SCI 823 – High Fill Culvert Analysis

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RECEIVED
AUG – 9 2006
TranSystems

August 8, 2006

Michael D. Weeks, P.E., P.S.
TranSystems Corporation
5747 Perimeter Drive, Suite 240
Dublin, OH 43017

Re: **Bearing Capacity and Settlement Evaluation**
(Culvert at STA. 404+13)
SCI-823-0.00 Portsmouth Bypass
DLZ Job No.: 0121-3070.03
Document # 0020

Dear Mr. Weeks:

This letter includes the findings of preliminary evaluations of the proposed culvert and embankment at STA 404+13 on the above-referenced project. The findings of other preliminary culvert and embankment evaluations will be submitted in separate documents at a later date.

It is our understanding that a new culvert will be constructed at STA 404+13 for the above referenced project. The culvert will be a 96-inch Type A conduit in accordance with ODOT Item 707.3 (Structural Plate Corrugated Steel Structures). The culvert will be installed using cut and fill construction procedure then an embankment approximately 54 ft high will be built over the culvert. The inlet and outlet of the culvert will be supported by headwalls flush with the face of the pipe at both ends. At the time of preparing this letter no further information was available regarding the size of the headwalls and the depth of the footings below the ground surface.

It should be noted that the results of these evaluations are based upon the findings of three culvert borings located along the centerline of the proposed alignment of the culvert (C-19, C-20, and C-21). The borings were advanced to depths ranging between 29 and 34 feet below the ground surface. The surveyed ground elevations at the boring locations are reported on the logs.

The soil encountered in the borings indicated relatively uniform soil conditions along the culvert alignment. However, the thickness of the soil layers and the consistency of the soil vary between the borings. Boring C-19 was used for settlement analysis due to the relatively thick cohesive layer within the boring. Borings C-19 and C-21 were used to evaluate the bearing capacity of the headwall at the inlet and outlet of the pipe, respectively.

Bearing Capacity Evaluation

The bottom of the headwall footings was not known at the time of preparing this letter. The project plans indicated that the invert elevations at the inlet and outlet of the culvert were 674.45 and 663.10, respectively. The bottom of the footings was assumed to be 4 feet below the invert elevation below the frost zone and to prevent scour of the headwall (Ohio BDM Section 200).

At the inlet, the footing bearing elevation was assumed to be at elevation 675. Preliminary evaluation of the bearing capacity indicated that the footings could be designed using an allowable bearing capacity of 1,500 psf. On the other hand, the footing bearing elevation at the outlet was assumed to be at elevation 662. The allowable bearing capacity at the assumed bearing elevation was 3,000 psf.

Settlement Evaluation

Settlement below the centerline of the embankment was evaluated using the maximum cover of the embankment (54 feet) as the surcharge load and using the soil profile encountered in boring C-19. The settlement analysis indicated that the soil below the embankment might observe a total settlement of 8.3 inches of which approximately 0.75 inch will be immediate in the sand layer at the end of the embankment construction. The analysis indicated that 80% of the consolidation settlement (6 inches) will occur within 120 days after the end of the embankment construction while the time required to achieve the total consolidation settlement (7.6 inches) will be approximately 7 years. It is anticipated that additional consolidation settlement of approximately one inch will take place after the 7 years period due to additional water dissipation with time over a period of 10 years. On the other hand, a total settlement of 0.6 inch might be observed below the headwall due to the embankment loading. No loading was assumed on the headwall.

It should be noted that angular distortion will be encountered between the face of the pipe (inlet or outlet) and the middle of the pipe. Angular distortion is defined as the difference in settlement between two points divided by the distance between them. The angular distortion of the pipe was estimated to be approximately 1/290. The angular distortion can affect the structural integrity of the pipe culvert depending on the size and material of the pipe and therefore should be evaluated by a structural engineer.

$1/290 = 0.0034 < 0.0050$

DLZ
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PLANNERS • SURVEYORS

We appreciate having the opportunity to be of service to you on this project. Please do not hesitate to call if you have any questions concerning our preliminary findings.

Respectfully submitted,

DLZ OHIO, INC.

Wael Alkasawneh, P.E.
Geotechnical Engineer

Arthur (Pete) Nix, P.E.
Geotechnical Division Manager

Encl: As noted.

cc: J. Greg Brown, P.E. (TranSystems Corporation), File

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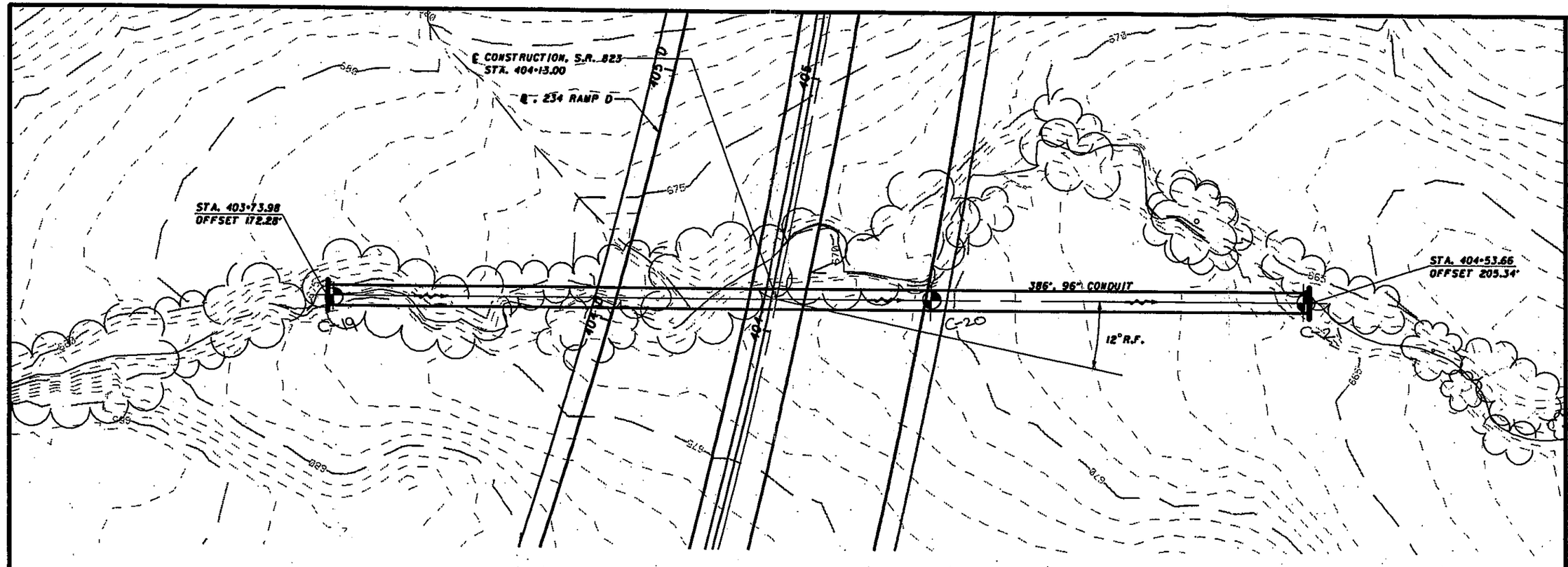
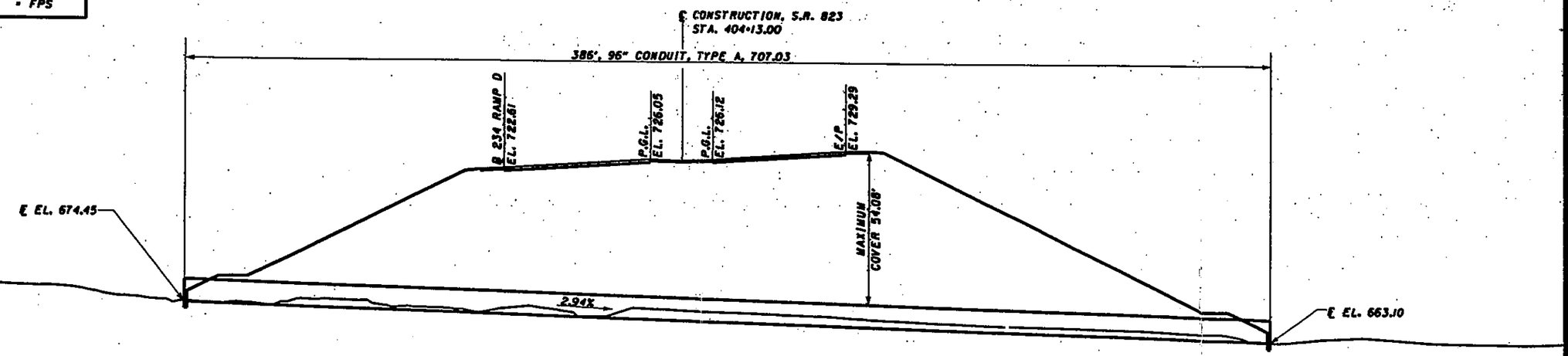


HYDRAULIC DESIGN DATA	
DRAINAGE AREA	= AC.
Q_{50}	= CFS
Q_{100}	= CFS
HW_{50}	=
HW_{100}	=
V_{50}	= FPS
V_{100}	= FPS

SOIL BORING



NOT FOR CONSTRUCTION

CALCULATED JGB
CHECKED HJS

HORIZONTAL SCALE IN FEET
0 20 40

PHASE I HEADWALL ALL LOCATION SUBMITTAL
S.R. 823 STA. 404+13

SCI-823-0.00

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-19 | Location: | Date Drilled: 06/15/06

WATER OBSERVATIONS: Water seepage at: None observed. Water level at completion: None observed.

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	679.2												
0.6	678.6	10 11 15	18	1		4.5+	Topsoil - 7" Hard brown SANDY SILT (A-4a), little clay, little gravel; damp.	13	23	–	20	31	13
3.0	676.2	3 3 4	17.5	2		1.5	Medium stiff to stiff brown and gray CLAY (A-7-6), trace to some silt, trace to little fine to coarse sand, trace gravel; (Varved); moist.						
5		2 3 5	20	3		1.75		5	0	–	0	7	88
		1 2 3	24	4		1.0							
10		1 2 2	21.5	5		1.0	@ 12.0', encountered thin layer of rock fragments.						
		2 3 3	26.5	6		1.5		2	0	–	0	12	86
15					P-1	2.25	@ 16.5'-18.5', very stiff.	1 1	5 4	– –	8 4	31 20	55 72
18.5	660.7	7 6 4	20	8		0.5	Soft to medium stiff brown SILT AND CLAY (A-6a), trace fine sand; moist.	0	0	–	1	63	36
20					P-2		@ 21.8', 4" Fine sand layer, moist to wet .		0	–	1	62	37
22.5	656.7						Soft to medium stiff brown SILT (A-4b), trace to some fine sand, some clay; wet.	0	0	–	1	71	28
24.5	654.7	1 2 12	22	10		0.5	Medium dense brown SANDY SILT (A-4a); contains sandstone fragments; damp to moist.	1	9	–	24	45	21
25													
26.5	652.7	12 27 50/0"	12	11			Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, argillaceous, laminated to very thinly bedded, moderately fractured, contains rust stains.						
30		Core	Rec	RQD	R-1								

GRADATION

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢——⊣ LL
Blows per foot - ○
10 20 30 40

65
57
66
77

FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-19 | Location: | Date Drilled: 06/15/06

WATER OBSERVATIONS: Water seepage at: None observed.
Water level at completion: None observed.

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N) / Natural Moisture Content, % - ● / PL — LL / Blows per foot - ○
30	649.2	60"	60"	36%										
32.0	647.2						Bottom of Boring - 32.0'							

10 20 30 40

35 40 45 50 55 60

FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-20 | Location: | Date Drilled: 06/14/06

WATER OBSERVATIONS: Water seepage at: 20.0' - 27.5'
Water level at completion: 22.5' (prior to coring)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	671.2	7 8 8	9	1			Medium dense brown GRAVEL WITH SAND AND SILT (A-2-4); damp.						
3.0	668.2	7 11 8	16	2		4.5+	Hard brown SANDY SILT (A-4a), little clay, little fine gravel; damp.	12	25	–	16	32	16
5		8 8 5	12	3		4.5+							
8.0	663.2				P-1		Stiff brown ELASTIC CLAY (A-7-5), little silt, trace fine sand; (Varved); damp to moist.	0	0	–	5	18	77
10													
10.5	660.7	2 3 6	23	5		0.25	Soft brown SILTY CLAY (A-6b), little fine to coarse sand, trace gravel; moist.	3	3	–	16	30	48
14.0	657.2	4 10 16	16	6			Medium dense brown FINE SAND (A-3), trace silty clay; damp.						
15		7 9 9	21	7			@ 17.0', Thin silty clay layer, encountered rock fragments.						
19.0	652.2	9 4 3	17	8			Very loose to loose brown COARSE AND FINE SAND (A-3a), little silty clay, trace gravel; moist to wet.	0	2	–	81	17	
20		20 24 17	19.5	9			@ 21.0'-22.5', dense. @ 21.0', encountered rock fragments.						
		1 1 1	16.5	10			@ 23.0', trace silty clay, wet.						
25		7 8 11	24	11									
28.0	643.2	50/3	4	12			Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, argillaceous, laminated to very						
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢——⊣ LL
Blows per foot - ○
10 20 30 40

51

Non-Plastic

FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-20 | Location: | Date Drilled: 06/14/06

WATER OBSERVATIONS: Water seepage at: 20.0' - 27.5'
Water level at completion: 22.5' (prior to coring)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
30	641.2	Core 60"	Rec 60"	RQD 85%	R-1		thinly bedded, moderately fractured, contains rust stains.						
34.0	637.2						Bottom of Boring - 34.0'						

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢——⊣ LL
Blows per foot - ○
10 20 30 40

FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-21 | Location: | Date Drilled: 06/15/06

WATER OBSERVATIONS: Water seepage at: 13.5' - 24.0'
Water level at completion: None observed.

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	666.1						Topsoil - 8"						
0.7	665.4	6 6 10	15	1		4.5+	Hard brown SANDY SILT (A-4a), little clay, trace to little gravel, contains organic material; damp.						
		6 7 8	18	2		4.5+	@ 4.5', Trace to little gravel.	9	25	--	21	30	15
5													
5.5	660.6	5 10 10	21	3	P-1		Medium dense brown COARSE AND FINE SAND (A-3a), little to some silty clay; damp.	0	0	--	81	19	
10													
		3 4 7	21	5									
		3 4 11	17.5	6									
15.0	651.1						Very loose to loose brown COARSE AND FINE SAND (A-3a), little to some silty clay; moist to wet.						
		3 5 2	15	7			@ 16.0', Moist to wet.						
							@ 18.0', Wet.						
		WOH WOH WOH	12.5	8									
20													
20.5	645.6						Very soft to soft gray SILT AND CLAY (A-6a), trace fine sand; wet.	0	0	--	1	62	37
					P-2	0.25		0	0	--	1	71	28
22.7	643.4						Very soft to soft gray SILT (A-4b), some clay, trace fine sand; wet.						
24.0	642.1	WOH 50/3	11	10			Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, argillaceous, laminated to very thinly bedded, moderately fractured, contains rust stains.						
25		Core 60"	Rec 59"	RQD 86%	R-1								
29.0	637.1						Bottom of Boring - 29.0'						
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢——⊣ LL
Blows per foot - ○
10 20 30 40

Non-Plastic

50+

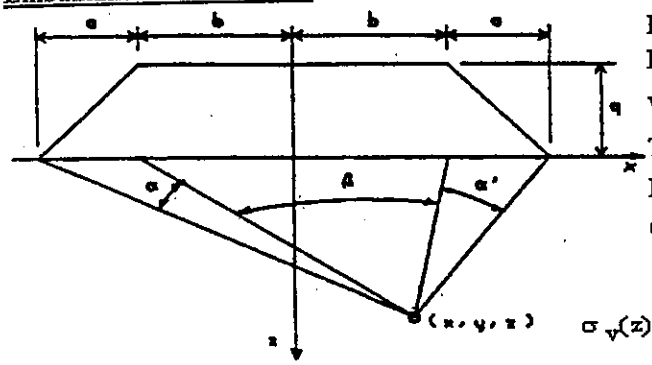
FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ SUBJECT

Client	TranSystems, Inc.	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00	SHEET NO. 1	OF 1
Item	Culvert at STA. 404+13	COMP. BY WMA	DATE 08/04/06
		CHECKED BY BEW	DATE

SETTLEMENT ANALYSIS - EMBANKMENT

Embankment Informaiton:



Groundwater Table:	D=	13.0	ft		
Embankment Height:	H =	54.08	ft		
Fill Unit Weight:	γ_{emb} =	120	pcf	q =	6,490 psf
Width of Slope:	a =	139			
Top half-width of Emb:	b =	54			
Distance from CL:	x =	0			
Output Range:	z =	0	to	25	ft

**See Data output Attached*

$$\sigma_v(z) := \left(\frac{q}{\pi}\right)\left(a\cdot(\alpha(z)+\beta(z)+\alpha'(z)) + b\cdot(\alpha(z)+\alpha'(z)) + x\cdot(\alpha(z)-\alpha'(z))\right)$$

$$\beta(z) := \operatorname{atan}\left[\frac{(b-x)}{z}\right] + \operatorname{atan}\left[\frac{(b+x)}{z}\right] \qquad \alpha'(z) := \operatorname{atan}\left[\frac{(a+b-x)}{z}\right] - \operatorname{atan}\left[\frac{(b-x)}{z}\right] \qquad \alpha(z) := \operatorname{atan}\left[\frac{(a+b+x)}{z}\right] - \operatorname{atan}\left[\frac{(b+x)}{z}\right]$$

Reference: US Army Corps of Engineers EM 1110-1-1904 "Settlement Analysis", Table C-1

Soil Properites: *Settlement is calculated at mid-point of layer*

No.	Bot. of Laye	Soil Type	γ_{soil} (pcf)	σ'_c (psf)	σ'_o (psf)	$\Delta\sigma z$ (psf)	σ'_f (psf)	Cohesionless Soils C'	Cohesive Soils C_r	Cohesive Soils C_c	Cohesive Soils e_o
1	16.0 ft	Clay	120	7,448	960	6,488	7,448	0.0	0.07	0.48	0.901
2	21.0 ft	Silty Clay	120	8,301	1,877	6,471	8,348	0.0	0.06	0.23	0.901
3	26.5 ft	Silt/Sandy Silt	110	0	2,152	6,452	8,604	53.0	0.00	0.00	0.000
4	0.0		0	0				0.0	0.00	0.00	0.000
5	0.0		0	0							
6	0.0		0	0							
7	0.0		0	0							
8	0.0		0	0							
9	0.0		0	0							
10	0.0		0	0							

No.	Settlement:		Total Settlement
1	0.524	ft	
2	0.103	ft	0.690 ft
3	0.062	ft	
4			
5			8.3 in
6			
7			
8			
9			
10			

Reference: Geotechnical Engineering Principles and Practices; Coduto, 1999

Overconsolidated Soils - Case I ($\sigma'_o<\sigma'_c$) Eqn:11.24

$$(\delta_c)_{ult} = \sum \frac{C_r}{1+e_0} H \log\left(\frac{\sigma'_f}{\sigma'_o}\right)$$

Overconsolidated Soils - Case II ($\sigma'_o<\sigma'_c<\sigma_f$) Eqn:11.25

$$(\delta_c)_{ult} = \sum\left[\frac{C_r}{1+e_0} H \log\left(\frac{\sigma'_c}{\sigma'_o}\right) + \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_f}{\sigma'_c}\right)\right]$$

Normally Consolidated Soils ($\sigma'_o=\sigma'_c$) Eqn: 11.23

$$(\delta_c)_{ult} = \sum \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_f}{\sigma'_o}\right)$$

Cohesionless Soils ($\sigma'_o=\sigma'_c$)

$$(\delta_c)_{ult} = \sum \frac{1}{C'} H \log\left(\frac{\sigma'_f}{\sigma'_o}\right)$$

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PLANNERS • SURVEYORS

RECEIVED
AUG – 9 2006
TranSystems

August 8, 2006

Michael D. Weeks, P.E., P.S.
TranSystems Corporation
5747 Perimeter Drive, Suite 240
Dublin, OH 43017

Re: **Bearing Capacity and Settlement Evaluation**
(Culvert at STA. 466+45)
SCI-823-0.00 Portsmouth Bypass
DLZ Job No.: 0121-3070.03
Document # 0021

Dear Mr. Weeks:

This letter includes the findings of preliminary evaluations of the proposed culvert and embankment at STA 466+45 on the above-referenced project. The findings of other preliminary culvert and embankment evaluations will be submitted in separate documents at a later date.

It is our understanding that a new culvert will be constructed at STA 466+45 for the above referenced project. The culvert will be a 84-inch Type A conduit in accordance with ODOT Item 707.3 (Structural Plate Corrugated Steel Structures). The culvert will be installed using cut and fill construction procedure then an embankment approximately 66 ft high will be built over the culvert. The inlet and outlet of the culvert will be supported by headwalls flush with the face of the pipe at both ends. At the time of preparing this letter no further information was available regarding the size of the headwalls and the depth of the footings below the ground surface.

It should be noted that the results of these evaluations are based upon the findings of three culvert borings located along the centerline of the proposed alignment of the culvert (C-10, C-11, and C-12). The borings were advanced to depths ranging between 14 and 19 feet below the ground surface. The surveyed ground surface elevations at the boring locations are reported on the logs.

The soil encountered in the borings indicated relatively uniform soil conditions along the culvert alignment. However, the thickness of the soil layers and the consistency of the soil vary between the borings. Boring C-11 was used for settlement analysis due to the relatively thick cohesive layer within the boring. Borings C-10 and C-12 were used to evaluate the bearing capacity of the headwall at the inlet and outlet of the pipe, respectively.

Bearing Capacity Evaluation

The bottom of the headwall footings was not known at the time of preparing this letter. The project plans indicated that the invert elevations at the inlet and outlet of the culvert were 666.28 and 661.8, respectively. The bottom of the footings was assumed to be 4 feet below the invert elevation below the frost zone and to prevent scour of the headwall (Ohio BDM Section 200).

At the inlet, the footing bearing elevation was assumed to be at elevation 662. Preliminary evaluation of the bearing capacity indicated that the footings could be designed using an allowable bearing capacity of 4000 psf. On the other hand, the footing bearing elevation at the outlet was assumed to be at elevation 652. The allowable bearing capacity at the assumed bearing elevation was 4,000 psf.

Settlement Evaluation

Settlement below the centerline of the embankment was evaluated using the maximum cover of the embankment (66 feet) as the surcharge load and using the soil profile encountered in boring C-11. The settlement analysis indicated that the soil below the embankment might observe a total settlement of 3.7 inches of which approximately 0.4 inch will be immediate in the cohesionless soil layer at the end of the embankment construction. The analysis indicated that 80% of the consolidation settlement (2.6 inches) will occur within 23 days after the end of the embankment construction while the time required to achieve the total consolidation settlement (3.3 inches) will be approximately 19 months. It is anticipated that additional consolidation settlement of approximately one inch will take place after the 19 months period due to additional water dissipation with time over a period of 10 years. On the other hand, a total settlement of 0.1 inch might be observed below the headwall due to the embankment loading. No loading was assumed on the headwall.

It should be noted that angular distortion will be encountered between the face of the pipe (inlet or outlet) and the middle of the pipe. Angular distortion is defined as the difference in settlement between two points divided by the distance between them. The angular distortion of the pipe was estimated to be approximately 1/813. The angular distortion can affect the structural integrity of the pipe culvert depending on the size and material of the pipe and therefore should be evaluated by a structural engineer.

$\frac{1}{813} = .0012 < 0.0050$

We appreciate having the opportunity to be of service to you on this project. Please do not hesitate to call if you have any questions concerning our preliminary findings.

Respectfully submitted,

DLZ OHIO, INC.

Wael Alkasawneh, P.E.
Geotechnical Engineer

Arthur (Pete) Nix, P.E.
Geotechnical Division Manager

Encl: As noted.

cc: J. Greg Brown, P.E. (TranSystems Corporation), File

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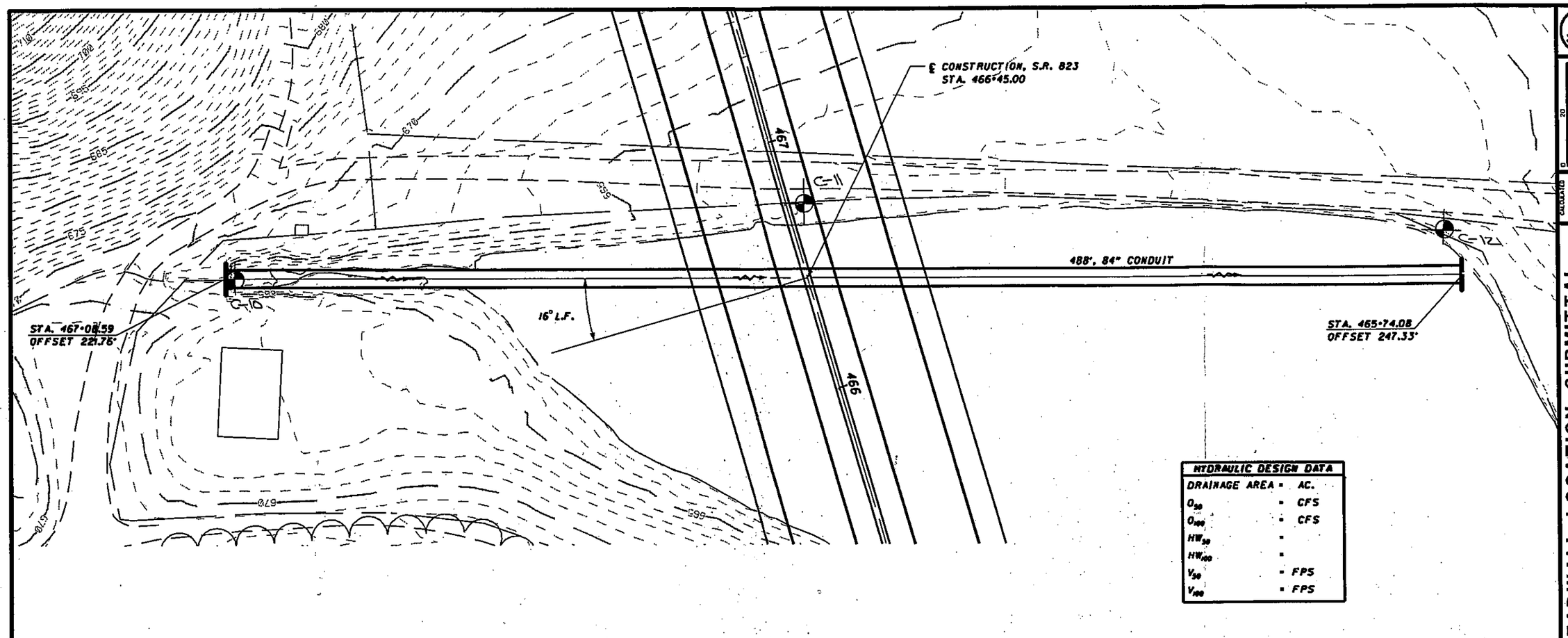
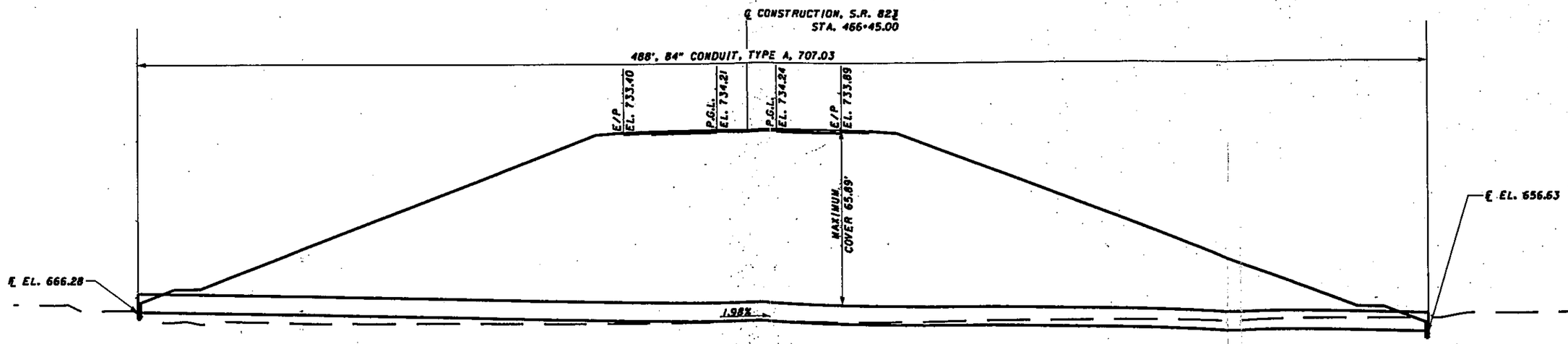




HORIZONTAL SCALE IN FEET
0 20 40

CALCULATED JGB
CHECKED HJS

PHASE I HEADWALL LOCATION SUBMITTAL
S.R. 823 STA. 466+45

SCI-823-0.00

NOT FOR CONSTRUCTION

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

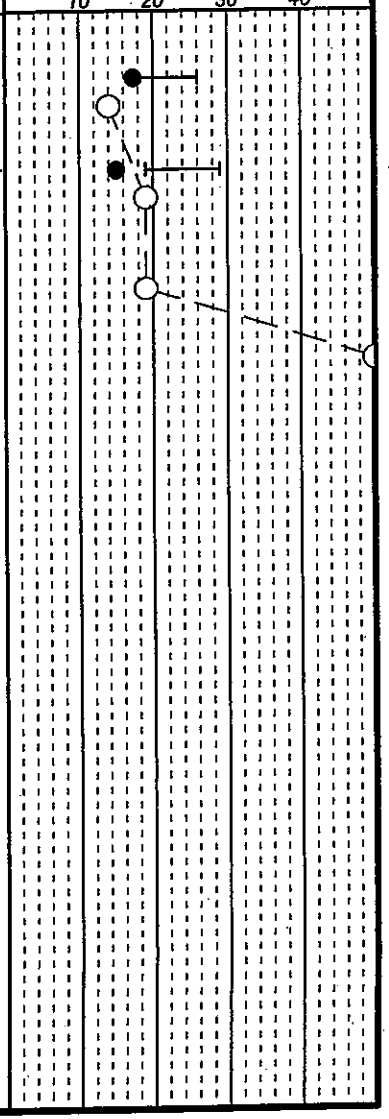
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-10 | Location: | Date Drilled: 06/28/06

