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Grand Canyon Unified School District Master Drainage Plan

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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.

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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.

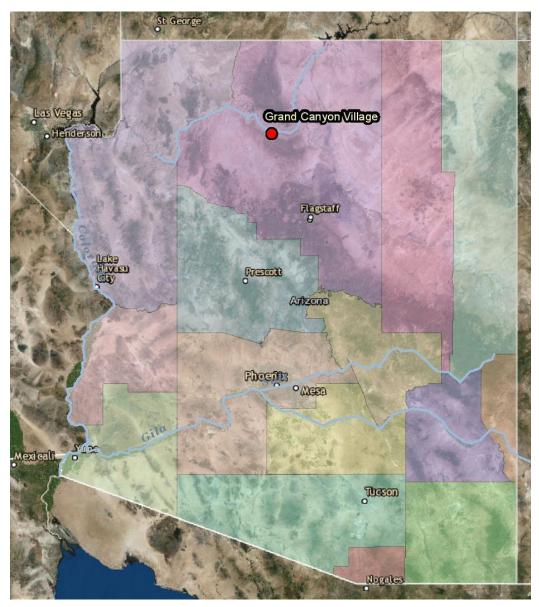


Figure 1: Geographical location of Grand Canyon village within Arizona [1].

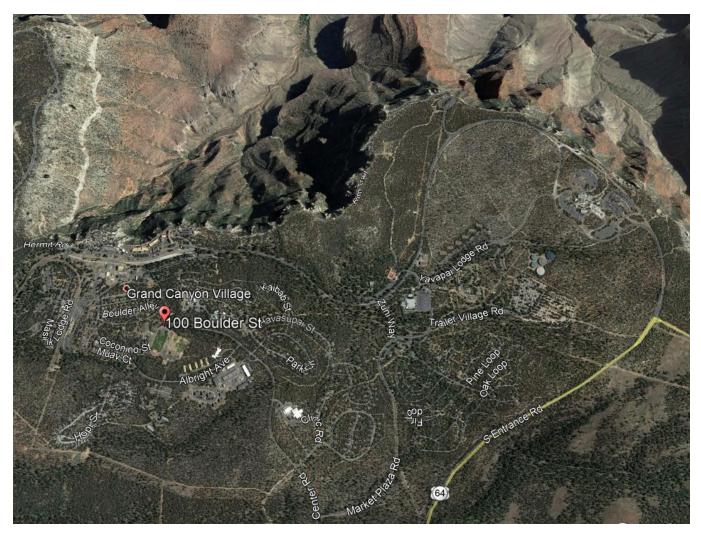


Figure 2: Regional map of GCUSD site [6]

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.

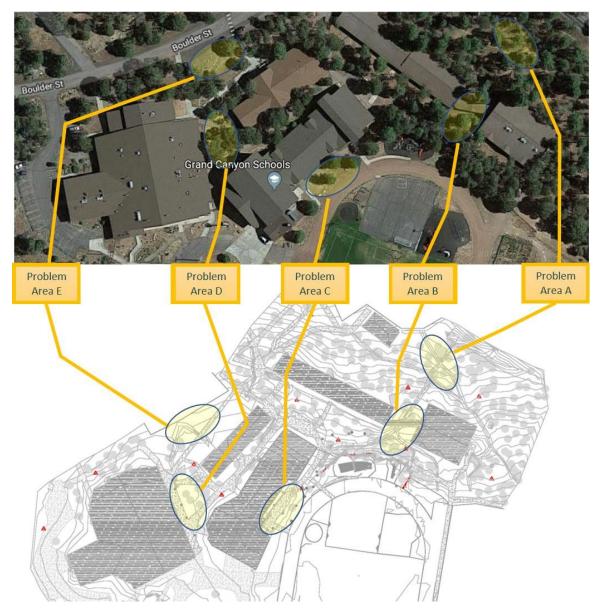


Figure 3: Aerial view of GCS Campus [1]

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.

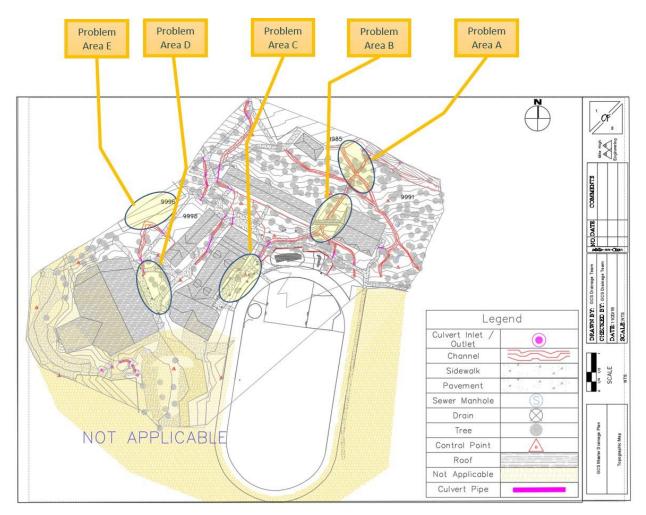


Figure 2: Completed topographic map of GCUSD campus with problem areas highlighted.

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.

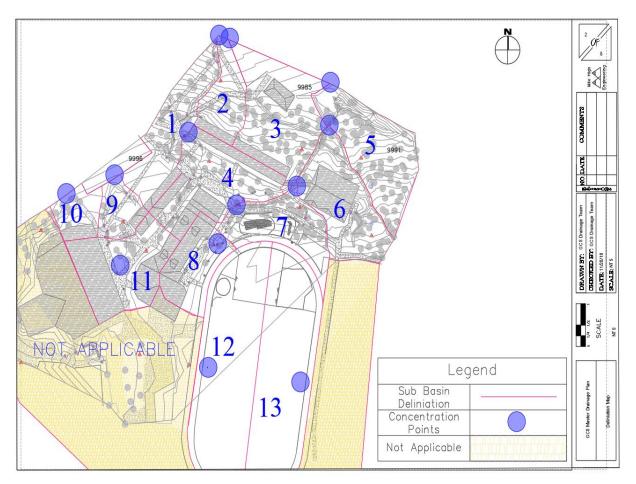


Figure 3: GCUSD campus watersheds delineated.

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.

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				

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

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				
Factor	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

$$Q = C_f * C_w * I * A$$

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.

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	

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

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

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	

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

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

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

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

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.

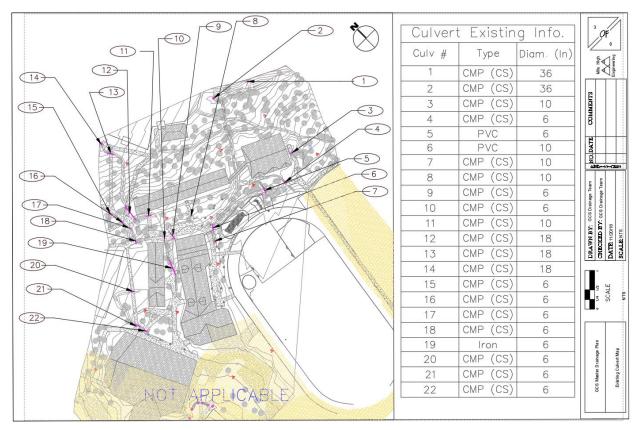


Figure 4: Inventory and location summary of existing culverts on GCUSD campus.

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			Insufficier	nt field data.							
2			Insufficier	nt field data.							
3	Beveled ring, 33.7° (1.5:1)bevels	1	Circular	CMP	18 inch	2	12				
4			Insufficier	nt 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			Insufficier	nt 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 Improve	ment Required							
12			No Improve	ment Required							
13			No Improve	ment Required							
14			Insufficier	nt 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	Вох	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 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 and 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].

	Material and Installation Cost for Problem area A									
Туре	# of Units	Material	Length	Cost (\$)/linear ft	Labor (\$) / Hour	# of Hours	Installation (\$)	Cost (\$)		
18" Dia. CMP Culv.	2	СМР	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		

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

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								
Туре	# 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

Туре	# 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

Туре	# 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

Туре	# of Units	Material	Length	Cost (\$)/linear ft	Labor (\$) / Hour	# of Hours	Installation (\$)	Cost (\$)
15" Dia. HDPE Culv.	1	СМР	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								
ltem	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 1.0 Field Work	Duration		Proposed			Computed		
1.0 Field Work	Duration	Start	End	Duration	Start	End		
	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.

	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

Table 21: Major Tasks and staff hours

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.

	Material and Installation Cost						
Culvert (Name)	Material	Equivalent diameter	Length	Cost (\$)/linear ft	Installation (\$)	Cost (\$)	
3	СМР	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	

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

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			Proposed	Actu	ual	
Position	Rate (\$/hr)	(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 US	D \$		73,202	83,2	68	

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				
	\$575				
Total Travel Cost for 5 days	· ·				
	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].

[2] "Coconino County Storm Water Quality and Runoff Control Ordinance," Cocnino.AZ.gov, 2018. [Online]. Available: 2018. [Accessed 14 August 2018].

[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.

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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

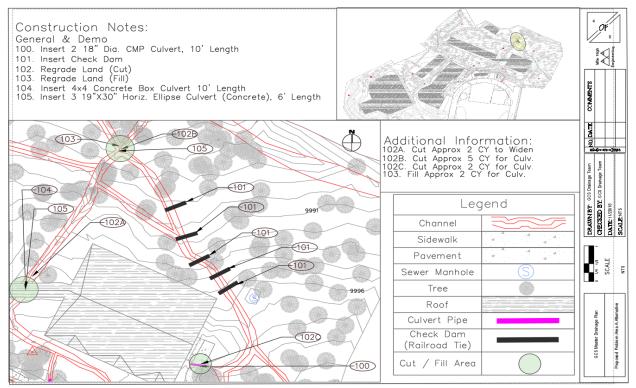


Figure 10: Topographic map of Problem Area A with the proposed alternatives, construction notes, details, and additional information.

Appendix C-2: Topographic Map of Area B

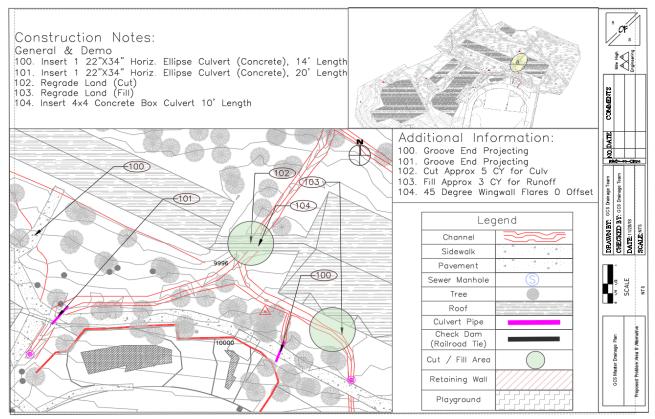


Figure 11: Topographic map of Problem Area B with the proposed alternatives, construction notes, details, and additional information.

Appendix C-3: Topographic Map of Area C

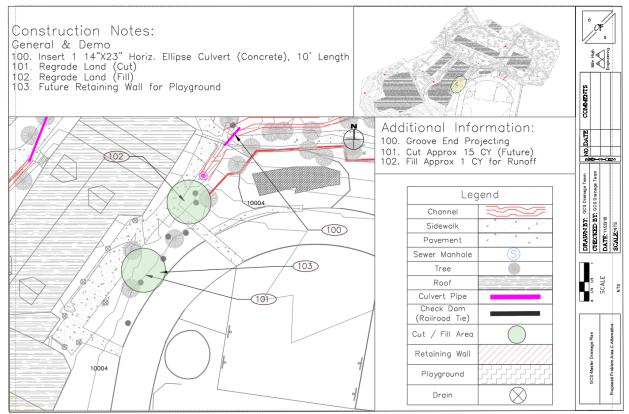


Figure 12: Topographic map of Problem Area C with the proposed alternatives, construction notes, details, and additional information.

APPENDIX C-4: TOPOGRAPHIC MAP OF AREA D

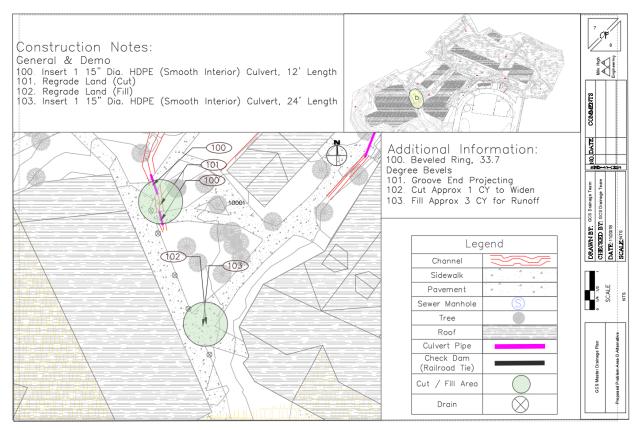


Figure 13: Topographic map of Problem Area D with the proposed alternatives, construction notes, details, and additional information.

APPENDIX C-5: TOPOGRAPHIC MAPS OF AREA E

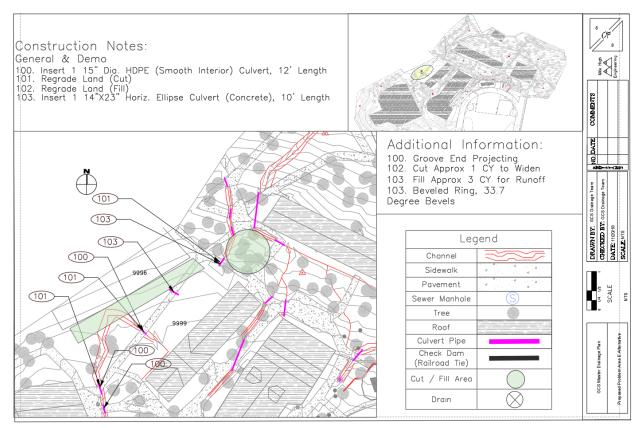


Figure 14: Topographic map of Problem Area E with the proposed alternatives, construction notes, details, and additional information.

