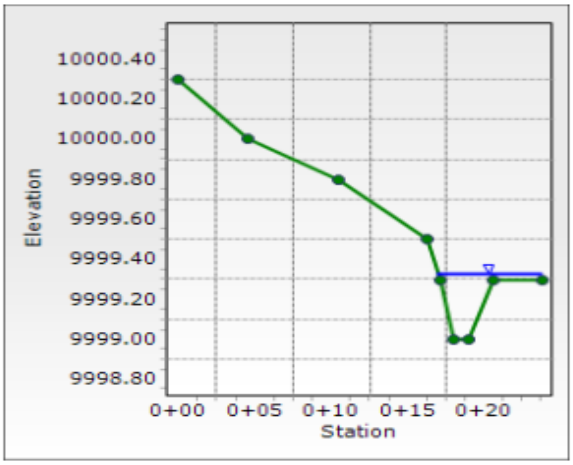
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	4.0
Discharge	5.40



Worksheet for RUR_CS2_25 years

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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	5.40

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,999.00
0+03	9,998.75
0+06	9,998.50
0+07	9,998.25
0+09	9,998.00
0+10	9,998.00
0+14	9,998.25
0+15	9,998.50
0+17	9,998.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,999.00)	(0+03, 9,998.75)	0.020
(0+03, 9,998.75)	(0+06, 9,998.50)	0.020
(0+06, 9,998.50)	(0+07, 9,998.25)	0.020
(0+07, 9,998.25)	(0+09, 9,998.00)	0.020
(0+09, 9,998.00)	(0+10, 9,998.00)	0.020
(0+10, 9,998.00)	(0+14, 9,998.25)	0.020
(0+14, 9,998.25)	(0+15, 9,998.50)	0.020
(0+15, 9,998.50)	(0+17, 9,998.50)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	3.2
Elevation Range	9,998.0 to 9,999.0 ft
Flow Area	1.1
Wetted Perimeter	6.5
Hydraulic Radius	2.0
Top Width	6.51
Normal Depth	3.2

Worksheet for RUR_CS2_25 years
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Results	
Critical Depth	4.6
Critical Slope	0.009
Velocity	5.00
Velocity Head	0.39
Specific Energy	0.65
Froude Number	2.163
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	3.2
Critical Depth	4.6
Channel Slope	0.050
Critical Slope	0.009

Cross Section for RUR_CS2_25 years
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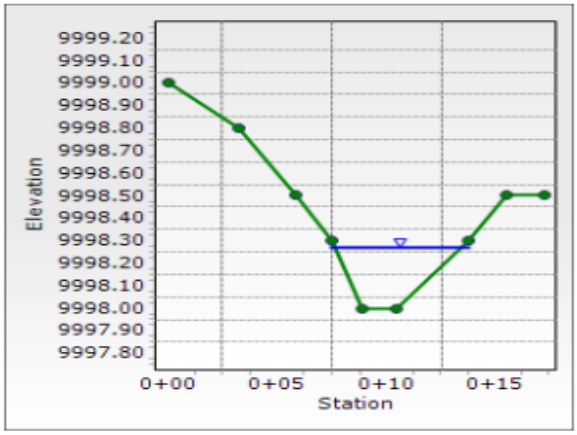
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	3.2
Discharge	5.40



Worksheet for LUR_CS1_25 years
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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Discharge	5.40

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,997.00
0+01	9,997.25
0+02	9,997.50
0+03	9,997.75
0+05	9,998.00
0+06	9,998.25
0+07	9,998.50
0+09	9,998.50
0+11	9,998.25
0+12	9,998.00
0+13	9,997.75
0+15	9,997.75
0+16	9,998.00
0+18	9,998.25
0+19	9,998.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,997.00)	(0+01, 9,997.25)	0.020
(0+01, 9,997.25)	(0+02, 9,997.50)	0.020
(0+02, 9,997.50)	(0+03, 9,997.75)	0.020
(0+03, 9,997.75)	(0+05, 9,998.00)	0.020
(0+05, 9,998.00)	(0+06, 9,998.25)	0.020
(0+06, 9,998.25)	(0+07, 9,998.50)	0.020
(0+07, 9,998.50)	(0+09, 9,998.50)	0.020
(0+09, 9,998.50)	(0+11, 9,998.25)	0.020
(0+11, 9,998.25)	(0+12, 9,998.00)	0.020
(0+12, 9,998.00)	(0+13, 9,997.75)	0.020
(0+13, 9,997.75)	(0+15, 9,997.75)	0.020
(0+15, 9,997.75)	(0+16, 9,998.00)	0.020
(0+16, 9,998.00)	(0+18, 9,998.25)	0.020
(0+18, 9,998.25)	(0+19, 9,998.50)	0.020