WATER OBSERVATIONS: Water seepage at: None observed.
Water level at completion: None (prior to coring)
3.5' (includes drilling water, measured inside augers)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	663.9												
		5 6 8	17	1		4.5+	Very stiff to hard brown and gray SILT (A-4b), little to some clay, little fine to coarse sand, trace gravel; damp.	2	6	--	6	60	26
		6 8 11	18	2		4.5+	@ 4.0', Mottled Brown and Gray.	2	9	--	9	62	18
5													
7.0	656.9	6 9 10	18	3		2.5	Medium dense brown SANDY SILT (A-4a), trace to little clay; damp to moist.						
8.5	655.4	34 50/1	5	4			Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, laminated to very thinly bedded, slightly fractured.						
10		Core 54"	Rec 54"	RQD 93%	R-1								
14.0	649.9						Bottom of Boring - 14.0'						
15													
20													
25													
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢——⊣ LL
Blows per foot - ○
10 20 30 40



FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

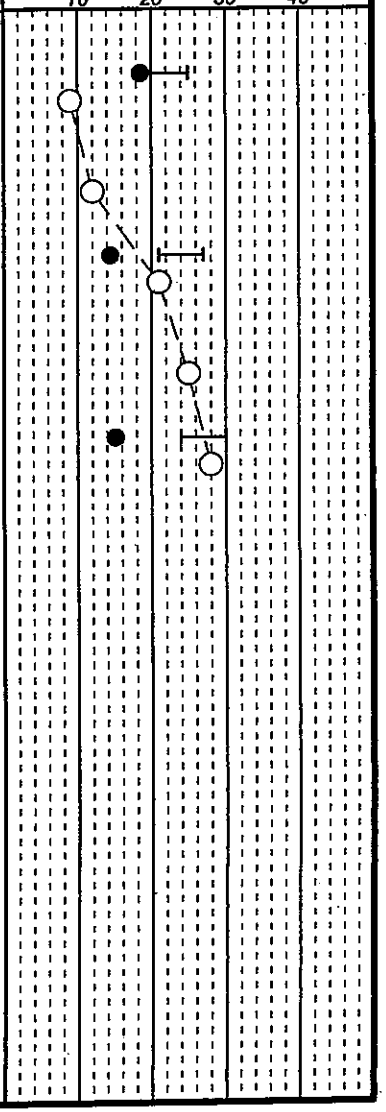
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-11 | Location: | Date Drilled: 06/28/06

WATER OBSERVATIONS: Water seepage at: None observed, Water level at completion: None (prior to coring) 0.5' (includes coring water, measured inside augers)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0.1	663.8						Topsoil - 1"						
		6 5 4	17	1		3.0	Very stiff brown SILT (A-4b), some clay, trace fine to coarse sand, trace gravel; damp.	0	2	--	5	68	26
		3 2 10	13	2		3.0	@ 4.5', Little gravel.						
5.0	658.9						Very stiff brown SANDY SILT (A-4a), little clay, little gravel; damp.						
		4 8 13	18	3		3.0		16	14	--	15	43	13
		4 12 13	18	4		3.0							
10													
10.5	653.4						Hard gray SILT (A-4b), little clay, trace fine to coarse sand, trace gravel; damp.						
		4 10 18	16	5		4.5+		0	0	--	7	77	16
13.0	650.9						Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, laminated to very thinly bedded, slightly fractured.						
15		Core 60"	Rec 53"	RQD 73%	R-1								
18.0	645.9						Bottom of Boring - 18.0'						
20													
25													
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢——⊣ LL
Blows per foot - ○
10 20 30 40



FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

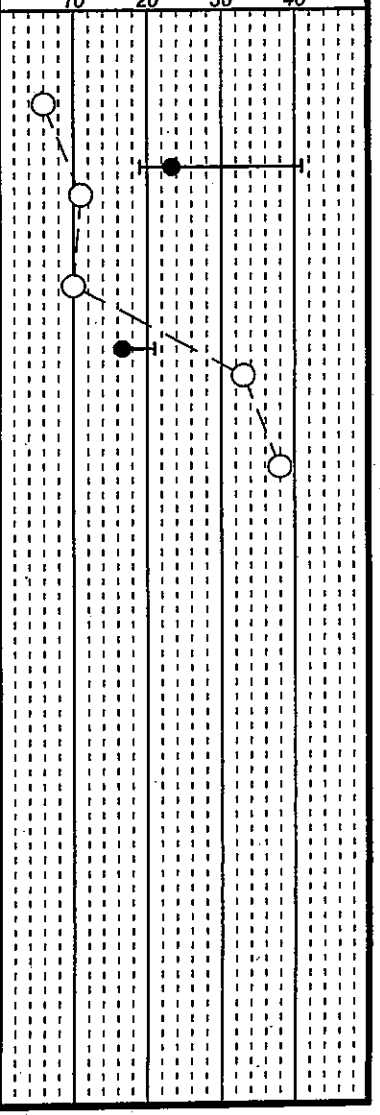
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-12 | Location: | Date Drilled: 06/28/06

WATER OBSERVATIONS: Water seepage at: None observed.
Water level at completion: None (prior to coring)
2.5' (includes drilling water, measured inside augers)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	661.8	4 3 3	5	1			Medium stiff brown SILT AND CLAY (A-6a), trace fine to coarse sand; damp.						
4.0	657.8	3 5 6	16	2		3.25	Stiff to very stiff mottled brown and gray CLAY (A-7-6), "and" silt, trace fine sand; damp to moist.	0	0	–	2	54	44
5		3 3 7	18	3		1.25	@ 6.0', trace to little gravel.						
9.0	652.8	4 15 18	18	4			Hard light brown SILT (A-4b), little clay, trace to little fine to coarse sand, trace gravel; damp.	1	3	–	8	71	17
10		4 13 25	14	5									
14.0	647.8	50/5	4	6			Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, laminated to very thinly bedded, slightly fractured.						
15		Core 60"	Rec 57"	RQD 62%	R-1								
18.5	643.3						Soft to medium hard gray CLAYSTONE; moderately weathered, arenaceous, slightly to moderately fractured.						
19.0	642.8						Bottom of Boring - 19.0'						
20													
25													
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢——⊣ LL
Blows per foot - ○
10 20 30 40



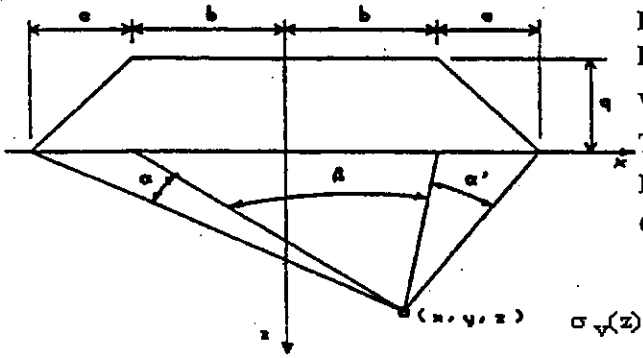
FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ SUBJECT

Client	TranSystems, Inc.	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00	SHEET NO. 1	OF 1
Item	Culvert at STA. 466+45	COMP. BY WMA	DATE 08/04/06
		CHECKED BY BEW	DATE

SETTLEMENT ANALYSIS - EMBANKMENT

Embankment Informaiton:



Groundwater Table:	D=	100.0	ft		
Embankment Height:	H =	65.89	ft		
Fill Unit Weight:	γ_{emb} =	120	pcf	q =	7,907 psf
Width of Slope:	a =	188			
Top half-width of Emb:	b =	57			
Distance from CL:	x =	0			
Output Range:	z =	0	to	25	ft

**See Data output Attached*

$$\sigma_v(z) := \left(\frac{q}{\pi \cdot a}\right)\cdot\left(a\cdot(\alpha(z)+\beta(z)+\alpha'(z)) + b\cdot(\alpha(z)+\alpha'(z)) + x\cdot(\alpha(z)-\alpha'(z))\right)$$

$$\beta(z) := \operatorname{atan}\left[\frac{(b-x)}{z}\right] + \operatorname{atan}\left[\frac{(b+x)}{z}\right] \qquad \alpha'(z) := \operatorname{atan}\left[\frac{(a+b-x)}{z}\right] - \operatorname{atan}\left[\frac{(b-x)}{z}\right] \qquad \alpha(z) := \operatorname{atan}\left[\frac{(a+b+x)}{z}\right] - \operatorname{atan}\left[\frac{(b+x)}{z}\right]$$

Reference: US Army Corps of Engineers EM 1110-1-1904 "Settlement Analysis", Table C-1

Soil Properites: *Settlement is calculated at mid-point of layer*

No.	Bot. of Laye		Soil Type	γ_{soil} (pcf)	σ'_c (psf)	σ'_o (psf)	$\Delta\sigma z$ (psf)	σ'_f (psf)	Cohesionless Soils C'	Cohesive Soils C_r	C_c	e_o
1	7.0	ft	Clay	120	7,448	420	7,907	8,327	0.0	0.05	0.30	0.990
2	8.5	ft	Silt/Sandy Silt	120	8,301	930	7,906	8,836	40.0	0.00	0.00	0.000
3	0.0			0	0				0.0	0.00	0.00	0.000
4	0.0			0	0							
5	0.0			0	0							
6	0.0			0	0							
7	0.0			0	0							
8	0.0			0	0							
9	0.0			0	0							
10	0.0			0	0							

No.	Settlement:		Total Settlement
1	0.271	ft	
2	0.037	ft	**0.307 ft**
3			
4			
5			**3.7 in**
6			
7			
8			
9			

Reference: Geotechnical Engineering Principles and Practices; Coduto, 1999

Overconsolidated Soils - Case I ($\sigma'_0<\sigma'_c$) Eqn:11.24

$$(\delta_c)_{ult} = \sum \frac{C_r}{1+e_0} H \log\left(\frac{\sigma'_f}{\sigma'_0}\right)$$

Overconsolidated Soils - Case II ($\sigma'_0<\sigma'_c<\sigma_f$) Eqn:11.25

$$(\delta_c)_{ult} = \sum\left[\frac{C_r}{1+e_0} H \log\left(\frac{\sigma'_c}{\sigma'_0}\right) + \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_f}{\sigma'_c}\right)\right]$$

Normally Consolidated Soils ($\sigma'_0=\sigma'_c$) Eqn: 11.23

$$(\delta_c)_{ult} = \sum \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_f}{\sigma'_0}\right)$$

Cohesionless Soils ($\sigma'_0=\sigma'_c$)

$$(\delta_c)_{ult} = \sum \frac{1}{C'} H \log\left(\frac{\sigma'_f}{\sigma'_0}\right)$$

DLZ
ENGINEERS • ARCHITECTS • SCIENTISTS
PLANNERS • SURVEYORS

RECEIVED
AUG - 9 2006
TranSystems

August 8, 2006

Michael D. Weeks, P.E., P.S.
TranSystems Corporation
5747 Perimeter Drive, Suite 240
Dublin, OH 43017

Re: **Bearing Capacity and Settlement Evaluation**
(Culvert at STA. 474+10)
SCI-823-0.00 Portsmouth Bypass
DLZ Job No.: 0121-3070.03
Document # 0022

Dear Mr. Weeks:

This letter includes the findings of preliminary evaluations of the proposed culvert and embankment at STA 474+10 on the above-referenced project. The findings of other preliminary culvert and embankment evaluations will be submitted in separate documents at a later date.

It is our understanding that a new culvert will be constructed at STA 474+10 for the above referenced project. The culvert will be a 72-inch Type A conduit in accordance with ODOT Item 707.3 (Structural Plate Corrugated Steel Structures). The culvert will be installed using cut and fill construction procedure then an embankment approximately 52 ft high will be built over the culvert. The inlet and outlet of the culvert will be supported by headwalls flush with the face of the pipe at both ends. At the time of preparing this letter no further information was available regarding the size of the headwalls and the depth of the footings below the ground surface.

It should be noted that the results of these evaluations are based upon the findings of three culvert borings located along the centerline of the proposed alignment of the culvert (C-13, C-14, and C-15). The borings were advanced to depths ranging between 12.5 and 28 feet below the ground surface. The surveyed ground elevations at the boring locations are reported on the logs.

The soil encountered in the borings indicated relatively uniform soil conditions along the culvert alignment. However, the thickness of the soil layers and the consistency of the soil vary between the borings. Boring C-14 was used for settlement analysis due to the relatively thick cohesive layer within the boring. Borings C-13 and C-15 were used to evaluate the bearing capacity of the headwall at the inlet and outlet of the pipe, respectively.

Bearing Capacity Evaluation

The bottom of the headwall footings was not known at the time of preparing this letter. The project plans indicated that the invert elevations at the inlet and outlet of the culvert were 679.40 and 658.72, respectively. The bottom of the footings was assumed to be 4 feet below the invert elevation below the frost zone and to prevent scour of the headwall (Ohio BDM Section 200).

At the inlet, the footing bearing elevation was assumed to be at elevation 675. Preliminary evaluation of the bearing capacity indicated that the footings could be designed using an allowable bearing capacity of 3,000 psf. On the other hand, the footing bearing elevation at the outlet was assumed to be at elevation 654. The allowable bearing capacity at the assumed bearing elevation was 5,000 psf.

Settlement Evaluation

Settlement below the centerline of the embankment was evaluated using the maximum cover of the embankment (approximately 52 feet) as the surcharge load and using the soil profile encountered in boring C-14. The settlement analysis indicated that the soil below the embankment might observe a total settlement of 3.9 inches of which approximately 0.6 inch will be immediate in the cohesionless soil layer at the end of the embankment construction. The analysis indicated that 80% of the consolidation settlement (2.6 inches) will occur within 23 days after the end of the embankment construction while the time required to achieve the total consolidation settlement (3.3 inches) will be approximately 17 months. It is anticipated that additional consolidation settlement of approximately 1.3 inches will take place after the 17 months period due to additional water dissipation with time over a period of 10 years. On the other hand, a total settlement of 0.2 inch might be observed below the headwall due to the embankment loading. No loading was assumed on the headwall.

It should be noted that angular distortion will be encountered between the face of the pipe (inlet or outlet) and the middle of the pipe. Angular distortion is defined as the difference in settlement between two points divided by the distance between them. The angular distortion of the pipe was estimated to be approximately 1/752. The angular distortion can affect the structural integrity of the pipe culvert depending on the size and material of the pipe and therefore should be evaluated by a structural engineer.

$1/752 = .0013 < .005$ OK

We appreciate having the opportunity to be of service to you on this project. Please do not hesitate to call if you have any questions concerning our preliminary findings.

Respectfully submitted,

DLZ OHIO, INC.

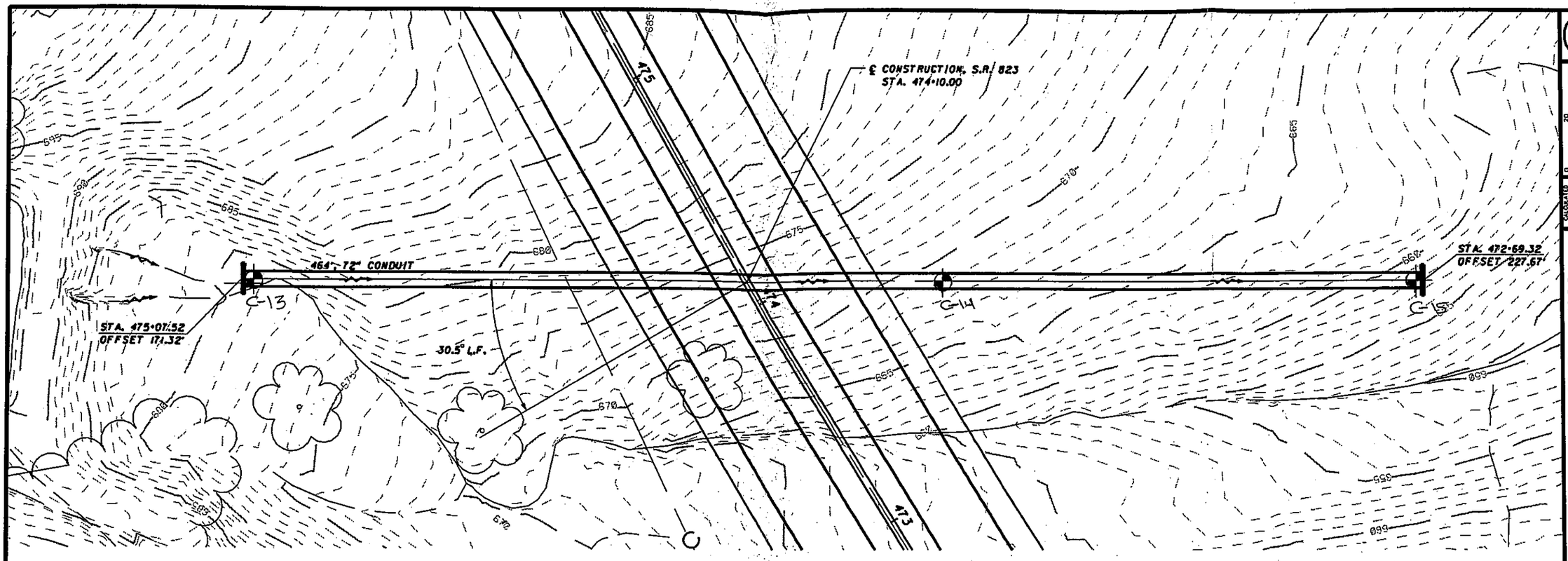
Wael Alkasawneh, P.E.
Geotechnical Engineer

Arthur (Pete) Nix, P.E.
Geotechnical Division Manager

Encl: As noted.

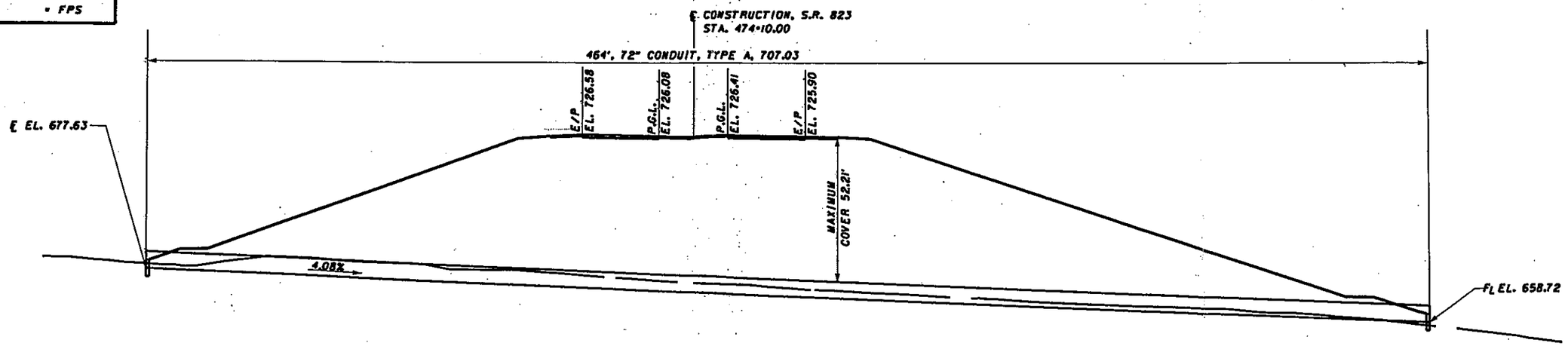
cc: J. Greg Brown, P.E. (TranSystems Corporation), File

M:\proj\0121\3070.03\Correspondence\Culvert Findings_STA 474+10.doc



HYDRAULIC DESIGN DATA	
DRAINAGE AREA	= AC.
Q_{50}	= CFS
Q_{100}	= CFS
HW_{50}	=
HW_{100}	=
V_{50}	= FPS
V_{100}	= FPS

SOIL BORING



NOT FOR CONSTRUCTION

HORIZONTAL SCALE IN FEET
0 20 40

DESIGNED JGB
DRAWN HJS

PHASE I HEADWALL LOCATION SUBMITTAL
S.R. 823 STA. 474+10

SCI-823-0.00

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-13 | Location: | Date Drilled: 06/29/06

WATER OBSERVATIONS: Water seepage at: 19.0' - 20.0'
Water level at completion: 20.0' (prior to coring)
2.0' (includes drilling water, measured inside augers)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N) / Natural Moisture Content, % / PL — LL / Blows per foot
0	679.4													
0.3	679.1	3 3 5	14	1		1.75	Topsoil - 4" Stiff grayish brown SILT (A-4b), little fine to coarse sand, trace gravel, trace clay; damp.	3	6	--	7	72	12	
4.0	675.4	4 5 5	15	2			Medium dense to dense brown SANDY SILT (A-4a), little clay, little gravel; damp.	14	20	--	13	42	11	Non-Plastic
5		6 14 18	18	3										
8.0	671.4	4 13 13	17	4			Medium dense brown and gray SILT (A-4b), trace to some fine to coarse sand, trace gravel, little clay; damp to moist.							
10		8 10 12	16	5				2	10	--	15	61	12	Non-Plastic
		5 7 8	13	6				1	7	--	11	69	12	Non-Plastic
15		4 7 9	16	7										
19.0	660.4	3 5 4	16	8			Loose gray SANDY SILT (A-4a), little to some gravel; damp. @ 20.5', very dense.							
20														
21.5	657.9	6 50/5"	10	9			Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, argillaceous, laminated to very thinly bedded, slightly fractured.							
25		Core 60"	Rec 59"	RQD 80%	R-1									
28.0	651.4						Bottom of Boring - 28.0'							
30														

FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-14 | Location: | Date Drilled: 06/29/06

WATER OBSERVATIONS: Water seepage at: None observed.
Water level at completion: None (prior to coring)
14.5' (includes drilling water, measured inside augers)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	668.8												
0.2	668.6						Topsoil - 2"						
		4 4 4	16	1			Loose brown SILT (A-4b), some clay, trace fine to coarse sand, trace gravel; damp.	3	2	–	5	69	21
4.0	664.8	4 6 19	18	2		4.5+	Hard brown SANDY SILT (A-4a), little clay, little fine to coarse sand, some gravel; damp.	27	21	–	11	29	12
5													
5.5	663.3	5 7 11	17	3			Very stiff mottled brown and gray SILT (A-4b), little to some clay, trace fine sand; damp.	0	0	–	4	77	19
		4 6 7	18	4		3.25		0	0	–	6	65	29
10													
10.5	658.3	3 4 4	18	5			Loose to medium dense brown SANDY SILT (A-4a), little clay; moist.						
13.5	655.3	17 50/3	8	6			Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, argillaceous, laminated to very thinly bedded, slightly fractured.						
15		Core 60"	Rec 58"	RQD 48%	R-1								
20.0	648.8						Bottom of Boring - 20.0'						
25													
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢——⊣ LL
Blows per foot - ○
10 20 30 40

FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring C-15 | Location: | Date Drilled: 06/29/06

WATER OBSERVATIONS: Water seepage at: None observed.
Water level at completion: None (prior to coring)
5.2' (includes drilling water, measured inside augers)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N) / Natural Moisture Content, % / PL — LL / Blows per foot
0	657.0	4 10 16	18	1		2.5	Very stiff to hard brown SILT (A-4b), trace to some fine to coarse sand, trace gravel, little clay; damp.	1	12	–	13	60	15	
		10 20 30	18	2		4.5+		1	1	–	12	68	18	
5														
6.5	650.5	13 50/3	9	3		4.5+	Soft to medium hard gray SANDSTONE; very fine to fine grained, slightly weathered, laminated to very thinly bedded, slightly fractured.							50+
10		Core 60"	Rec 60"	RQD 97%	R-1									
12.5	644.5						Bottom of Boring - 12.5'							
15														
20														
25														
30														

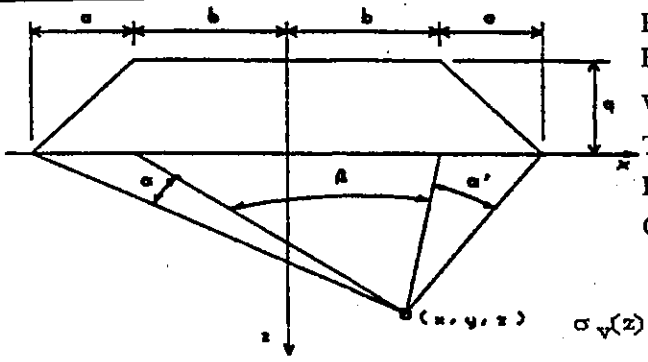
FILE: 0121-3070-03 [8/4/2006 2:12 PM]

DLZ SUBJECT

Client	TranSystems, Inc.	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00	SHEET NO. 1	OF 1
Item	Culvert at STA. 474+10	COMP. BY WMA	DATE 08/04/06
		CHECKED BY BEW	DATE

SETTLEMENT ANALYSIS - EMBANKMENT

Embankment Informaiton:



Groundwater Table:	D=	20.0	ft		
Embankment Height:	H =	52.21	ft		
Fill Unit Weight:	γ_{emb} =	120	pcf	q =	6,265 psf
Width of Slope:	a =	167			
Top half-width of Emb:	b =	65			
Distance from CL:	x =	0			
Output Range:	z =	0	to	25	ft

**See Data output Attached*

$$\sigma_v(z) := \left(\frac{q}{\pi}\right)\left(a\cdot(\alpha(z)+\beta(z)+\alpha'(z)) + b\cdot(\alpha(z)+\alpha'(z)) + x\cdot(\alpha(z)-\alpha'(z))\right)$$

$$\beta(z) := \operatorname{atan}\left[\frac{(b-x)}{z}\right] + \operatorname{atan}\left[\frac{(b+x)}{z}\right] \qquad \alpha'(z) := \operatorname{atan}\left[\frac{(a+b-x)}{z}\right] - \operatorname{atan}\left[\frac{(b-x)}{z}\right] \qquad \alpha(z) := \operatorname{atan}\left[\frac{(a+b+x)}{z}\right] - \operatorname{atan}\left[\frac{(b+x)}{z}\right]$$

Reference: US Army Corps of Engineers EM 1110-1-1904 "Settlement Analysis", Table C-1

Soil Properites: *Settlement is calculated at mid-point of layer*

No.	Bot. of Laye		Soil Type	γ_{soil} (pcf)	σ'_c (psf)	σ'_o (psf)	$\Delta\sigma z$ (psf)	σ'_f (psf)	Cohesionless Soils C'	Cohesive Soils C_r	Cohesive Soils C_c	Cohesive Soils e_o
1	10.5	ft	Cohesive Silt	120	7,448	630	6,265	6,895	0.0	0.05	0.14	0.990
2	13.5	ft	Sandy Silt	120	8,301	1,440	6,262	7,702	46.0	0.00	0.00	0.000
3	0.0			0	0				0.0	0.00	0.00	0.000
4	0.0			0	0							
5	0.0			0	0							
6	0.0			0	0							
7	0.0			0	0							
8	0.0			0	0							
9	0.0			0	0							
10	0.0			0	0							

No.	Settlement:		Total Settlement
1	0.274	ft	
2	0.047	ft	**0.322 ft**
3			
4			
5			**3.9 in**
6			
7			
8			
9			

Reference: Geotechnical Engineering Principles and Practices; Coduto, 1999

Overconsolidated Soils - Case I ($\sigma'_o<\sigma'_c$) Eqn:11.24

$$(\delta_c)_{ult} = \sum \frac{C_r}{1+e_o} H \log\left(\frac{\sigma'_f}{\sigma'_o}\right)$$

Overconsolidated Soils - Case II ($\sigma'_o<\sigma'_c<\sigma_f$) Eqn:11.25

$$(\delta_c)_{ult} = \sum\left[\frac{C_r}{1+e_o} H \log\left(\frac{\sigma'_c}{\sigma'_o}\right) + \frac{C_c}{1+e_o} H \log\left(\frac{\sigma'_f}{\sigma'_c}\right)\right]$$

Normally Consolidated Soils ($\sigma'_o=\sigma'_c$) Eqn: 11.23

$$(\delta_c)_{ult} = \sum \frac{C_c}{1+e_o} H \log\left(\frac{\sigma'_f}{\sigma'_o}\right)$$

Cohesionless Soils ($\sigma'_o=\sigma'_c$)

$$(\delta_c)_{ult} = \sum \frac{1}{C'} H \log\left(\frac{\sigma'_f}{\sigma'_o}\right)$$

CN-Ramnarayan Nunna

From: Bill.Ujvari@dot.state.oh.us
Sent: Monday, July 23, 2007 3:59 PM
To: CN-Ramnarayan Nunna
Subject: Re: FW: BMP's for Portsmouth Bypass Project (SCI-823-0.00)
Attachments: bmp1.pdf

Ram,

See my comments below in red text.

Bill

<rnunna@transystems.com>

07/20/2007 03:32 PM

To <Bill.Ujvari@dot.state.oh.us>
cc
Subject FW: BMP's for Portsmouth Bypass Project (SCI-823-0.00)

Mr. Ujvari:

Did you get a chance to review our phone conversation regarding ditch BMP's? I have a meeting with ODOT-9 on Tuesday, July 24, 2007 at 9:00 AM and we are going to discuss this issue and I appreciate if I can get your review confirmation before that.

Again appreciate your help.

Thank you

Ram Nunna, P.E.

From: CN-Ramnarayan Nunna
Sent: Friday, July 13, 2007 12:16 PM
To: Bill.Ujvari@dot.state.oh.us
Cc: CN-Ramnarayan Nunna
Subject: FW: BMP's for Portsmouth Bypass Project (SCI-823-0.00)

Ujvari:

Thanks for talking time and talking to me yesterday (July 12, 2007 at 10:15 AM) regarding the ditch BMP options as indicated in the

e-mail below from me and John Stains.

Please review the summarized telephone conversation and please e-mail me the confirmation.

Summary of telephone conversation:

- 10 feet ditch width in the rock cut sections, was established based on the OGE rock catchment design to minimize the rock cut on the project.

1. **Agree**

- In order to have a consistent ditch width through out the mainline, the 10 feet rock catchment ditch width was also used in the toe of fill ditches.

1. **Agree, we do not want to reduce the downstream ditch width from that which was calculate for the upstream section.**

- Since the roadway runoff cannot be treated in the rock cut ditches, the runoff that is collected in the ditch has to be treated in the toe of fill ditches before it outlets to the outfall. Two Options were presented to ODOT/Hydraulics by Transystems, Option 1 and Option 2 (see the below e-mail)

1. **Agree**

- Option 1 (Cumulative Drainage Area Method) as described in the below e-mail is in not in compliance with the L&D Volume 2 design methodology, however it is in compliance with the Ohio EPA. ODOT, Office of Production is currently in communications with Ohio EPA regarding this methodology.