Appendix	D:	Raw	Data	Table	for	Weighted C
лррспал	υ.	1.0.44	Dutu	TUDIC	101	Weighted e

Table 26: Raw data table for weighted runoff coefficients

			RAW DATA TOF C	כמורתומרו הוו הו אבו	Naw Data IOI Calculation of Weighten Kunon Coenticients	ILIEIILS				
asin	ub Basin Woods, Gravelly Steep	Woods, Gravelly Average	Landscaping Flat	Sidewalk	Parking Lot	Dense Vegitation	Roof	Total Area (Acres)	Weighted C	
-	27.00%	35.20%	11.90%	18.40%	0.00%	0.00%	2	7.40% 0.48	8	0.345
2	48.10%	25.80%	%00:0	16.50%	%00'0	%00:0	6	9.90% 0.27	7	0.364
ю	29.00%	0:00%	0:00%	2.80%	0.00%	0.00%		18.60% 0.53	Ω.	0.338
4	0.00%	45.30%	0:00%	20.60%	%00'0	0.00%		34.10% 0.63	3	0.574
5	51.70%	48.00%	%00:0	%00'0	%00'0	00.00%	0	0.00% 0.62	2	0.145
9	48.90%	15.30%	0:00%	6.90%	0.00%	0.00%	29	29.20% 0.58	80	0.444
7	51.20%	14.20%	14.90%	12.30%	00.00%	0.00%		7.00% 0.44	4	0.302
∞	0.00%	26.10%	13.50%	15.30%	%00'0	0.00%	42	45.00% 0.35	5	0.618
6	0.00%	%00:0	29.66%	19.10%	%00'0	12.60%	8	8.32% 0.18	8	0.339
10	0.00%	65.99%	0.00%	13.19%	0.00%	0.00%		20.65% 0.18	8	0.401
11	0.00%	0:00%	22.19%	19.02%	%00'0	0.00%		58.62% 0.58	80	0.760
12	0.00%	%00:0	73.25%	%00'0	%00'0	26.43%	0	0.00%	1	0.113
13	0.00%	0.00%	74.62%	%00'0	%00'0	25.24%	0	0.00% 0.95	5	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	1				
Design Discha	rge 6	.56 cfs	Check Disch	harge	8.80	cfs
Grades Model: I	nverts					
Invert Upstrea	m 9,999	.75 ft	Invert Down	stream	9,999.63	ft
Length	12	.00 ft	Slope		0.010000	ft/ft
Drop	0	.12 ft				
Headwater Mod	lel: Maximum Allowable	HW				
Headwater Ele	evation 10,000	.75 ft				
Taihuatas Candil	ions: Constant Tailwate	r				
Tailwater Condit						
Tailwater Condi	ation M	N/A ft				
	ation f	N/A ft Discha	rge HW Elev.	Velocity		
Tailwater Eleva		Discha	rge HW Elev. cf s 0,003.31 ft	Velocity 8.43 ft/s		
Tailwater Eleva	Description	Dischar 6.56	0			
Tailwater Elev Name x Trial-1	Description 1-12 inch Circular	Dischar 6.56 6.56	cfs10,003.31 ft	8.43 ft/s		
Tailwater Elev Name x Trial-1 Trial-2	Description 1-12 inch Circular 1-60 inch Circular	Dischar 6.56 6.56 6.56	cfs10,003.31 ft cfs10,000.73 ft	8.43 ft/s 3.93 ft/s		

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Design:Trial-1

Solve For: Headwater Elevation

2.2.2					
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		Constructed Slope	0.010000	
Hydraulic Profile					
Profile CompositeM2Pr	essureProfile		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 TypeBeveled ring, 45°	° (1:1) bevels		Area Full	0.8	ft²
К	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	A	
С	0.03000		Equation Form	1	
Y	0.74000				

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Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.75	ft	Storm Event	Design	
Computed Headwater Elev			Discharge	6.56	cfs
Headwater Depth/Height	0.20		Tailwater Elevation	N/A	
Inlet Control HW Elev.	10,000.66	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	10,000.73				
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	
Flow Regime	Subcritical		Critical Depth	0.70	
Velocity Downstream	3.93	ft/s	Critical Slope	0.012241	
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
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	10,000.66	ft	Flow Control	N/A	
Inlet Topperveled ring, 33.7° (1.5:1) bevels		Area Full	19.6	ft²
к	0.00180		HDS 5 Chart	3	
Μ	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000				

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Design:Trial-3

Solve For: Section Size

2.72					
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	
Flow Regime	Subcritical		Critical Depth	0.66	
Velocity Downstream	3.96	ft/s	Critical Slope	0.016110	
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					
	10,000,05		Eleve Ocentral	F1/A	
Inlet Control HW Elev.	10,000.65	it	Flow Control	N/A	£12
Inlet Toppes/eled ring, 33.7° (a second a second second second		Area Full	4.8	11*
К	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

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Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.75	ft	Storm Event	Design	
Computed Headwater Elev			Discharge	6.56	ofe
Headwater Depth/Height	0.70	n.	Tailwater Elevation	0.30 N/A	
Inlet Control HW Elev.	10,000.57	ft	Control Type	Outlet Control	n
Outlet Control HW Elev.	10,000.63		Control Type	Outlet Control	
Outlet Control Hwy Elev.	10,000.03	n			
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	
Flow Regime	Subcritical		Critical Depth	0.59	
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 Topperveled ring, 33.7° (Area Full	3.7	ft²
К	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	в	
C	0.02430		Equation Form	1	
Y	0.83000				

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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		Dopth Downstroam	0.80	ft
Slope Type	Mild		Depth, Downstream Normal Depth	0.80	
Flow Regime	Subcritical		Critical Depth	0.99	
Velocity Downstream	4.56	ft/s	Critical Slope	0.018909	
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 Toppeveled ring, 33.7° (it.	Area Full	3.5	ft ²
K	0.00180		HDS 5 Chart	3.5	i.
M	2.50000		HDS 5 Scale	в	
C	0.02430		Equation Form	1	
Y	0.83000				

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CULVERT 5 REPORT

Culvert Designer/Analyzer Report Culvert 05

Comments: Actual diameter of existing is 6 inches.

Peak Discharge I	Method: User-Specified					
Design Dischar	ge 5.38	cfs	Check Discl	narge	7.20	cfs
Grades Model: Ir	verts					
Invert Upstream	9,999.75	ft	Invert Down	stream	9,999.61	ft
Length	14.00	ft	Slope		0.010000	ft/ft
Drop	0.14	ft				
	ons: Constant Tailwater					
Tailwater Eleva	tion N/A	ft				
Name	Description	Discharge	HW Elev.	Velocity		
Name Trial-1	Description 1-12 inch Circular	0	HW Elev.	Velocity 9.22 ft/s		
		7.20 cfs	0,003.10 ft			
Trial-1	1-12 inch Circular	7.20 cfs llip3s@0 cfs	0,003.10 ft	9.22 ft/s		

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Eleva	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 CompositeM2Pres	ssureProfile		Depth, Downstream	0.98	ft
Slope Type	Mild		Normal Depth	N/A	
Flow Regime	Subcritical		Critical Depth	0.98	
Velocity Downstream	9.22	ft/s	Critical Slope	0.031008	ft/ft
Section Section Shape	Circular		Manzing Coofficient	0.012	
Section Shape Section Mgaberia HDPE (Smo			Mannings Coefficient Span	1.00	ft
Section Size	12 inch		Rise	1.00	
Number Sections	12 1101		Nie	1.00	'n
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	
	d projecting		Area Full	0.8	ft ²
Inlet Type Groove en	,,		HDS 5 Chart	1	
Inlet Type Groove en K	0.00450				
	0.00450 2.00000		HDS 5 Scale	3	
к					

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Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Eleva	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		Dopth Downstream	0.65	ft
	Steep		Depth, Downstream Normal Depth	0.65	
Slope Type Flow Regime S	Supercritical		Critical Depth	0.81	
Velocity Downstream	5.49	ft/s	Critical Slope	0.003903	
Section					
	ontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.83	ft
Section Size	22x34 inch		Rise	1.79	
Number Sections	1				
Outlet Control Properties					
Outlet Control HW Elev.	10,000.88	ft	Upstream Velocity Hea	id 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	
GindetveTypenel projecting (horizo			Area Full	4.0	ft²
K	0.00450		HDS 5 Chart	29	
			HDS 5 Scale	3	
м	2.00000		HDS 5 Scale	5	
M C	2.00000 0.03170		Equation Form	1	

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Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Eleva	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	
	Supercritical		Critical Depth	0.84	
Velocity Downstream	5.70	ft/s	Critical Slope	0.003320	
Section	2218 301			1000 EXTERNA	
Section Shape	Circular		Mannings Coefficient	0.012	
Section Maderia HDPE (Smo			Span	3.00	
Section Size Number Sections	36 inch 1		Rise	3.00	π
Number Sections	1				
Outlet Control Properties					
Outlet Control HW Elev.	10,000.96	ft	Upstream Velocity Hea	d 0.30	ft
Ке	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, 3			Area Full	7.1	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000				

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Design:Trial-4

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Ele	eva 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/f
Section					
Section Shape	Arch		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.17	ft
Section Size 2	6.0 x 15.5 inch		Rise	1.29	ft
Number Sections	1				
Outlet Control Properties					
Outlet Control HW Elev.	10,000.97	ft	Upstream Velocity Hea	id 0.37	ft
Ke	0.20		Entrance Loss	0.07	ft
nlet Control Properties					
Inlet Control HW Elev.	10,000.93	ft	Flow Control	N/A	
Inlet Type Groove end pr	ojecting (arch)		Area Full	2.2	ft²
к	0.00450		HDS 5 Chart	0	
м	2.00000		HDS 5 Scale	0	
С	0.03170		Equation Form	1	
Y	0.69000				

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CULVERT 6 REPORT

Culvert Designer/Analyzer Report Culvert 06

Comments: Actual diameter of existing is 10 inches.

1-72 inch Circular

Trial-4

our biooriaige ii	lethod: User-Specifi	eu				
Design Discharg	le	5.38 cfs	Check Disc	harge	7.20	cfs
Grades Model: Inv	verts					
Invert Upstream	9,99	99.00 ft	Invert Down	stream	9,998.80	ft
Length	2	20.00 ft	Slope		0.010000	ft/ft
Drop		0.20 ft				
Headwater Mode	: Maximum Allowab	le HW				
Headwater Elev	ation 10,00	00.00 ft				
Tailwater Conditio	ns: Constant Tailwa	ter				
Tailwater Elevat	ion	N/A ft				
Name	Description	Discha	rge HW Elev.	Velocity		
Trial-1	1-12 inch Circula	ar 5.38	cfs10,001.17 ft	7.05 ft/s		
Trial-1						
x Trial-1	1-22x34 inch Ho	oriz Ellip5s688	cfs9,999.96 ft	5.21 ft/s		

7.20 cfs 9,999.98 ft 3.92 ft/s

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,000.00	ft	Storm Event	Design	
Computed Headwater Eleva	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 CompositeM2Pres	sureProfile		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	
SectionnMathemathHDPE (Smo	oth 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			Area Full	0.8	ft²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,000.00	ft	Storm Event	Design	
Computed Headwater Eleva	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	
	Supercritical		Critical Depth	0.67	
Velocity Downstream	5.21	ft/s	Critical Slope	0.003941	
Section					
	ontal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.83	ft
Section Size	22x34 inch		Rise	1.79	
Number Sections	1				
Outlet Control Properties					
Outlet Control HW Elev.	9,999.96	ft	Upstream Velocity Hea	ad 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	
GholetveTypenel projecting (horizo			Area Full	4.0	ft²
К	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

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Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.00	ft	Storm Event	Check	
Computed Headwater Eleva	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	
1 11	percritical		Critical Depth	0.70	
Velocity Downstream	5.32	ft/s	Critical Slope	0.003630	
Section Section Shape Horizor	ntal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	4.13	ft
	2x50 inch		Rise	2.63	
Number Sections	1				
Outlet Control Properties					
Outlet Control HW Elev.	9,999.99	ft	Upstream Velocity Hea	d 0.25	ft
Ке	0.20		Entrance Loss	0.05	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,999.93	ft	Flow Control	N/A	
GholeteType projecting (horizon			Area Full	8.5	ft²
К	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

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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	
Flow Regime	Subcritical		Critical Depth	0.70	
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 Topperveled ring, 33.7° (Area Full	28.3	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000		25 C		

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 Project Engineer: jwm255

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CULVERT 8 REPORT

Trial-4

Culvert Designer/Analyzer Report Culvert 08

Comments: Actual diameter of existing is 10 inches.