Worksheet for LUR_CS1_25 years
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Options	
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	7.6
Elevation Range	9,997.0 to 9,998.5 ft
Flow Area	0.8
Wetted Perimeter	3.4
Hydraulic Radius	2.9
Top Width	2.73
Normal Depth	7.6
Critical Depth	10.3
Critical Slope	0.011
Velocity	6.47
Velocity Head	0.65
Specific Energy	1.28
Froude Number	2.063
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	7.6
Critical Depth	10.3
Channel Slope	0.050
Critical Slope	0.011

Cross Section for LUR_CS1_25 years
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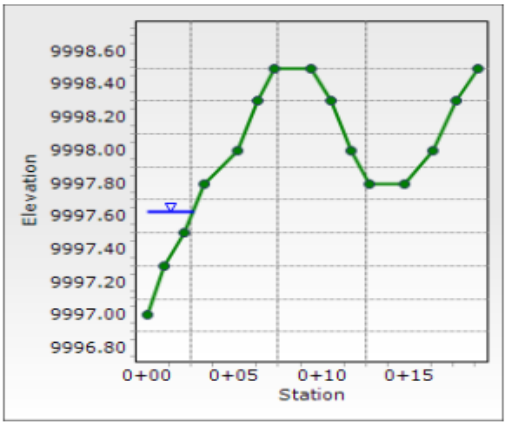
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	7.6
Discharge	5.40



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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Discharge	5.40

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,996.50
0+03	9,996.75
0+05	9,997.00
0+07	9,997.25
0+07	9,997.25
0+08	9,997.00
0+09	9,996.75
0+10	9,996.75
0+11	9,997.00
0+12	9,997.25
0+15	9,997.25
0+19	9,997.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coeffident
(0+00, 9,996.50)	(0+03, 9,996.75)	0.020
(0+03, 9,996.75)	(0+05, 9,997.00)	0.020
(0+05, 9,997.00)	(0+07, 9,997.25)	0.020
(0+07, 9,997.25)	(0+07, 9,997.25)	0.020
(0+07, 9,997.25)	(0+08, 9,997.00)	0.020
(0+08, 9,997.00)	(0+09, 9,996.75)	0.020
(0+09, 9,996.75)	(0+10, 9,996.75)	0.020
(0+10, 9,996.75)	(0+11, 9,997.00)	0.020
(0+11, 9,997.00)	(0+12, 9,997.25)	0.020
(0+12, 9,997.25)	(0+15, 9,997.25)	0.020
(0+15, 9,997.25)	(0+19, 9,997.50)	0.020

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	4.6

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Results	
Elevation Range	9,996.5 to 9,997.5 ft
Flow Area	1.1
Wetted Perimeter	6.4
Hydraulic Radius	2.0
Top Width	5.98
Normal Depth	4.6
Critical Depth	6.1
Critical Slope	0.010
Velocity	5.04
Velocity Head	0.39
Specific Energy	0.78
Froude Number	2.098
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	4.6
Critical Depth	6.1
Channel Slope	0.050
Critical Slope	0.010

Cross Section for LUR_CS2_25 years
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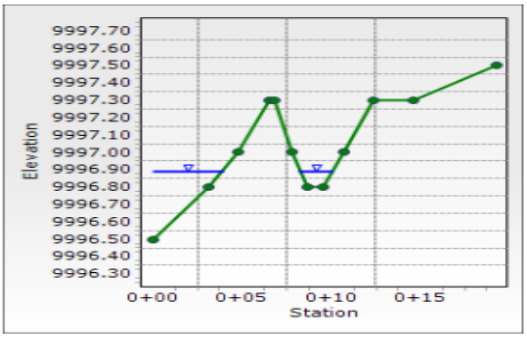
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	4.6
Discharge	5.40



Appendix E-4: Area B problem for 50 years [7]

Worksheet for LDR_CS4_50YR

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Discharge	8.80

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,994.50
0+00	9,994.50
0+02	9,994.75
0+06	9,994.75
0+08	9,994.50
0+09	9,994.25
0+11	9,994.00
0+14	9,994.00
0+16	9,994.25
0+17	9,994.50
0+18	9,994.75

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,994.50)	(0+06, 9,994.75)	0.060
(0+06, 9,994.75)	(0+16, 9,994.25)	0.020
(0+16, 9,994.25)	(0+18, 9,994.75)	0.060