1. **Lets say the method currently prescribed in Vol 2 used to calculate the EBW from which the drainage area based on 100 foot strips is not what EPA endorses. The Ohio EPA has indicated that the cumulative drainage area method needs to be used in order to be in compliance with the NPDES permit.**

- Option 2 (Incremental Drainage Area Method) as described in the below e-mail is in compliance with design methodology as published in the current L&D Volume 2, Section 1118.3(January 19, 2007 Revision). Mr. Ujvari indicated that this option is not in compliance with Ohio EPA and he also indicated that ODOT will stop endorsing Figure 1118-4, as described in Section 1118.3.1.C.4 and Section 1118.3.2 of L&D Volume 2, because the 6 inch berm separating the runoff's will be eroded with time combining the roadway runoff and offsite runoff. Ram Nunna indicated that the slopes form cut to the fill sections on this project varies any where between 25% to 33% and the 6 inch berm will not work anyway.

We have performed a preliminary analysis of the method prescribed in Vol. 2 regarding use of the incremental drainage area when calculating the EBW and have significant reservation over its appropriateness. The basis for using the cumulative drainage approach has far greater merit and justifiable logic.

2. **We do not endorse the use of the 6" earth dike serving to create a conveyance ditch shown in figure 1118-4. There is no durability to this design providing an extended and productive life.**

- Preliminary calculations show that Option 1 can be used and all the runoff from the cut sections can be treated in the toe of fill ditches by providing 15' maximum ditch bottom (95% of the locations) for an average length of 300 feet. For 5% of the locations the ditch bottom width is greater than 15 feet.

1. **What we are really doing here is following Vol. 2 Section 1118.3.1.C.1 with the exception that we are not going to provide the conveyance ditch. In this situation where the calculated EBW using the total drainage area results in a 15' ditch and without the use of the 6" conveyance dike is acceptable. The 10' maximum width of the EBW referenced in Vol. 2 is arbitrary to limit right of way takes. However, when the EBW exceeds 10' and places the design into another category where the alternative design has questionable performance (ie conveyance ditch w/ 6" earth dike), it is acceptable at this time to use the 15' ditch width as an alternative solution.**

- By providing a maximum of 15 feet ditch bottom width 95% of the locations will comply with Option 1 (Cumulative Area Method). 5% will require more than 15 feet and less than 20 feet.

1. **While we have not refined the maximum limit of the EBW calculation using cumulative drainage areas, the use of an EBW equal to 15' is reasonable in this particular situation. It might not be the case with other project conditions but here it appears reasonable. The 15' EBW looks like it will handle up to and 18 acre drainage area whereas the 20' EBW looks like it is good up to nearly 40 acres. At this point in time I would draw the EBW limit at the 15' mark on the basis that it treats 95% of the area considered.**

- By providing a maximum 15 feet ditch bottom, 5 feet extra width will require additional ROW, however compared to the cost of the overall project the additional ROW cost is not significant and currently the ROW for this project is not established.

1. **While the cost of an additional 5' of right of way is small compared to the total cost of the project, I wouldn't use that as the justification to support the position to expand the width of the EBW from 15' to 20'. In this situation we are making a good faith effort to improve water quality and quantity issues by providing an EBW at 15'.**

- Recommendation is use maximum 15 feet ditch bottom and treat all the runoff using Option 1 (Cumulative Area Method). At the locations where it requires greater than 15 feet just use 15 feet maximum.

1. **Agree**

Again appreciate your time and effort and please review and e-mail me the confirmation of the telephone conversation.

Ram Nunna, P.E
Senior Transportation Engineer
Transystems
720 East Pete Rose Way
Cincinnati, OH 45202

From: John.Stains@dot.state.oh.us [mailto:John.Stains@dot.state.oh.us]
Sent: Tuesday, July 10, 2007 7:51 AM
To: CN-Ramnarayan Nunna
Cc: Bill.Ujvari@dot.state.oh.us; David.Riley@dot.state.oh.us; Benjamin.Goldsberry@dot.state.oh.us
Subject: RE: BMP's

Ram,

In summary of our conversation yesterday regarding the Portsmouth Bypass, below is the requested direction concerning the vegetated biofilter post construction BMP design.

Based on what is currently in Volume 2 of the Location and Design Manual, the vegetated biofilter ditch width is sized first hydraulically and then by the enhanced bankfull width equation found in section 1118.3.1, and the larger of the two widths is furnished. The drainage area is based on 100 foot check sections, and once calculated the area is removed from the next downstream drainage area. The calculations you provided in **Option 2** are in compliance with what is currently in L&D Volume 2.

Based on the most recent direction the Hydraulic Section has received from Ohio EPA, the vegetated biofilter ditch width is to be sized based on the total, cumulative drainage area at all points in the ditch. The calculations you provided in **Option 1** are in compliance with the most recent direction from Ohio EPA.

Please be aware that the BMP policy responsibility has been transferred from the Hydraulics Section to the Office of Production. Since we have been removed from all negotiations and communication with Ohio EPA, I am unable to give you any guidance beyond what has been provided above. I will direct your question to Bill Ujvari for further direction and clarification to ensure that the above statements are in accordance with Department policy.

Respectfully,

John P. Stains, P.E.
Ohio Department of Transportation
Roadway Hydraulics, Structural Engineering
1980 West Broad Street
Columbus, Ohio 43223
Phone: 614.728.1998
Fax: 614.752.4824

<rnunna@transystems.com>

07/09/2007 12:15 PM

To <John.Stains@dot.state.oh.us>
cc <rnunna@transystems.com>
Subject RE: BMP's

John:

nks for taking time and talking to me at 11:00 AM today morning regarding the Ditch BMP's.

Attached pdf file contains the two options we discussed, please review and send me a confirmation e-mail.

10 feet ditch bottom was established in the rock cut sections per the OGE as part of the rock catchment area design and the same ditch bottom width was carried on to the fill sections.

Option 1:

Cumulative Area Method it considers all the water from the rock cut section to the fill sections and up to the outfall. (I understand that EPA is pushing for this Option and ODOT is still negotiating with EPA)

Option 2:

Individual area method, per ODOT L& D Volume 2 (Once the area is treated upstream it is not included in the downstream calculations).

Please confirm our conversations via e-mail.

Again I appreciate your effort and help.

ThanQ

Ram Nunna, P.E

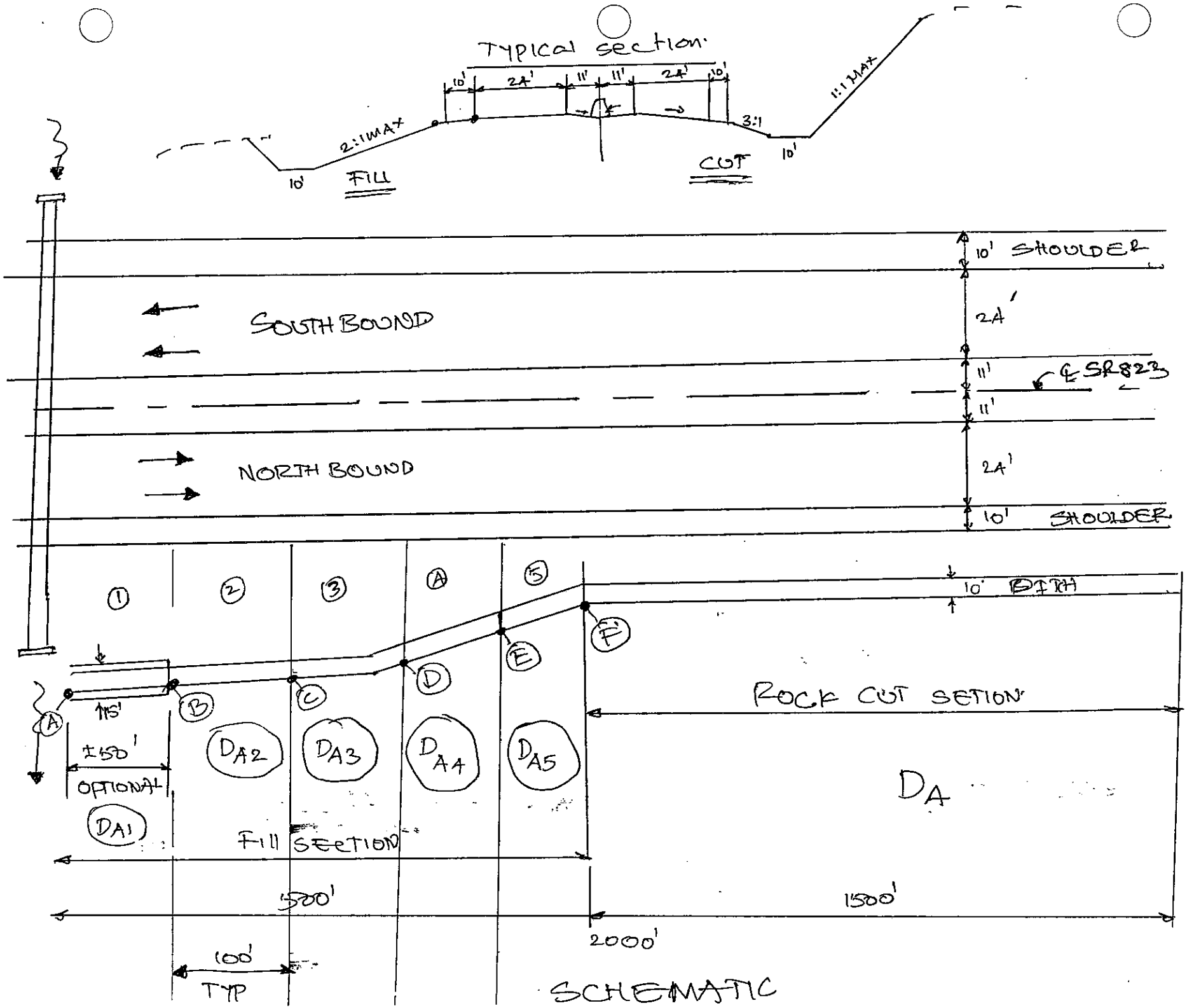
From: CN-Ramnarayan Nunna
Sent: Monday, July 09, 2007 10:57 AM
To: 'John.Stains@dot.state.oh.us'
Subject: BMP's

John:

Attached is the schematic of a BMP scenario, I will call you in 5 minutes to talk to you, so that I have a clear direction.

I really appreciate your help.

Ram Nunna P.E.



07/04/2007
BY RD

OPTION 1 (CUMMULATIVE AREA METHOD)

TOTAL DRAINAGE AREA = $D_{TA} = (D_A + DA_1 + DA_2 + DA_3 + DA_4 + DA_5)$

$$EBW = (5.4)(D_{TA})^{0.356}$$

If EBW < 10' "NO FURTHER ANALYSIS REQUIRED"

If EBW > 10', FOLLOW THE PROCESS;

① CALCULATE EBW FOR DRAINAGE AREA D_A, POINT F ON THE SCHEMATIC
MAXIMUM DITCH WIDTH AT THE ROCK CUT SECTION IS 10'

EVEN IF CALCULATED EBW IS GREATER THAN 10' USE 10'.

② CALCULATE EBW FOR DRAINAGE AREA $D_A + D_{A5}$, POINT E ON THE SCHEMATIC

③ CALCULATE EBW FOR DRAINAGE AREA $D_A + D_{A5} + D_{A4}$, POINT D ON THE SCHEMATIC.

CALCULATE EBW FOR EVERY 100' (TYPICAL) TILL THE OUTFALL AND USE A CONSISTENT EBW FOR THE DESIGN.
EBW SHOULD BE LESS THAN 15'

OPTION 2 (INDIVIDUAL AREA METHOD), PER UDD VOL. 2

TOTAL DRAINAGE AREA : $D_{TA} = D_A + D_{A1} + D_{A2} + D_{A3} + D_{A4} + D_{A5}$

$$EBW = (5.4)(D_{TA})^{0.356}$$

If $EBW < 10'$ "NO FURTHER ANALYSIS REQUIRED"

If $EBW > 10'$, FOLLOW THE FOLLOWING PROCESS

(1) CALCULATE EBW FOR DRAINAGE AREA D_A, POINT F ON THE SCHEMATIC

- MAXIMUM DITCH WIDTH AT THE ROCKCUT SECTION IS 10'
- EVEN IF THE CALCULATED EBW IS GREATER THAN 10' USE 10'

(2) CALCULATE EBW FOR DRAINAGE AREA D_{A5}, POINT E ON THE SCHEMATIC D_A IS NOT INCLUDED IN THIS CALCULATION SINCE IT IS BEEN TREATED IN THE U/S RUN

(3) CALCULATE EBW FOR DRAINAGE AREA D_{A4}, POINT D ON THE SCHEMATIC.

CALCULATE EBW FOR INDIVIDUAL DRAINAGE AREA'S TILL THE OUT FALL AND USE A CONSISTENT EBW FOR THE DESIGN.

$EBW < 15'$

SCI-823-0.00; PID: 77366
PHASE 3
PORTSMOUTH BYPASS
HIGH FILL BOX CULVERTS

MEMORANDUM

SCI-823-0.00, PID 77366, PHASE 3, PORTSMOUTH BYPASS

PREPARED FOR: ODOT, District 9

PREPARED BY: Ram Nunna/Transystems

SUBJECT: Response to ODOT-9 comments on the Design of Four High Fill Box Culverts dated June 22, 2007

DATE: July 19, 2007

This memo documents the design and hydraulic analysis of the four high fill box culverts and the cost comparisons of the options considered.

BACKGROUND

A meeting was held on January 30, 2007 at District 9 to discuss the options for culvert design of the four high fill culverts (See Appendix A for meeting minutes). As the byproduct of the culvert meeting Transystems analyzed the culvert options and presented the summary of the preferred option in a memorandum to ODOT-9 on May 3, 2007 (See Appendix B). Cost comparisons of the different options were not presented in the memorandum submitted to ODOT-9 on May 3, 2007. ODOT reviewed the memorandum and submitted comments via e-mail on June 22, 2007 (See Appendix C).

This memo also documents the response to the ODOT review comments dated June 22, 2007.

Culvert at Sta. 234+05.47 and Culvert at Sta. 239+18.19

Comment # 1: It appears that the 9'x6' culvert located at Sta. 239+18.19 could be extended thereby reducing the need for the 25' AS Per Plan headwall. Would not the culvert be at or close to the toe of the embankment if you were to extend it 50'. Would there be a substantial cost savings incurred by being able to use a standard headwall? By lengthening the Sta. 239+18.19 culvert this would force the Sta. 234+05.47 culvert to be relocated (rotated approximately 1.25 degrees clockwise) and it appears more excavation would be required by this relocation. However, would the cost savings from the standard headwall vs. 25' As Per Plan headwall cover the addition excavation and culvert construction?

Response: **Two Options were evaluated (See Appendix D for plan view and profiles view) at this Culvert Location and Option 1 was presented in the memo Dated May 3, 2007.**

Option 1: **As per Plan Headwalls**
Option 2: **Standard Head Walls**

See Appendix F for Cost Comparison Table. Cost of Option 1 is approximately $2.97 Million and the cost of Option 2 is $2.93 million. Option 1 was selected because of the reduced rock excavation. The big issue on this project is where to place the excess of rock excavation. Option 2 produces approximately 15,000 cu.yd of extra rock cut.

Comment # 2 Was there any consideration for improved inlets at each of the culverts? Would there be any reason why we could not use an improved inlet on the culverts, i.e. environmental considerations, etc.? The culvert size could be reduced with the application of these improvements. This in effect could provide considerable cost savings also.

Response#2: **Improved inlets were not considered during evaluating the alignment options. However improved inlets can reduce the cost. See Appendix E for the summary of hydraulic analysis.**

Culvert at Sta. 297+56.24 and Culvert at Sta. 300+89.44

Comment# 1: Can the 8'x8' culvert at Sta. 300+89.44 be extended also. This would be described similar to that as stated in Item No. 1 in the previous comments (Culvert at Sta. 234+05.47 & Culvert at Sta. 239+18.19).

Response: **Two Options were evaluated (See Appendix D for plan view and profiles view) at this Culvert Location and Option 1 was presented in the memo Dated May 3, 2007.**

Option 1: **As Per Plan Headwalls**
Option 2: **Standard Head Walls**

In the memo dated May 3, 2007 the As Per Plan Headwall height was shown as 17′ which is incorrect. Actual height is 15′

See Appendix F for Cost Comparison Table. Cost of Option 1 is approximately $4.28 Million and the cost of Option 2 is $4.27 million. Option 1 was selected because of the reduced rock excavation. The big issue on this project is where to place the excess of rock excavation. Option 2 produces approximately 6,400 cu.yd of extra rock cut.

Comment#2: Could the culvert at Sta. 300+89.44 be relocated approximately to Sta. 301+65 with the inlet at the intersection of the roadway ditches and the existing stream? This alignment would follow the approximate toe of the existing slope and more earthwork maybe involved. However, it would also provide a better transition from the outlet to the existing stream.

Response: The Culvert can be relocated. It produces 5,500 cu.yds of extra rock cut.

Comment#3 Was there any consideration for improved inlets at each of the culverts? Would there be any reason why we could not use an improved inlet on the culverts, i.e. environmental considerations, etc.? The culvert size could be reduced with the application of these improvements. This in effect could provide considerable cost savings also.

Response: Improved inlets were not considered during evaluating the alignment options. However improved inlets can reduce the cost. See Appendix E for the summary of hydraulic analysis

Comment#4 Was there a cost comparison done with submitted alignment of the Sta. 297+56.24 culvert and relocating it to run parallel with the roadway and outleting at the inlet of the Sta. 300+89.44 ;culvert? I believe we discussed this briefly at the Jan. 30, 2007 meeting. There was the issue of the addition earthwork (+/- 75' below existing grade), however, after further evaluation it seems that this alignment may reduce the length by approximately 500'. How would this cost savings compare with the addition excavation? Would options such as jacking a conduit through the hill, blasting a trench, etc. become practical options? Additionally the culvert at Sta 300+89.44 would increase in size and so would cost. Would the previously discussed inlet improvement help keep this size down if used?

Response: These options were evaluated and dismissed during the preliminary stages of the design.

Location 1: Culverts at Sta. 234+00 and 239+56.
The Culvert at Sta. 234+00 runs parallel to the SR823 roadway and discharges into the culvert at Sta. 239+00. The new size of culvert at Sta. 297+56 is 10′ x 7′ or 8′ x 8′ (conventional design). If an improved inlet is used at this location the new size would be 8′ x 6′ (side tapered). This option produces 357,111 cu.yds of extra rock cut. (See Appendix G for earthwork calculations and cost comparison)

Location 2: Culverts at Sta. 297+50 and 300+89.
The Culvert at Sta. 297+50 runs parallel to SR823 Roadway and discharges in to the culvert at Sta. 300+89.00. The new size of the culvert at Sta. 300+89.00 is 12′ x 10′ for single box, and 8′-8′ for a bouble box (conventional design). If an improved inlet is used the new size would be 10′ x 8′ (sloped tapered). This option produces 102,875 cu. yds of extra rock cut. (See Appendix G for earthwork calculations and cost comparison)

SCI-823 Portsmouth Bypass

Meeting Minutes
Culvert Design Meeting

Date: January 30, 2007

Attendees:

Tom Barnitz	**District 9**
John Wetzel	**District 9**
Dave Riley	**OSE Hydraulics**
John Stains	**OSE Hydraulics**
Ben Goldsberry	**OSE Hydraulics**
Ram Nunna	**TranSystems**
Mike Weeks	**TranSystems**

A meeting was held this date at ODOT District 9 to discuss design options for several culvert crossing locations on Phase 2 and Phase 3 of the Portsmouth Bypass. The following locations were discussed:

1. Sta. 234+00±
   Two box culvert crossings (8'x5' & 8'x7') converge at the outlet on the right side of the mainline. Various options were discussed, including curved/chord alignments and using junction chamber to defelect the box culverts. The resolution was that TranSystems will investigate optimizing the design without using a curved alignments or a junction chamber. One outlet headwall should be considered with high retaining walls or wingwalls and possibly steeper slopes (1.5:1) to minimize culvert lengths and to eliminate the defelection in the alignment. DLZ will be engaged to determine possible geotechnical issues regarding the slope stability and the use of the retaining wall. Estimated costs for culvert, retaining walls, excavation, etc. shall be determined to optimize the design.

2. Sta. 300+00 ±
   Two box culvert crossings (8'x7' & 10'x8') converge at the outlet on the right side of the mainline. Various options were discussed, including curved/chord alignments and using junction chamber to defelect the box culverts. Same conclusions that were discussed at location Sta. 234+00 will also apply at this location.

3. Sta. 623 ±
   A 60" pipe culvert is proposed at this location. The pipe profile is to be flattened to provide lower velocity and shorter pipe length. The pipe can be constructed in the fill and outletted onto the slope with the appropriate outlet protection (rock channel or dissipator) and tied into the roadside ditch

APPENDIX A

4 Since the box culverts are under high fills greater than 150', minimum box culvert height should be 6'
5 If the hydraulic size of a pipe is 48" or 54" and they are under high fills bump the pipe size to 60" so that a structutal steel pipe can be used.
6 HY-8 can be used instead of CDSS to evaluate the box culvert or pipe culvert hydraulics.

Other Hydraulic/BMP Items:

- The new BMP requirements in L&D Volume 2 stipulate no treatment is required in cut sections, only in fill ditches.
  Ram Nunna talked to John Stains on February 1, 2007 at 10:30 AM to get additional clarification regarding this issue. Summary of conversation:

  > Ram indicated to John that the L&D Volume 2 does not directly address the treatment at the cut sections. John agreed and indicated that the intent is to treat the cut ditch as a regular ditch and treat the water at the toe of fill ditches just before they outlet to a outfall by widening the ditches per L&D Volume 2, Section 1118.3.1 (January 2007 revision) Based on this requirement curb is not required along the outside shoulders to treat water in the cut sections.
- The steep ditches in the fill sections should utilize Item 601 Tied Concrete Block Mat, Type 2 in lieu of rock channel protection where required for erosion protection.

Other Project Items:

- John will confirm with OSE that the MSE walls approved with the BTS for SR 823 over Webster (SR 140) and SR 823 over Blue Run Rd. are still valid for TS&L design completion.

  2/1/07 – John confirmed that OSE accepts the MSE wall designs for 823 over SR 140 and CR 29.

- The northwest corner of the SR 140 interchange has recently undergone some earthwork removal (apparently to construct the Wal-Mart store site pad). The cross sections for ramp 140B will not be accurate for the existing ground. D-9 indicated the final design team will correct this with additional field work. This will be added to the Red Flag list for Phase 3.

- Curb is not required along the outside shoulders in the cuts since the new BMP guidelines do not require treatment for cuts. This will be added the Phase 1 Red Flag list. Phases 2 and 3 will not provide the curb.

- John W. will check with D-9 Real Estate for the additional property costs associated with the reconfigured Slocum/Pershing intersection. These costs will be added to the differential construction cost analysis to be provided to Noel Alcala at OES for the FEIS update.

- D-9 provided comments on the trial plot of the updated exhibit mapping. All information provided at the Preferred Alternative stage will be added except for contours. A legend will be added. Another trial plot will be submitted prior to providing the 5 final plots.

- TranSystems is setting up a meeting with HDR in Cincinnati to go over the information requested. D-9 will be informed of the meeting.

- D-9 requested that TranSystems provide the backup calculations and information for the Stage 1 cost estimates.

Minutes were prepared by Mike Weeks -- please advise if there are additions or revisions.

APPENDIX A

Appendix B

MEMORANDUM

SCI-823-0.00, PID 77366, PHASE 3

PREPARED FOR: ODOT, District 9

PREPARED BY: Ram Nunna/Transystems

SUBJECT: Design of Four High Fill Box Culverts that were discussed on January 30, 2007 Culvert Design Meeting at ODOT, D-9

DATE: May 3, 2007

This memo documents the design of the four box culverts that were discussed at the Culvert Design Meeting on January 30, 2007 at District 9. The locations and sizes of the culverts are as follows:

8′ (span) x 6′ (height) at Sta. 234+05.47
9′ (span) x 6′ (height) at Sta. 239+18.19
10′ (span) x 8′ (height) at Sta. 297+56.24
8′ (span) x 8′ (height) at Sta.

1. **Culvert at Sta. 234+05.47 and Culvert at Sta. 239+18.19**

The box culverts (8′ x 6′ and 9′ x 6′) carry water from two individual streams on the left hand side of SR823 (upstream end) and discharges into the existing stream with a common headwall on the right hand side of SR823 (downstream end). See the attached plan view and profile view of the culverts. In order to minimize the impacts to the down stream end of the existing stream, a 23 feet high AS PER PLAN combined headwall is required. Per DLZ's recommendations 2:1 maximum fill slopes were used at these culvert locations. Fill slopes of 1.5:1 were investigated to minimize the length of the culvert and the height of the AS PER PLAN headwall as discusses on the January 30, 2007 culvert design meeting, however based on DLZ' recommendations 1.5:1 were not used. See the attached e-mail from DLZ dated February 15, 2007

In order to waste the excess waste (Rock) from the project 6:1 side slopes were used in between the inlet and outlet ends of the skewed culvert. See the attached cross-sections between stations, Sta. 229+50.00 to Sta. 241+00

Summary:

- Standard Full Height Head walls at the inlet ends
- 23′ AS PER PLAN common headwall at the outlet end.
- Maximum 2:1 side slopes at the culvert locations.
- Energy Dissipater is required at the outlet end and will be designed in Stage 2

APPENDIX B

2. **Culvert at Sta. 297+56.24 and Culvert at Sta. 300+89.44**

The box culverts (10' x 8' and 8' x 8') carry water from two individual streams on the left hand side of SR823 (upstream end) and discharges into the existing stream with a common headwall on the right hand side of SR823 (downstream end). See the attached plan view and profile view of the culverts. In order to minimize the impacts to the down stream end of the existing stream, a ~~17~~ 15' feet high AS PER PLAN combined headwall is required. Per DLZ's recommendations 2:1 maximum fill slopes were used at these culvert locations. Fill slopes of 1.5:1 were investigated to minimize the length of the culvert and the height of the AS PER PLAN headwall as discusses on the January 30, 2007 culvert design meeting, however based on DLZ' recommendations 1.5:1 were not used. See the attached e-mail from DLZ dated February 15, 2007

In order to waste the excess waste (Rock) from the project 6:1 side slopes were used in between the inlet and outlet ends of the skewed culvert. See the attached cross-sections between stations, Sta. 290+00.00 to Sta. 304+00

Summary:

- Standard Full Height Head walls at the inlet ends
- ~~25~~ 15' AS PER PLAN common headwall at the outlet end.
- Maximum 2:1 side slopes at the culvert locations.
- Energy Dissipater is required at the outlet end and will be designed in Stage 2

3. On a side note Phase-2 Culvert at Sta. 623+00 was also discussed at the culvert design meeting. The pipe profile was developed with out using any special design hence plan and profile views are not provided with this memo.

END

APPENDIX B

APPENDIX C

CN-Ramnarayan Nunna

From: John.Wetzel@dot.state.oh.us
Sent: Friday, June 22, 2007 11:38 AM
To: CO-Michael Weeks
Cc: Tom.Barnitz@dot.state.oh.us; CN-Ramnarayan Nunna
Subject: SCI-823: Phase 3 High Fill Culverts-Comments on Submission

Mike,

We have reviewed the information furnished in the submission you prepared for the above referenced culvert and offer the following comments:

Culvert at Sta. 234+05.47 & Culvert at Sta. 239+18.19

1) It appears that the 9'x6' culvert located at Sta. 239+18.19 could be extended thereby reducing the need for the 25' AS Per Plan headwall. Would not the culvert be at or close to the toe of the embankment if you were to extend it 50'. Would there be a substantial cost savings incurred by being able to use a standard headwall? By lengthening the Sta. 239+18.19 culvert this would force the Sta. 234+05.47 culvert to be relocated (rotated approximately 1.25 degrees clockwise) and it appears more excavation would be required by this relocation. However, would the cost savings from the standard headwall vs. 25' As Per Plan headwall cover the addition excavation and culvert construction?

2) Was there any consideration for improved inlets at each of the culverts? Would there be any reason why we could not use an improved inlet on the culverts, i.e. environmental considerations, etc.? The culvert size could be reduced with the application of these improvements. This in effect could provide considerable cost savings also.

Culvert at Sta. 297+56.24 & Culvert at Sta. 300+89.44

1) Can the 8'x8' culvert at Sta. 300+89.44 be extended also. This would be described similar to that as stated in Item No. 1 in the previous comments (Culvert at Sta. 234+05.47 & Culvert at Sta. 239+18.19).

2) Could the culvert at Sta. 300+89.44 be relocated approximately to Sta. 301+65 with the inlet at the intersection of the roadway ditches and the existing stream? This alignment would follow the approximate toe of the existing slope and more earthwork maybe involved. However, it would also provide a better transition from the outlet to the existing stream.

3) Was there any consideration for improved inlets at each of the culverts? Would there be any reason why we could not use an improved inlet on the culverts, i.e. environmental considerations, etc.? The culvert size could be reduced with the application of these improvements. This in effect could provide considerable cost savings also.

4) Was there a cost comparison done with submitted alignment of the Sta. 297+56.24 culvert and relocating it to run parallel with the roadway and outleting at the inlet of the Sta. 300+89.44 culvert? I believe we discussed this briefly at the Jan. 30, 2007 meeting. There was the issue of the addition earthwork (+/- 75' below existing grade), however, after further evaluation it seems that this alignment may reduce the length by approximately 500'. How would this cost savings compare with the addition excavation? Would options such as jacking a conduit through the hill, blasting a trench, etc. become practical options? Additionally the culvert at Sta 300+89.44 would increase in size and so would cost. Would the previously discussed inlet improvement help keep this size down if used?

As part of the meeting held Jan. 30, 2007, Transystems was to optimize the design for the discussed culverts using the recommendations/comments by the department as a basis for the design. It does not appear that this has been done. Please provide the basis for design (construction costs, hydraulic capacities, etc.) of the culverts

submitted.