Design Discharg	ge	5.38	3 cfs	Check Disc	harge	7.20	cfs
Grades Model: In	verts						
Invert Upstream	ı	9,996.75	5 ft	Invert Down	stream	9,996.61	ft
Length		14.00) ft	Slope		0.010000	ft/ft
Drop		0.14	l ft				
Tailwater Conditio							
Tailwater Eleva	ion	N/A	A ft				
1212	Des	cription	Discharge	HW Elev.	Velocity		
Name				11.00.00.0			
Name Trial-1	1-12 inch	n Circular	5.38 cfs	9,999.55 ft	7.05 ft/s		
		n Circular inch Horiz E			7.05 ft/s 5.09 ft/s		

1-72 inch Circular 7.20 cfs 9,997.73 ft 3.92 ft/s

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,997.75	f4	Storm Event	Design	
				5.38	ofo
Computed Headwater Eleva Headwater Depth/Height	9,999.55 2.80	п	Discharge Tailwater Elevation	5.36 N/A	
Inlet Control HW Elev.	9,998.72	£4		Outlet Control	n
Outlet Control HW Elev.	9,998.72		Control Type	Outlet Control	
Outlet Control HW Elev.	9,999.00	п			
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 CompositeM2Pre	ssureProfile		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 Toppeveled ring, 33.7° (1	and a second sec		Area Full	0.8	ft²
ĸ	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,997.75	ft	Storm Event	Design	
Computed Headwater Eleva	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	echologia agender ved Stando – 1 dan da		
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	0.58	
	upercritical		Critical Depth	0.53	
Velocity Downstream	5.09	ft/s	Critical Slope	0.003941	
Section					
Section Shape Horizon	ntal 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 Hea	ad 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	
GindletveTypenel projecting (horizon	tal ellipse)		Area Full	4.0	ft²
К	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

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Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,997.75	ft	Storm Event	Check	
Computed Headwater Eleva	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 B	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	
	upercritical		Critical Depth	0.70	
Velocity Downstream	5.18	ft/s	Critical Slope	0.003630	ft/ft
Section	····				
	ntal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	4.13	
	32x50 inch		Rise	2.63	π
Number Sections	1				
Outlet Control Properties					
Outlet Control HW Elev.	9,997.74	ft	Upstream Velocity Hea	d 0.25	ft
Ке	0.20		Entrance Loss	0.05	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,997.68	ft	Flow Control	Unsubmerged	
GholetveTypenel projecting (horizor	tal ellipse)		Area Full	8.5	ft²
к	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,997.75	ft	Storm Event	Check	
Computed Headwater Eleva	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	
Flow Regime	Subcritical		Critical Depth	0.70	
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
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,997.66	ft	Flow Control	N/A	
Inlet Topperveled ring, 33.7° (1	.5:1) bevels		Area Full	28.3	ft²
к	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 9 REPORT

Trial-4

Culvert Designer/Analyzer Report Culvert 09

Comments: Actual diameter of existing is 6 inches.

Design Dischar	ge 2.	63 cfs	Check Disch	narge	3.50	cfs
Grades Model: In	verts					
Invert Upstream	9,998.	00 ft	Invert Down	stream	9,997.85	ft
Length	15.	00 ft	Slope		0.010000	ft/ft
Drop	0.	15 ft				
Headwater Elev	ation 9,999.	00 ft				
Tailwater Conditic	ons: Constant Tailwater					
Tailwater Conditio Tailwater Elevat		I/A ft				
			rge HW Elev.	Velocity		
Tailwater Elevat	ion N	I/A ft Dischar	rge HW Elev. cfs 9,999.61 ft	Velocity 5.20 ft/s		
Tailwater Elevat Name	ion N Description	I/A ft Dischar 3.50	cfs9,999.61 ft			

1-21 inch Circular 3.50 cfs 9,998.99 ft 4.04 ft/s

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,999.00	ft	Storm Event	Check	
Computed Headwater Elev			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 CompositeM2Pr	essureProfile		Depth, Downstream	0.80	ft
Slope Type	Mild		Normal Depth	N/A	
Flow Regime	Subcritical		Critical Depth	0.80	
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 Topperveled ring, 33.7° (1.5:1) bevels		Area Full	0.8	ft²
к	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000				

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.00	ft	Storm Event	Design	
Computed Headwater Eleva	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	0.43	
	upercritical		Critical Depth	0.52	
Velocity Downstream	4.51	ft/s	Critical Slope	0.004463	
Section					
Section Shape Horizon	ntal 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 Hea	ad 0.20	ft
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,998.72	ft	Flow Control	N/A	
GholetveTypel projecting (horizon	tal ellipse)		Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

Design:Trial-3

Solve For: Section Size

16 12 18					
Culvert Summary					
Allowable HW Elevation	9,999.00	ft	Storm Event	Check	
Computed Headwater Eleva	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	0.50	
	upercritical		Critical Depth	0.49	
Velocity Downstream	4.89	ft/o	Critical Slope	0.004692	
Velocity Downstream	4.00	100		0.001002	TUT
Section					
Section Shape Horizon	ntal 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 Hea	ad 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	
Gindet/eTypel projecting (horizor			Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.00	ft	Storm Event	Check	
Computed Headwater Eleva	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
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,998.93	ft	Flow Control	N/A	
Inlet Toppesveled ring, 33.7° (1	.5:1) bevels		Area Full	2.4	ft²
к	0.00180		HDS 5 Chart	3	
М	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 10 REPORT

Trial-4

Culvert Designer/Analyzer Report Culvert 10

Comments: Actual diameter of existing is 6 inches.

1-21 inch Circular

Dealers Diashas		2.0	0 -6-	Ohardy Diard		2.50	
Design Discharg	je	2.6	3 cfs	Check Disc	narge	3.50	CIS
Grades Model: In	verts						
Invert Upstream		9,997.5	0 ft	Invert Down	stream	9,997.40	ft
Length		10.0	0 ft	Slope		0.010000	ft/ft
Drop		0.1	0 ft				
Headwater Elev Tailwater Conditio		9,998.5 t Tailwater	0 ft				
Tailwater Elevat	ion	N//	A ft				
	Desr	cription	Discharge	HW Elev.	Velocity		
Name	Door						
Name Trial-1	1-12 inch	Circular	2.63 cfs	s 9,998.63 ft	4.51 ft/s		
	1-12 inch			s 9,998.63 ft s 9,998.25 ft	4.51 ft/s 4.41 ft/s		

3.50 cfs 9,998.49 ft 4.04 ft/s

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,998.50		Storm Event	Design	
Computed Headwater Elev		ft	Discharge	2.63	
Headwater Depth/Height	1.13		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,998.54		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	0.70 N/A	
Flow Regime	Subcritical		Critical Depth	0.70	
Velocity Downstream	4.51	ft/e	Critical Slope	0.026986	
Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	
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 Toppesveled ring, 33.7° (it.	Area Full	0.8	ft ²
K	0.00180		HDS 5 Chart	3	
	0.00.00			в	
M	2.50000		HDS 5 Scale	в	
	2.50000 0.02430		HDS 5 Scale Equation Form	в 1	

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,998.50	ft	Storm Event	Design	
Computed Headwater Eleva	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	
	upercritical		Critical Depth	0.52	
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	ft/ft
Section					
Section Shape Horizon	ntal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	
	14x23 inch		Rise	1.19	ft
Number Sections	1				
Outlet Control Properties					
Outlet Control HW Elev.	9,998.25	ft	Upstream Velocity Hea	ad 0.20	ft
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,998.22	ft	Flow Control	N/A	
GholetveTypenel projecting (horizor	tal ellipse)		Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
Μ	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

Design:Trial-3

Solve For: Section Size

2 J					
Culvert Summary					
Allowable HW Elevation	9,998.50	ft	Storm Event	Check	
Computed Headwater Eleva	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	
	upercritical		Critical Depth	0.49	
Velocity Downstream	4.77	ft/e	Critical Slope	0.004692	
Section					
Section Shape Horizon	ntal 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 Hea	ad 0.24	ft
Ке	0.20		Entrance Loss	0.05	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,998.35	ft	Flow Control	N/A	
GholetreTypenel projecting (horizor			Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,998.50	ft	Storm Event	Check	
Computed Headwater Eleva	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 Topperveled ring, 33.7° (1	.5:1) bevels		Area Full	2.4	ft²
к	0.00180		HDS 5 Chart	3	
Μ	2.50000		HDS 5 Scale	В	
С	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.

Design Discharge	2.63	cfs (Check Disch	narge	3.50	cfs
Grades Model: Inve	rts					
Invert Upstream	9,993.25	ft I	nvert Down	stream	9,993.14	ft
Length	11.00	ft S	Slope		0.010000	ft/ft
Drop	0.11	ft				
Headwater Model: N	Maximum Allowable HW					
Headwater Model: M Headwater Elevati						
Headwater Elevati						
Headwater Elevati	ion 9,994.25 s: Constant Tailwater	ft				
Headwater Elevati Tailwater Conditions	ion 9,994.25 s: Constant Tailwater n N/A	ft	HW Elev.	Velocity		

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Design:Trial-1

Solve For: Headwater Elevation

Culurat Summary					
Culvert Summary				-	
Allowable HW Elevation	9,994.25		Storm Event	Check	
Computed Headwater Eleva		ft	Discharge	3.50	
Headwater Depth/Height	0.86		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,994.05		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	
Flow Regime	Subcritical		Critical Depth	0.56	
Velocity Downstream	3.84	ft/s	Critical Slope	0.022257	
Section					
	Circular		Manninga Coofficient	0.024	
Section Shape Section Material	CIrcular		Mannings Coefficient	1.00	4
Section Material	12 inch		Span Rise	1.00	
Number Sections	12 inch 2		Rise	1.00	π
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 Toppereled ring, 33.7° (1	second black		Area Full	1.6	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
				1	
С	0.02430		Equation Form		

CULVERT 12 REPORT

Culvert Designer/Analyzer Report Culvert 12

Design Discharge	2.63	cfs	Check Disch	arge	3.50	cfs
5 5				0		
Grades Model: Inver	ts					
Invert Upstream	9,992.75	ft	Invert Down	stream	9,992.38	ft
Length	37.00	ft	Slope		0.010000	ft/ft
Drop	0.37	ft				
Headwater Model: N	Maximum Allowable HW	/				
Headwater Model: M Headwater Elevatio						
	on 9,994.25					
Headwater Elevatio	on 9,994.25 : Constant Tailwater	ft				
Headwater Elevatio	on 9,994.25 : Constant Tailwater	ft				
Headwater Elevatio	on 9,994.25 : Constant Tailwater n N/A	ft	ge HW Elev.	Velocity		

 Title: CENE 486 CULVERTMASTER
 Project Engineer: jwm255

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Design:Trial-1

Solve For: Headwater Elevation

Culved Summer					
Culvert Summary	0.004.05		0	0	
Allowable HW Elevation	9,994.25		Storm Event	Check	
Computed Headwater Eleva	9,993.81	ft	Discharge	3.50	
Headwater Depth/Height	0.71		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,993.74		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	
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 Toppeveled ring, 33.7° (1	.5:1) bevels		Area Full	1.8	ft²
К	0.00180		HDS 5 Chart	3	
М	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	

CULVERT 13 REPORT

Culvert Designer/Analyzer Report Culvert 13

Design Discharge	e 2.6	3 cfs	Check Disch	arge	3.50	cfs
Grades Model: Inve	erts					
Invert Upstream	9,980.7	5 ft	Invert Downs	stream	9,980.60	ft
Length	15.0	0 ft	Slope		0.010000	ft/ft
Drop	0.1	5 ft				
Headwater Model:	Maximum Allowable H	W				
Headwater Model: Headwater Eleva						
Headwater Eleva						
Headwater Eleva	tion 9,982.2 is: Constant Tailwater					
Headwater Eleva Tailwater Condition Tailwater Elevatic	tion 9,982.2 is: Constant Tailwater on N/	5 ft A ft	me HW Flev	Velocity		
Headwater Eleva Tailwater Condition	tion 9,982.2 is: Constant Tailwater	5 ft A ft Discha	rge HW Elev. cfs9.981.65 ft	Velocity 3.86 ft/s		

 Title: CENE 486 CULVERTMASTER
 Project Engineer: jwm255

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,982.25	ft	Storm Event	Design	
Computed Headwater Eleva	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				administration of	
Profile	M2		Depth, Downstream	0.61	
Slope Type	Mild		Normal Depth	0.72	
Flow Regime	Subcritical		Critical Depth	0.61	
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 Properties	0.004.50				
Inlet Control HW Elev.	9,981.59	ft	Flow Control	N/A	612
Inlet Control HW Elev. Inlet Toppeveled ring, 33.7° (1	.5:1) bevels	ft	Area Full	1.8	ft²
Inlet Control HW Elev. Inlet Topesreled ring, 33.7° (1 K	.5:1) bevels 0.00180	ft	Area Full HDS 5 Chart	1.8 3	ft²
Inlet Control HW Elev. Inlet Toppeveled ring, 33.7° (1	.5:1) bevels	ft	Area Full	1.8	ft²

CULVERT 15 REPORT

Culvert Designer/Analyzer Report Culvert 15

Comments: Actual diameter of existing is 6 inches.

1-21 inch Circular

Trial-4

Design Dischar		2.63	ofo			2 50	ofo
Design Dischar	Je	2.03	CIS	Check Disch	large	3.50	cis
Grades Model: In	verts						
Invert Upstream	1	9,990.25	ft	Invert Down	stream	9,990.15	ft
Length		10.00	ft	Slope		0.010000	ft/ft
Drop		0.10	ft				
Tailwater Conditio							
Tailwater Eleva	lion	N/A	π				
Name	Des	cription	Discharge	HW Elev.	Velocity		
Name Trial-1	17 10 10 March 20	cription n Circular		HW Elev. 9,991.38 ft	Velocity 4.51 ft/s		
	1-12 inch		2.63 cfs	9,991.38 ft	<u> </u>		

3.50 cfs 9,991.24 ft 4.04 ft/s

 Title: CENE 486 CULVERTMASTER
 Project Engineer: jwm255

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Design:Trial-1

Solve For: Headwater Elevation

<u></u>					
Culvert Summary					
Allowable HW Elevation	9,991.25	ft	Storm Event	Design	
Computed Headwater Eleva	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	0.70 N/A	
Flow Regime	Subcritical		Critical Depth	0.70	
Velocity Downstream	3ubcritical 4.51	ft/c	Critical Slope	0.026986	
Velocity Downstream	4.01	103	Onitear olope	0.020300	iun
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
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,991.29	ft	Flow Control	N/A	
Inlet Toppereled ring, 33.7° (1	and a second sec		Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
	2.50000		HDS 5 Scale	в	
				0	
M C	0.02430		Equation Form	1	

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,991.25	ft	Storm Event	Design	
Computed Headwater Eleva	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	
	upercritical		Critical Depth	0.52	
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	
Section					
Section Shape Horizon	ntal 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 Hea	ad 0.20	ft
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,990.97	ft	Flow Control	N/A	
Gindetve graded projecting (horizon			Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,991.25	ft	Storm Event	Check	
Computed Headwater Eleva	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	
	upercritical		Critical Depth	0.59	
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	
Section					
	ntal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.90	
	14x23 inch		Rise	1.19	ft
Number Sections	1				
Outlet Control Properties					
Outlet Control HW Elev.	9,991.14	ft	Upstream Velocity Hea	ad 0.24	ft
Ке	0.20		Entrance Loss	0.05	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,991.10	ft	Flow Control	N/A	
GholetveTypenel projecting (horizor	ntal ellipse)		Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,991.25	ft	Storm Event	Check	
Computed Headwater Eleva	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 Toppereled ring, 33.7° (1	.5:1) bevels		Area Full	2.4	ft²
к	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	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.