Options	
Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	3.1
Elevation Range	9,994.0 to 9,994.8 ft
Flow Area	1.3
Wetted Perimeter	6.9
Hydraulic Radius	2.3
Top Width	6.81
Normal Depth	3.1
Critical Depth	5.4
Critical Slope	0.009
Velocity	6.81

Worksheet for LDR_CS4_50YR
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Results	
Velocity Head	0.72
Specific Energy	0.98
Froude Number	2.754
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	3.1
Critical Depth	5.4
Channel Slope	0.081
Critical Slope	0.009

Cross Section for LDR_CS4_50YR
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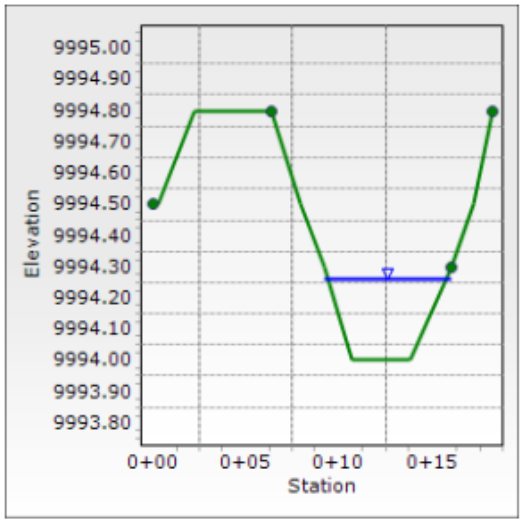
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.081
Normal Depth	3.1
Discharge	8.80



Worksheet for RUR_CS1_50 years
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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	7.20

Section Definitions

Station (ft)	Elevation (ft)
0+00	10,000.25
0+05	10,000.00
0+10	9,999.75
0+16	9,999.50
0+17	9,999.25
0+18	9,999.00
0+19	9,999.00
0+21	9,999.25
0+24	9,999.25

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 10,000.25)	(0+05, 10,000.00)	0.020
(0+05, 10,000.00)	(0+10, 9,999.75)	0.020
(0+10, 9,999.75)	(0+16, 9,999.50)	0.020
(0+16, 9,999.50)	(0+17, 9,999.25)	0.020
(0+17, 9,999.25)	(0+18, 9,999.00)	0.020
(0+18, 9,999.00)	(0+19, 9,999.00)	0.020
(0+19, 9,999.00)	(0+21, 9,999.25)	0.020
(0+21, 9,999.25)	(0+24, 9,999.25)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	4.4
Elevation Range	9,999.0 to 10,000.3 ft
Flow Area	1.3
Wetted Perimeter	7.2
Hydraulic Radius	2.2
Top Width	7.05
Normal Depth	4.4

Worksheet for RUR_CS1_50 years
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Results	
Critical Depth	6.0
Critical Slope	0.009
Velocity	5.39
Velocity Head	0.45
Specific Energy	0.82
Froude Number	2.185
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	4.4
Critical Depth	6.0
Channel Slope	0.050
Critical Slope	0.009

Cross Section for RUR_CS1_50 years
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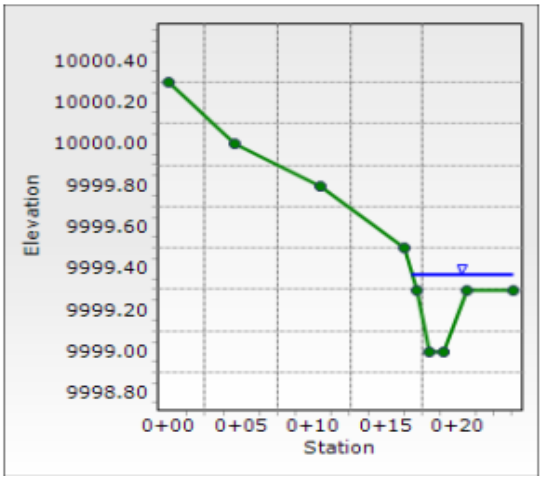
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	4.4
Discharge	7.20



Worksheet for RUR_CS2_50 years

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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	7.20

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,999.00
0+03	9,998.75
0+06	9,998.50
0+07	9,998.25
0+09	9,998.00
0+10	9,998.00
0+14	9,998.25
0+15	9,998.50
0+17	9,998.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coeffident
(0+00, 9,999.00)	(0+03, 9,998.75)	0.020
(0+03, 9,998.75)	(0+06, 9,998.50)	0.020
(0+06, 9,998.50)	(0+07, 9,998.25)	0.020
(0+07, 9,998.25)	(0+09, 9,998.00)	0.020
(0+09, 9,998.00)	(0+10, 9,998.00)	0.020
(0+10, 9,998.00)	(0+14, 9,998.25)	0.020
(0+14, 9,998.25)	(0+15, 9,998.50)	0.020
(0+15, 9,998.50)	(0+17, 9,998.50)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	3.6
Elevation Range	9,998.0 to 9,999.0 ft
Flow Area	1.3
Wetted Perimeter	7.0
Hydraulic Radius	2.3
Top Width	6.99
Normal Depth	3.6