Thanks,

John K. Wetzel III, PE, PS
ODOT-District 9 Production
650 Eastern Avenue
Chillicothe, Ohio 45601
Office: (740)-774-9080
Fax: (740)-774-9076

APPENDIX D

OPTION 1

9' X 6' BOX

OPTION 2

STA. 234+05.47 & 239+18.19

AND

STA. 233+79.80 & 239+05.02

OPTION 1

OPTION 2

8' X 8' BOX

SCI-823-0.00

PHASE 3 - PID:77366

PORTSMOUTH BYPASS

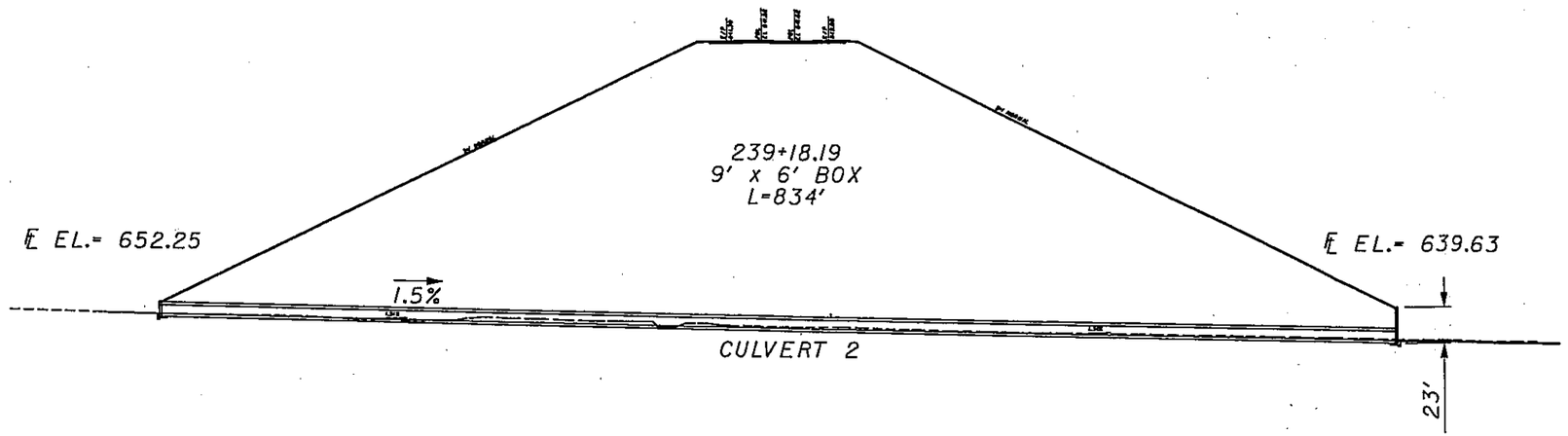
LOCATION 1 - STA. 234+00 & 239+00

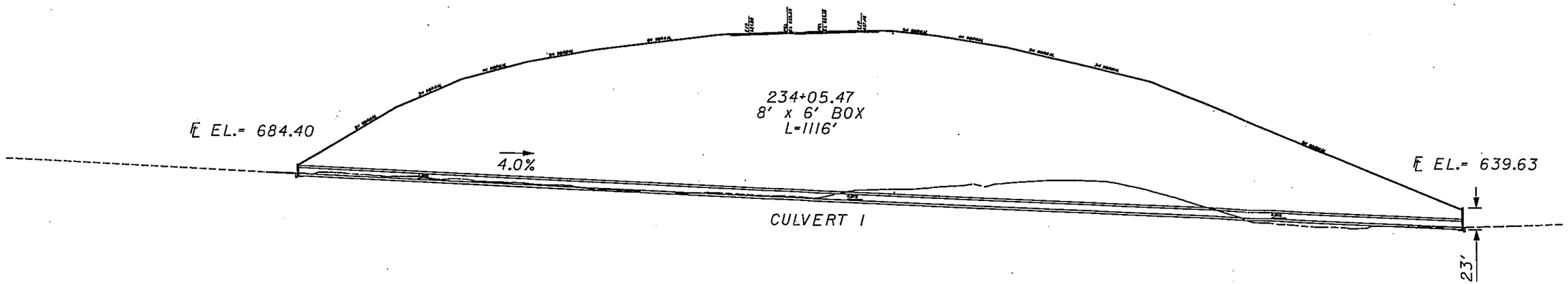
SCALE: 50:1

APPENDIX D

APPENDIX D
LOCATION 1
STA. 234+00 & 239+00

LOCATION I - OPTION I



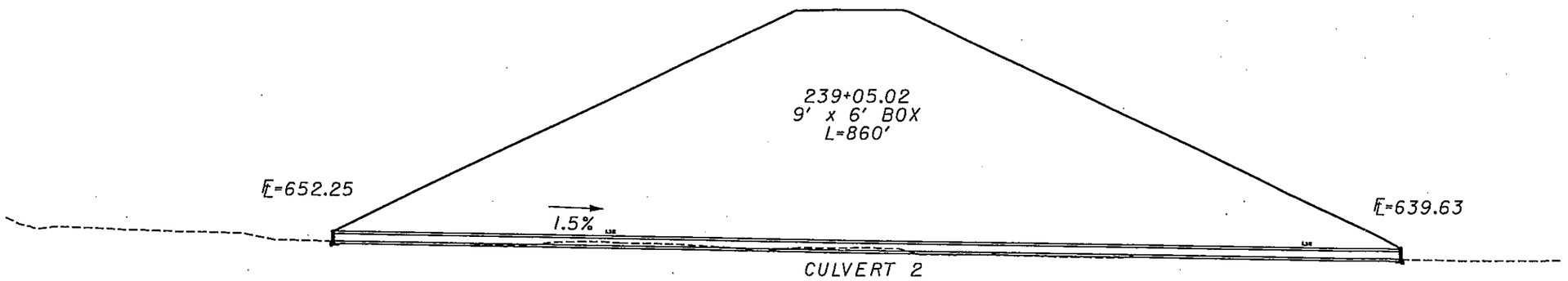


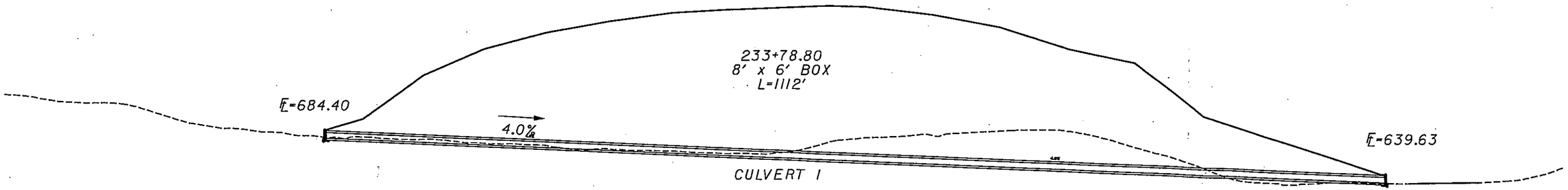
LOCATION I - OPTION I

SCI-823-0.00
PHASE 3 - PID: 77366
PORTSMOUTH BYPASS
SCALE: 100:1

APPENDIX D

LOCATION 1 - OPTION 2



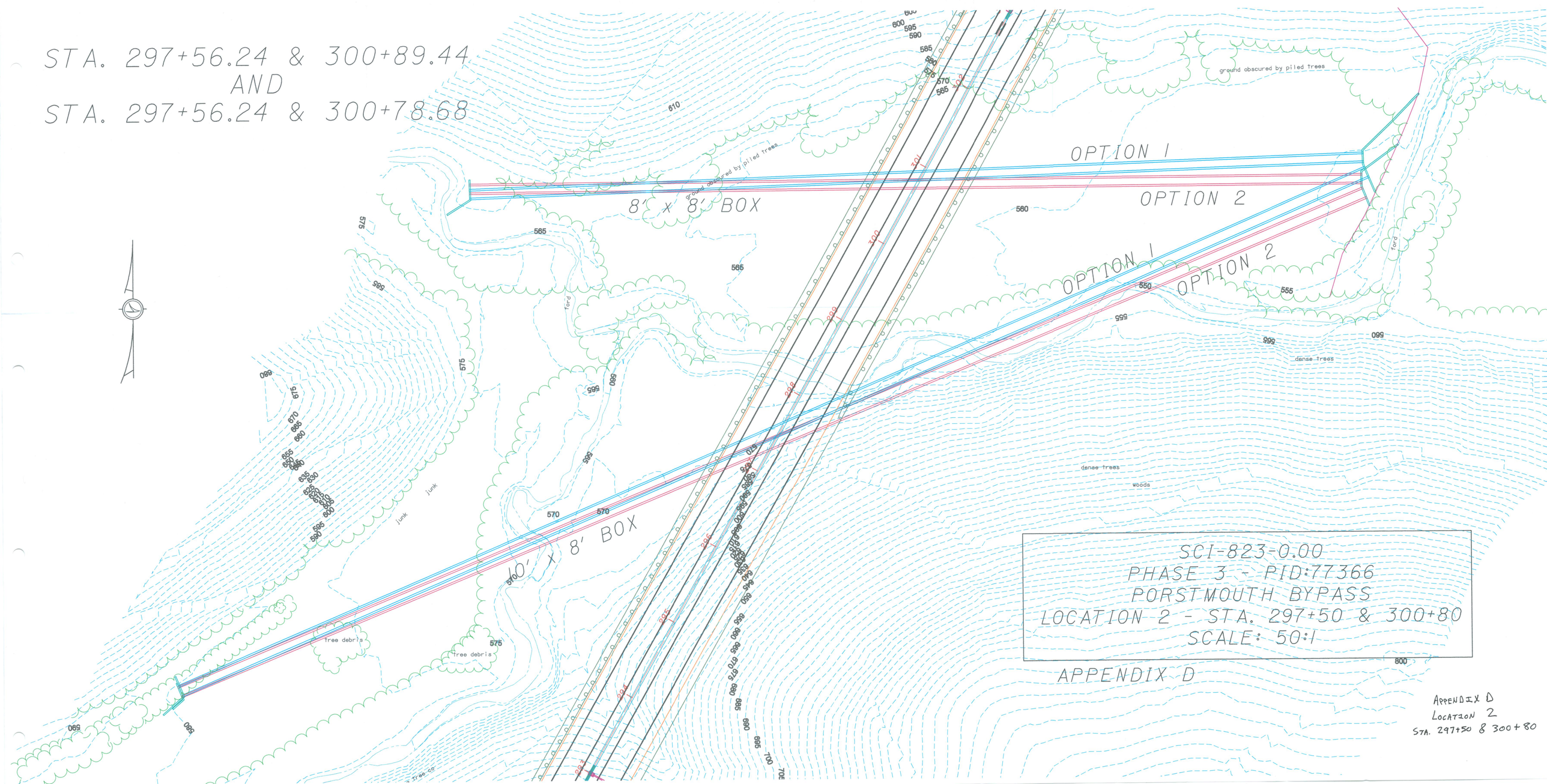


LOCATION 1 - OPTION 2

SCI-823-0.00
PHASE 3 - PID: 77366
PORTSMOUTH BYPASS
SCALE: 100:1

APPENDIX D

STA. 297+56.24 & 300+89.44
AND
STA. 297+56.24 & 300+78.68

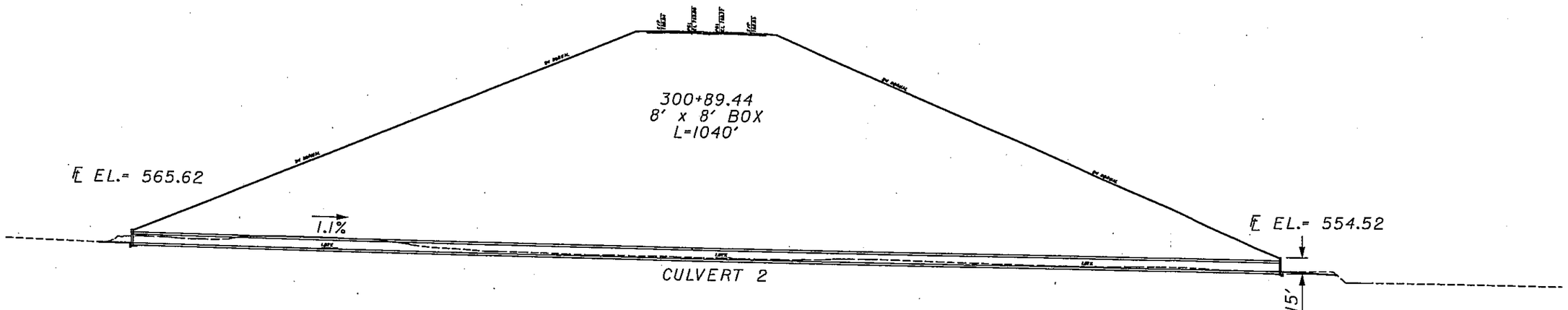


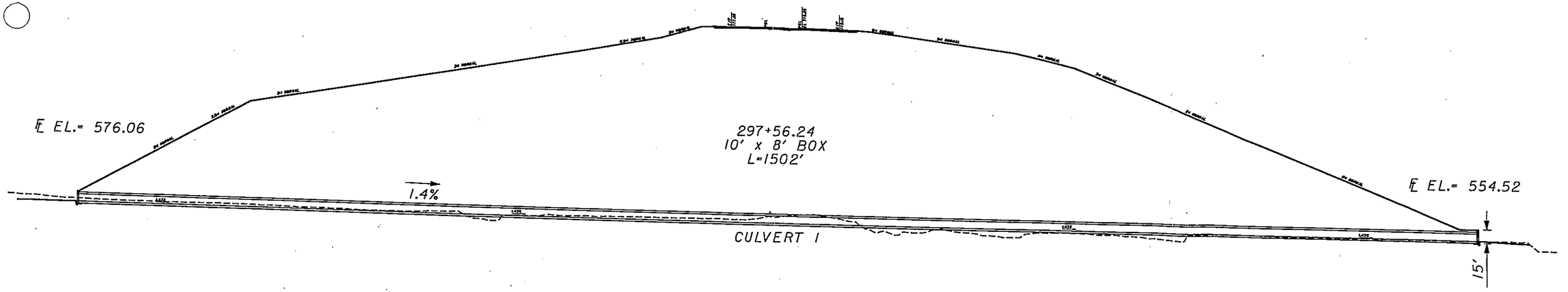
SCI-823-0.00
PHASE 3 - PID:77366
PORSTMOUTH BYPASS
LOCATION 2 - STA. 297+50 & 300+80
SCALE: 50:1

APPENDIX D

APPENDIX D
LOCATION 2
STA. 297+50 & 300+80

LOCATION 2 - OPTION 1



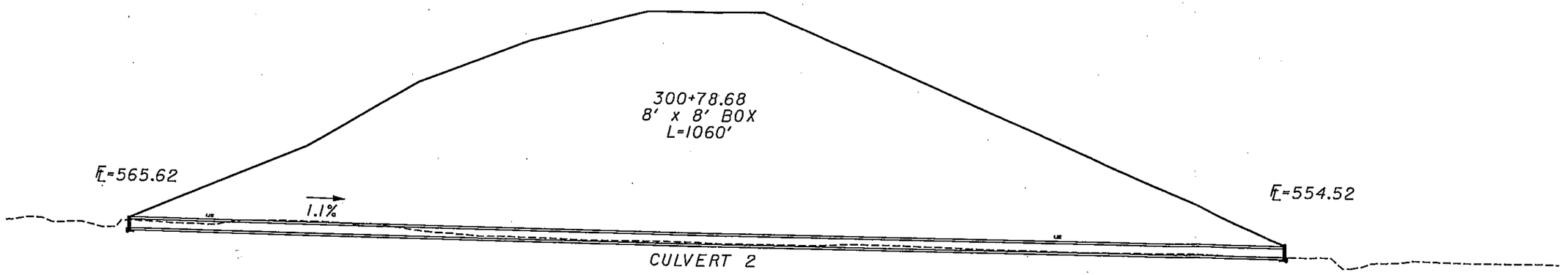


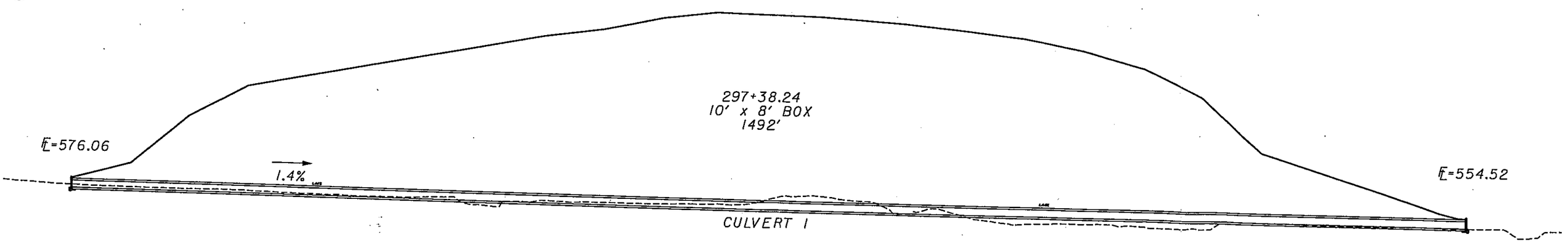
LOCATION 2- OPTION 1

SCI-823-0.00
PHASE 3 - PID: 77366
PORTSMOUTH BYPASS
SCALE: 100:1

APPENDIX D

LOCATION 2 - OPTION 2





LOCATION 2- OPTION 2

SCI-823-0.00
PHASE 3 - PID: 77366
PORTSMOUTH BYPASS
SCALE: 100:1

APPENDIX D

APPENDIX E

or 8x6?

Can use.

PORTSMOUTH BYPASS, SCI-823-0.00
PHASE 3
HIGH FILL BOX CULVERTS HYDRAULIC ANALYSIS SUMMARY

				HY-8 ANALYSIS							ODOT CDSS ANALYSIS			IMPROVED INLETS
CULVERT STATION	INLET ELEVATION	ALLOWABLE HEADWATER DEPTH (H=D+2)	ALLOWABLE HEADWATER ELEVATION	CULVERT SIZE		Q_{50}	Q_{100}	HWE_{50}	HWE_{100}	REMARKS	CULVERT SIZE (Design)	CULVERT SIZE (Design+1)	REMARKS	
234+05.47	684.4	8	692.4	6	6	108.6	130.4	687.62	688.06	Design HWE is below Allowable HWE				
	684.4	8	692.4	8	6	108.6	130.4	687.05	687.39	MIN. 8' Span is used	8' x 4'	8' x 5'	Size Selected 8' x 6'	NA
239+18.19	652.25	8	660.25	6	6	375.0	444.8	660.46	662.09	Design HWE is above the Allowable HWE				
	652.25	8	660.25	7	6	375.0	444.8	659.38	660.59	Design HWE is below Allowable HWE for 50 year and above for 100 year				7' X 6' SIDE TAPERED
	652.25	**8**	**660.25**	**8**	**6**	**375.0**	**444.8**	**658.64**	**659.61**	**Design HWE is below Allowable HWE**				HWE_{50} = 658.83
	652.25	8	660.25	9	6	375.0	444.8	658.1	658.92	Design HWE is below Allowable HWE	8' x 6'	8' x 7'	Size Selected, 9' x 6' to match the height of the culvert at Sta. 234+05.47 so that the culvert heights match at the outlet end.	HWE_{100} = 659.67
297+56.24	576.06	8	584.06	6	6	564.3	666.2	590.62	594.68	Design HWE is above the Allowable HWE				
	576.06	8	584.06	7	6	564.3	666.2	587.97	590.86	Design HWE is above the Allowable HWE				
	576.06	8	584.06	8	6	564.3	666.2	586.26	588.46	Design HWE is above the Allowable HWE				
	576.06	8	584.06	9	6	564.3	666.2	585.09	586.82	Design HWE is above the Allowable HWE				
	576.06	8	584.06	10	6	564.3	666.2	584.24	585.66	Design HWE is below Allowable HWE for 50 year and above for 100 year				7' X 8' SIDE TAPERED
	576.06	9	585.06	10	7	564.3	666.2	583.94	585.07	Design HWE is below Allowable HWE for 50 year and above for 100 year				HWE_{50} = 584.74
	576.06	10	586.06	10	8	564.3	666.2	583.84	584.84	Design HWE is below Allowable HWE	10' x 7'	10' x 8'	Size Selected, 10' x 8'	HWE_{100} = 585.81
300+89.44	565.62	8	573.62	6	6	404.2	479.2	575.34	577.40	Design HWE is above the Allowable HWE				
	565.62	8	573.62	7	6	404.2	479.2	573.98	575.51	Design HWE is above the Allowable HWE				7' X 6' SIDE TAPERED
	565.62	**8**	**573.62**	**8**	**6**	**404.2**	**479.2**	**573.07**	**574.27**	**Design HWE is below Allowable HWE for 50 year and above for 100 year**				HWE_{50} = 572.59
	565.62	10	575.62	8	8	404.2	479.2	572.85	573.76	Design HWE is below Allowable HWE	8' x 6'	8' x 7'	Size Selected, 8 x 8' to match the height of the culvert at Sta. 297+56.24 so that the culvert heights match at the outlet end.	HWE_{100} = 573.49

Decide

1. Size of STA 234+05 culvert. 6x6 or 8x6 or 8x4
2. " " " 239+18 culvert. 8x6 or 9x6 or 8x7
3. Option 1/2
4. Improved Inlet?

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5. re-align 10x8 to connect to 8x8?
6. D+4? Currently D+2
7. Extend outlets to stream w/o headwall?

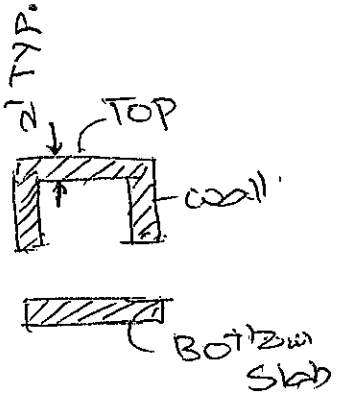
D

APPENDIX F

SCI-823-0.00 - PID: 77366
BOX CULVERT UNIT COST

CLASS "C"

UNIT COST CONCRETE FOR TOP SLAB AND WALLS = 600 $/CU.YD.
UNIT COST CONCRETE FOR BOTTOM SLAB = 350 $/CU.YD.



SPAN (FT)	X	RISE (FT)	AREA TOP SLAB (SQ.FT.)	AREA WALLS (SQ.FT.)	AREA BOTTOM SLAB (SQ.FT.)	UNIT COST ($/FT)
6	X	6	20	24	20	1237
6	X	7	20	28	20	1326
7	X	6	22	24	22	1307
7	X	7	22	28	22	1396
8	X	6	24	24	24	1378
8	X	7	24	28	24	1467
8	X	8	24	32	24	1556
9	X	6	26	24	26	1448
10	X	6	28	24	28	1519
10	X	7	28	28	28	1607
10	X	8	28	32	28	1696

SCI-823-0.00 - PID:77366
PORTSMOUTH BYPASS
HIGH FILL BOX CULVERT COST COMPARISON

LOCATION 1 - OPTION 1 (234+05.47 & 239+18.19)

ITEM	CULVERT 1	CULVERT 2	TOTAL
STATION	234+05.47	239+18.19	
SIZE (FT x FT)	8' x 6'	9' x 6'	
LENGTH (FT)	1116	834	
UNIT COST ($/FT)	1378	1448	
COST CULVERT ($)	1537600	1207756	**2745356**
HEIGHT HEADWALL (FT)	21		
AREA HEADWALL (SQ.FT.)	1462.5		
UNIT COST HEADWALL ($/SQ.FT.)	115		
COST HEADWALL ($)	168187.5		**168188**
EXCAVATION (1:1 SLOPE)	16563	0	
UNIT COST ROCK EXCAVATION ($/CU.YD)	3.5	3.5	
COST EXCAVATION ($)	57970	0	**57970**
			$2,971,513

LOCATION 1 - OPTION 2 (233+79.80 & 239+05.02)

ITEM	CULVERT 1	CULVERT 2	TOTAL
STATION	233+79.80	239+05.02	
SIZE (FT x FT)	8' x 6'	9' x 6'	
LENGTH (FT)	1112	860	
UNIT COST ($/FT)	1378	1448	
COST CULVERT ($)	1532089	1245407	**2777496**
HEIGHT HEADWALL (FT)	10		
AREA HEADWALL (SQ.FT.)	370		
UNIT COST HEADWALL ($/SQ.FT.)	115		
COST HEADWALL ($)	42550		**42550**
EXCAVATION (1:1 SLOPE) (CY)	31507	0	
UNIT COST ROCK EXCAVATION ($/CU.YD)	3.5	3.5	
COST EXCAVATION ($)	110276	0	**110276**
			$2,930,322

?

SCI-823-0.00 - PID:77366
PORTSMOUTH BYPASS
HIGH FILL BOX CULVERT COST COMPARISON

LOCATION 2 - OPTION 1 (297+56.24 & 300+89.44)

ITEM	CULVERT 1	CULVERT 2	TOTAL
STATION	297+56.24	300+89.44	
SIZE (FT x FT)	10' x 8'	8' x 8'	
LENGTH (FT)	1502	1040	
UNIT COST ($/FT)	1696	1556	
COST CULVERT ($)	2547837	1617778	**4165615**
HEIGHT HEADWALL (FT)	13		
AREA HEADWALL (SQ.FT.)	898.5		
UNIT COST HEADWALL ($/SQ.FT.)	115		
COST HEADWALL ($)	103327.5		**103328**
EXCAVATION (1:1 SLOPE)	3918	0	
UNIT COST ROCK EXCAVATION ($/CU.YD)	3.5	3.5	
COST EXCAVATION ($)	13714	0	**13714**
			$4,282,657

LOCATION 2 - OPTION 2 (297+56.24 & 300+78.68)

ITEM	CULVERT 1	CULVERT 2	TOTAL
STATION	297+38.24	300+78.68	
SIZE (FT x FT)	10' x 8'	8' x 8'	
LENGTH (FT)	1492	1060	
UNIT COST ($/FT)	1696	1556	
COST CULVERT ($)	2530874	1648889	**4179763**
HEIGHT HEADWALL (FT)	12		
AREA HEADWALL (SQ.FT.)	491		
UNIT COST HEADWALL ($/SQ.FT.)	115		
COST HEADWALL ($)	56465		**56465**
EXCAVATION (1:1 SLOPE)	10298 +6K CY	0	
UNIT COST ROCK EXCAVATION ($/CU.YD)	3.5	3.5	
COST EXCAVATION ($)	36043	0	**36043**
			$4,272,271

?

SCI-823-0.00 - PID:77366
PORTSMOUTH BYPASS
BOX CULVERT AND HEADWALL QUANTITIES

LOCATION 1 - CULVERT 1 (STA. 234+05.47 OR 233+79.80)

BOX CULVERT 1

AREA 1 - CONCRETE UNIT COST 600 (BASED ON BRIDGE QUANTITES FOR DECKS AND WALLS)
AREA 2 - CONCRETE UNIT COST 350 (BASED ON BRIDGE QUANTITES PIER FOOTINGS)

OPTION	LENGTH (FT)	AREA 1 (T/SLAB & WALL) (SQ.FT.)	AREA 2 (BOT/SLAB) (SQ.FT.)	COST/FT CULVERT ($/FT)	**COST CULVERT**
OPTION 1 - STA. 234+05.47	1116	48.0	24.0	1378	**$1,537,600**
OPTION 2 - STA. 233+79.80	1112	48.0	24.0	1378	**$1,532,089**

LOCATION 1 - CULVERT 2 (STA. 239+18.19 OR 238+05.02)

AREA 1 - CONCRETE COST PER 600 (BASED ON BRIDGE QUANTITES FOR DECKS AND WALLS)
AREA 2 - CONCRETE COST PER 350 (BASED ON BRIDGE QUANTITES PIER FOOTINGS)

OPTION	LENGTH (FT)	AREA 1 (T/SLAB & WALL) (SQ.FT.)	AREA 2 (BOT/SLAB) (SQ.FT.)	COST/FT CULVERT ($/FT)	**COST CULVERT**
OPTION 1 - STA. 239+18.19	834	50.0	26.0	1448	**$1,207,756**
OPTION 2 - STA. 239+05.02	860	50.0	26.0	1448	**$1,245,407**

LOCATION 1 - HEADWALL(S)

HEADWALL

CONCRETE UNIT COST ($/SQ.FT. 115 (BASED ON ODOT ESTIMATING VALUES)

OPTION	MAX HEIGHT HW (FT)	END HEIGHT HW (FT)	LENGTH LT (SLOPED) (FT)	LENGTH ABOVE CULVERTS (AT MAX HEIGHT) (FT)	LENGTH RT (SLOPED) (FT)	WIDTH BETWEEN CULVERTS (FT)	AREA (SQ.FT.)	**COST HW**
OPTION 1 - STA. 234+05.47 & 239+18.19	21	2	45	32	46	0	1463	**$168,188**
OPTION 2 - STA. 233+79.80 & 239+05.02	10	2	16	36	23	8	370	**$42,550**

SCI-823-0.00 - PID:77366
PORTSMOUTH BYPASS
BOX CULVERT AND HEADWALL QUANTITIES

LOCATION 2 - CULVERT 1 (STA. 297+56.24 OR 297+38.24)

BOX CULVERT 1

AREA 1 - CONCRETE UNIT COST 600 (BASED ON BRIDGE QUANTITES FOR DECKS AND WALLS)
AREA 2 - CONCRETE UNIT COST 350 (BASED ON BRIDGE QUANTITES PIER FOOTINGS)

OPTION	LENGTH (FT)	AREA 1 (T/SLAB & WALL) (SQ.FT.)	AREA 2 (BOT/SLAB) (SQ.FT.)	COST/FT CULVERT ($/FT)	**COST CULVERT**
OPTION 1 - STA. 297+56.24	1502	60.0	28.0	1696	**$2,547,837**
OPTION 2 - STA. 297+38.24	1492	60.0	28.0	1696	**$2,530,874**

LOCATION 2 - CULVERT 2 (STA. 300+89.44 OR 300+78.68)

AREA 1 - CONCRETE COST PER 600 (BASED ON BRIDGE QUANTITES FOR DECKS AND WALLS)
AREA 2 - CONCRETE COST PER 350 (BASED ON BRIDGE QUANTITES PIER FOOTINGS)

OPTION	LENGTH (FT)	AREA 1 (T/SLAB & WALL) (SQ.FT.)	AREA 2 (BOT/SLAB) (SQ.FT.)	COST/FT CULVERT ($/FT)	**COST CULVERT**
OPTION 1 - STA. 300+89.44	1040	56.0	24.0	1556	**$1,617,778**
OPTION 2 - STA. 300+78.68	1060	56.0	24.0	1556	**$1,648,889**

LOCATION 2 - HEADWALL(S)

HEADWALL

CONCRETE UNIT COST ($/SQ.FT. 115 (BASED ON ODOT ESTIMATING VALUES)

OPTION	MAX HEIGHT HW (FT)	END HEIGHT HW (FT)	LENGTH LT (SLOPED) (FT)	LENGTH ABOVE CULVERTS (AT MAX HEIGHT) (FT)	LENGTH RT (SLOPED) (FT)	WIDTH BETWEEN CULVERTS (FT)	AREA (SQ.FT.)	**COST HW**
OPTION 1 - STA. 297+56.24 & 300+89.44	13	2	18	32	89	0	899	**$103,328**
OPTION 2 - STA. 297+38.24 & 300+78.68	12	2	9	32	52	0	491	**$56,465**