1-21 inch Circular

Trial-4

Dealer Diashas		0.00				2.50	
Design Dischar	je	2.63	3 cfs	Check Disc	harge	3.50	CIS
Grades Model: In	verts						
Invert Upstream	ı	9,992.25	5 ft	Invert Down	stream	9,992.15	ft
Length		10.00) ft	Slope		0.010000	ft/ft
Drop		0.10) ft				
Headwater Elev Tailwater Conditio	ons: Constar						
Tailwater Eleva	ion	N/A	A ft				
		·	Discharge	HW Elev.	Velocity		
Name	Des	cription	Discharge				
Name Trial-1	17 52 SCAR - 20	n Circular		9,993.38 ft	4.51 ft/s		
	1-12 incl		2.63 cfs	9,993.38 ft	4.51 ft/s 4.41 ft/s		

3.50 cfs 9,993.24 ft 4.04 ft/s

 Title: CENE 486 CULVERTMASTER
 Project Engineer: jwm255

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,993.25	ft	Storm Event	Design	
Computed Headwater Eleva	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	0.70 N/A	
Flow Regime	Subcritical		Critical Depth	0.70	
Velocity Downstream	3ubcritical 4.51	ft/s	Critical Slope	0.026986	
·,					
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 Toppeveled ring, 33.7° (1	and a second sec		Area Full	0.8	ft ²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
				5	
C	0.02430		Equation Form	1	

Design:Trial-2

Solve For: Section Size

0.1					
Culvert Summary					
Allowable HW Elevation	9,993.25		Storm Event	Design	
Computed Headwater Eleva	9,993.00	ft	Discharge	2.63	
Headwater Depth/Height	0.63		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,992.97		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	0.44	
	upercritical		Critical Depth	0.42	
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	
and a set of the set o				2003/01/2048	
Section					
Section Shape Horizon	ntal 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 Hea	ad 0.20	ft
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,992.97	ft	Flow Control	N/A	
Ghodet/eTypenel projecting (horizon			Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
0	0.03170		Equation Form	1	
C	0.03170		Lquation Form		

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,993.25	ft	Storm Event	Check	
Computed Headwater Eleva	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		Constructed Slope	0.010000	
Hydraulic Profile					
Profile	S2		Depth, Downstream	0.51	ft
Slope Type	Steep		Normal Depth	0.49	ft
Flow Regime Si	upercritical		Critical Depth	0.59	ft
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	ft/ft
Section					
Section Shape Horizon	ntal 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 Hea	ad 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	
Gindet/eType projecting (horizor			Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
-	har browners and		Enveting Enve	1	
С	0.03170		Equation Form	1	

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,993.25	ft	Storm Event	Check	
Computed Headwater Eleva	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 Topperveled ring, 33.7° (1	.5:1) bevels		Area Full	2.4	ft²
к	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 17 REPORT

Trial-4

Culvert Designer/Analyzer Report Culvert 17

Comments: Actual diameter of existing is 6 inches.

	Method: User-Specified					
Design Dischar	ge 2	.63 cfs	Check Disc	harge	3.50	cfs
Grades Model: In	verts					
Invert Upstream	9,993	.50 ft	Invert Down	stream	9,993.40	ft
Length	10	.00 ft	Slope		0.010000	ft/ft
Drop	0	.10 ft				
Headwater Elev Tailwater Conditio	ons: Constant Tailwate	.50 ft r				
Tailwater Eleva	lion I	N/A ft				
Cannator Eleva						
Name	Description	Discha	rge HW Elev.	Velocity		
	Description 1-12 inch Circular	0. 00M	rge HW Elev. cfs9,994.77 ft	Velocity 4.51 ft/s		
Name		2.63	cfs9,994.77 ft			

1-21 inch Circular 3.50 cfs 9,994.49 ft 4.04 ft/s

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 Project Engineer: jwm255

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,994.50	ft	Storm Event	Design	
Computed Headwater Eleva	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		Dopth Downstroom	0.70	4
Slope Type	Mild		Depth, Downstream Normal Depth	0.70 N/A	
Flow Regime	Subcritical		Critical Depth	0.70	
Velocity Downstream	4.51	ft/e	Critical Slope	0.026986	
Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	
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	9,994.71 Projecting	it.	Area Full	N/A 0.8	ft2
К	0.03400		HDS 5 Chart	2	n.
M	1.50000		HDS 5 Scale	3	
	1.00000		10000000		
С	0.05530		Equation Form	1	

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 Project Engineer: jwm255

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Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,994.50	ft	Storm Event	Design	
Computed Headwater Eleva	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	
	upercritical		Critical Depth	0.52	
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	
Section					
and and another and the second	ntal Ellipse		Mannings Coefficient	0.013	
Section Material Section Size	Concrete 14x23 inch		Span Rise	1.90 1.19	
Number Sections	14x23 Inch 1		Rise	1.19	n
Outlet Control Properties					
Outlet Control HW Elev.	9,994.25	ft	Upstream Velocity Hea	ad 0.20	ft
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,994.22	ft	Flow Control	N/A	
GholetveTypenel projecting (horizor	ntal ellipse)		Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
Μ	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

Design:Trial-3

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	9,994.50	ft	Storm Event	Check	
Computed Headwater Eleva	9,994.39		Discharge	3.50	cfs
Headwater Depth/Height	0.75	i.	Tailwater Elevation	N/A	
Inlet Control HW Elev.	9,994.35	ft	Control Type	Entrance Control	ii.
Outlet Control HW Elev.	9,994.39		control type		
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	
Slope Type	Steep		Normal Depth	0.49	
	upercritical		Critical Depth	0.59	
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	ft/ft
Section					
Section Shape Horizon	ntal 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 Hea	ad 0.24	ft
Ке	0.20		Entrance Loss	0.05	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,994.35	ft	Flow Control	N/A	
GholetveType projecting (horizor			Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,994.50	ft	Storm Event	Check	
Computed Headwater Eleva	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	
Flow Regime	Subcritical		Critical Depth	0.68	
Velocity Downstream	4.04	ft/s	Critical Slope	0.016193	
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 Toppereled ring, 33.7° (1			Area Full	2.4	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
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.

1-21 inch Circular

Trial-4

Dealers Diashas		0.01	0 -6-	Ohard Diad		2.50	
Design Dischar	je	2.63	3 cfs	Check Disc	narge	3.50	CIS
Grades Model: In	verts						
Invert Upstream	ı	9,995.75	5 ft	Invert Down	stream	9,995.65	ft
Length		10.00	D ft	Slope		0.010000	ft/ft
Drop		0.10	0 ft				
Tailwater Conditio							
Tailwater Eleva	ion	N/A	A ft				
	Des	cription	Discharge	HW Elev.	Velocity		
Name							
Name Trial-1	17 32 START 31	n Circular	2.63 cfs	9,996.82 ft	5.09 ft/s		
	1-12 inch	n Circular inch Horiz E			5.09 ft/s 4.41 ft/s		

3.50 cfs 9,996.74 ft 4.04 ft/s

Design:Trial-1

Solve For: Headwater Elevation

Culvet Summer					
Culvert Summary	0.000 75		Ota and Frank	Dei	
Allowable HW Elevation	9,996.75		Storm Event	Design	
Computed Headwater Eleva		π	Discharge	2.63	
Headwater Depth/Height	1.07	-	Tailwater Elevation	N/A	Ħ
Inlet Control HW Elev.	9,996.81		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			Normal Depth	0.63	
	Steep Supercritical		Critical Depth	0.61	
Velocity Downstream	Supercritical 5.09	ft/a	Critical Slope	0.006746	
velocity Downstream	5.05	105	Childai Slope	0.000740	ivit
Section					
Section Shape	Circular		Mannings Coefficient	0.012	
SectionnMadeeta HDPE (Smo	ooth 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 Hea	ad 0.32	ft
Outlet Control HW Elev. Ke	9,996.82 0.20	ft	Upstream Velocity Hea Entrance Loss	ad 0.32 0.06	
		ft			
Ke Inlet Control Properties	0.20		Entrance Loss	0.06	
Ke Inlet Control Properties Inlet Control HW Elev.	9,996.81		Entrance Loss	0.06	ft
Ke Inlet Control Properties Inlet Control HW Elev. Inlet Type Groove er	0.20 9,996.81 ad projecting		Entrance Loss Flow Control Area Full	0.06 N/A 0.8	ft
Ke Inlet Control Properties Inlet Control HW Elev. Inlet Type Groove er K	0.20 9,996.81 od projecting 0.00450		Flow Control Area Full HDS 5 Chart	0.06 N/A 0.8 1	ft
Ke Inlet Control Properties Inlet Control HW Elev. Inlet Type Groove er	0.20 9,996.81 ad projecting		Entrance Loss Flow Control Area Full	0.06 N/A 0.8	ft

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,996.75	ft	Storm Event	Design	
Computed Headwater Eleva	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	0.44	
	upercritical		Critical Depth	0.52	
Velocity Downstream	4.41	ft/s	Critical Slope	0.004463	
Section					
Section Shape Horizon	ntal 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 Hea	ad 0.20	ft
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,996.47	ft	Flow Control	N/A	
GhowletveTypenel projecting (horizor	tal ellipse)		Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,996.75	ft	Storm Event	Check	
Computed Headwater Eleva	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	60		Dooth Downstroom	0.51	4
	S2		Depth, Downstream	0.51	
Slope Type	Steep upercritical		Normal Depth Critical Depth	0.49 0.59	
Flow Regime Su Velocity Downstream	upercritical 4.77	ft/e	Critical Slope	0.004692	
Velocity Downstream	4.11	100		0.004002	ion
Section					
Section Shape Horizon	ntal 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 Hea	ad 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	
Gindetve gonel projecting (horizon	at 10 10000 10		Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
M	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	

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 Project Engineer: jwm255

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Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,996.75	ft	Storm Event	Check	
Computed Headwater Eleva	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 Toppereled ring, 33.7° (1	.5:1) bevels		Area Full	2.4	ft²
к	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000				

CULVERT 19 REPORT

Trial-4

Trial-5 Trial-6

Culvert Designer/Analyzer Report Culvert 19

Comments: Actual diameter of existing is 6 inches.

can bischarge in	lethod: User-Specified					
Design Discharg	je 2.6	i3 cfs	Check Disch	narge	3.50	cfs
Grades Model: Inv	verts					
Invert Upstream	10,000.0	00 ft	Invert Down	stream	9,999.65	ft
Length	35.0	0 ft	Slope		0.010000	ft/ft
Drop	0.3	5 ft				
Headwater Eleva Tailwater Conditio	ation 10,001.0 ns: Constant Tailwater					
Tailwater Elevat	ion N/	'A ft				
Tailwater Elevat Name	ion N/ Description	A ft Discharg	e HW Elev.	Velocity		
		Discharg	e HW Elev. 510,001.07 ft	Velocity 5.28 ft/s		
Name	Description	Discharg 2.63 cf	f s 10,001.07 ft	<u> </u>		

1-21 inch Circular 3.50 cfs0,000.99 ft 4.04 ft/s

2.63 cfs0,000.71 ft 4.45 ft/s

3.50 cf\$0,000.84 ft 4.79 ft/s

2-12 inch Circular

2-12 inch Circular

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 Project Engineer: jwm255

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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		Constructed Slope	0.010000	
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	
SectionnMaderia HDPE (Sm	ooth 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 Hea	ad 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 er	nd projecting		Area Full	0.8	ft²
К	0.00450		HDS 5 Chart	1	
М	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Design	
Computed Headwater Eleva	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	
	upercritical		Critical Depth	0.52	
Velocity Downstream	4.69	ft/s	Critical Slope	0.004463	
Section					
Section Shape Horizo	ntal 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 Hea	d 0.20	ft
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	10,000.72	ft	Flow Control	N/A	
Gholet/eType projecting (horizon			Area Full	1.8	ft²
К	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000				

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Eleva	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	
	upercritical		Critical Depth	0.49	
Velocity Downstream	5.09	ft/s	Critical Slope	0.004692	
Section					
Section Shape Horizo	ntal 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 Hea	ad 0.24	ft
Ке	0.20		Entrance Loss	0.05	ft
Inlet Control Properties					
Inlet Control HW Elev.	10.000.85	ft	Flow Control	N/A	
Ginalety of yapmed projecting (horizon			Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	
Y	0.69000		25 C		

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 Toppeveled ring, 33.7° (1.5:1) bevels		Area Full	2.4	ft²
к	0.00180		HDS 5 Chart	3	
М	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000				

Design:Trial-5

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Design	
Computed Headwater Eleva	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	
	Supercritical		Critical Depth	0.40	
Velocity Downstream	4.45	ft/s	Critical Slope	0.005164	
·,					10.00
Section					
Section Shape	Circular		Mannings Coefficient	0.012	
SectionnMathemathHDPE (Smo	oth 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 Hea	ad 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, 3			Area Full	1.6	ft²
	0.00180		HDS 5 Chart	3	
К				0	
	2,50000		HDS 5 Scale	B	
K M C	2.50000 0.02430		HDS 5 Scale Equation Form	B 1	

Design:Trial-6

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00	ft	Storm Event	Check	
Computed Headwater Eleva	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	
	Supercritical		Critical Depth	0.56	
Velocity Downstream	4.79	ft/s	Critical Slope	0.005564	
Section					
Section Shape	Circular		Mannings Coefficient	0.012	
SectionnMateria HDPE (Smo	ooth 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 Hea	ad 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, 3			Area Full	1.6	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
0	0.02430		Equation Form	1	
С	0.02430				

CULVERT 20 REPORT

Trial-4

Culvert Designer/Analyzer Report Culvert 20

Comments: Actual diameter of existing is 6 inches.