Worksheet for RUR_CS2_50 years
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Results	
Critical Depth	5.3
Critical Slope	0.009
Velocity	5.45
Velocity Head	0.46
Specific Energy	0.76
Froude Number	2.210
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	3.6
Critical Depth	5.3
Channel Slope	0.050
Critical Slope	0.009

Cross Section for RUR_CS2_50 years
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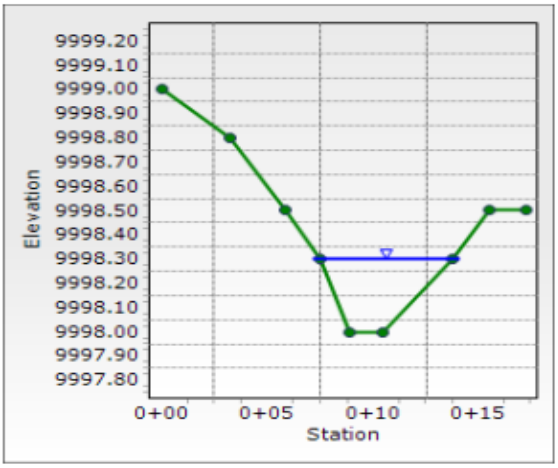
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	3.6
Discharge	7.20



Worksheet for LUR_CS1_50 years

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Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Discharge	7.20

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,997.00
0+01	9,997.25
0+02	9,997.50
0+03	9,997.75
0+05	9,998.00
0+06	9,998.25
0+07	9,998.50
0+09	9,998.50
0+11	9,998.25
0+12	9,998.00
0+13	9,997.75
0+15	9,997.75
0+16	9,998.00
0+18	9,998.25
0+19	9,998.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,997.00)	(0+01, 9,997.25)	0.020
(0+01, 9,997.25)	(0+02, 9,997.50)	0.020
(0+02, 9,997.50)	(0+03, 9,997.75)	0.020
(0+03, 9,997.75)	(0+05, 9,998.00)	0.020
(0+05, 9,998.00)	(0+06, 9,998.25)	0.020
(0+06, 9,998.25)	(0+07, 9,998.50)	0.020
(0+07, 9,998.50)	(0+09, 9,998.50)	0.020
(0+09, 9,998.50)	(0+11, 9,998.25)	0.020
(0+11, 9,998.25)	(0+12, 9,998.00)	0.020
(0+12, 9,998.00)	(0+13, 9,997.75)	0.020
(0+13, 9,997.75)	(0+15, 9,997.75)	0.020
(0+15, 9,997.75)	(0+16, 9,998.00)	0.020
(0+16, 9,998.00)	(0+18, 9,998.25)	0.020
(0+18, 9,998.25)	(0+19, 9,998.50)	0.020

Worksheet for LUR_CS1_50 years
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Options	
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results	
Normal Depth	8.4
Elevation Range	9,997.0 to 9,998.5 ft
Flow Area	1.0
Wetted Perimeter	3.8
Hydraulic Radius	3.2
Top Width	3.07
Normal Depth	8.4
Critical Depth	11.1
Critical Slope	0.010
Velocity	6.93
Velocity Head	0.75
Specific Energy	1.45
Froude Number	2.101
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	8.4
Critical Depth	11.1
Channel Slope	0.050
Critical Slope	0.010

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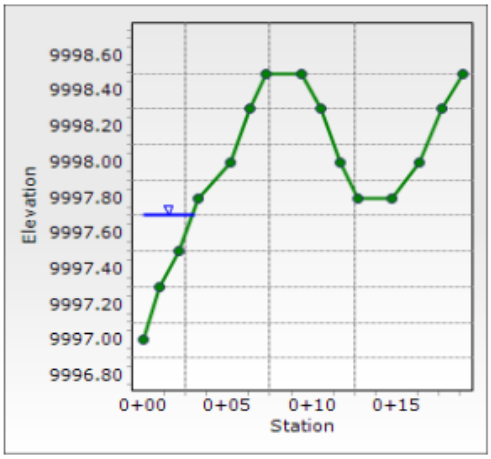
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	8.4
Discharge	7.20



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Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.050
Discharge	7.20