SCI-823-0.00 - PID:77366
PORTSMOUTH BYPASS
ROCK EXCAVATION QUANTITIES

LOCATION 1 - CULVERT 1 - EXCAVATION ONLY

OPTION 1 - STA. 234+05.47

	Area (sq.ft.)		Ave. Area (sq.ft.)			Volume (cu.yd.)	
Station	1:1 Slope	0.5:1 Slope	1:1 Slope	0.5:1 Slope	Length (ft)	1:1 Slope	0.5:1 Slope
10+50	40.6	38.1	-	-	-	-	-
11+50	0.0	0.0	20.3	19.1	100	75.2	70.6
12+00	0.0	0.0	0.0	0.0	50	0.0	0.0
12+50	0.0	0.0	0.0	0.0	50	0.0	0.0
13+00	352.1	245.2	176.1	122.6	50	326.0	227.0
13+50	1109.0	680.4	730.6	462.8	50	1352.9	857.0
14+00	1806.7	1040.4	1457.9	860.4	50	2699.7	1593.3
14+50	1730.0	966.4	1768.4	1003.4	50	3274.7	1858.1
15+00	1303.7	704.1	1516.9	835.3	50	2809.0	1546.8
15+50	957.2	541.6	1130.5	622.9	50	2093.4	1153.4
16+00	702.6	385.5	829.9	463.6	50	1536.9	858.4
16+50	302.9	170.5	502.8	278.0	50	931.0	514.8
17+00	60.9	54.5	181.9	112.5	50	336.9	208.3
17+50	59.8	55.4	60.4	55.0	50	111.8	101.8
18+00	46.3	40.2	53.1	47.8	50	98.2	88.5
18+50	33.9	30.4	40.1	35.3	50	74.3	65.4
19+00	45.5	41.6	39.7	36.0	50	73.5	66.7
19+50	70.7	64.5	58.1	53.1	50	107.6	98.2
20+00	80.5	71.5	75.6	68.0	50	140.0	125.9
20+50	94.2	83.5	87.4	77.5	50	161.8	143.5
21+00	86.5	76.3	90.4	79.9	50	167.3	148.0
21+50	71.3	60.7	78.9	68.5	66 *	192.9	167.4
					TOTAL =	16563	9893

* 16 ft to the end of the culvert

OPTION 2 - STA. 233+79.80

	Area (sq.ft.)		Ave. Area (sq.ft.)			Volume (cu.yd.)	
Station	1:1 Slope	0.5:1 Slope	1:1 Slope	0.5:1 Slope	Length (ft)	1:1 Slope	0.5:1 Slope
10+50	20.4	19.7	-	-	-	-	-
11+50	0.0	0.0	10.2	9.9	100	37.8	36.5
12+00	0.0	0.0	0.0	0.0	50	0.0	0.0
12+50	468.0	311.3	234.0	155.7	50	433.3	288.2
13+00	1265.9	786.4	867.0	548.9	50	1605.5	1016.4
13+50	2401.8	1389.2	1833.9	1087.8	50	3396.0	2014.4
14+00	3116.7	1707.3	2759.3	1548.3	50	5109.7	2867.1
14+50	2874.4	1516.2	2995.6	1611.8	50	5547.3	2984.7
15+00	2295.6	1239.1	2585.0	1377.7	50	4787.0	2551.2
15+50	1795.1	1006.9	2045.4	1123.0	50	3787.7	2079.6
16+00	1347.0	786.2	1571.1	896.6	50	2909.4	1660.3
16+50	671.5	365.0	1009.3	575.6	50	1869.0	1065.9
17+00	144.4	107.1	408.0	236.1	50	755.5	437.1
17+50	78.8	69.0	111.6	88.1	50	206.7	163.1
18+00	69.1	64.4	74.0	66.7	50	136.9	123.5
18+50	65.3	56.6	67.2	60.5	50	124.4	112.0
19+00	30.3	27.1	47.8	41.9	50	88.5	77.5
19+50	63.8	61.5	47.1	44.3	50	87.1	82.0
20+00	70.0	64.0	66.9	62.8	50	123.9	116.2
20+50	96.7	87.9	83.4	76.0	50	154.4	140.6
21+00	83.8	75.3	90.3	81.6	50	167.1	151.1
21+50	84.5	69.2	84.2	72.3	58 *	180.1	154.7
					TOTAL =	31507	18122

* 8 ft to the end of the culvert

LOCATION 2 - CULVERT 1 - EXCAVATION ONLY

OPTION 1 - STA. 297+56.24

Station	Area (sq.ft.)		Ave. Area (sq.ft.)		Length (ft)	Volume (cu.yd.)	
	1:1 Slope	0.5:1 Slope	1:1 Slope	0.5:1 Slope		1:1 Slope	0.5:1 Slope
10+50	40.0	38.0	-	-	-	-	-
11+00	31.6	30.0	40.0	38.0	50	74.1	70.4
11+50	17.5	17.1	35.8	30.0	50	66.3	55.6
12+00	12.1	11.9	24.6	23.6	50	45.5	43.6
12+50	12.8	12.5	14.8	14.5	50	27.4	26.9
13+00	24.7	24.1	12.5	12.2	50	23.1	22.6
13+50	9.3	9.2	18.8	18.3	50	34.7	33.9
14+00	0.0	0.0	17.0	16.7	50	31.5	30.8
14+50	0.0	0.0	4.7	4.6	50	8.6	8.5
15+00	0.0	0.0	0.0	0.0	50	0.0	0.0
15+50	0.0	0.0	0.0	0.0	50	0.0	0.0
16+00	0.0	0.0	0.0	0.0	50	0.0	0.0
16+50	8.0	7.3	0.0	0.0	50	0.0	0.0
17+00	223.0	70.7	4.0	3.7	50	7.4	6.8
17+50	403.8	272.4	115.5	39.0	50	213.9	72.2
18+00	301.6	210.9	313.4	171.6	50	580.4	317.7
18+50	106.3	91.8	352.7	241.7	50	653.1	447.5
19+00	104.6	93.3	204.0	151.4	50	377.7	280.3
19+50	91.1	82.6	105.5	92.6	50	195.3	171.4
20+00	76.8	70.2	97.9	88.0	50	181.2	162.9
20+50	65.5	60.3	84.0	76.4	50	155.5	141.5
21+00	0.0	0.0	71.2	65.3	50	131.8	120.8
21+50	88.5	80.3	32.8	30.2	50	60.6	55.8
22+00	49.9	46.8	44.3	40.2	50	81.9	74.4
22+50	49.6	46.3	69.2	63.6	50	128.1	117.7
23+00	68.0	63.0	49.8	46.6	50	92.1	86.2
23+50	81.6	74.7	58.8	54.7	50	108.9	101.2
24+00	93.7	84.8	74.8	68.9	50	138.5	127.5
24+50	85.6	78.0	87.7	79.8	50	162.3	147.7
25+00	93.5	84.5	89.7	81.4	50	166.0	150.7
25+50	118.6	102.7	89.6	81.3	52 *	172.5	156.5
					TOTAL =	3918	3031

* 2 ft to the end of the culvert

OPTION 2 - STA. 297+38.24

Station	Area (sq.ft.)		Ave. Area (sq.ft.)		Length (ft)	Volume (cu.yd.)	
	1:1 Slope	0.5:1 Slope	1:1 Slope	0.5:1 Slope		1:1 Slope	0.5:1 Slope
10+50	0.0	0.0	-	-	-	-	-
11+00	26.6	25.8	13.3	12.9	50	24.6	23.9
11+50	18.2	17.7	22.4	21.8	50	41.5	40.3
12+00	18.2	17.6	18.2	17.7	50	33.7	32.7
12+50	25.2	24.4	21.7	21.0	50	40.2	38.9
13+00	38.4	36.9	31.8	30.7	50	58.9	56.8
13+50	0.0	0.0	19.2	18.5	50	35.6	34.2
14+00	0.0	0.0	0.0	0.0	50	0.0	0.0
14+50	0.0	0.0	0.0	0.0	50	0.0	0.0
15+00	0.0	0.0	0.0	0.0	50	0.0	0.0
15+50	0.0	0.0	0.0	0.0	50	0.0	0.0
16+00	278.0	106.6	139.0	53.3	50	257.4	98.7
16+50	733.4	236.9	505.7	171.8	50	936.5	318.1
17+00	1000.0	600.0	866.7	418.5	50	1605.0	774.9
17+50	1200.0	800.0	1100.0	700.0	50	2037.0	1296.3
18+00	700.0	400.0	950.0	600.0	50	1759.3	1111.1
18+50	201.5	180.7	450.8	290.4	50	834.7	537.7
19+00	150.7	120.6	176.1	150.7	50	326.1	279.0
19+50	125.6	100.4	138.2	110.5	50	255.8	204.6
20+00	101.3	90.6	113.5	95.5	50	210.1	176.9
20+50	57.1	52.7	79.2	71.7	50	146.7	132.7
21+00	0.0	0.0	28.6	26.4	50	52.9	48.8
21+50	110.0	100.3	55.0	50.2	50	101.9	92.9
22+00	63.8	61.0	86.9	80.7	50	160.9	149.4
22+50	69.5	64.6	66.7	62.8	50	123.4	116.3
23+00	77.7	72.2	73.6	68.4	50	136.3	126.7
23+50	115.3	98.4	96.5	85.3	50	178.7	158.0
24+00	121.3	100.5	118.3	99.5	50	219.1	184.2
24+50	118.6	113.2	120.0	106.9	50	222.1	197.9
25+00	120.5	100.0	119.6	106.6	50	221.4	197.4
25+50	152.6	119.5	136.6	109.8	55 *	278.2	223.6
					TOTAL =	10298	6652

* 5 ft to the end of the culvert

TRANSYSTEMS CORPORATION
Calculations For

Made By CAS Date 4/17/07 Job No. 77386
Checked By RN Date 4/18/07 Sheet No. 1/6

¼ U.S. Grid

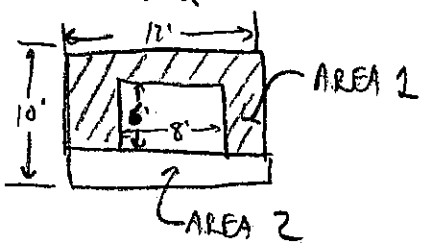
BOX CULVERT COMPARISON

CULVERT STA. 234+05.47

LOCATION 1 (STA 234+05.47 & 239+18.19) - OPTION 1 ✓

STA. 234+05.47

8'x6' BOX



AREA 1 ⇒ TOP/SLAB & WALLS ✓

$A_1 = 2(8)(2) + 8(2) = 48$ SQ FT ✓

AREA 2 ⇒ BOTTOM SLAB ✓

$A_2 = 12(2) = 24$ SQ FT ✓

COST:

AREA 1 - BASED ON STRUCTURAL CONCRETE (S) TYPES COSTS FOR BRIDGE CONSTRUCTION. REQUIRES MUCH MORE FORM-WORK.

- CONCRETE @ $600 /CU YD ✓

AREA 2 ⇒ BASED ON STRUCTURAL CONCRETE (S) TYPES COSTS FOR BRIDGE CONSTRUCTION; LITTLE FORMING NEEDED

- CONCRETE @ ~~$550~~ $350 /CU YD ✓

UNIT COST @ STA 234+05.47

$UC = (48 \text{ sq ft})\left(\frac{1}{27}\right)(600 \text{ \$/cu yd}) + (24 \text{ sq ft})\left(\frac{1}{27}\right)(350 \text{ \$/cu yd})$

$UC = \$1378 /FT$ ✓

TRANSYSTEMS CORPORATION

Calculations For

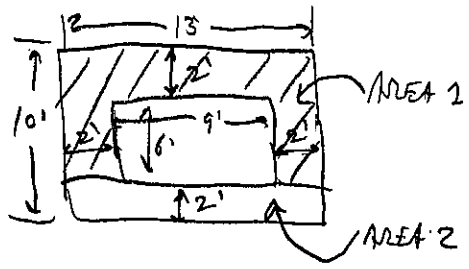
Made By CAS Date 4/17/07 Job No. 17366

Checked By RW Date 4/18/07 Sheet No. 2/6

¼ U.S. Grid

STA. 239+18.19

9'x6' BOX ✓



CULVERT @ STA. 239+18.19

AREA 1 ⇒ T/SLAB & WALLS

$A_1 = 2(8)(2) + 9(2) = 50$ sq FT ✓

AREA 2 ⇒ BOT /SLAB

$A_2 = (13)2 = 26$ sq FT

COST: SEE SHEET 1 FOR EXPLANATION

UNIT COST @ STA. 239+18.19

$UC = (50 \text{ sq FT})\left(\frac{1}{27}\right)(600 \text{ \$/cu yd}) + (26 \text{ sq FT})\left(\frac{1}{27}\right)(350 \text{ \$/cu yd})$

UC = $1448 /FT OF BOX CULVERT

LOCATION 1 (STA 233+79.80 & 239+05.02) - OPTION 2 ✓

STA. 234+05.97 ✓

8'x6' BOX ⇒ SAME AS OPTION 1 ⇒ UC = 1398 $/FT ✓

STA 239+05.02 ✓

9'x6' BOX ⇒ SAME AS OPTION 1 ⇒ UC = $1448 /FT ✓

TRANSYSTEMS CORPORATION

Made By CAS Date 4/17/07 Job No. 72368
Checked By RN Date 04/18/07 Sheet No. 3/6

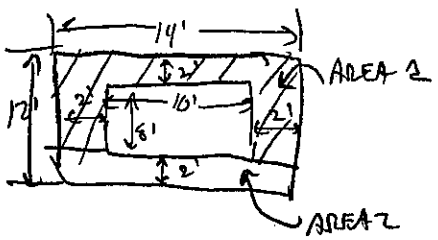
Calculations For

LOCATION 2 (STA. 297+56.24 & 300+89.44) - OPTION 1

½ U.S. Grid

297+56.24 CULVERT STA. 297+56.24

10' X 8' BOX



AREA 1 ⇒ T/SLAB & WALLS ✓

$A_1 = 10(2)(2) + 10(2) = 60$ SQ FT ✓

AREA 2 ⇒ BOT SLAB

$A_2 = 14(2) = 28$ SQ FT ✓

COST: SEE SHEET 1 FOR EXPLANATION ✓

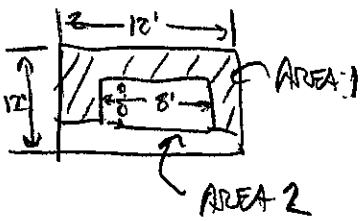
UNIT COST @ 297+56.24

$UC = (60 \text{ sq ft})\left(\frac{1}{27}\right)(600 \$/\text{cu yd}) + (28 \text{ sq ft})\left(\frac{1}{27}\right)(350 \$/\text{cu yd}) \Rightarrow$

UC = $1696 /cu yd ✓

300+89.44 ✓ CULVERT STA. 300+89.44

8' X 8' BOX ✓



AREA 1 ⇒ T/SLAB & WALLS

$A_1 = (10)(2)(2) + 8(2) = 56$ SQ FT ✓

AREA 2 ⇒ BOT SLAB

$A_2 = (12)(2) = 24$ SQ FT ✓

COST: SEE SHEET 1 FOR EXPLANATION

UNIT COST @ 300+89.44 ✓

$UC = (56 \text{ sq ft})\left(\frac{1}{27}\right)(600 \$/\text{cu yd}) + (24 \text{ sq ft})\left(\frac{1}{27}\right)(350 \$/\text{cu yd})$

UC = $1556 /cu yd ✓

TRANSYSTEMS CORPORATION

Calculations For

Made By DS Date 4/17/07 Job No. 72366

Checked By RN Date 04/18/07 Sheet No. 4/6

¼ U.S. Grid

LOCATION 2 (297+38.24 & 300+78.68) - OPTION 2

297+38.24

10'x8' BOX => SAME AS OPTION 1 => UC = $1696 /COLD

300+78.68

8'x8' BOX => SAME AS OPTION 2 => UC = $1556 /COLD

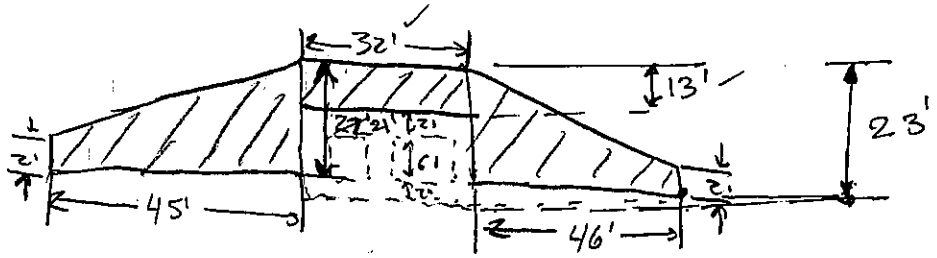
TRANSYSTEMS CORPORATION
Calculations For

Made By CAS Date 4/17/07 Job No. 77366
Checked By RN Date 4/18/07 Sheet No. 5 of 6

¼ U.S. Grid

LOCATION 1 - OPTION 1 (234+05.47 & 239+16.19)

HEADWALL



$A = 32\left(\frac{21}{22}-6-2\right) + (45+46)\left(\frac{2+\frac{21}{22}}{2}\right) = 1540$ sq FT
$= 416 + 10 \times 6.5 = 1462.5 = 1463$ sq ft

COST: BASED ON ODOT TABLE FOR RETAINING WALL ESTIMATING COSTS; SEE ~~FOLLOWING SHEETS~~ Attached Sheets

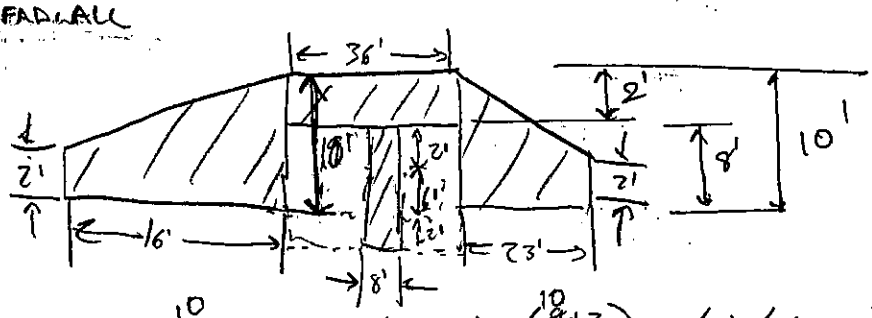
UC = $115 / sq FT

COST OF Loc 1 - OPT 1:

$(\$115/\text{sq FT})(1540\ \text{sq FT}) = \$177100 = \$\ 168{,}245$
1X63

LOCATION 1 - OPTION 2 (233+79.80 & 239+05.02)

HEADWALL



$A = 36\left(\frac{10}{9}\cdot 6-2\right) + (16+23)\left(\frac{10+2}{2}\right) + (8)(6+2) = 331$ sq FT
$= 72 + 234 + 64 = 370$ SQ.FT.

COST: SEE ABOVE EXPLANATION

COST OF Loc 1-OPT 2

$(\$115/\text{sq FT})(331\ \text{sq FT}) = \$38008 \quad \$\ 42{,}550$
370

TRANSYSTEMS CORPORATION

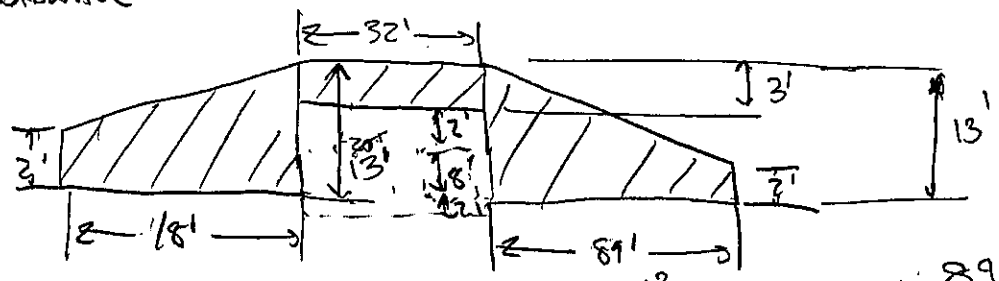
Made By CAS Date 4/19/07 Job No. 77366
Checked By DN Date 4/18/07 Sheet No. 6/6

Calculations For

¼ U.S. Grid

LOCATION 2 - OPTION 1 (297+56.24 & 300+89.44)

HEADWALL



AREA = $32\left(\frac{13}{2}-8-2\right) + (18+89)\left(\frac{13}{2}+2\right)$ = 96 + 802.5 = 898.5 = ~~1497~~ SQ FT

COST: BASED ON ODOT ESTIMATING TABLE 1. FOR RETAINING WALLS SEE ~~SHEETS ATTACHED~~ Attached sheets

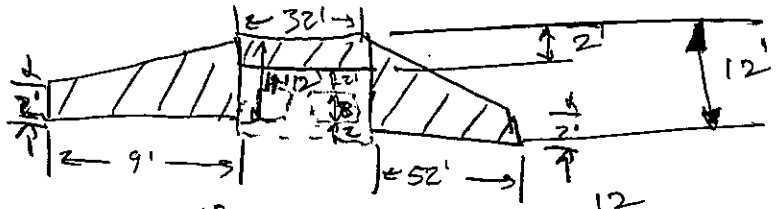
UC = $115 / SQ FT

COST FOR LOC 2 - OPT 1

(115 $/SQFT)(898.5 SQFT) = ~~$172155~~ $103,329

LOCATION 1 - OPTION 2 (297+38.24 & 300+78.68)

HEADWALL



AREA = $32\left(\frac{12}{2}-8-2\right) + (52+9)\left(\frac{12}{2}+2\right)$ = 64 + 427 = 491 = ~~429~~ SQ FT

COST: SEE PREVIOUS STATEMENT & FOLLOWING SHEETS

COST FOR LOC 2 - OPT 2

(115 $/SQ FT)(491 SQFT) = ~~$49298~~ $56,465

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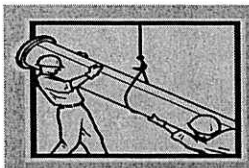


DRAINAGE COST INFORMATION

Back to J&P Category-DRAINAGE

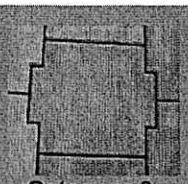
Contact Us

Category 3	Category 4	Category 5	Category 6	UNIT	COSTS	NOTES
Major Cost Drivers						
	Underdrains					
				ft	$8	
	Conceptual Estimating Techniques			mile	$150,000	four lane divided with outside & inside shoulder drainage
	Culverts					
		Type A: < 5'				
						Pipe Structures - Reinforced concrete pipe, 706.02. Includes granular bed, setting pipe and backfill
				ft	$350	up to 60"
				ft	$35	Removal of existing (up to 60")
				cy	$1,200	Concrete Masonry - In place headwalls / wingwalls
		Conceptual Estimating Techniques		each	$1,000	Concrete Masonry - In place headwalls for Type A
						Corrugated Metal Pipe, 707.02 / Structural Plate Pipe, 707.03. Includes granular bed, setting pipe and backfill. (headwalls, cofferdams & sheeting costs are separate)
				ft	$300	up to 60"
				ft	$35	Removal of existing (up to 60")
				cy	$1,200	Concrete Masonry - In place headwalls / wingwalls
		Conceptual Estimating Techniques		each	$1,000	Concrete Masonry - In place headwalls
		Type A: 5'-10'				
						Pipe Structures - Reinforced concrete pipe, 706.02. Includes granular bed, setting pipe and backfill
				ft	$500	66" - 78"
				ft	$900	84" - 108"
				ft	$100	Removal of existing (66" - 108")
				cy	$350	Concrete Footing
				cy	$1,200	Concrete - headwalls / wingwalls
		Conceptual Estimating Techniques		each	$1,750	Concrete - In place headwalls / wingwalls
						Corrugated Metal Pipe, 707.02 / Structural Plate Pipe, 707.03. Includes granular bed, setting pipe and backfill. (headwalls, cofferdams & sheeting costs are separate)
				ft	$550	66" - 78"
				ft	$700	84" - 108"
				sq ft	$12	Removal of existing structure, based upon sq ft of deck / surface area
				cy	$350	Concrete Footing
				cy	$1,200	Concrete - headwalls / wingwalls
		Conceptual Estimating Techniques		each	$1,750	Concrete - In place headwalls / wingwalls
						Precast Box Structures, 706.05 Includes granular bed, setting pipe and backfill. (headwalls, cofferdams & sheeting costs are separate)
				ft	$850	6' x 4' thru 8' x 4'
				ft	$1,200	8' x 5' thru 10'x 4'
				ft	$1,600	10' x 5' thru 12' x 4'
				sq ft	$20	surface area
				cy	$350	Concrete Footing
				cy	$1,200	Concrete - headwalls / wingwalls
		Conceptual Estimating Techniques		each	$7,500	Concrete - In place headwalls / wingwalls
		Type A: 10'- 20'				
						Corrugated Metal Pipe, 707.02 / Structural Plate Pipe, 707.03. Includes granular bed, setting pipe and backfill. (headwalls, cofferdams & sheeting costs are separate)
				ft	$1,400	114" - 150"
				sq ft	$15	Removal of existing structure, based upon sq ft of deck / surface area
				cy	$350	Concrete Footing
				cy	$1,200	Concrete - headwalls / wingwalls
		Conceptual Estimating Techniques		each	$7,500	Concrete - In place headwalls / wingwalls

APPENDIX F

				Precast Box Structures, 706.05 Includes granular bed, setting pipe and backfill. (headwalls, cofferdams & sheeting costs are separate)
			ft	$1,500	12' x 5' thru 14' x 4'
			ft	$1,800	14' x 5' thru 16' x 4'
			ft	$2,200	16' x 5' thru 18' x 4'
			ft	$2,800	18' x 5' thru 20' x 10'
			sq ft	$18	Removal of existing structure, based upon sq ft of deck / surface area
			cy	$350	Concrete Footing
			cy	$1,200	Concrete - headwalls / wingwalls
	Conceptual Estimating Techniques		each	$10,000	Concrete - In place headwalls / wingwalls
	Median Drainage		ft	$150	
			each	$5,000	Barrier Median Inlet, Single Slope
	BMP's		lump	***	BMP - Best Management Practices *** This item is designated as a future pay item. There is no current cost data available.
	Closed Storm System		lump	**	** Contact Office of Estimating for specific cost requests. Individual item costs are available in *Estimator* 2.2. Includes granular bed, setting pipe and backfill.
			ft	$70	Storm, Type B or C
			each	$1,500	Catch Basin, No. 3A
			each	$3,000	Manhole, No. 3
	Conceptual Estimating Techniques		ft	$200	Average cost of storm per foot of curbed road. Includes Storm, Type B or C, Catch Basin, No. 3A, and Manholes.
Other Drainage Costs			lump		See 'Other' costs below
	Constructible Risk Contingency	**if needed as determined by estimating team**	lump	0% - 50%	** See Constructible Risk Contingency Cost page
				**	** Contact Office of Estimating for specific cost requests. Individual item costs are available in *Estimator* 2.2.