Design Dischar	ge 2.6	63 cfs	Check Disch	narge	3.50	cfs
Grades Model: In	verts					
Invert Upstream	9,998.5	50 ft	Invert Down	stream	9,998.40	ft
Length	10.0	00 ft	Slope		0.010000	ft/ft
Drop	0.1	IO ft				
Headwater Elev		50 ft				
Tailwater Conditio	ns: Constant Tailwater					
Tailwater Conditic Tailwater Elevat		/A ft				
		/A ft Discharg	je HW Elev.	Velocity		
Tailwater Elevat	ion N	Discharg	je HW Elev. fs10,000.21 ft	Velocity 5.20 ft/s		
Tailwater Elevat Name	ion N. Description	Discharg 3.50 c	f s 0,000.21 ft			

1-21 inch Circular 3.50 cfs 9,999.49 ft 4.91 ft/s

Design:Trial-1

Solve For: Headwater Elevation

Outlet Control HW Elev. 10,000.21 ft Grades		
Headwater Depth/Height 1.71 Tailwater Elevation Inlet Control HW Elev. 10,000.13 ft Control Type Ou Outlet Control HW Elev. 10,000.21 ft Control Type Ou Grades Upstream Invert 9,998.50 ft Downstream Invert Length 10.00 ft Constructed Slope Hydraulic Profile Profile CompositeM2PressureProfile Depth, Downstream Slope Type Mild Normal Depth Flow Regime Subcritical Critical Depth Velocity Downstream 5.20 ft/s Critical Slope Section Section Shape Circular Mannings Coefficient Section Material CMP Span Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control Properties Outlet Control Properties Inlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss	Check	
Inlet Control HW Elev. 10,000.13 ft Control Type Ou Outlet Control HW Elev. 10,000.21 ft Outlet Control HW Elev. 10,000.21 ft Outlet Control HW Elev. 10,000.21 ft Outlet Constructed Slope Outlet Constructed Slope Outlet Constructed Slope Outlet Constructed Slope Outlet Control Properties Outlet Control Properties Outlet Control HW Elev. 10,000.21 ft Outlet Control HW Elev. 10,000.13 ft Flow Control Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart	3.50	cfs
Outlet Control HW Elev. 10,000.21 ft Grades	N/A	ft
Grades Upstream Invert 9,998.50 ft Downstream Invert Length 10.00 ft Constructed Slope Hydraulic Profile Profile CompositeM2PressureProfile Depth, Downstream Slope Type Mild Normal Depth Flow Regime Subcritical Critical Depth Velocity Downstream 5.20 ft/s Critical Slope Section Section Shape Circular Mannings Coefficient Section Staze 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart	Outlet Control	
Upstream Invert 9,998.50 ft Downstream Invert Length 9,998.50 ft Constructed Slope Hydraulic Profile Profile CompositeM2PressureProfile Depth, Downstream Slope Type Mild Normal Depth Flow Regime Subcritical Critical Depth Velocity Downstream 5.20 ft/s Critical Slope Section Shape Circular Mannings Coefficient Section Shape 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart		
Length 10.00 ft Constructed Slope Hydraulic Profile Profile CompositeM2PressureProfile Depth, Downstream Slope Type Mild Normal Depth Flow Regime Subcritical Critical Depth Velocity Downstream 5.20 ft/s Critical Slope Section Shape Circular Mannings Coefficient Section Shape Circular Mannings Coefficient Section Material CMP Span Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control Properties Outlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart		
Length 10.00 ft Constructed Slope Hydraulic Profile Profile CompositeM2PressureProfile Depth, Downstream Slope Type Mild Normal Depth Flow Regime Subcritical Critical Depth Velocity Downstream 5.20 ft/s Critical Slope Section Shape Circular Mannings Coefficient Section Shape Circular Mannings Coefficient Section Material CMP Span Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control Properties Outlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart	9,998.40	ft
Profile CompositeM2PressureProfile Depth, Downstream Slope Type Mild Normal Depth Flow Regime Subcritical Critical Depth Velocity Downstream 5.20 ft/s Critical Slope Section Section Material CMP Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control Properties 0.90 Entrance Loss Inlet Control Properties 10,000.13 ft Flow Control Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart	0.010000	ft/ft
Profile CompositeM2PressureProfile Depth, Downstream Slope Type Mild Normal Depth Flow Regime Subcritical Critical Depth Velocity Downstream 5.20 ft/s Critical Slope Section Section Material CMP Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control Properties 0.90 Entrance Loss Inlet Control Properties 10,000.13 ft Flow Control Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart		_
Slope Type Mild Normal Depth Flow Regime Subcritical Critical Depth Velocity Downstream 5.20 ft/s Critical Slope Section Section Shape Circular Mannings Coefficient Section Material CMP Span Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control Properties 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss Inlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Control HW Elev. 10,000.13 ft Flow Control Krea Full K 0.03400 HDS 5 Chart Start		
Flow Regime Subcritical Critical Depth Velocity Downstream 5.20 ft/s Critical Depth Section Section Shape Circular Mannings Coefficient Section Material CMP Span Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control Properties Outlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss	0.80	
Velocity Downstream 5.20 ft/s Critical Slope Section Section Shape Circular Mannings Coefficient Section Material CMP Span Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss Inlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart	N/A	
Section Section Material Section Material CMP Span Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke Under Section Under Section Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Control HW Elev. 0.03400 HDS 5 Chart	0.80	
Section Shape Circular Mannings Coefficient Section Material CMP Span Section Size 12 inch Rise Number Sections 1 Inch Outlet Control Properties 0.90 Entrance Loss Inlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type K 0.3400 HDS 5 Chart Index 5 Chart	0.034479	ft/ft
Section Material CMP Span Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss Inlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart		
Section Size 12 inch Rise Number Sections 1 Outlet Control Properties Outlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss Inlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Ype Projecting Area Full K 0.03400 HDS 5 Chart	0.024	
Number Sections 1 Outlet Control Properties	1.00	ft
Outlet Control Properties Outlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss Inlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Projecting Area Full K 0.03400 HDS 5 Chart	1.00	ft
Outlet Control HW Elev. 10,000.21 ft Upstream Velocity Head Ke 0.90 Entrance Loss Inlet Control Properties Inlet Control HW Elev. 10,000.13 ft Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart		
Ke 0.90 Entrance Loss Inlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart		
Inlet Control Properties Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart	0.31	ft
Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart	0.28	ft
Inlet Control HW Elev. 10,000.13 ft Flow Control Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart		
Inlet Type Projecting Area Full K 0.03400 HDS 5 Chart		
K 0.03400 HDS 5 Chart	N/A	
	0.8	ft²
	2	
M 1.50000 HDS 5 Scale	3	
C 0.05530 Equation Form Y 0.54000	1	

Design:Trial-2

Solve For: Section Size

16 12 18					
Culvert Summary					
Allowable HW Elevation	9,999.50	ft	Storm Event	Design	
Computed Headwater Eleva	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	0.44	
	upercritical		Critical Depth	0.42	
Velocity Downstream	4.41	ft/e	Critical Slope	0.004463	
appresse choirty — The special special transmission and		0.000		2003/07/2006 - 4399/30	
Section					
Section Shape Horizo	ntal 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 Hea	ad 0.20	ft
Ке	0.20		Entrance Loss	0.04	ft
Inlet Control Properties					
Inlet Control HW Elev.	9,999.22	ft	Flow Control	N/A	
GholetreTypenel projecting (horizor			Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
С	0.03170		Equation Form	1	

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.50		Storm Event	Check	
Computed Headwater Eleva	9,999.39	ft	Discharge	3.50	
Headwater Depth/Height	0.75		Tailwater Elevation	N/A	ft
Inlet Control HW Elev.	9,999.35		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	
	upercritical		Critical Depth	0.59	
Velocity Downstream	4.77	ft/s	Critical Slope	0.004692	
Section					
Section Shape Horizon	ntal 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 Hea	ad 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	
Ghodet/eTypenel projecting (horizon			Area Full	1.8	ft²
K	0.00450		HDS 5 Chart	29	
М	2.00000		HDS 5 Scale	3	
0	0.00470		Equation Form	1	
С	0.03170		Lyuation Form		

Design:Trial-4

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	9,999.50	ft	Storm Event	Check	
Computed Headwater Eleva	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	
1 21	Supercritical		Critical Depth	0.68	
Velocity Downstream	4.91	ft/s	Critical Slope	0.004751	
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 Hea	ad 0.25	ft
Ке	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
к	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	

CULVERT 21 REPORT

Culvert Designer/Analyzer Report Culvert 21

Comments: Actual diameter of existing is 6 inches.

						1.00
Design Dischar	je 2.0	0 cfs	Check Disch	narge	2.70	cfs
Grades Model: In	verts					
Invert Upstream	9,999.5	50 ft	Invert Down	stream	9,999.38	ft
Length	12.0	00 ft	Slope		0.010000	ft/ft
Drop	0.1	2 ft				
Headwater Elev						
Tailwater Condition	ns. Constant Talwater					
Tailwater Conditio		/A ft				
		'A ft Dischar	ge HW Elev.	Velocity		
Tailwater Eleva	iion N/	Dischar	ge HW Elev. cfs10,000.55 ft	Velocity 4.04 ft/s		
Tailwater Eleva Name	tion N/	Dischar		<u> </u>		

 Title: CENE 486 CULVERTMASTER
 Project Engineer: jwm255

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10 000 50		Storm Event	Desire	
	10,000.50			Design	
Computed Headwater Eleva	10,000.55	π	Discharge	2.00	
Headwater Depth/Height	1.05		Tailwater Elevation	N/A	π
Inlet Control HW Elev.	10,000.49		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	
Flow Regime	Subcritical		Critical Depth	0.60	
Velocity Downstream	4.04	ft/s	Critical Slope	0.023390	
Section	No. 1976 1970				
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.00	
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
Ке	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	ft ²
К	0.03400		HDS 5 Chart	2	
M	1.50000		HDS 5 Scale	3	
				5	
C	0.05530		Equation Form	1	

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.50	ft	Storm Event	Design	
Computed Headwater Eleva	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	
	Supercritical		Critical Depth	0.60	
Velocity Downstream	4.77	ft/s	Critical Slope	0.005848	ft/ft
Section					
Section Shape	Circular		Mannings Coefficient	0.012	
SectionnMaterialHDPE (Smo	oth Interior)		Span	1.00	
Section Size	12 inch		Rise	1.00	ft
Number Sections	1				
Outlet Control Properties					
Outlet Control HW Elev.	10,000.41	ft	Upstream Velocity Hea	id 0.25	ft
Ке	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, 3			Area Full	0.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	

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Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,000.50	ft	Storm Event	Check	
Computed Headwater Eleva	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	0.57	
	Supercritical		Critical Depth	0.66	
Velocity Downstream	5.00	ft/s	Critical Slope	0.004980	
	100.000				
Section					
Section Shape	Circular		Mannings Coefficient	0.012	
SectionnMathemathHDPE (Smo	oth 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 Hea	ad 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, 3			Area Full	1.2	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	

CULVERT 22 REPORT

x Trial-3

Culvert Designer/Analyzer Report Culvert 22

Comments: Actual diameter of existing is 6 inches.