Section Definitions

Station (ft)	Elevation (ft)
0+00	9,996.50
0+03	9,996.75
0+05	9,997.00
0+07	9,997.25
0+07	9,997.25
0+08	9,997.00
0+09	9,996.75
0+10	9,996.75
0+11	9,997.00
0+12	9,997.25
0+15	9,997.25
0+19	9,997.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,996.50)	(0+03, 9,996.75)	0.020
(0+03, 9,996.75)	(0+05, 9,997.00)	0.020
(0+05, 9,997.00)	(0+07, 9,997.25)	0.020
(0+07, 9,997.25)	(0+07, 9,997.25)	0.020
(0+07, 9,997.25)	(0+08, 9,997.00)	0.020
(0+08, 9,997.00)	(0+09, 9,996.75)	0.020
(0+09, 9,996.75)	(0+10, 9,996.75)	0.020
(0+10, 9,996.75)	(0+11, 9,997.00)	0.020
(0+11, 9,997.00)	(0+12, 9,997.25)	0.020
(0+12, 9,997.25)	(0+15, 9,997.25)	0.020
(0+15, 9,997.25)	(0+19, 9,997.50)	0.020

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	5.1

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Results	
Elevation Range	9,996.5 to 9,997.5 ft
Flow Area	1.3
Wetted Perimeter	7.1
Hydraulic Radius	2.2
Top Width	6.57
Normal Depth	5.1
Critical Depth	6.9
Critical Slope	0.010
Velocity	5.44
Velocity Head	0.46
Specific Energy	0.89
Froude Number	2.140
Flow Type	Supercritical

GVF Input Data	
Downstream Depth	0.0
Length	0.0
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0
Profile Description	N/A
Profile Headloss	0.00
Downstream Velocity	Infinity
Upstream Velocity	Infinity
Normal Depth	5.1
Critical Depth	6.9
Channel Slope	0.050
Critical Slope	0.010

Cross Section for LUR_CS2_50 years
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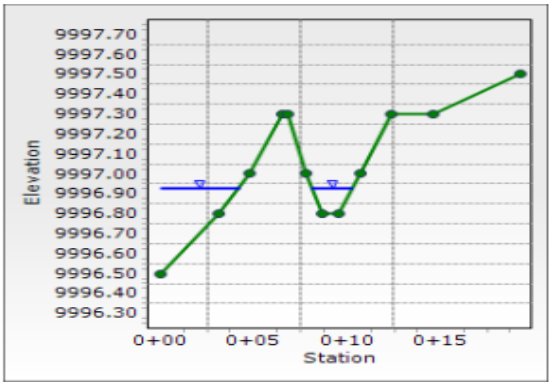
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Channel Slope	0.050
Normal Depth	5.1
Discharge	7.20



Item	Unsatisfactory Pts = < 75	Average Pts = 75-89	Above Average Pts = 90-100
I. Appearance, grammar, technical writing style (10%)	Required sections missing; Poor formatting or appearance; Hard to follow, wordy, obvious multiple authors; Grammatical errors	All required elements present but some errors in: • appearance • organization • readability • grammar errors	All required elements present; High quality appearance; Organized, easy read; Few or no grammatical errors
II. Technical Content – background (project description, constraints, tasks, references) (15%)	Poorly detailed project description with poor quality, hard-to-read maps, irrelevant exclusions; insufficient or low quality technical background research; incomplete/incorrect cites	Sufficient detail in project description with acceptable maps and exclusions; may have minor omissions in technical background and/or cites.	Excellent project description with high quality graphics/maps, well defined exclusions; Well researched, relevant technical background w/ appropriate citations
III. Technical Content – fieldwork, testing/analysis & alternatives (15%)	Limited or no breadth of alternatives indicating lack of creativity	Acceptable breadth of alternatives but evidence of constrained, pre-conceived solution	Excellent demonstration of well thought-out, creative alternatives
IV. Technical Content – final design & cost, appendices (40%)	Obvious errors leading to limited, poor design and cost estimate, lack of thought of impacts, poor quality appendices or references	Sufficient but technical analysis could be better detailed, some errors/omissions in design/justification, not fully complete cost estimate, minimally acceptable evaluation of impacts, lower quality appendices or references.	Demonstrated professional approach, high quality technical analysis, complete design with understandable justification, complete detail in cost estimate, fully supported impacts analysis, appropriate appendix and reference use
V: Comparison to proposal (schedule, staffing) (10%)	Hard to follow, details missing, insufficient explanation, obvious errors	Sufficient but could be better detailed	Easy to follow; clear explanatory narrative
VI: Conclusion (10%)	Hard to follow, incomplete, and or irrelevant	Complete, relevant and but not intuitive to use	Complete, relevant and easy to use