APPENDIX F



Back to J&P Category-RETAINING WALLS

RETAINING WALLS COST INFORMATION

Contact Us

Category 3	Category 4	Category 5	Category 6	UNIT	COSTS	NOTES
Major Cost Drivers						
	Retaining Walls					
	Conceptual Estimating Techniques			**sq ft**	**$75**	**Retaining Wall - MSE** Per square foot of wall includes excavation, embankment, concrete leveling pads, precast panels and straps, drainage conduit, granular backfill, concrete coping cap on the top of the wall, and sealing of the concrete surfaces. Does not include concrete caps, barrier on top, or testing.
				sq ft	**$90**	**Retaining Wall - MSE** Same as wall above except in extreme urban - high volume areas
				sq ft	**$115**	**Retaining Wall - Poured in place**
						Earth Wall Costs if you have estimated quantities of each wall item
				sq ft	**$30**	**Mechanically Stablized Earth Wall**
				cu yd	**$15**	**Wall Excavation**
				sq yd	**$15**	**Foundation Preparation**
				cu yd	**$30**	**Select Granular Backfill**
				cu yd	**$70**	**Porous Backfill w/Filter Fabric**
				lin ft	**$10**	**Drainage Pipe**
				lin ft	**$100**	**Concrete Coping**
				per day	**$1,200**	**On-Site Assistance**
				LS	***see note**	**SGB Inspection and Compaction Testing** * very roughly use $1 per sf face of wall until further notice.
Other Retaining Wall Costs				**lump**	**	** Contact Office of Estimating for specific cost requests. Individual item costs are available in *Estimator* 2.2.
	Constructible Risk Contingency			**lump**	**0% - 50%**	**if needed as determined by estimating team** ** See Constructible Risk Contingency Cost page

APPENDIX F

SCI-823-0.00 - PID:77366
PORTSMOUTH BYPASS
ROCK EXCAVATION QUANTITIES

LOCATION 1 (234+00 & 239+00)
LEFT HAND SIDE - EXCAVATION ONLY

OPTION 1 - STA. 234+05.47

Station (Along SR823)	Area (sq.ft.)		Ave. Area (sq.ft.)		Length (ft)	Volume (cu.yd.)	
	1:1 Slope	0.5:1 Slope	1:1 Slope	0.5:1 Slope		1:1 Slope	0.5:1 Slope
230+00	289	-	-	-	-	-	-
230+50	1130	-	710	-	50	1314	-
231+00	2630	-	1880	-	50	3481	-
231+50	4697	-	3664	-	50	6784	-
232+00	7115	-	5906	-	50	10937	-
232+50	9805	-	8460	-	50	15667	-
233+00	12669	-	11237	-	50	20809	-
233+50	15642	-	14156	-	50	26214	-
234+00	18196	-	16919	-	50	31331	-
234+50	20288	-	19242	-	50	35633	-
235+00	22202	-	21796	-	50	40364	-
235+50	22899	-	22627	-	50	41902	-
236+00	22355	-	20870	-	50	38648	-
236+50	19385	-	16734	-	50	30989	-
237+00	14083	-	11714	-	50	21693	-
237+50	9345	-	7336	-	50	13585	-
238+00	5327	-	5327	-	50	9865	-
238+50	2585	-	2585	-	50	4787	-
239+00	771.0	-	1678	-	50	3107	-
					TOTAL =	357111	0

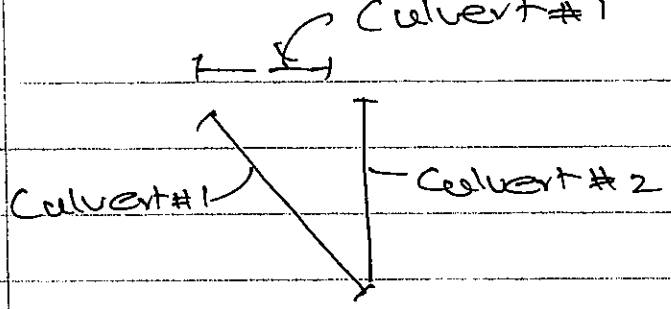
LOCATION 2 (297+50 & 300+89)
LEFT HAND SIDE - EXCAVATION ONLY

Station (Along SR823)	Area (sq.ft.)		Ave. Area (sq.ft.)		Length (ft)	Volume (cu.yd.)	
	1:1 Slope	0.5:1 Slope	1:1 Slope	0.5:1 Slope		1:1 Slope	0.5:1 Slope
291+50	219	-	-	-	-	-	-
292+00	951	-	585	-	50	1083	-
292+50	2435	-	1693	-	50	3135	-
293+00	4667	-	3551	-	50	6576	-
293+50	6462	-	5565	-	50	10305	-
294+00	8454	-	7458	-	50	13811	-
294+50	8965	-	8710	-	50	16129	-
295+00	9538	-	9252	-	50	17132	-
295+50	8006	-	8772	-	50	16244	-
296+00	4350	-	6178	-	50	11441	-
296+50	1545	-	2948	-	50	5458	-
297+00	140	-	843	-	50	1560	-
					TOTAL =	102875	0

EARTHWORK REQUIRED TO PLACE THE PIPE OR BOX CULVERT PARALLEL TO SR823 ON THE LEFTSIDE

BY RV

LOCATION 4



CULVERT #1	$8' \times 6'$	$8' \times 6'$
	L = 1116	L = 1940
	$ 1537600	$ 1295320
CULVERT 2	$9' \times 6'$	~~$8' \times 6'$~~ $8' \times 8'$
	L = 834'	L = 834
	$ 1207756	$ ~~1449252~~ 1297704
	$2745356	$ 2593024

Cost Saving = $ 152,332 on culvert

Difference in Excavation 16,563 cu·yd − 357,111 cu·y

= − 340,548 Cu·y

= −340,548 × $3.50

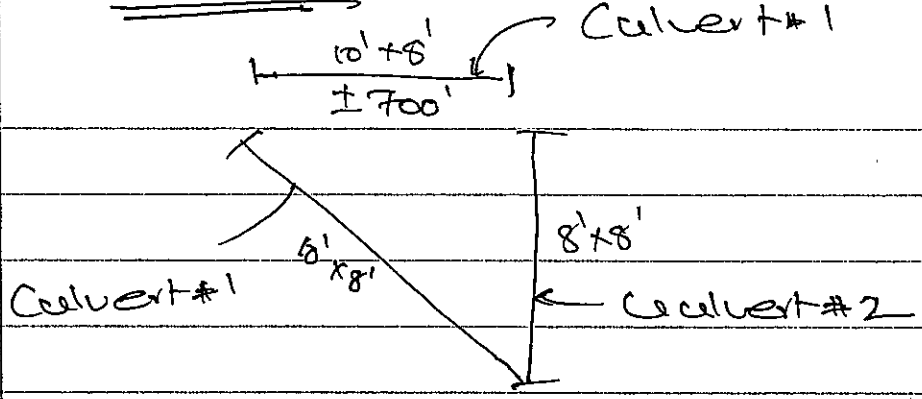
= $ 1,191,918

Approximately 1 $ 1M More

APPENDIX

By RN

LOCATION # 2



Culvert #1	10'x8'	10'x8'
	L=1502'	L = ±700'
	$ 25x7837	$ 1187200
Culvert #2	8'x8'	2-8'x8' or 12'x10'
	L= 1060'	L = 860'
	$ 1,648,889	$ 2676320
	$ 4196726	$ 3,863,520

Cost Savings on Culvert = 4196726 - 3,863,520

= $ 333,206

Difference in Excavation = 31507 - 102875

= $ 71,368 x $ 3.50

= - $ 249,788

Overall Savings = 333,206 - 249,788

= $ 83,418

APPENDIX G

HY-8 Calculations

HY-8 Culvert Analysis Reports

COMBINED 23+00 ± and 239+00 ±

HY-8 Culvert Analysis Report

IMPROVED INLET 8' x 6'

Table 1 - Summary of Culvert Flows at Crossing: 234+05_239+18_IMPINL

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
652.25	0.00	0.00	0.00	1
653.81	57.50	57.50	0.00	1
654.75	115.00	115.00	0.00	1
655.60	172.50	172.50	0.00	1
656.38	230.00	230.00	0.00	1
657.10	287.50	287.50	0.00	1
657.76	345.00	345.00	0.00	1
658.40	402.50	402.50	0.00	1
659.01	460.00	460.00	0.00	1
659.27	484.00	484.00	0.00	1
660.22	575.00	575.00	0.00	1

Rating Curve Plot for Crossing: 234+05_239+18_IMPINL

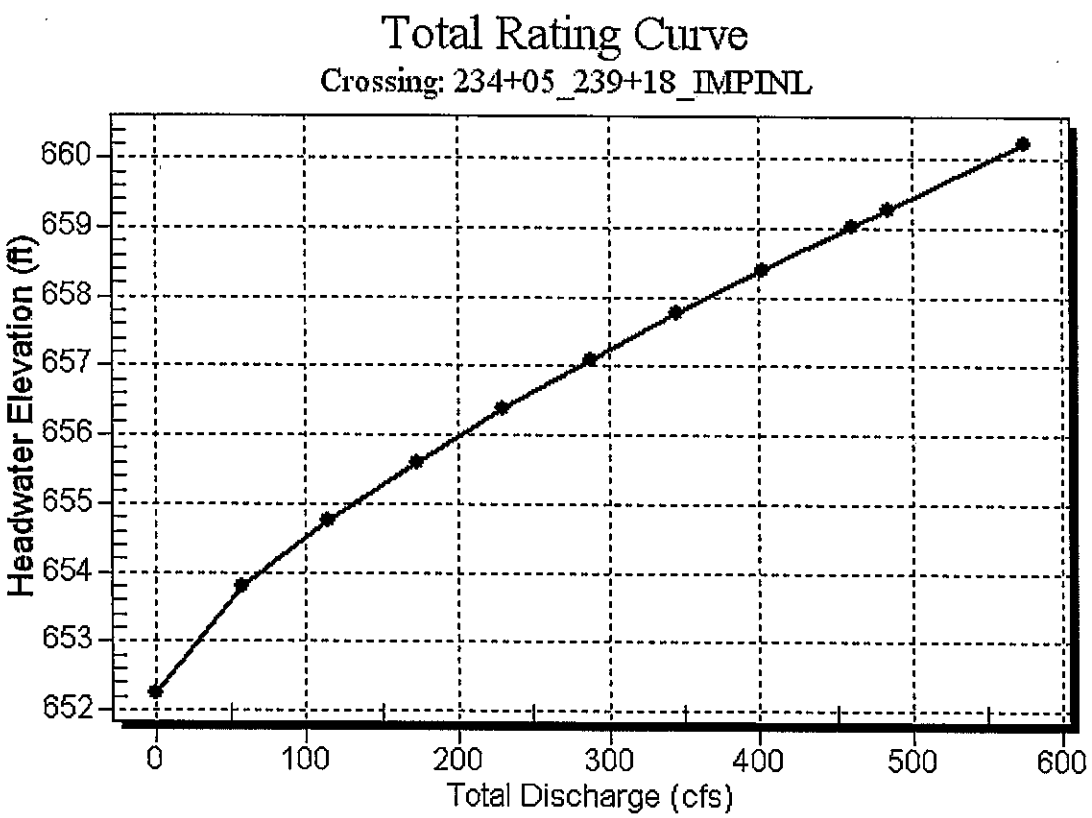


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	652.25	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
57.50	57.50	653.81	1.557	1.557	1-S2n	0.666	1.173	0.672	0.994	10.693	4.450
115.00	115.00	654.75	2.501	2.501	1-S2n	1.043	1.862	1.052	1.550	13.661	5.707
172.50	172.50	655.60	3.353	3.353	1-S2n	1.375	2.440	1.380	2.023	15.622	6.559
230.00	230.00	656.38	4.130	4.130	1-S2n	1.675	2.956	1.676	2.451	17.152	7.219
287.50	287.50	657.10	4.846	4.846	1-S2n	1.955	3.430	1.962	2.851	18.313	7.756
345.00	345.00	657.76	5.514	5.514	1-S2n	2.220	3.874	2.228	3.232	19.358	8.211
402.50	402.50	658.40	6.150	6.150	5-S2n	2.479	4.293	2.483	3.599	20.263	8.602
460.00	460.00	659.01	6.763	6.763	5-S2n	2.724	4.693	2.732	3.953	21.049	8.951
484.00	484.00	659.27	7.015	7.015	5-S2n	2.826	4.855	2.866	4.098	21.113	9.085
575.00	575.00	660.22	7.970	7.970	5-S2n	3.203	5.445	3.258	4.636	22.058	9.541

****

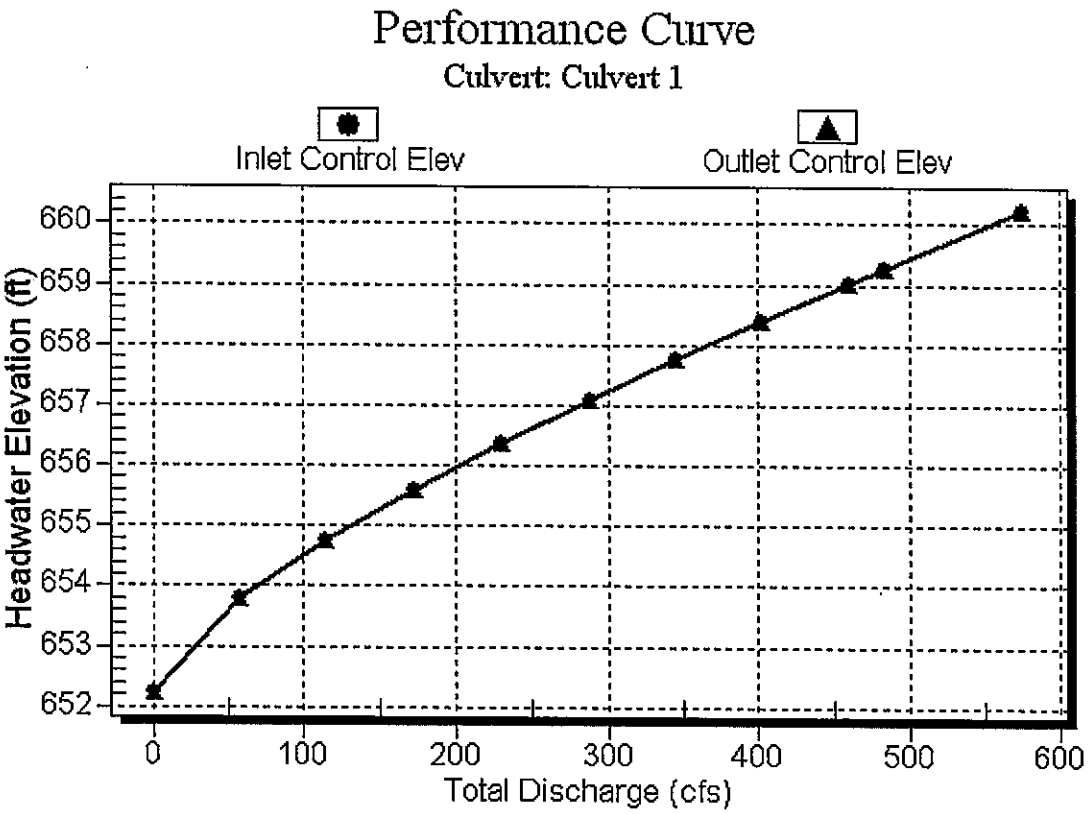
Inlet Elevation (invert): 652.25 ft, Outlet Elevation (invert): 639.63 ft

Culvert Length: 816.10 ft, Culvert Slope: 0.0151

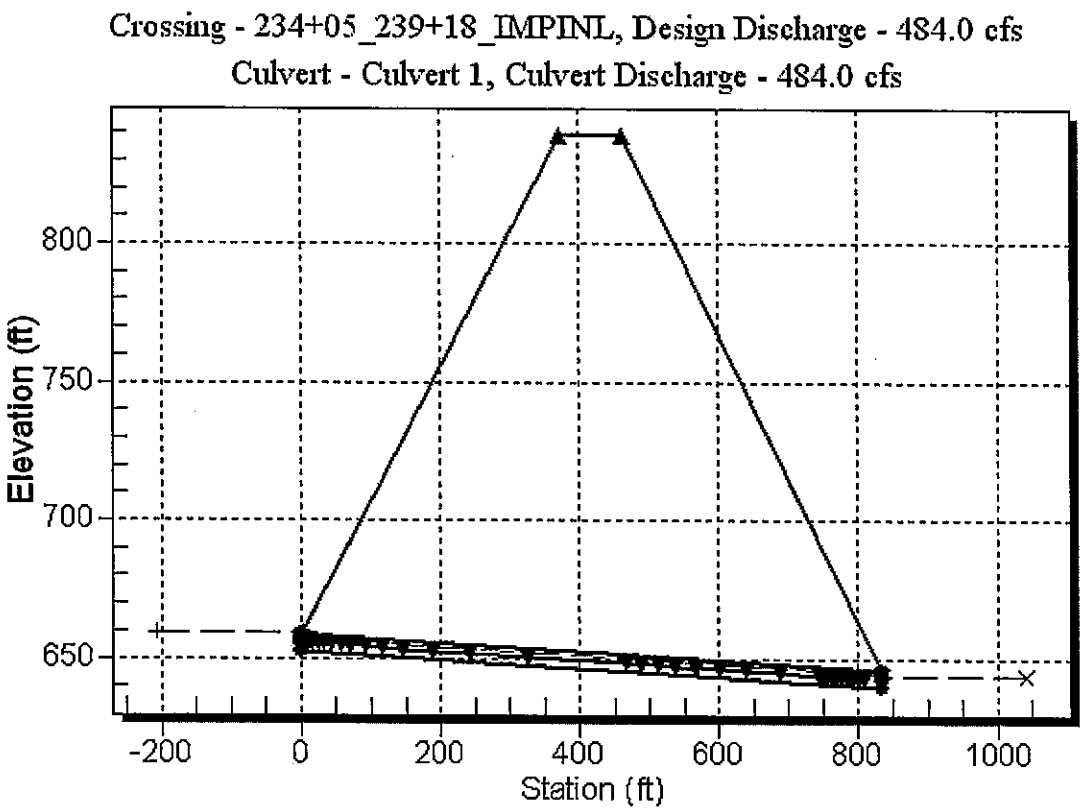
Inlet Throat Elevation: 651.98 ft, Inlet Crest Elevation: 0.00 ft

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 652.25 ft

Outlet Station: 834.00 ft

Outlet Elevation: 639.63 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Side-Tapered

Inlet Edge Condition: Square Edge Top (26-90° Wingwall)

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 234+05_239+18_IMPINL)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	639.63	0.00	0.00	0.00	0.00
57.50	640.62	0.99	4.45	1.09	0.79
115.00	641.18	1.55	5.71	1.69	0.81
172.50	641.65	2.02	6.56	2.21	0.81
230.00	642.08	2.45	7.22	2.68	0.81
287.50	642.48	2.85	7.76	3.11	0.81
345.00	642.86	3.23	8.21	3.53	0.80
402.50	643.23	3.60	8.60	3.93	0.80
460.00	643.58	3.95	8.95	4.32	0.79
484.00	643.73	4.10	9.08	4.48	0.79
575.00	644.27	4.64	9.54	5.06	0.78

Tailwater Channel Data - 234+05_239+18_IMPINL

Tailwater Channel Option: Rectangular Channel

Bottom Width: 13.00 ft

Channel Slope: 0.0175

Channel Manning's n: 0.0400

Channel Invert Elevation: 639.63 ft

Roadway Data for Crossing: 234+05_239+18_IMPINL

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 838.62 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

COMBINED 297+56± and 300+89±

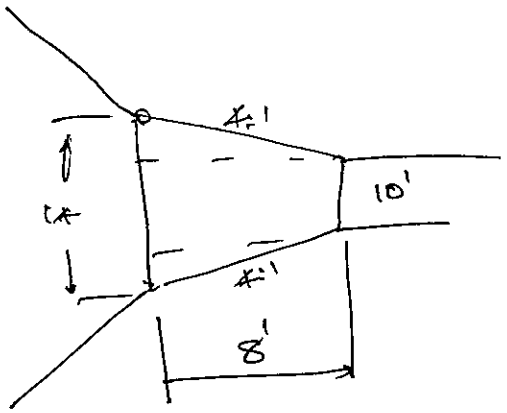
HY-8 Culvert Analysis Report

~~CONVENTIONAL~~
IMPROVED INLET

SLOPE TAPERED WITH 2' FALL

SIZE 10' x 8'

~~FACE~~ WIDTH = 14'



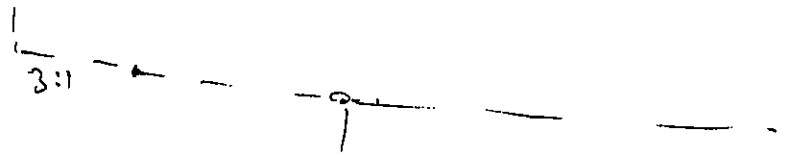


Table 1 - Summary of Culvert Flows at Crossing: 297+56_300+89_IMPINL

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
565.62	0.00	0.00	0.00	1
567.65	114.50	114.50	0.00	1
568.84	229.00	229.00	0.00	1
569.84	343.50	343.50	0.00	1
570.73	458.00	458.00	0.00	1
571.55	572.50	572.50	0.00	1
572.32	687.00	687.00	0.00	1
573.05	801.50	801.50	0.00	1
573.74	916.00	916.00	0.00	1
574.08	969.00	969.00	0.00	1
575.40	1145.00	1145.00	0.00	1

Allowable Head = 565.62 + 8 + 2

= 575.62

HW_{50} = 574.08 < 575.62

HW_{100} = 575.40 < 575.62 OK

10' x 8' IMPROVED INLET ISOK

Rating Curve Plot for Crossing: 297+56_300+89_IMPINL

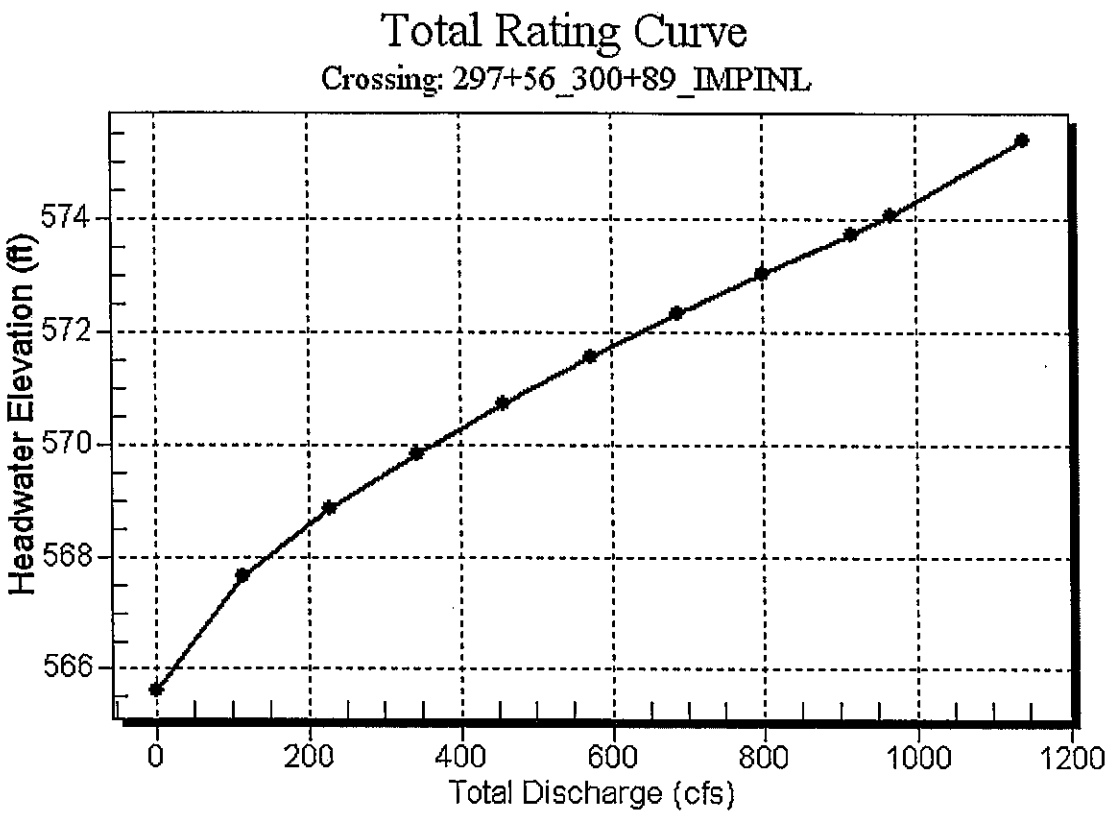


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	565.62	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
114.50	114.50	567.65	2.030	2.030	1-S2n	0.980	1.600	0.990	1.010	11.563	7.550
229.00	229.00	568.84	3.222	0.000	1-S2n	1.578	2.540	1.579	1.507	14.501	9.491
343.50	343.50	569.84	4.222	0.000	1-S2n	2.061	3.329	2.069	1.896	16.605	10.792
458.00	458.00	570.73	5.114	0.000	1-S2n	2.524	4.032	2.531	2.225	18.093	11.797
572.50	572.50	571.55	5.935	0.000	1-S2n	2.948	4.679	2.969	2.517	19.282	12.611
687.00	687.00	572.32	6.702	0.000	1-S2n	3.360	5.284	3.374	2.781	20.363	13.312
801.50	801.50	573.05	7.427	0.000	1-S2n	3.753	5.856	3.799	3.023	21.099	13.922
916.00	916.00	573.74	8.119	0.000	5-S2n	4.140	6.401	4.141	3.247	22.121	14.474
969.00	969.00	574.08	8.458	0.000	5-S2n	4.313	6.645	4.377	3.345	22.136	14.711
1145.00	1145.00	575.40	9.781	0.000	5-S2n	4.885	7.428	4.968	3.655	23.049	15.426

****

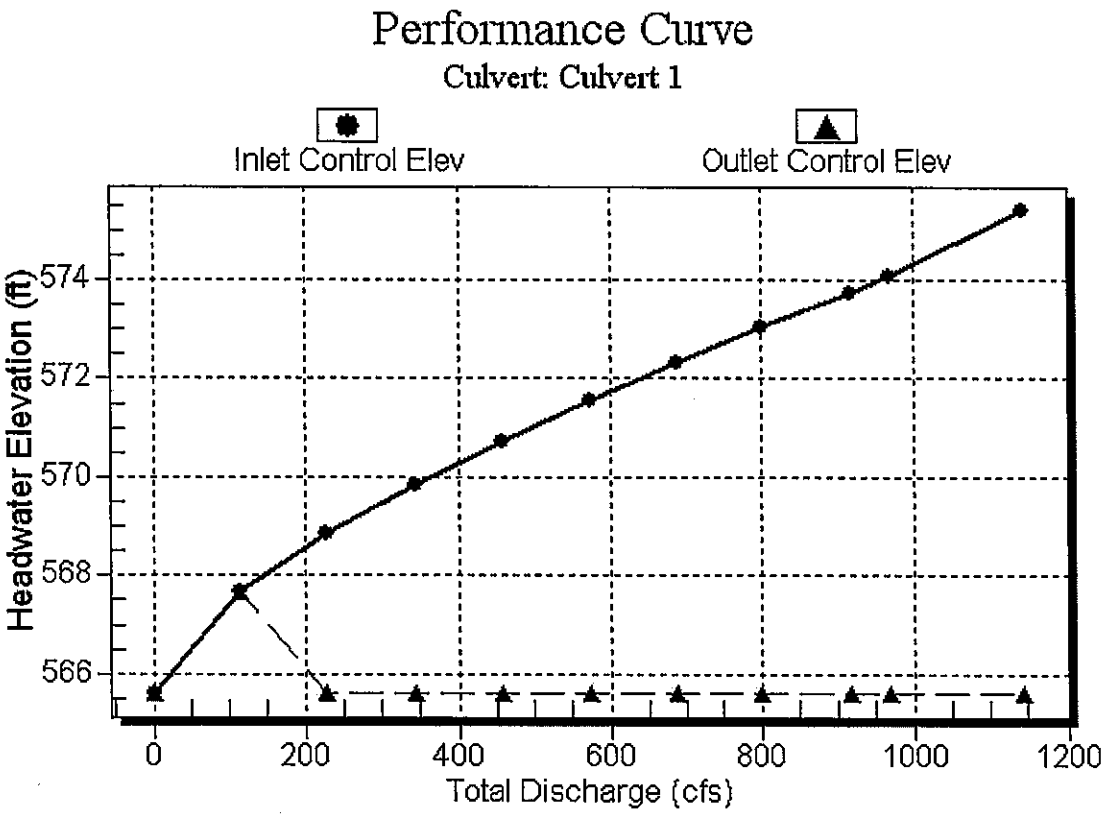
Inlet Elevation (invert): 565.62 ft, Outlet Elevation (invert): 554.52 ft

Culvert Length: 1040.06 ft, Culvert Slope: 0.0107

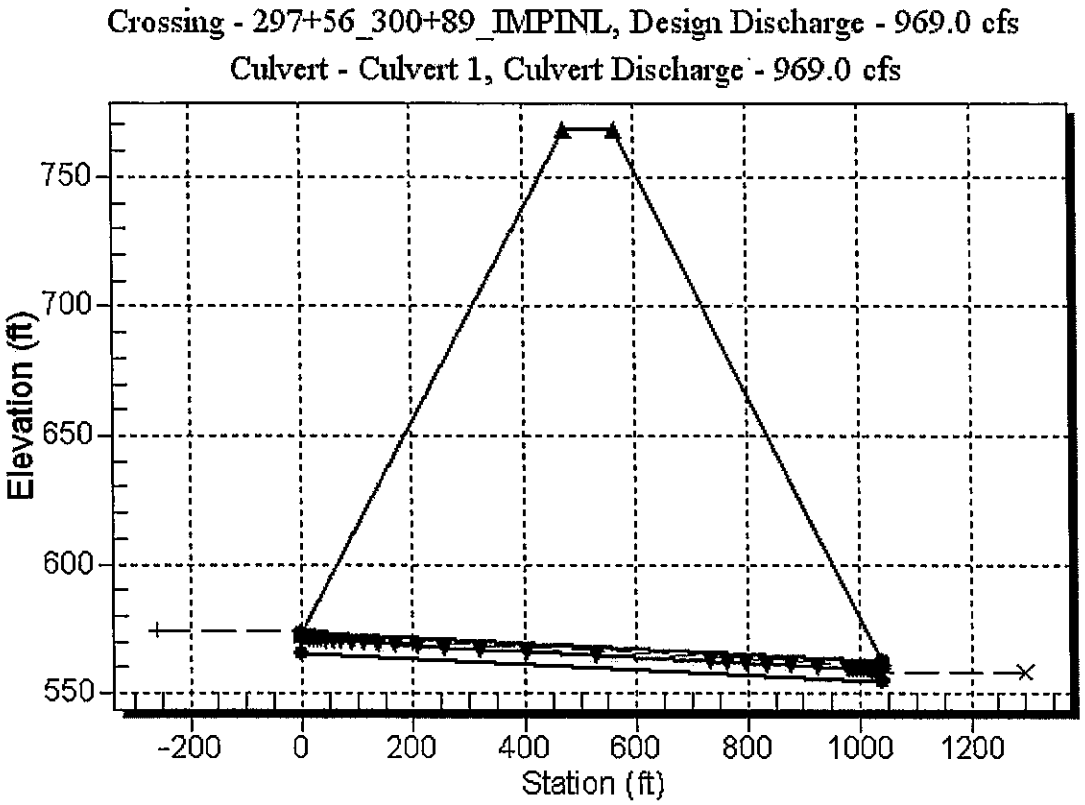
Inlet Throat Elevation: 563.62 ft, Inlet Crest Elevation: 565.62 ft

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 565.62 ft

Outlet Station: 1040.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 8.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Slope-Tapered

Inlet Edge Condition: Square Edge Top (26-90° Wingwall)

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 297+56_300+89_IMPINL)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
114.50	555.53	1.01	7.55	3.15	1.41
229.00	556.03	1.51	9.49	4.70	1.49
343.50	556.42	1.90	10.79	5.91	1.53
458.00	556.74	2.22	11.80	6.94	1.56
572.50	557.04	2.52	12.61	7.85	1.58
687.00	557.30	2.78	13.31	8.68	1.60
801.50	557.54	3.02	13.92	9.43	1.62
916.00	557.77	3.25	14.47	10.13	1.63
969.00	557.87	3.35	14.71	10.44	1.64
1145.00	558.17	3.65	15.43	11.40	1.66

Tailwater Channel Data - 297+56_300+89_IMPINL

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 297+56_300+89_IMPINL

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 768.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 234+05.47

6' x 6' BOX CULVERT

APPENDIX E

Table 1 - Summary of Culvert Flows at Crossing: 234+05.47

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
684.40	0.00	0.00	0.00	1
685.18	13.04	13.04	0.00	1
685.64	26.08	26.08	0.00	1
686.02	39.12	39.12	0.00	1
686.37	52.16	52.16	0.00	1
686.68	65.20	65.20	0.00	1
686.98	78.24	78.24	0.00	1
687.26	91.28	91.28	0.00	1
687.53	104.32	104.32	0.00	1
687.62	108.60	108.60	0.00	1
688.06	130.40	130.40	0.00	1

Size 6' x 6'