1-15 inch Circular

Peak Discharge Method	: User-Specified					
Design Discharge	2.00	cfs	Check Disch	large	2.70	cfs
Grades Model: Inverts						
Invert Upstream	10,000.25	ft	Invert Down	stream	10,000.13	ft
Length	12.00	ft	Slope		0.010000	ft/ft
Drop	0.12	ft				
Headwater Elevation	10,001.25	it.				
Tailwater Conditions: Co	nstant Tailwater					
Tailwater Conditions: Co Tailwater Elevation	nstant Tailwater N/A	ft				
	N/A	ft Discharge	HW Elev.	Velocity		
Tailwater Elevation	N/A	Discharge	HW Elev. 0,001.30 ft	Velocity 4.04 ft/s		

2.70 cf\$0,001.22 ft 5.00 ft/s

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	10,001.25	ft	Storm Event	Design	
Computed Headwater Eleva	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	
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	
	0.54000				

Design:Trial-2

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.25	ft	Storm Event	Design	
Computed Headwater Eleva	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	
	Supercritical		Critical Depth	0.60	
Velocity Downstream	4.77	ft/s	Critical Slope	0.005848	
Section					
Section Shape	Circular		Mannings Coefficient	0.012	
SectionnMateria HDPE (Smo	ooth 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 Hea	ad 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, 3			Area Full	0.8	ft²
К	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
			23 C		

Design:Trial-3

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.25	ft	Storm Event	Check	
Computed Headwater Eleva	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
Liudenulia Desfile					
Hydraulic Profile			Death Daveater	0.57	£
Profile	S2		Depth, Downstream	0.57	
Slope Type	Steep		Normal Depth	0.54	
•	Supercritical		Critical Depth	0.66	
Velocity Downstream	5.00	ft/s	Critical Slope	0.004980	π/π
Section					
Section Shape	Circular		Mannings Coefficient	0.012	
SectionnMathemathHDPE (Smo	ooth 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 Hea	d 0.26	ft
Ke	0.20		Entrance Loss	0.05	ft
Inlet Control Properties	to the schools where		Verdagen 1993 - 20 Ve	Jacobie (1972) and 1974	
Inlet Control HW Elev.	10,001.18	ft	Flow Control	N/A	
Inlet Type Beveled ring,			Area Full	1.2	ft²
К	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	В	
С	0.02430		Equation Form	1	
Y	0.83000				

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CULVERT 23 REPORT

Culvert Designer/Analyzer Report Problem Area A Culvert

Design Discharge	6.60	cfs	Check Discharge	8.80	cfs
Design Discharge	0.00	013	Check Discharge	0.00	013
Grades Model: Inverte	3				
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			
	aximum Allowable HW				
Headwater Model: Ma Headwater Elevatio					
Headwater Elevatio	n 10,001.00				
	n 10,001.00				
Headwater Elevatio	n 10,001.00	ft			
Headwater Elevatio	n 10,001.00 Constant Tailwater N/A	ft	je HW Elev. Velocity		
Headwater Elevatio Tailwater Conditions: Tailwater Elevation Name	n 10,001.00 Constant Tailwater N/A	ft ft Discharg			

 Title: CENE 486 CULVERTMASTER
 Project Engineer: jwm255

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Culvert Designer/Analyzer Report Problem Area A Culvert

Design:Trial-1

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	10,001.00		Storm Event	Design	
Computed Headwater Eleva	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		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/f
Hydraulic Profile					
Profile	S2		Depth, Downstream	0.27	ft
Slope Type	Steep		Normal Depth	0.23	
	Supercritical		Critical Depth	0.58	ft
Velocity Downstream	11.00	ft/s	Critical Slope	0.004463	ft/f
Section					
Section Shape Horizo	ontal 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 He	ad 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	
entedgeywith headwall (horizo	ntal ellipse)		Area Full	3.6	ft²
к	0.01000		HDS 5 Chart	29	
Μ	2.00000		HDS 5 Scale	1	
			F 1	1	
С	0.03980		Equation Form	1	

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 Eleva	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		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/
Hydraulic Profile					
Profile	S2		Depth, Downstream	0.29	ft
Slope Type	Steep		Normal Depth	0.25	
	upercritical		Critical Depth	0.62	
Velocity Downstream	11.25	ft/s	Critical Slope	0.004081	
Section Section Shape Horizo	ntal Ellipse		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.52	ft
	19x30 inch		Rise	1.60	
Number Sections	2				
Outlet Control Properties					
Outlet Control HW Elev.	10,000.97	ft	Upstream Velocity He	ad 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	
			Area Full	6.6	ft2
	ntal ellipse)		Area Full	0.0	
	ntal ellipse) 0.01000		HDS 5 Chart	29	
entellgēyveth headwall (horizor	and a second second second				

CULVERT 24 REPORT

Culvert Designer/Analyzer Report Problem Area B Culvert

Peak Discharge Me	thod: User-Specifie	d					
Design Discharge	5	5.40	cfs (Check Disch	narge	7.20	cfs
Grades Model: Inve	rts						
Invert Upstream	10,000	0.00	ft I	nvert Down	stream	9,999.88	ft
Length	12	2.00	ft S	Slope		0.010000	ft/ft
Drop	C).12	ft				
Headwater Elevat	ion 100,001	.00	ft				
Tailwater Conditions	e: Constant Tailwate						
		N/A	ft				
Tailwater Elevatio							
Tailwater Elevatio	Description		Discharge	HW Elev.	Velocity		
			Discharge	HW Elev. 0,000.67 ft	Velocity 4.25 ft/s		

 Northern Arizona UniversityFL4
 Project Engineer: jwm255

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 Page 1 of 3

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 Ele	eva 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	0.32	
Flow Regime	Supercritical		Critical Depth	0.38	
Velocity Downstream	4.25	ft/s	Critical Slope	0.005226	
Section					
Section Shape	Box		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	
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 Hea	ıd 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° wingwal	I flares - offset		Area Full	8.0	ft²
к	0.49700		HDS 5 Chart	13	
М	0.66700		HDS 5 Scale	1	
С	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 Ele	eva 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	
Flow Regime	Supercritical		Critical Depth	0.47	
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 Hea	d 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	
	I flares - offset		Area Full	8.0	ft²
K	0.49700		HDS 5 Chart	13	
M	0.66700		HDS 5 Scale	1	
С	0.03020		Equation Form	2	
Y	0.83500				

APPENDIX F: FLOW MASTER RESULTS

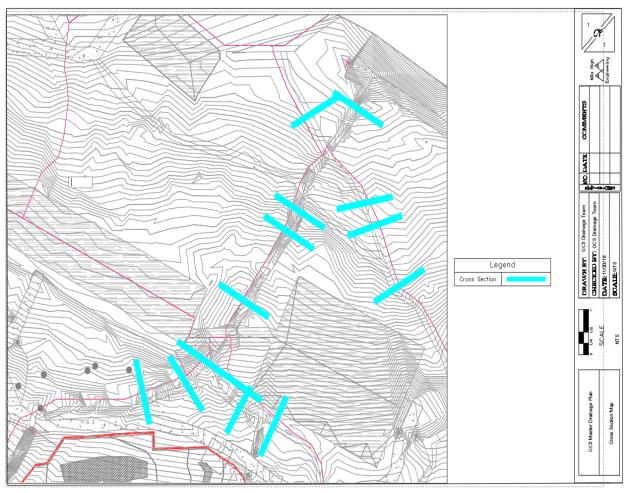


Figure 16: Location of cross sections for Problem Area A and B. [5]

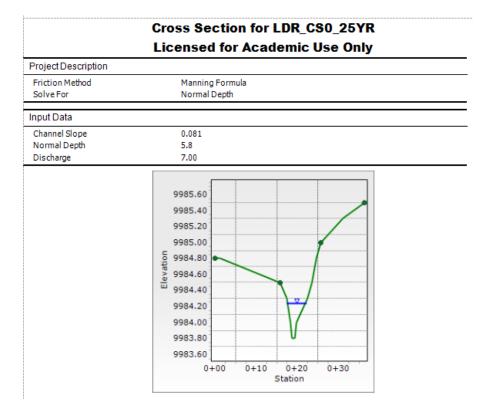
Appendix F-1: Area A problem for 25 years [7]

		Ombr
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Project Description		
Friction Method Solve For	Manning Formula Normal Depth	
Input Data		
Channel Slope Discharge	0.081 7.00	
	Section Definitions	
Station (ft)		Elevation (ft)
(14)	0+00	9,984.7
	0+01	9,984.7
	0+16	9,984.5
	0+17	9,984.2
	0+18	9,984.0
	0+19	9,983.7
	0+19	9,983.7
	0+20	9,984.0
	0+22	9,984.2
	0+24	9,984.5
	0+25	9,984.7
	0+26	9,985.0
	0+31	9,985.2
	0+36	9,985.5
	Roughness Segment Definitions	:
Start Station & Elevation	Roughness Segment Definitions End Station & Elevation	Roughness Coefficient
Start Station & Elevation (0+00, 9,984.75)		
	End Station & Elevation	Roughness Coefficient
(0+00, 9,984.75)	End Station & Elevation (0+16, 9,984.50)	Roughness Coefficient 0.06
(0+00, 9,984.75) (0+16, 9,984.50)	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00)	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00)	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50)	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00) Options	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50)	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00) Options Current Roughness Weighted Methor	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50)	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00) Options Current Roughness Weighted Method Open Channel Weighting Method Closed Channel Weighting Method Results	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50) d Pavlovskii's Method Pavlovskii's Method Pavlovskii's Method	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00) Options Current Roughness Weighted Method Open Channel Weighting Method Closed Channel Weighting Method Results Normal Depth	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50) d Pavlovskii's Method Pavlovskii's Method Pavlovskii's Method 5.8	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00) Options Current Roughness Weighted Method Open Channel Weighting Method Closed Channel Weighting Method Results Normal Depth Elevation Range	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50) d Pavlovskii's Method Pavlovskii's Method Pavlovskii's Method 5.8 9,983.8 to 9,985.5 ft	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00) Options Current Roughness Weighted Method Open Channel Weighting Method Closed Channel Weighting Method Results Normal Depth Elevation Range Flow Area	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50) d Pavlovskii's Method Pavlovskii's Method Pavlovskii's Method 5.8 9,983.8 to 9,985.5 ft 1.0	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00) Options Current Roughness Weighted Method Open Channel Weighting Method Closed Channel Weighting Method Results Normal Depth Elevation Range Flow Area Wetted Perimeter	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50) d Pavlovskii's Method Pavlovskii's Method Pavlovskii's Method 5.8 9,983.8 to 9,985.5 ft 1.0 5.1	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00) Options Current Roughness Weighted Method Open Channel Weighting Method Closed Channel Weighting Method Results Normal Depth Elevation Range Flow Area Wetted Perimeter Hydraulic Radius	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50) d Pavlovskii's Method Pavlovskii's Method Pavlovskii's Method 5.8 9,983.8 to 9,985.5 ft 1.0 5.1 2.3	Roughness Coefficient 0.06 0.02
(0+00, 9,984.75) (0+16, 9,984.50) (0+26, 9,985.00) Options Current Roughness Weighted Method Open Channel Weighting Method Closed Channel Weighting Method Results Normal Depth Elevation Range Flow Area Wetted Perimeter	End Station & Elevation (0+16, 9,984.50) (0+26, 9,985.00) (0+36, 9,985.50) d Pavlovskii's Method Pavlovskii's Method Pavlovskii's Method 5.8 9,983.8 to 9,985.5 ft 1.0 5.1	Roughness Coefficient 0.06 0.02

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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	



	orksheet for LDR_CS1_25		
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Project Description			_
Friction Method Solve For	Manning Formula Normal Depth		_
Input Data			-
Channel Slope Discharge	0.081 6.60		
	Section Definitions		-
Station		Elevation	
(ft)	0+00	(ft)	9,988.0
	0+02		9,988.0
	0+11		9,988.0
	0+12		9,987.7
	0+12		9,987.7
	0+13		9,987.2
	0+14		9,987.5
	0+15		9,987.7
	0+17		9,988.0
	0+18		9,988.2
	Roughness Segment Definitions		
Start Station & Elevation	End Station & Elevation	Roughness Coefficient	
(0+00, 9,988.00)	(0+11, 9,988.00)		0.06
(0+11, 9,988.00)	(0+15, 9,987.75)		0.02
(0+15, 9,987.75)	(0+18, 9,988.25)		0.06
Options			_
Current Roughness Weighted Method			
Open Channel Weighting Method	Pavlovskii's Method		
Closed Channel Weighting Method	Pavlovskii's Method		_
Results			_
Normal Depth Elevation Range	7.5		
Flow Area	9,987.3 to 9,988.3 ft 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		
and the second sec	F 2F		
Velocity Velocity Head	5.35		

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 Licensed for Academic Use Only

Project Description	
Friction Method Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope	0.081
Normal Depth	7.5
Discharge	6.60
	9988.50
	9988.40
	9988.30
	0088 20



Worksheet for LDR_CS2_25YR

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Project Description		
Friction Method Solve For	Manning Formula Normal Depth	
Input Data		
Channel Slope Discharge	0.081 6.60	

Section Definitions

	-1
Station	Elevation
(ft)	(ft)
0+	9,989.50
0+	9,989.50
0+	9,989.75
0+	9,990.00
0+	10 9,990.30
0+	12 9,990.00
0+	12 9,989.80
0+	13 9,989.75
0+	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

	Pavlovskii's Method Pavlovskii's 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	

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Worksheet for LDR_CS3_25YR

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Project Description		
Friction Method Solve For	Manning Formula 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

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

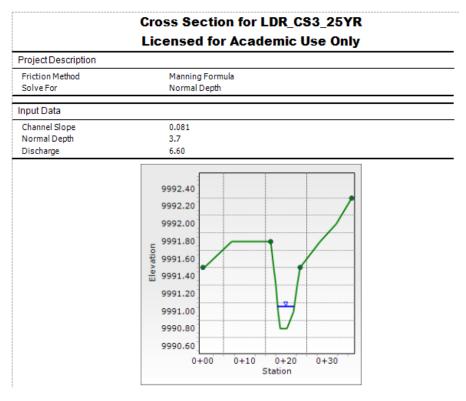
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Normal Depth	3.7
Elevation Range	9,990.8 to 9,992.3 ft
Flow Area	0.9
Wetted Perimeter	4.1
Hydraulic Radius	2.5
Top Width	4.04

Worksheet for LDR_CS3_25YR

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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	



Worksheet for RDR_CS1_25 years

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Project Description		
Friction Method Solve For	Manning Formula 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 Open Channel Weighting Method	Pavlovskii's Method Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method
Results	
Normal Depth	2.6

Normal Depth	2.0	
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 Licensed for Academic Use Only Project Description Manning Formula Normal Depth Friction Method Solve For Input Data Channel Slope 0.050 Normal Depth 2.6 6.60 Discharge 9993.60 9993.40 9993.20 9993.00 Elevation 9992.80 9992.60 9992.40 9992.20 9992.00 9991.80 9991.60 0+00 0+10 0+20 Station 0+30

Worksheet for RDR_CS2_25 years

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Project Description		
Friction Method Solve For	Manning Formula Normal Depth	
Input Data		
Channel Slope	0.050	
Discharge	6.60	

Section Definitions

Ot-11	
Station	Elevation
(ft)	(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

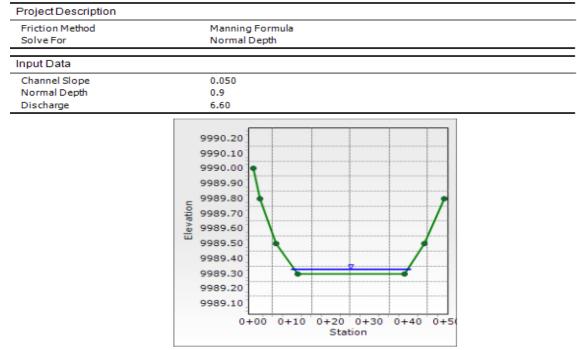
Normal Depth	0.9
Elevation Range	9,989.3 to 9,990.0 ft
Flow Area	2.3
Wetted Perimeter	31.0
Hydraulic Radius	0.9
Top Width	31.01
Normal Depth	0.9
Critical Depth	1.4
Critical Slope	0.012
Velocity	2.91
Velocity Head	0.13

Worksheet for RDR_CS2_25 years

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Results		
Specific Energy Froude Number	0.21 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	

Cross Section for RDR_CS2_25 years Licensed for Academic Use Only



Worksheet for RDR_CS3_25 years Licensed for Academic Use Only

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.
	0+07		9,988.
	0+13		9,988.
	0+17		9,988.
	0+19		9,988.
	0+24		9,988.
	Roughness Segment Definitions		
Start Station & Elevation	End Station & Elevation	Roughness Coefficient	
(0+00, 9,989.00)	(0+07, 9,988.75)		0.0
(0+07, 9,988.75)	(0+13, 9,988.50)		0.0
(0+13, 9,988.50)	(0+17, 9,988.50)		0.0
(0+17, 9,988.50)	(0+19, 9,988.75)		0.0
(0+19, 9,988.75)	(0+24, 9,988.75)		0.0
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		

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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	

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Friction Method	Manning Formula	
Solve For	Normal Depth	
301761 01	Normal Deput	
Input Data		
Channel Slope	0.050	
Normal Depth	2.4	
Discharge	6.60	
	9989.20	
	9989.10	
	9989.00	
	+	
	9988.90	
	ឝ្ន៍ 9988.80	-
	등 9988.80 실 9988.70	
	9988.60	
	9988.50	
	9988.40	
	9988.30	
	0+00 0+05 0+10 0	+15 0+20
	Station	

	ksheet for RDR_CS4_25 y		
Lic	ensed for Academic Use	Only	_
Project Description			
Friction Method Solve For	Manning Formula Normal Depth		_
Input Data			-
Channel Slope Discharge	0.050 7.00		_
	Section Definitions		-
Station (ft)		Elevation (ft)	
	0+00 0+07 0+13 0+18 0+22 0+24		9,986.0 9,985.7 9,985.5 9,985.5 9,985.7 9,985.7
	Roughness Segment Definitions		
Start Station & Elevation (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)	End Station & Elevation (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 Coefficient	t 0.02 0.02 0.02 0.02 0.02
Options			-
Current Roughness Weighted Method Open Channel Weighting Method Closed Channel Weighting Method	Pavlovskii's Method Pavlovskii's Method Pavlovskii's Method		_ _
Results			_
Normal Depth Elevation Range Flow Area Wetted Perimeter Hydraulic Radius Top Width Normal Depth Critical Depth Critical Slope Velocity Velocity Head Specific Energy	2.3 9,985.5 to 9,986.0 ft 1.6 12.2 1.6 12.20 2.3 3.4 0.011 4.33 0.29 0.48		

Worksheet for RDR_CS4_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	2.3	
Critical Depth	3.4	
Channel Slope	0.050	
Critical Slope	0.011	

Cross Section for RDR_CS4_25 years Licensed for Academic Use Only

Project Description	
Friction Method Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope Normal Depth Discharge	0.050 2.3 7.00
	9986.20 9986.10 9986.00 9985.90 9985.80 9985.70 9985.60 9985.50 9985.40 9985.30 0+00 0+05 0+10 0+15 0+20 Station

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

Worksheet for LDR_CS0_50YR

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Project Description		
Friction Method Solve For	Manning Formula 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	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			

6.4

Normal Depth

Worksheet for LDR_CS0_50YR

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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 Licensed for Academic Use Only

Project Description	
Friction Method Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope Normal Depth Discharge	0.081 6.4 9.40
	9985.60 9985.40 9985.20 9985.00 9984.80 9984.40 9984.20 9984.00 9984.00 9983.80 9983.60 0+00 0+10 0+20 0+30

Worksheet for LDR_CS1_50YR

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Project Description		
Friction Method Solve For	Manning Formula 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

•

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

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 Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope Normal Depth Discharge	0.081 8.5 8.80
	9988.50 9988.40 9988.20 9988.20 9988.10 9988.00 9987.90 9987.70 9987.70 9987.60 9987.60 9987.20 9987.10 0+00 0+05 0+10 0+15 Station

Worksheet for LDR_CS2_50YR

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Project Description		
Friction Method Solve For	Manning Formula 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

0	nti	or	10	
U	թս	υı	15	

Current Roughness Weighted 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

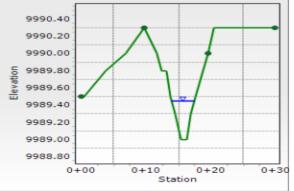
Worksheet for LDR_CS2_50YR

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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	

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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 Solve For	Manning Formula 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

Resu	ılts

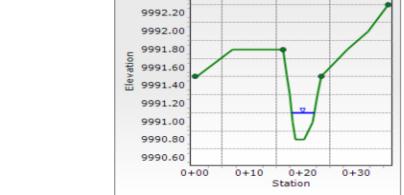
Normal Depth	4.3
Elevation Range	9,990.8 to 9,992.3 ft
Flow Area	1.1
Wetted Perimeter	4.4
Hydraulic Radius	2.9
Top Width	4.31

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		
riojectbescription		
Friction Method	Manning Formula	

Channel Slope 0.081 Normal Depth 4.3 Discharge 8.80



	ksheet for RDR_CS1_50 year	
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Project Description		
Friction Method Solve For	Manning Formula Normal Depth	
Input Data		
Channel Slope Discharge	0.050 8.80	
	Section Definitions	
Station	E	Elevation
(ft)	0+00	(ft) 9,993.00
	0+00	9,993.0
	0+05	9,992.5
	0+00	9,992.2
	0+13	9,992.0
	0+16	9,991.7
	0+18	9,991.7
	0+27	9,992.0
	0+34	9,992.2
	0+37	9,993.5
	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)	0.02
(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		
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	
	145	
Wetted Perimeter Hydraulic Radius	14.5	

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 Licensed for Academic Use Only

Project Description	
Friction Method Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope Normal Depth Discharge	0.050 3.0 8.80
	9993.60 9993.40 9993.20 9993.00 9992.80 9992.80 9992.40 9992.20 9992.00 9992.00 9991.80 9991.60 0+00 0+10 0+20 0+30

Worksheet for RDR_CS2_50 years Licensed for Academic Use Only

	chised for Academic Ose (,	_
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)	
(17)	0+00	(14)	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)	Kouginicas coerniden	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			
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		

Worksheet for RDR_CS2_50 years

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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	

Cross Section for RDR_CS2_50 years Licensed for Academic Use Only

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.050
Normal Depth	1.1
Discharge	8.80
	9990.20 9990.10 9990.00 9989.90 9989.80 9989.70 9989.60 9989.60 9989.40 9989.20 9989.20 9989.10 0+00 0+10 0+20 0+30 0+40 0+50 Station

	ksheet for RDR_CS3_50	-	
Lice	ensed for Academic Use	Only	_
ProjectDescription			
Friction Method	Manning Formula		_
Solve For	Normal Depth		_
Input Data			-
Channel Slope	0.050		_
Discharge	8.80 Section Definitions		-
	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	2.8		_
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		
	4.1		
Critical Depth			
-	0.010		
Critical Slope	0.010 4.83		
-	4.83		
Critical Slope Velocity			

Worksheet for RDR_CS3_50 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	2.8	
Critical Depth	4.1	
Channel Slope	0.050	
Critical Slope	0.010	

Cross Section for RDR_CS3_50 years Licensed for Academic Use Only

Project Description	
Friction Method Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope Normal Depth Discharge	0.050 2.8 8.80
	9989.20 9989.10 9989.00 9988.90 9988.80 9988.80 9988.60 9988.60 9988.40 9988.30

0+00 0+05 0+10 0+15 0+20 Station

Worksheet for RDR_CS4_50 years

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Project Description		
Friction Method Solve For	Manning Formula 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 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

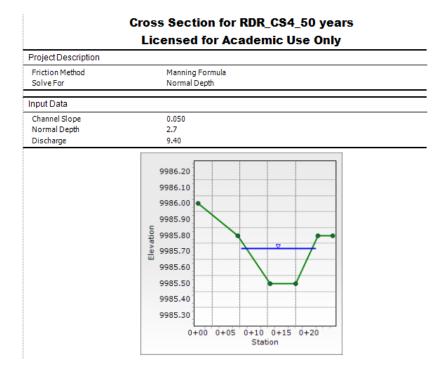
Options

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

Results	
Normal Depth	2.7
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

Worksheet for RDR_CS4_50 years

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	



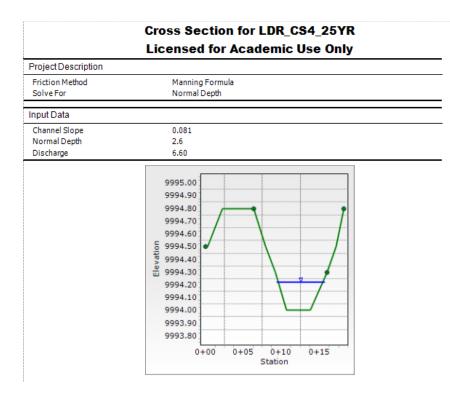
Appendix E-3: Area B problem for 25 years [7]

Worksheet for LDR_CS4_25YR

LICO	ensed for Academic Use	Uniy	_
Project Description			_
Friction Method Solve For	Manning Formula Normal Depth		
Input Data			-
Channel Slope Discharge	0.081 6.60		_
	Section Definitions		_
Station (ft)		Elevation (ft)	
	0+00		9,994.5
	0+00		9,994.5
	0+02		9,994.7
	0+06		9,994.7
	0+08		9,994.5
	0+09		9,994.2
	0+11 0+14		9,994.0
	0+14 0+16		9,994.0 9,994.2
	0+10		9,994.5
	0+18		9,994.7
	Roughness Segment Definitions		
Start Station & Elevation	End Station & Elevation	Roughness Coefficient	
(0+00, 9,994.50)	(0+06, 9,994.75)		0.06
(0+06, 9,994.75)	(0+16, 9,994.25)		0.020
(0+16, 9,994.25)	(0+18, 9,994.75)		0.06
Options			-
Current Roughness Weighted 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 Wetted Perimeter	1.0 6.3		
welled Permeter	01		
Hydraulic Dadius			
Hydraulic Radius Top Width	2.0		
Top Width	2.0 6.29		
Top Width Normal Depth	2.0 6.29 2.6		
Top Width	2.0 6.29		

Worksheet for LDR_CS4_25YR Licensed for Academic Use Only

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	



	ksheet for RUR_CS1_	
	ensed for Academic	Use Only
Project Description		
Friction Method Solve For	Manning Formula Normal Depth	
Input Data		
Channel Slope Discharge	0.050 5.40	
-	Section Definitions	
Station		Elevation
(ft)		(ft)
	0+00 0+05	10,000.2
	0+05 0+10	10,000.0
	0+10	9,999.7 9,999.5
	0+10	9,999.2
	0+18	9,999.0
	0+19	9,999.0
	0+21	9,999.2
	0+24	9,999.2
	Roughness Segment Defini	itions
Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 10,000.25)	(0+05, 10,00	0.02 0.02
(0+05, 10,000.00)	(0+10, 9,99	-
(0+10, 9,999.75)	(0+16, 9,99	
(0+16, 9,999.50)	(0+17, 9,99	-
(0+17, 9,999.25)	(0+18, 9,99	-
(0+18, 9,999.00)	(0+19, 9,9	
(0+19, 9,999.00) (0+21, 9,999.25)	(0+21, 9,99 (0+24, 9,99	-
Options Current Roughness Weighted Method	Paulovskii's Mathed	
Open Channel Weighting Method	Pavlovskiis 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 Licensed for Academic Use Only

Project Description	
Friction Method Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope Normal Depth Discharge	0.050 4.0 5.40
	10000.40 10000.20 10000.00 9999.80 9999.60 9999.40 9999.20 9999.20 9999.00 9999.80 0+00 0+05 0+10 0+15 0+20 Station

Lic	ensed for Academ	ic Use Only	
Project Description			-
Friction Method Solve For	Manning Formula Normal Depth		_
Input Data			-
Channel Slope Discharge	0.050 5.40		_
	Section Definition	ns	-
Station		Elevation	
(ft)		(ft)	
	0+00		9,999.00
	0+03		9,998.75
	0+06 0+07		9,998.50
	0+09		9,998.25
	0+10		9,998.00
	0+14		9,998.25
	0+15		9,998.50
	0+17		9,998.50
	Roughness Segment De	finitions	
Start Station & Elevation	End Station & Elevatio		
		-	
(0+00, 9,999.00) (0+03, 9,998.75)		, 9,998.75) , 9,998.50)	0.020
(0+05, 9,998.50)		, 9,998.25)	0.020
(0+07, 9,998.25)		, 9,998.00)	0.020
(0+09, 9,998.00)		, 9,998.00)	0.020
(0+10, 9,998.00)		, 9,998.25)	0.020
(0+14, 9,998.25)		, 9,998.50)	0.020
(0+15, 9,998.50)		, 9,998.50)	0.020
Options			-
Current Roughness Weighted 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 Normal Depth	6.51		
	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 Licensed for Academic Use Only