Allowable head = 6 + 2 + 684.40

= 692.40

HWE_{50} = 687.62 < 692.40 OK 6' x 6' Culvert

HWE_{100} = 688.06 < 692.40 OK 6' x 6' Culvert

Rating Curve Plot for Crossing: 234+05.47

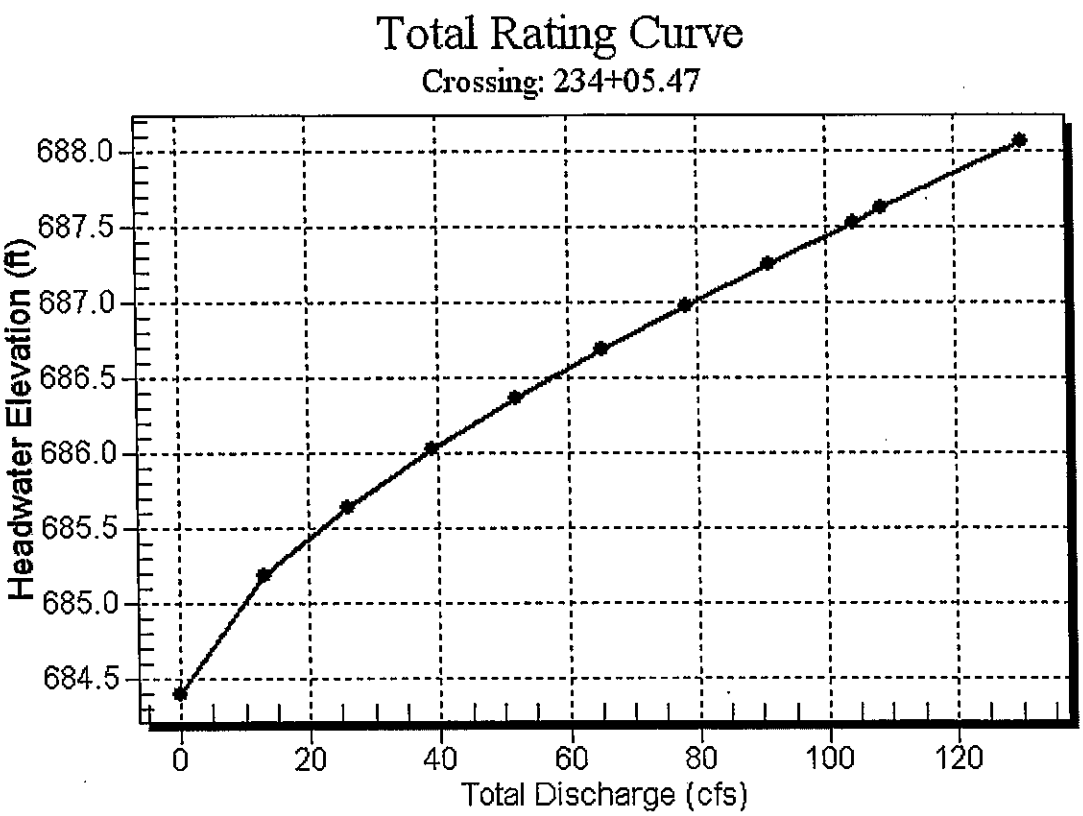


Table 2 - Culvert Summary Table: Culvert 1

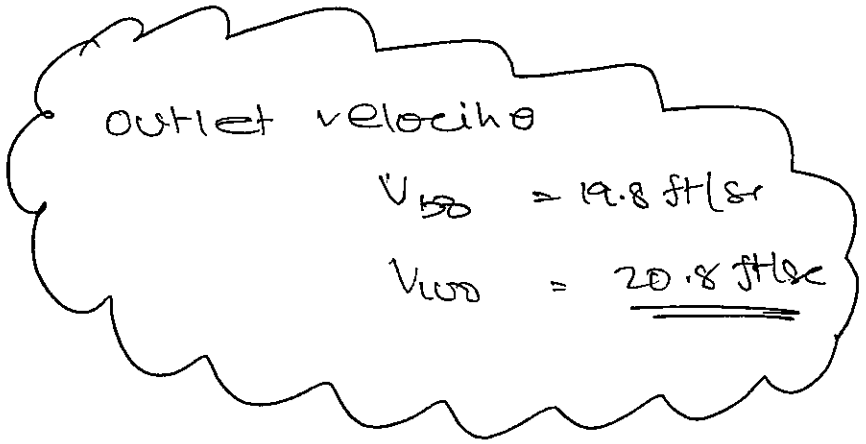
Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	684.40	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
13.04	13.04	685.18	0.782	0.782	1-S2n	0.139	0.529	0.219	0.383	9.946	2.474
26.08	26.08	685.64	1.239	1.239	1-S2n	0.278	0.839	0.329	0.577	13.213	3.191
39.12	39.12	686.02	1.623	1.623	1-S2n	0.416	1.099	0.489	0.733	13.323	3.690
52.16	52.16	686.37	1.966	1.966	1-S2n	0.555	1.332	0.562	0.867	15.474	4.086
65.20	65.20	686.68	2.281	2.281	1-S2n	0.650	1.545	0.654	0.988	16.605	4.407
78.24	78.24	686.98	2.576	2.576	1-S2n	0.725	1.745	0.735	1.098	17.738	4.688
91.28	91.28	687.26	2.855	2.855	1-S2n	0.799	1.934	0.824	1.201	18.462	4.936
104.32	104.32	687.53	3.131	3.131	1-S2n	0.874	2.114	0.904	1.297	19.231	5.159
108.60	108.60	687.62	3.221	3.221	1-S2n	0.898	2.172	0.912	1.327	19.857	5.230
130.40	130.40	688.06	3.661	3.661	1-S2n	1.023	2.453	1.043	1.474	20.834	5.547

****

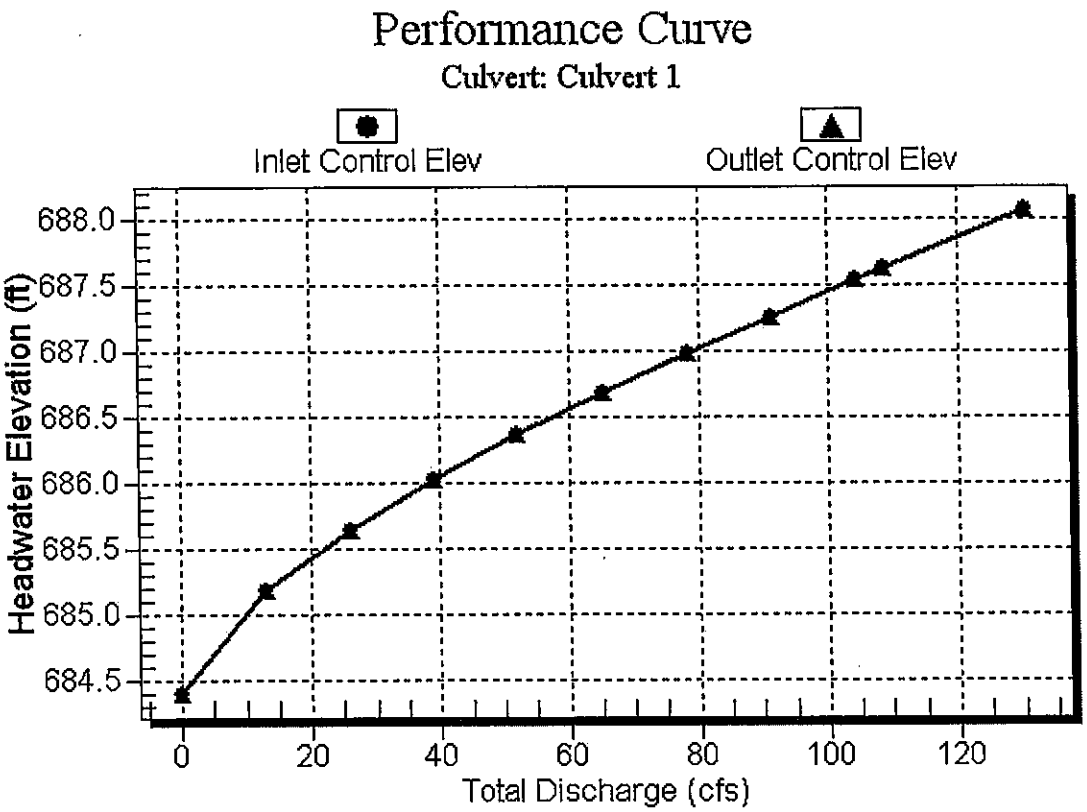
Inlet Elevation (invert): 684.40 ft, Outlet Elevation (invert): 639.63 ft

Culvert Length: 1116.90 ft, Culvert Slope: 0.0401

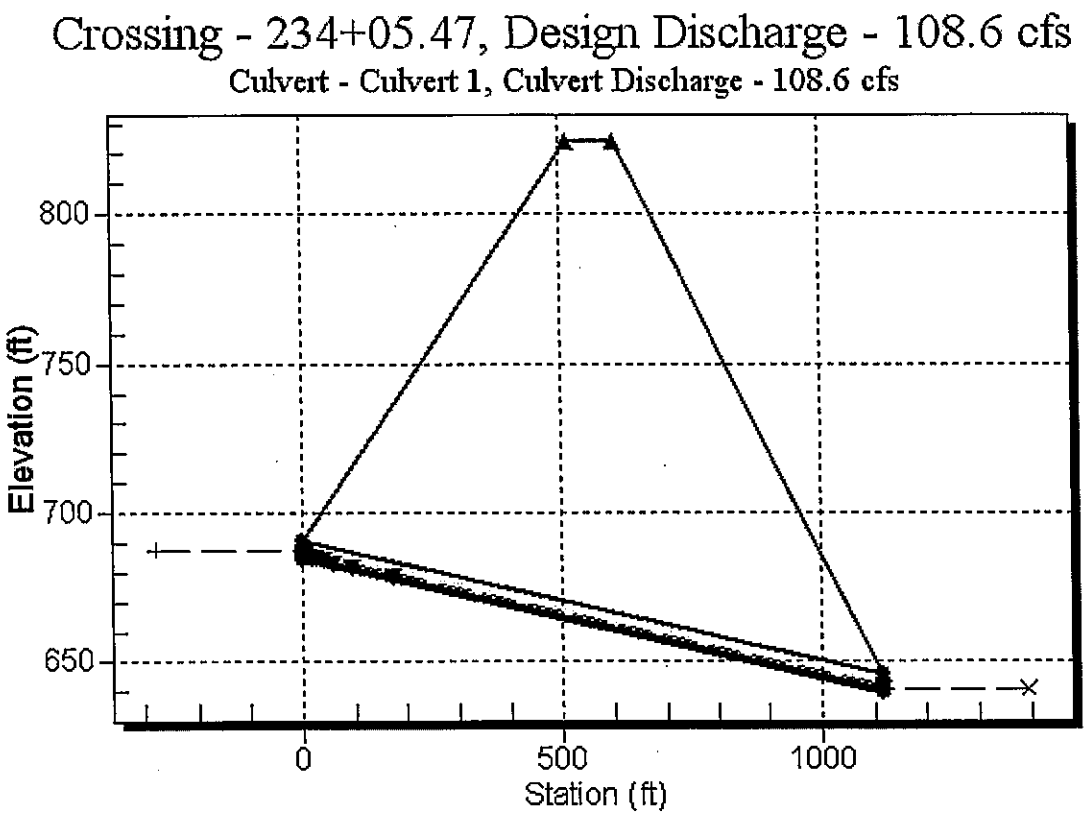
****



Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 684.40 ft

Outlet Station: 1116.00 ft

Outlet Elevation: 639.63 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 6.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (30-75° flare) Wingwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 234+05.47)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	639.63	0.00	0.00	0.00	0.00
13.04	640.01	0.38	2.47	0.42	0.72
26.08	640.21	0.58	3.19	0.63	0.77
39.12	640.36	0.73	3.69	0.80	0.80
52.16	640.50	0.87	4.09	0.95	0.82
65.20	640.62	0.99	4.41	1.08	0.83
78.24	640.73	1.10	4.69	1.20	0.84
91.28	640.83	1.20	4.94	1.31	0.85
104.32	640.93	1.30	5.16	1.42	0.86
108.60	640.96	1.33	5.23	1.45	0.87
130.40	641.10	1.47	5.55	1.61	0.88

Tailwater Channel Data - 234+05.47

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0175

Channel Manning's n: 0.0400

Channel Invert Elevation: 639.63 ft

Roadway Data for Crossing: 234+05.47

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 824.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 234+05.47

8' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 234+05.47_option1

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
684.40	0.00	0.00	0.00	1
685.06	13.04	13.04	0.00	1
685.42	26.08	26.08	0.00	1
685.74	39.12	39.12	0.00	1
686.02	52.16	52.16	0.00	1
686.28	65.20	65.20	0.00	1
686.53	78.24	78.24	0.00	1
686.76	91.28	91.28	0.00	1
686.98	104.32	104.32	0.00	1
687.05	108.60	108.60	0.00	1
687.39	130.40	130.40	0.00	1

Size 8' x 6'

Allowable Head = 6 + 2 + 684.40

= 692.40

HWE_{50} = 687.05 < 692.40 OK

HWE_{100} = 687.39 < 692.40 OK

Rating Curve Plot for Crossing: 234+05.47_option1

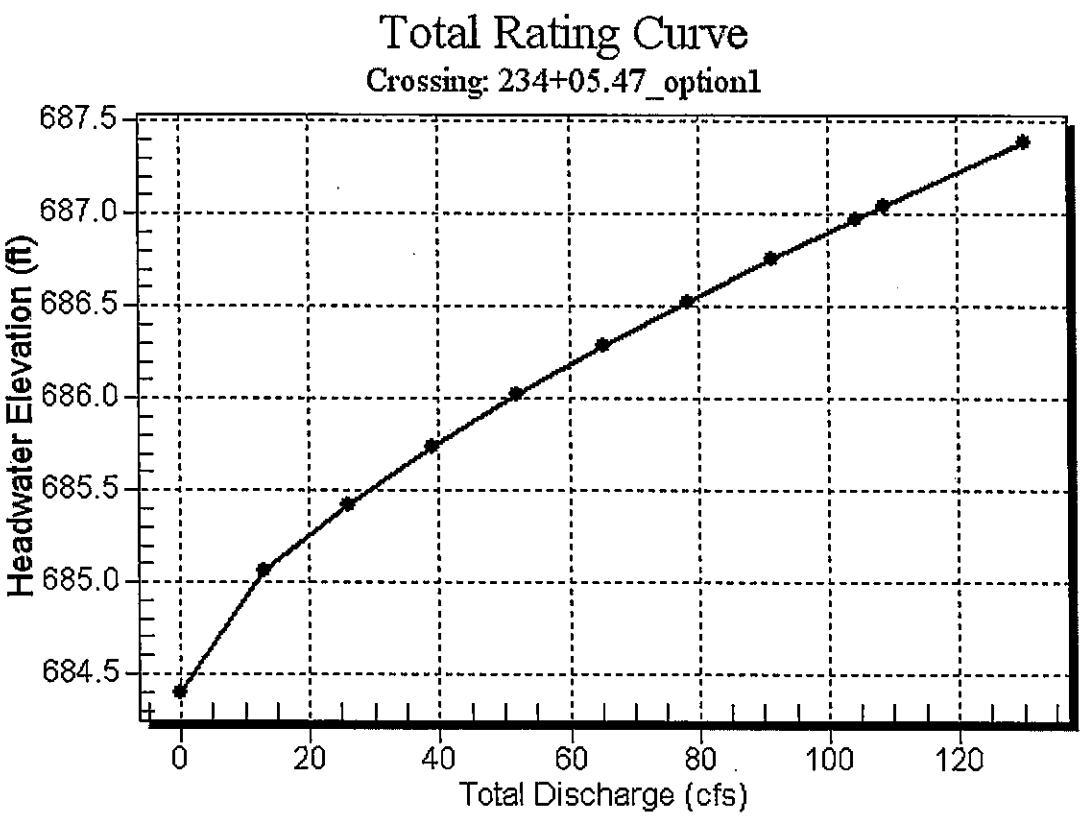


Table 2 - Culvert Summary Table: Culvert 1

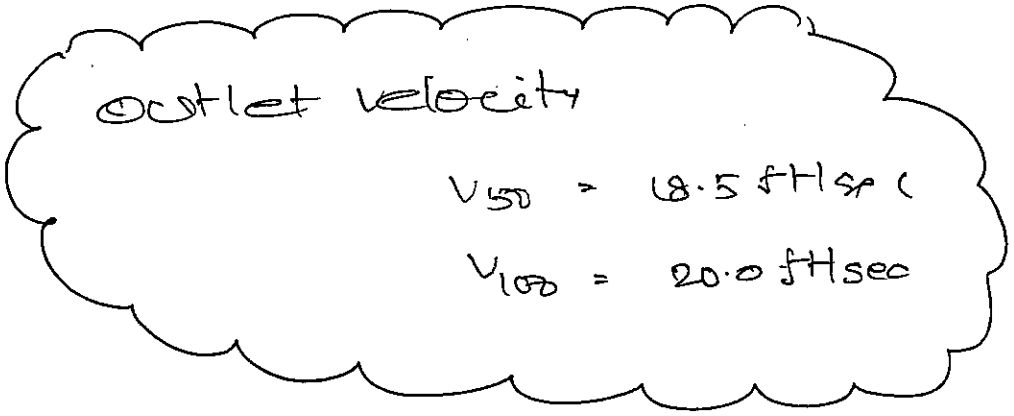
Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	684.40	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
13.04	13.04	685.06	0.659	0.659	1-S2n	0.101	0.436	0.186	0.383	8.750	2.474
26.08	26.08	685.42	1.022	1.022	1-S2n	0.202	0.693	0.283	0.577	11.537	3.191
39.12	39.12	685.74	1.340	1.340	1-S2n	0.304	0.908	0.308	0.733	15.902	3.690
52.16	52.16	686.02	1.623	1.623	1-S2n	0.405	1.099	0.489	0.867	13.323	4.086
65.20	65.20	686.28	1.883	1.883	1-S2n	0.506	1.276	0.566	0.988	14.407	4.407
78.24	78.24	686.53	2.126	2.126	1-S2n	0.604	1.441	0.605	1.098	16.177	4.688
91.28	91.28	686.76	2.357	2.357	1-S2n	0.656	1.596	0.656	1.201	17.380	4.936
104.32	104.32	686.98	2.576	2.576	1-S2n	0.709	1.745	0.735	1.297	17.738	5.159
108.60	108.60	687.05	2.646	2.646	1-S2n	0.726	1.793	0.733	1.327	18.531	5.230
130.40	130.40	687.39	2.989	2.989	1-S2n	0.814	2.025	0.815	1.474	19.999	5.547

****

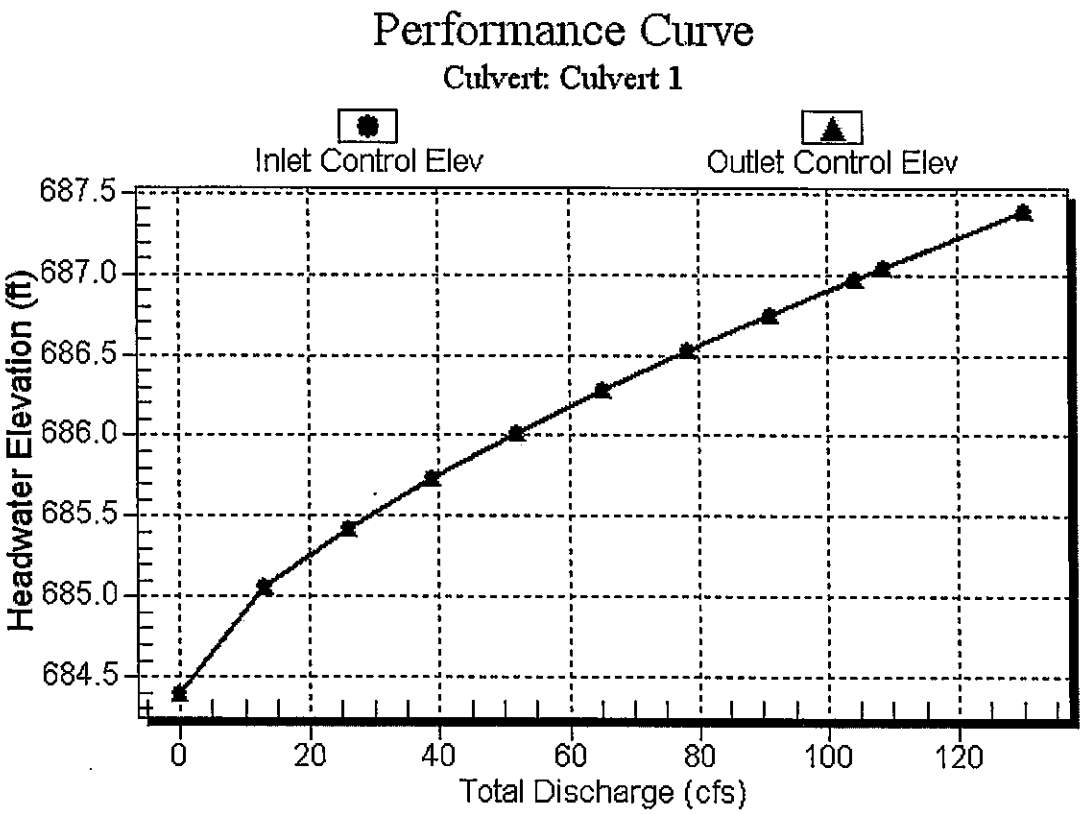
Inlet Elevation (invert): 684.40 ft, Outlet Elevation (invert): 639.63 ft

Culvert Length: 1116.90 ft, Culvert Slope: 0.0401

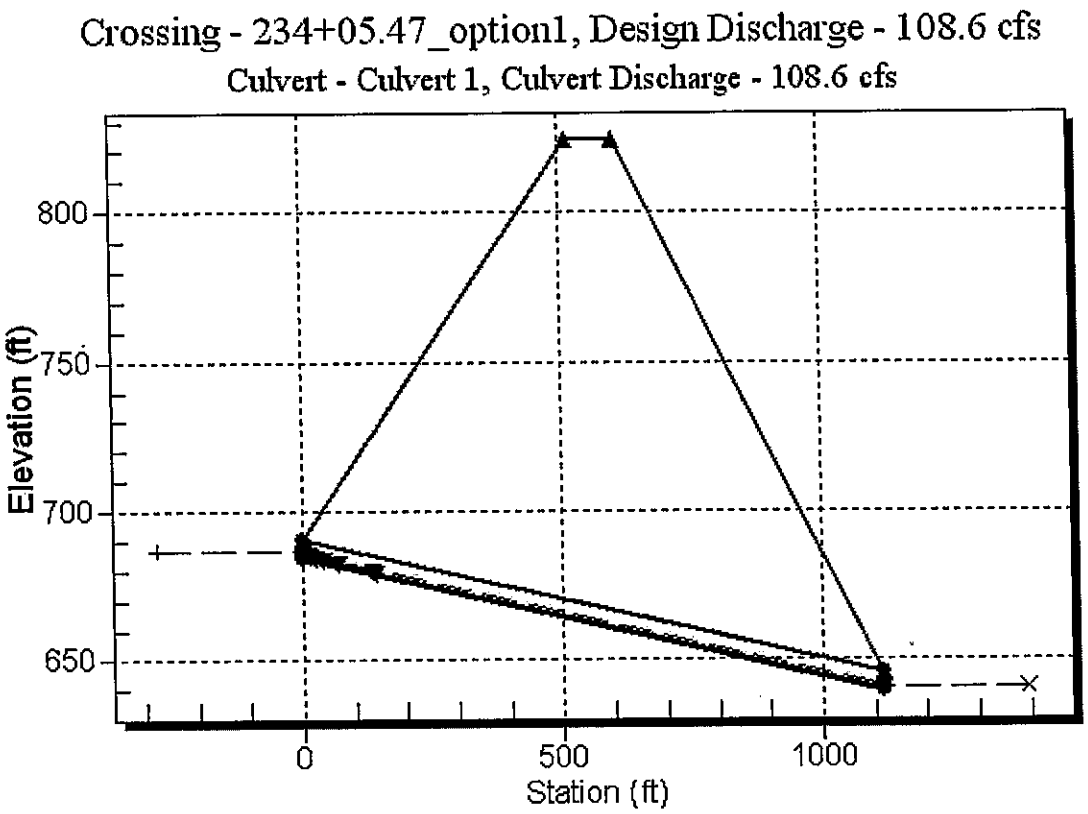
****



Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 684.40 ft

Outlet Station: 1116.00 ft

Outlet Elevation: 639.63 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (30-75° flare) Wingwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 234+05.47_option1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	639.63	0.00	0.00	0.00	0.00
13.04	640.01	0.38	2.47	0.42	0.72
26.08	640.21	0.58	3.19	0.63	0.77
39.12	640.36	0.73	3.69	0.80	0.80
52.16	640.50	0.87	4.09	0.95	0.82
65.20	640.62	0.99	4.41	1.08	0.83
78.24	640.73	1.10	4.69	1.20	0.84
91.28	640.83	1.20	4.94	1.31	0.85
104.32	640.93	1.30	5.16	1.42	0.86
108.60	640.96	1.33	5.23	1.45	0.87
130.40	641.10	1.47	5.55	1.61	0.88

Tailwater Channel Data - 234+05.47_option1

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0175

Channel Manning's n: 0.0400

Channel Invert Elevation: 639.63 ft

Roadway Data for Crossing: 234+05.47_option1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 824.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 239+18.19

6' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 239+18.19

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
652.25	0.00	0.00	0.00	1
654.06	44.50	44.50	0.00	1
655.13	89.00	89.00	0.00	1
656.05	133.50	133.50	0.00	1
656.86	178.00	178.00	0.00	1
657.63	222.50	222.50	0.00	1
658.39	267.00	267.00	0.00	1
659.19	311.50	311.50	0.00	1
660.06	356.00	356.00	0.00	1
660.46	375.00	375.00	0.00	1
662.09	445.00	445.00	0.00	1

SIZE 6' x 6'

Allowable Head = 6 + 2 + 652.25

= 660.25

HW_{50} = 660.46 > 660.25 } Increase Hx Size.

HW_{100} = 662.09 > 660.25 }

Rating Curve Plot for Crossing: 239+18.19

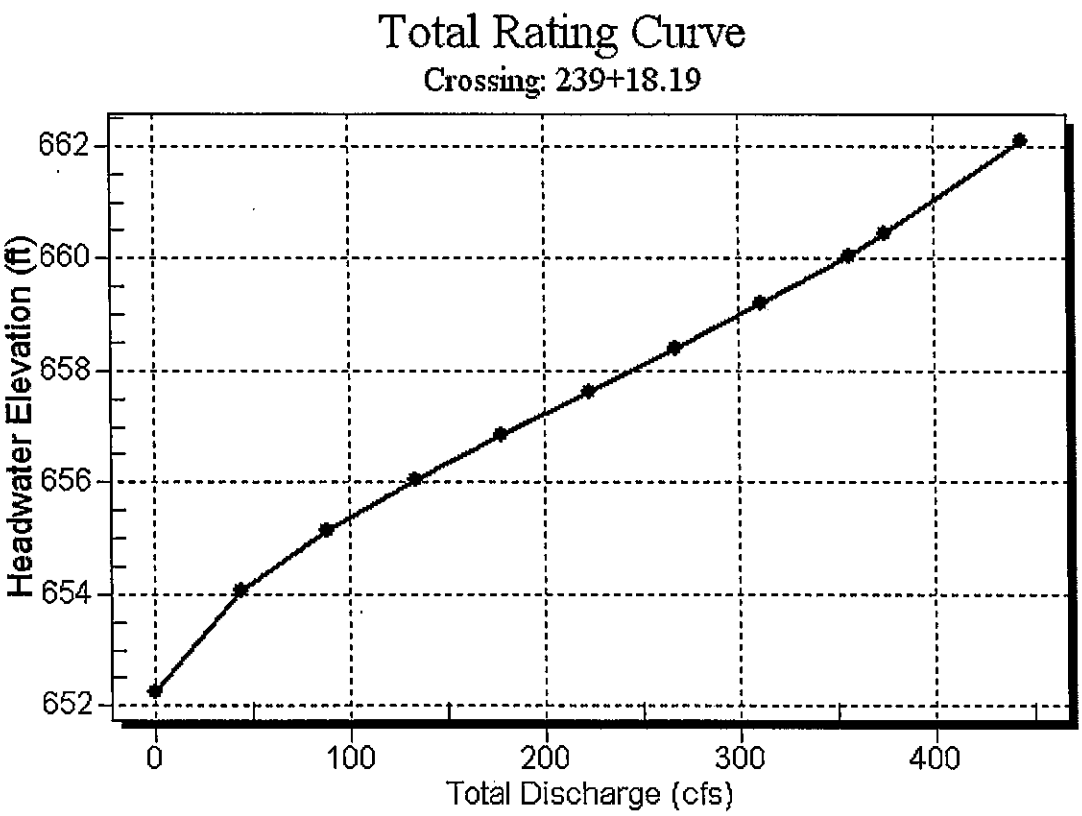


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	652.25	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
44.50	44.50	654.06	1.811	1.811	1-S2n	0.692	1.198	0.697	0.790	10.641	3.863
89.00	89.00	655.13	2.875	2.875	1-S2n	1.106	1.902	1.112	1.183	13.343	4.897
133.50	133.50	656.05	3.797	3.797	1-S2n	1.460	2.492	1.482	1.494	15.015	5.589
178.00	178.00	656.86	4.612	0.000	1-S2n	1.798	3.019	1.798	1.759	16.502	6.125
222.50	222.50	657.63	5.377	0.000	1-S2n	2.101	3.503	2.102	1.994	17.643	6.570
267.00	267.00	658.39	6.139	0.000	5-S2n	2.405	3.956	2.406	2.206	18.499	6.949
311.50	311.50	659.19	6.939	0.000	5-S2n	2.689	4.384	2.697	2.404	19.250	7.277
356.00	356.00	660.06	7.808	0.000	5-S2n	2.974	4.792	2.982	2.587	19.898	7.573
375.00	375.00	660.46	8.206	0.000	5-S2n	3.092	4.961	3.100	2.661	20.162	7.693
445.00	445.00	662.09	9.839	0.000	5-S2n	3.521	5.561	3.530	2.920	21.013	8.089