Project Description	
Friction Method Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope Normal Depth Discharge	0.050 3.2 5.40
	9999.20 9999.10 9998.00 9998.80 9998.70 9998.60 9998.50 9998.10 9998.10 9998.10 9998.10 9998.10 9998.10

0+00 0+05 0+10

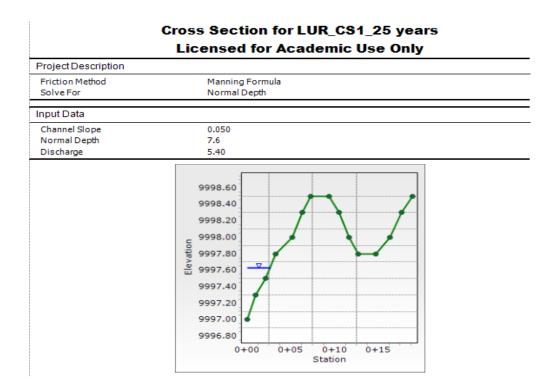
Station

0+15

Worksheet for LUR_CS1_25 years Licensed for Academic Use Only Project Description Friction Method Manning Formula Solve For Normal Depth Input Data Channel Slope 0.050 Discharge 5.40 Section Definitions Station Elevation (ft) (ft) 0+009,997.00 0+01 9,997.25 0+02 9,997.50 9,997.75 0+03 0+05 9,998.00 0+06 9,998.25 0+07 9,998.50 0+09 9,998.50 0 + 119,998.25 0+12 9,998.00 0+13 9,997.75 0 + 159,997.75 0+16 9,998.00 0 + 189,998.25 9,998.50 0+19 Roughness Segment Definitions Start Station & Elevation End Station & Elevation Roughness Coefficient (0+00, 9, 997.00)(0+01, 9, 997.25)0.020 0.020 (0+01, 9,997.25) (0+02, 9,997.50) (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+07, 9, 998.50)(0+06, 9, 998.25)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 Licensed for Academic Use Only

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



Worksheet for LUR_CS2_25 years

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Project Description		-	
Friction Method Solve For	Manning Formula Normal Depth		
Input Data			
Channel Slope Discharge	0.050 5.40		
	Section Definitions		
Station		Elevation	
(ft)	0.00	(ft)	
	0+00	9,996	
	0+03	9,996	
	0+05 0+07	9,997 9,997	
	0+07	9,997	
	0+08	9,997	
	0+09	9,996	
	0+10	9,996	
	0+11	9,997	
	0+12	9,997	7.25
	0+15	9,997	7.25
	0+19	9,997	7.50
	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)		.020
(0+07, 9,997.25)	(0+07, 9,997.25)		.020
(0+07, 9,997.25)	(0+08, 9,997.00)		.020
(0+08, 9,997.00)	(0+09, 9,996.75)		.020
(0+09, 9,996.75) (0+10, 9,996.75)	(0+10, 9,996.75) (0+11, 9,997.00)		.020 .020
(0+10, 9,996.75) (0+11, 9,997.00)	(0+11, 9,997.00) (0+12, 9,997.25)		.020
(0+12, 9,997.25)	(0+12, 9,997.25)		.020
(0+15, 9,997.25)	(0+19, 9,997.50)		.020
Options			
Current Roughness Weighted Method	Pavlovskii's Method		
Open Channel Weighting Method	Pavlovskiis Method		
Closed Channel Weighting Method	Pavlovskiis Method		
	/		

Results

Normal Depth

Worksheet for LUR_CS2_25 years Licensed for Academic Use Only

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	
· · · · · · · · · · · · · · · · · · ·		
Length Number Of Steps	0.0	
Length Number Of Steps GVF Output Data Upstream Depth	0.0	
Length Number Of Steps GVF Output Data Upstream Depth Profile Description	0.0 0	
Length Number Of Steps GVF Output Data Upstream Depth	0.0	
Length Number Of Steps GVF Output Data Upstream Depth Profile Description Profile Headloss Downstream Velodty	0.0 0 0.0 N/A 0.00 Infinity	
Length Number Of Steps GVF Output Data Upstream Depth Profile Description Profile Headloss Downstream Velodty Upstream Velodty	0.0 0 0.0 N/A 0.00 Infinity Infinity	
Length Number Of Steps GVF Output Data Upstream Depth Profile Description Profile Headloss Downstream Velocity	0.0 0 0.0 N/A 0.00 Infinity	
Length Number Of Steps GVF Output Data Upstream Depth Profile Description Profile Headloss Downstream Velodty Upstream Velodty	0.0 0 0.0 N/A 0.00 Infinity Infinity	
Length Number Of Steps GVF Output Data Upstream Depth Profile Description Profile Headloss Downstream Velodty Upstream Velodty Normal Depth	0.0 0 0.0 N/A 0.00 Infinity Infinity 4.6	

Cross Section for LUR_CS2_25 years Licensed for Academic Use Only

Project Description	
Friction Method Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope Normal Depth Discharge	0.050 4.6 5.40
	9997.70 9997.60 9997.40 9997.20 9997.20 9997.20 9997.00 9996.90 9996.50 9996.50 9996.40 9996.40 9996.40 9996.40 9996.40 9996.40 9996.40 9996.50

Worksheet for LDR_CS4_50YR Licensed for Academic Use Only

Project Description		
Friction Method Solve For	Manning Formula Normal Depth	
Input Data		
Channel Slope	0.081	
Discharge	8.80	

Section Definitions

Station	Elevation
(ft)	(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 Specific Energy Froude Number Flow Type	0.72 0.98 2.754 Supercritical	
GVF Input Data		
Downstream Depth Length Number Of Steps	0.0 0.0 0	
GVF Output Data		
Upstream Depth Profile Description Profile Headloss Downstream Velodty Upstream Velodty Normal Depth Critical Depth Channel Slope Critical Slope	0.0 N/A 0.00 Infinity 3.1 5.4 0.081 0.009	

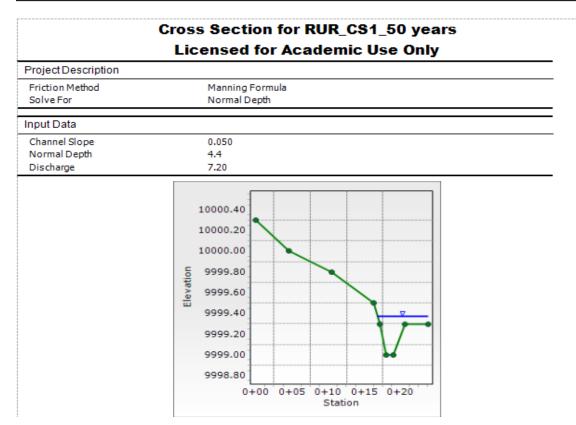
Cross Section for LDR_CS4_50YR

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Channel Slope	0.081
Normal Depth	3.1
Discharge	8.80
	9995.00 9994.90 9994.80 9994.70 9994.60 9994.40 9994.40 9994.20 9994.10 9994.00 9994.00 9993.90 9993.80 0+00 0+05 0+10 0+15 Station

10,000.25 10,000.00 9,999.75 9,999.00 9,999.00 9,999.00 9,999.25 9,999.25
10,000.00 9,999.75 9,999.50 9,999.25 9,999.00 9,999.00 9,999.25
9,999.75 9,999.50 9,999.25 9,999.00 9,999.00 9,999.00
9,999.50 9,999.25 9,999.00 9,999.00 9,999.00
9,999.25 9,999.00 9,999.00 9,999.25
9,999.00 9,999.00 9,999.25
9,999.00 9,999.25
9,999.25
ficient
0.020
0.020
0.020
0.020
0.020
0.020
0.020
0.020
-

Worksheet for RUR_CS1_50 years

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	



	ksheet for RUR_CS2_	-
Lice	ensed for Academic l	Use Only
Project Description		
Friction Method Solve For	Manning Formula Normal Depth	
Input Data		
Channel Slope Discharge	0.050 7.20	
	Section Definitions	
Station		Elevation
(ft)		(ft)
	0+00	9,999.0
	0+03	9,998.7
	0+06	9,998.5
	0+07	9,998.2
	0.005	9,998.0
	0+10	9,998.0
	0+14	9,998.2
	0+15 0+17	9,998.5
	0+1/	9,998.5
	Roughness Segment Definit	tions
Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,999.00)	(0+03, 9,99	98.75) 0.02
(0+03, 9,998.75)	(0+06, 9,99	
(0+06, 9,998.50)	(0+07, 9,99	98.25) 0.02
(0+07, 9,998.25)	(0+09, 9,99	-
(0+09, 9,998.00)	(0+10, 9,99	-
(0+10, 9,998.00)	(0+14, 9,99	-
(0+14, 9,998.25)	(0+15, 9,99	
(0+15, 9,998.50)	(0+17, 9,99	98.50) 0.02
Options		
Current Roughness Weighted 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 Licensed for Academic Use Only

Project Description			
Friction Method	Manning Formula		
Solve For	Normal Depth		
Input Data			
Channel Slope	0.050		
Normal Depth	3.6		
Discharge	7.20		
	9999.20 9999.10 9999.00 9998.90 9998.80 9998.70 9998.60 9998.50 9998.10 9998.10 9998.10 9998.10 9997.90 9997.80		
	0+00 0+05 0+10 0+15 Station		

Worksheet for LUR_CS1_50 years

	Licenseu for Academic Os	eomy
Project Description		
Friction Method	Manning Formula	
Solve For	Normal Depth	
Input Data		
Channel Slope	0.050	
Discharge	7.20	
	Section Definitions	
	ation	Elevation
	(ft)	(ft)
	0+00	9,997.0
	0+01	9,997.2
	0+02	9,997.5
	0+03	9,997.7
	0+05	9,998.0
	0+06	9,998.2
	0+07	9,998.5
	0+09	9,998.5
	0+11	9,998.2
	0+12	9,998.0
	0+13	9,997.7
	0+15	9,997.7
	0+16	9,998.0
	0+18	9,998.2
	0+19	9,998.5
	Roughness Segment Definition	15
Start Station & Elevat	tion End Station & Elevation	Roughness Coefficient
(0+00, 9,997.00)	(0+01, 9,997.2	
(0+01, 9,997.25)	(0+02, 9,997.50	
(0+02, 9,997.50)	(0+03, 9,997.75	-
+03, 9,997.75) (0+05, 9,998.00)		-
(0+05, 9,998.00)		
+06, 9,998.25) (0+07, 9,998.50)		
	+07, 9,998.50) (0+09, 9,998.50)	
(0+09, 9,998.50)	(0+11, 9,998.2	-
(0+11, 9,998.25)	(0+12, 9,998.00	-
(0+12, 9,998.00)	(0+13, 9,997.75	
(0+13, 9,997.75)	(0+15, 9,997.75	-
(0+15, 9,997.75) (0+16, 9,998.00)	(0+16, 9,998.00 (0+18, 9,998.25	
(0+18, 9,998.00) (0+18, 9,998.25)	(0+10, 9,998.2)	
(0+10, 3,330,23)	(0+13, 3,330.5)	0.02

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	
Hvdraulic 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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	Cross Section for LUR_CS1_50 years
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Project Description	
Friction Method Solve For	Manning Formula Normal Depth
Input Data	
Channel Slope Normal Depth Discharge	0.050 8.4 7.20
	9998.60 9998.40 9998.20 9998.20 9997.80 9997.80 9997.40 9997.20 9997.20 9997.00 9997.00 9996.80 0+00 0+05 0+10 0+15

Project Description		
Friction Method Solve For	Manning Formula Normal Depth	
Input Data		
Channel Slope Discharge	0.050 7.20	
	Section Definitions	
Station		Elevation
(ft)		(ft)
	0+00	9,996
	0+03	9,996
	0+05 0+07	9,997 9,997
	0+07	9,997
	0+08	9,997
	0+09	9,996
	0+10	9,996
	0+11	9,997
	0+12	9,997
	0+15 0+19	9,997 9,997
	Roughness Segment Definitions	
Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+00, 9,996.50)	(0+03, 9,996.75)	0.0
(0+03, 9,996.75)	(0+05, 9,997.00)	0.0
(0+05, 9,997.00)	(0+07, 9,997.25)	0.0
(0+07, 9,997.25)	(0+07, 9,997.25)	0.0
(0+07, 9,997.25)	(0+08, 9,997.00)	0.0
(0+08, 9,997.00)	(0+09, 9,996.75)	0.0
(0+09, 9,996.75)	(0+10, 9,996.75)	0.0
(0+10, 9,996.75) (0+11, 9,997.00)	(0+11, 9,997.00)	0.0
(0+12, 9,997.25)	(0+12, 9,997.25) (0+15, 9,997.25)	0.0
(0+15, 9,997.25)	(0+19, 9,997.50)	0.0
Options		
Current Roughness Weighted Method	Pavlovskii's Method	
Open Channel Weighting Method	Pavlovskii's Method	
Closed Channel Weighting Method	Pavlovskii's Method	

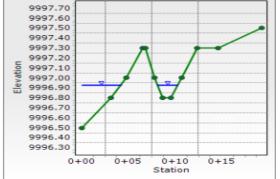
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Results		
Elevation Range	9,996.5 to 9,997.5 ft	
Flow Area	1.3	
Wetted Perimeter	7.1	
Hydraulic Radius	2.2	
Top Width	6.57	
Normal Depth	5.1	
Critical Depth	6.9	
Critical Slope	0.010	
Velocity	5.44	
Velocity Head	0.46	
Specific Energy	0.89	
Froude 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 Licensed for Academic Use Only

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Project Description		
Friction Method Solve For	Manning Formula 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