****

Inlet Elevation (invert): 652.25 ft, Outlet Elevation (invert): 639.63 ft

Culvert Length: 834.10 ft, Culvert Slope: 0.0151

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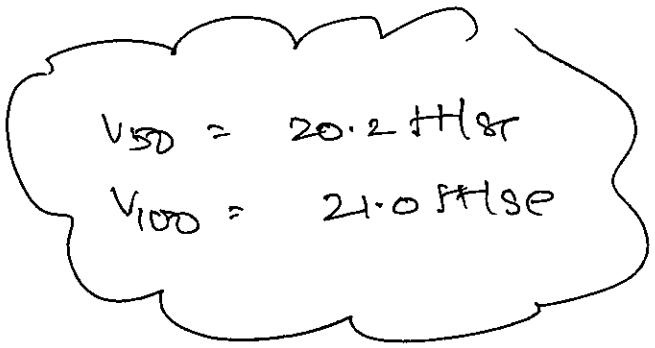
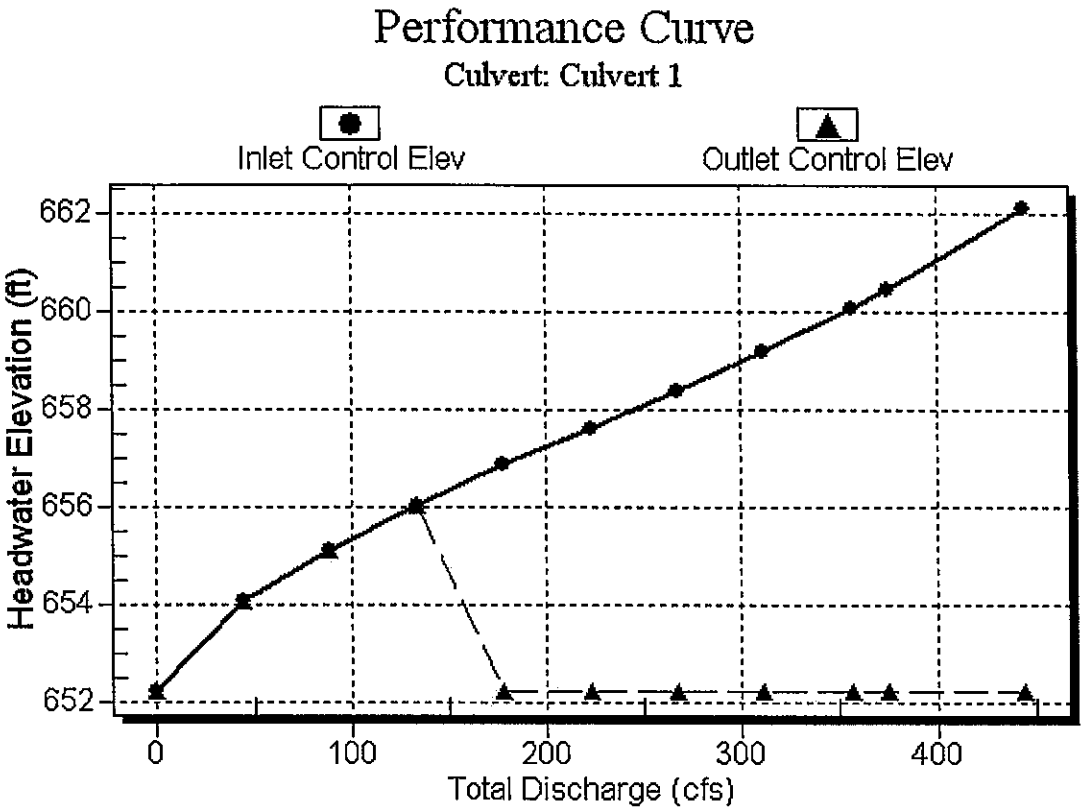
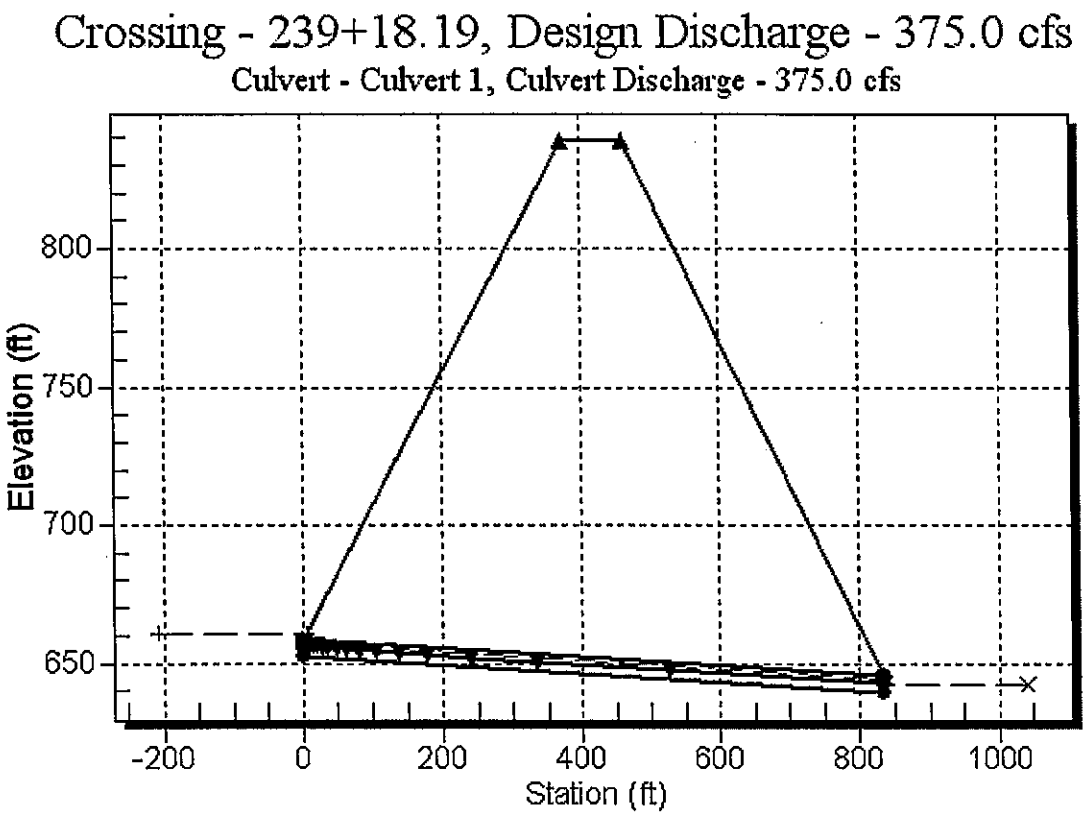


Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 652.25 ft

Outlet Station: 834.00 ft

Outlet Elevation: 639.63 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 6.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (30-75° flare) Wingwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 239+18.19)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	639.63	0.00	0.00	0.00	0.00
44.50	640.42	0.79	3.86	0.86	0.81
89.00	640.81	1.18	4.90	1.29	0.85
133.50	641.12	1.49	5.59	1.63	0.88
178.00	641.39	1.76	6.12	1.92	0.90
222.50	641.62	1.99	6.57	2.18	0.91
267.00	641.84	2.21	6.95	2.41	0.92
311.50	642.03	2.40	7.28	2.62	0.93
356.00	642.22	2.59	7.57	2.82	0.94
375.00	642.29	2.66	7.69	2.91	0.94
445.00	642.55	2.92	8.09	3.19	0.95

Tailwater Channel Data - 239+18.19

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0175

Channel Manning's n: 0.0400

Channel Invert Elevation: 639.63 ft

Roadway Data for Crossing: 239+18.19

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 838.62 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 239+18.19

7' x 6' BOX CULVERT

OPTION 4

Table 1 - Summary of Culvert Flows at Crossing: 239+18.19_OPTION 1

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
652.25	0.00	0.00	0.00	1
653.89	44.50	44.50	0.00	1
654.84	89.00	89.00	0.00	1
655.67	133.50	133.50	0.00	1
656.41	178.00	178.00	0.00	1
657.08	222.50	222.50	0.00	1
657.73	267.00	267.00	0.00	1
658.39	311.50	311.50	0.00	1
659.07	356.00	356.00	0.00	1
659.38	375.00	375.00	0.00	1
660.59	445.00	445.00	0.00	1

SIZE 7' x 6'

Allowable Head = 6 + 2 + 652.25

= 660.25

HWE_{50} = 659.38 < 660.25 OK

HWE_{100} = 660.59 > 660.25 NOT OK

Increase the SIZE.

Rating Curve Plot for Crossing: 239+18.19_OPTION 1

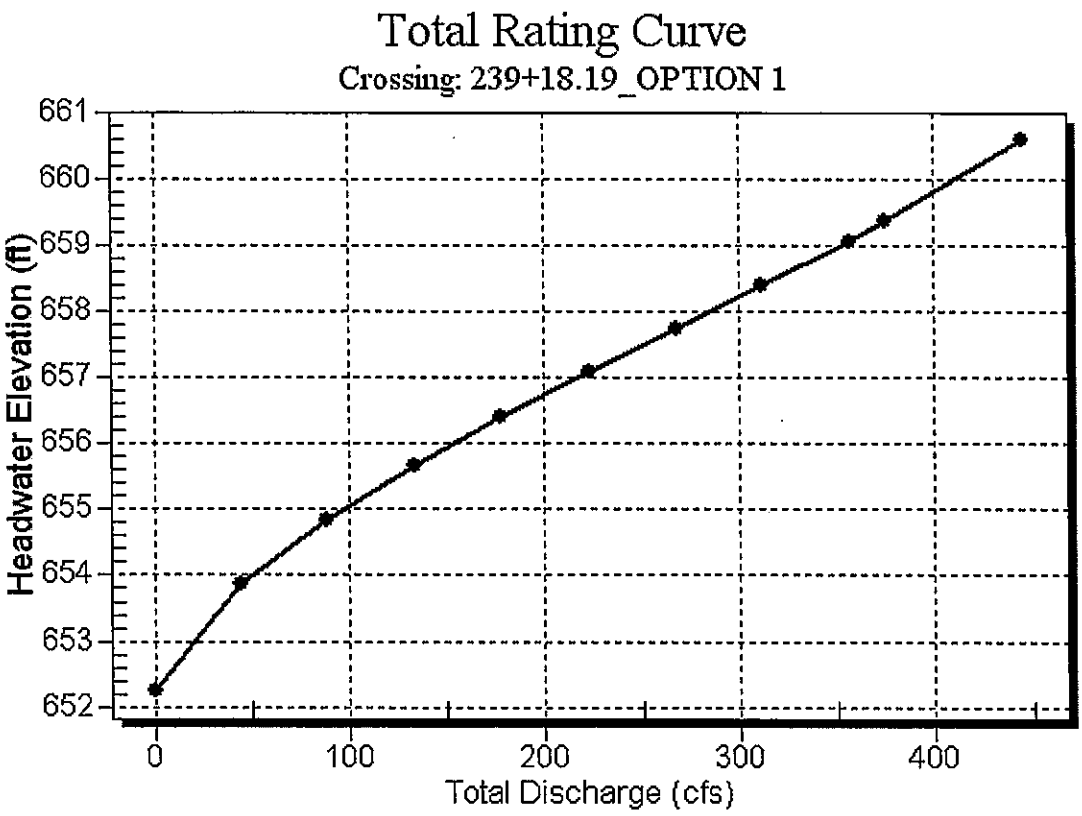


Table 2 - Culvert Summary Table: Culvert 1

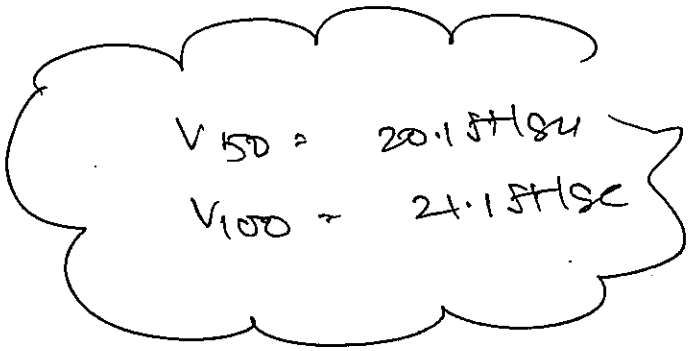
Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	652.25	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
44.50	44.50	653.89	1.635	1.635	1-S2n	0.627	1.081	0.630	0.790	10.091	3.863
89.00	89.00	654.84	2.594	2.594	1-S2n	0.969	1.716	1.006	1.183	12.639	4.897
133.50	133.50	655.67	3.417	3.417	1-S2n	1.290	2.249	1.298	1.494	14.698	5.589
178.00	178.00	656.41	4.156	4.156	1-S2n	1.566	2.724	1.577	1.759	16.126	6.125
222.50	222.50	657.08	4.834	4.834	1-S2n	1.837	3.161	1.840	1.994	17.277	6.570
267.00	267.00	657.73	5.485	5.485	1-S2n	2.083	3.569	2.088	2.206	18.265	6.949
311.50	311.50	658.39	6.139	6.139	5-S2n	2.328	3.956	2.335	2.404	19.061	7.277
356.00	356.00	659.07	6.821	6.821	5-S2n	2.562	4.324	2.569	2.587	19.800	7.573
375.00	375.00	659.38	7.126	7.126	5-S2n	2.659	4.476	2.666	2.661	20.091	7.693
445.00	445.00	660.59	8.344	0.000	5-S2n	3.018	5.017	3.021	2.920	21.040	8.089

****

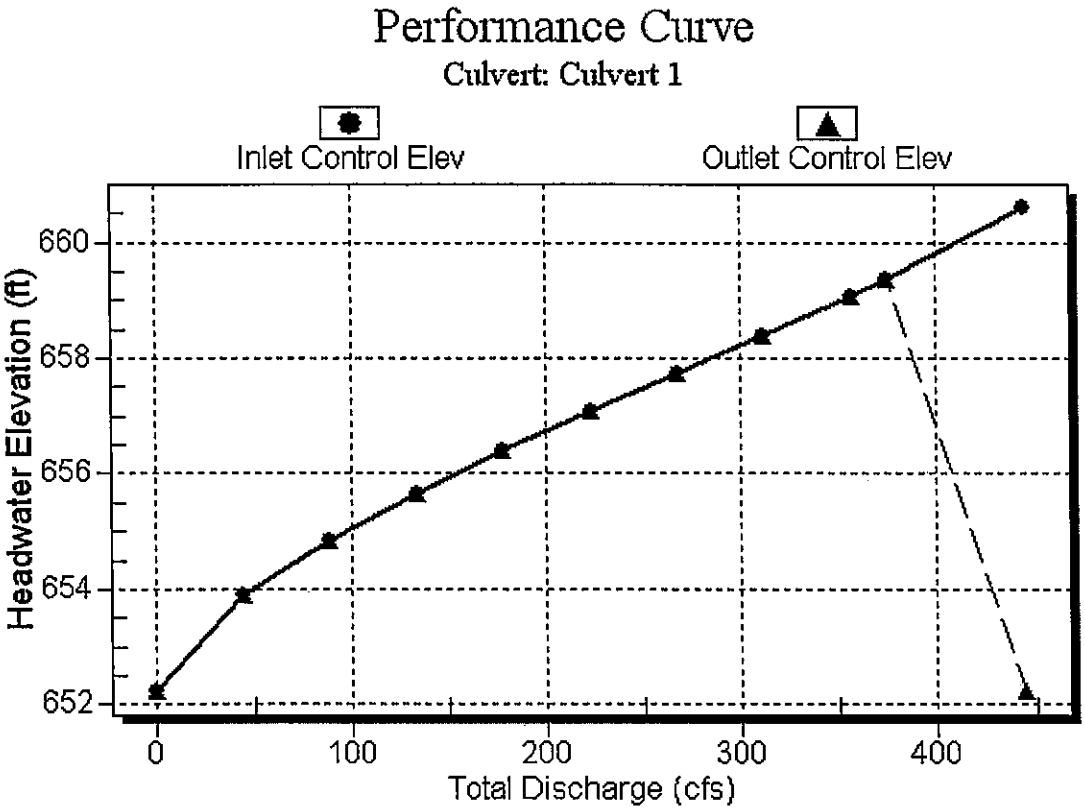
Inlet Elevation (invert): 652.25 ft, Outlet Elevation (invert): 639.63 ft

Culvert Length: 834.10 ft, Culvert Slope: 0.0151

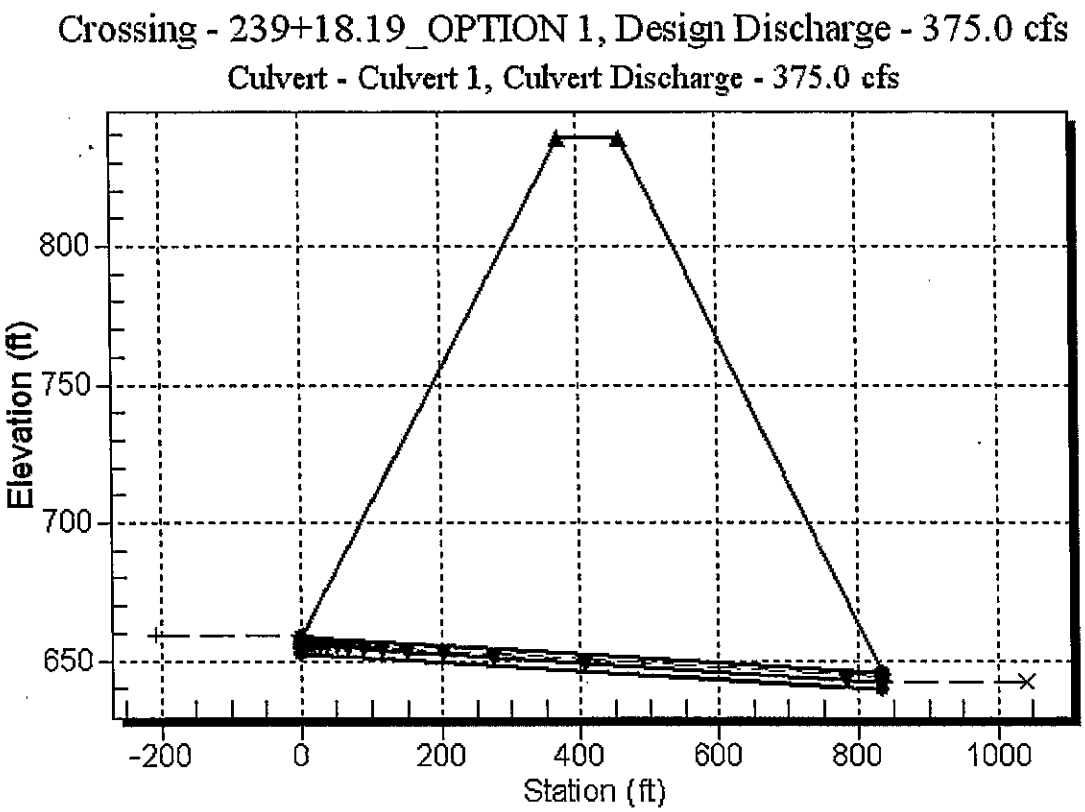
****



Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 652.25 ft

Outlet Station: 834.00 ft

Outlet Elevation: 639.63 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 7.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (30-75° flare) Wingwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 239+18.19_OPTION 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	639.63	0.00	0.00	0.00	0.00
44.50	640.42	0.79	3.86	0.86	0.81
89.00	640.81	1.18	4.90	1.29	0.85
133.50	641.12	1.49	5.59	1.63	0.88
178.00	641.39	1.76	6.12	1.92	0.90
222.50	641.62	1.99	6.57	2.18	0.91
267.00	641.84	2.21	6.95	2.41	0.92
311.50	642.03	2.40	7.28	2.62	0.93
356.00	642.22	2.59	7.57	2.82	0.94
375.00	642.29	2.66	7.69	2.91	0.94
445.00	642.55	2.92	8.09	3.19	0.95

Tailwater Channel Data - 239+18.19_OPTION 1

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0175

Channel Manning's n: 0.0400

Channel Invert Elevation: 639.63 ft

Roadway Data for Crossing: 239+18.19_OPTION 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 838.62 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 239+18.19

8' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 239+18.19_8'X6'

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
652.25	0.00	0.00	0.00	1
653.75	44.50	44.50	0.00	1
654.62	89.00	89.00	0.00	1
655.37	133.50	133.50	0.00	1
656.05	178.00	178.00	0.00	1
656.67	222.50	222.50	0.00	1
657.25	267.00	267.00	0.00	1
657.82	311.50	311.50	0.00	1
658.39	356.00	356.00	0.00	1
658.64	375.00	375.00	0.00	1
659.61	445.00	445.00	0.00	1

Size $8' \times 6'$

Allowable Head $= 6 + 2 + 652.25$

$= 660.25$

$HWE_{50} = 658.64 < 660.25$

$HWE_{100} = 659.61 < 660.25$

Ok

Rating Curve Plot for Crossing: 239+18.19_8'X6'

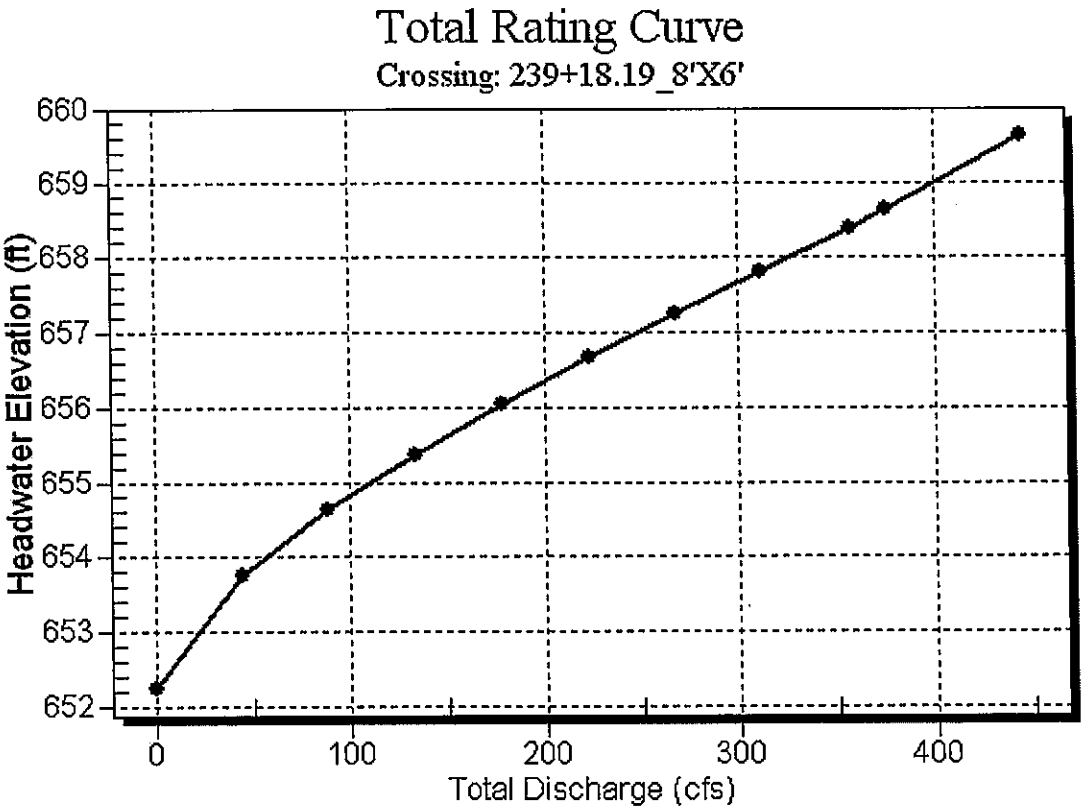


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	652.25	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
44.50	44.50	653.75	1.497	1.497	1-S2n	0.562	0.989	0.579	0.790	9.609	3.863
89.00	89.00	654.62	2.374	2.374	1-S2n	0.872	1.570	0.890	1.183	12.503	4.897
133.50	133.50	655.37	3.116	3.116	1-S2n	1.164	2.057	1.166	1.494	14.312	5.589
178.00	178.00	656.05	3.797	3.797	1-S2n	1.404	2.492	1.416	1.759	15.714	6.125
222.50	222.50	656.67	4.415	4.415	1-S2n	1.636	2.892	1.642	1.994	16.942	6.570
267.00	267.00	657.25	4.998	4.998	1-S2n	1.860	3.265	1.864	2.206	17.902	6.949
311.50	311.50	657.82	5.566	5.566	1-S2n	2.066	3.619	2.069	2.404	18.822	7.277
356.00	356.00	658.39	6.139	6.139	5-S2n	2.271	3.956	2.278	2.587	19.532	7.573
375.00	375.00	658.64	6.390	6.390	5-S2n	2.358	4.095	2.364	2.661	19.827	7.693
445.00	445.00	659.61	7.363	7.363	5-S2n	2.660	4.590	2.660	2.920	20.911	8.089

****

Inlet Elevation (invert): 652.25 ft, Outlet Elevation (invert): 639.63 ft

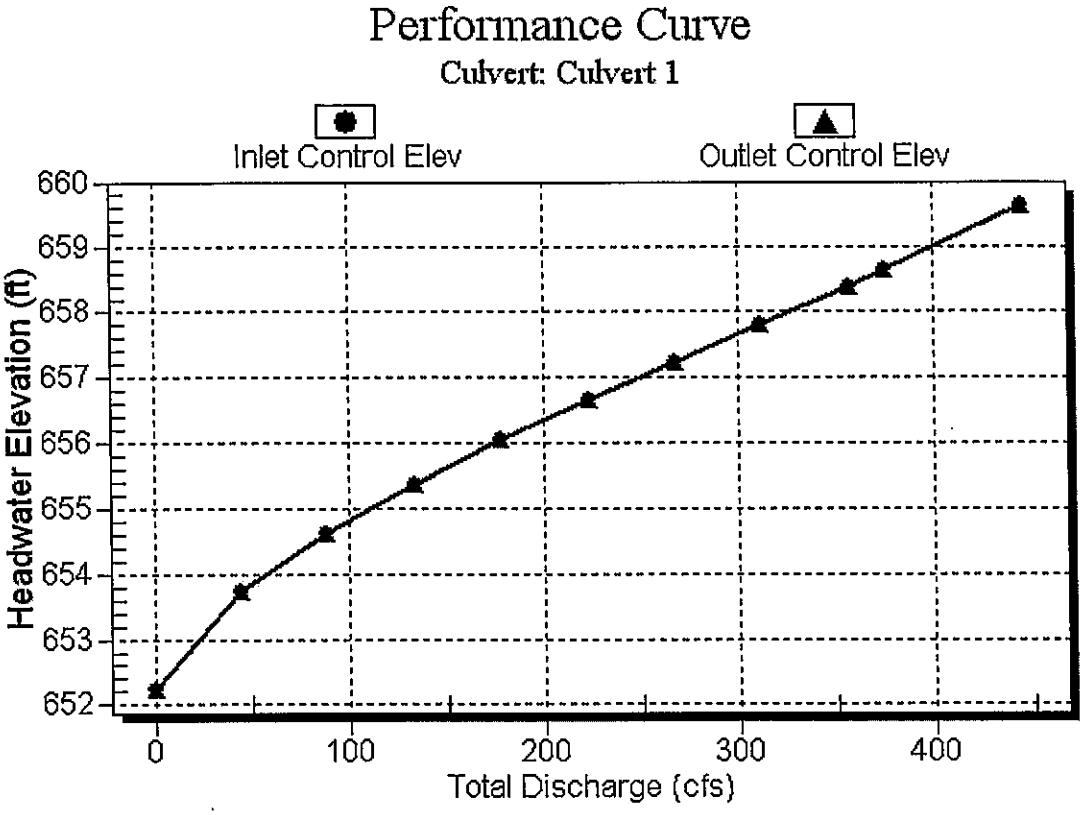
Culvert Length: 834.10 ft, Culvert Slope: 0.0151

****

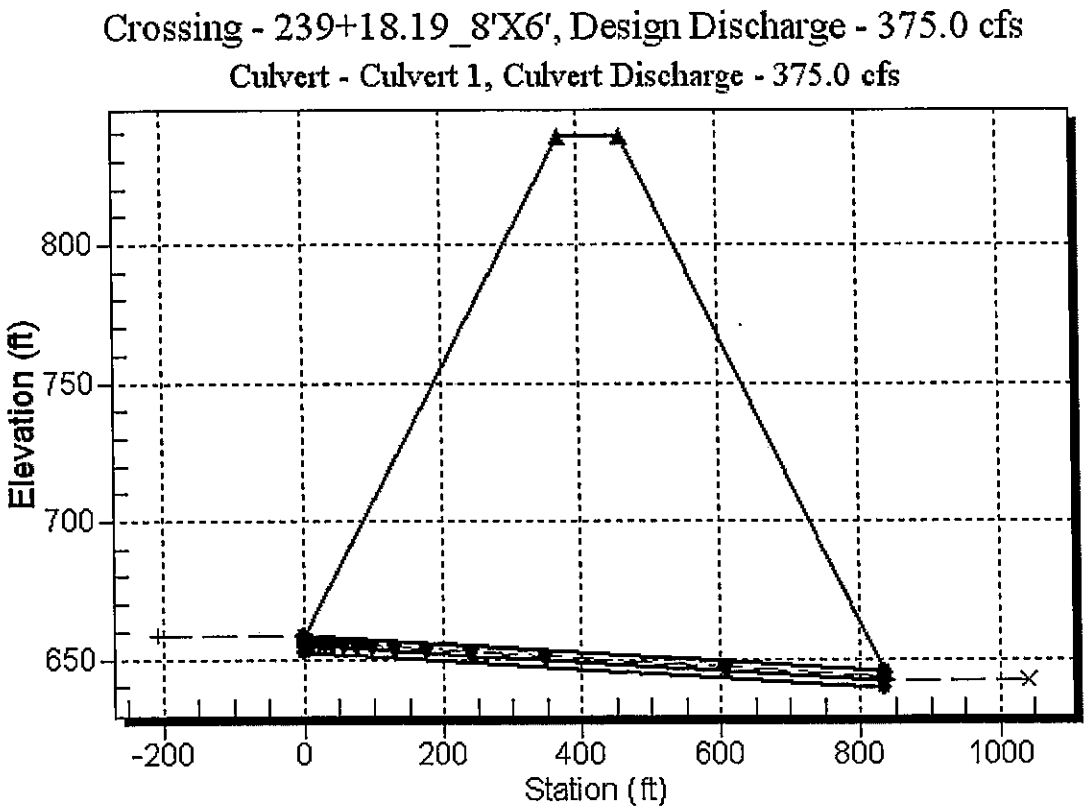
$V_{50} = 19.8$ ft/s

$V_{100} = 20.9$ ft/sec

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 652.25 ft

Outlet Station: 834.00 ft

Outlet Elevation: 639.63 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (30-75° flare) Wingwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 239+18.19_8'X6')

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	639.63	0.00	0.00	0.00	0.00
44.50	640.42	0.79	3.86	0.86	0.81
89.00	640.81	1.18	4.90	1.29	0.85
133.50	641.12	1.49	5.59	1.63	0.88
178.00	641.39	1.76	6.12	1.92	0.90
222.50	641.62	1.99	6.57	2.18	0.91
267.00	641.84	2.21	6.95	2.41	0.92
311.50	642.03	2.40	7.28	2.62	0.93
356.00	642.22	2.59	7.57	2.82	0.94
375.00	642.29	2.66	7.69	2.91	0.94
445.00	642.55	2.92	8.09	3.19	0.95

Tailwater Channel Data - 239+18.19_8'X6'

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0175

Channel Manning's n: 0.0400

Channel Invert Elevation: 639.63 ft

Roadway Data for Crossing: 239+18.19_8'X6'

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 838.62 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 239+18.19

9' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 239+18.19_9'X6'

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
652.25	0.00	0.00	0.00	1
653.63	44.50	44.50	0.00	1
654.44	89.00	89.00	0.00	1
655.13	133.50	133.50	0.00	1
655.75	178.00	178.00	0.00	1
656.33	222.50	222.50	0.00	1
656.86	267.00	267.00	0.00	1
657.37	311.50	311.50	0.00	1
657.88	356.00	356.00	0.00	1
658.10	375.00	375.00	0.00	1
658.92	445.00	445.00	0.00	1

Size 9'x6'

Allowable Head = 6+2+652.25

= 660.25

HWE 30 = 658.10 < 660.25

HWE 100 = 658.92 < 660.25

OK

Rating Curve Plot for Crossing: 239+18.19_9'X6'

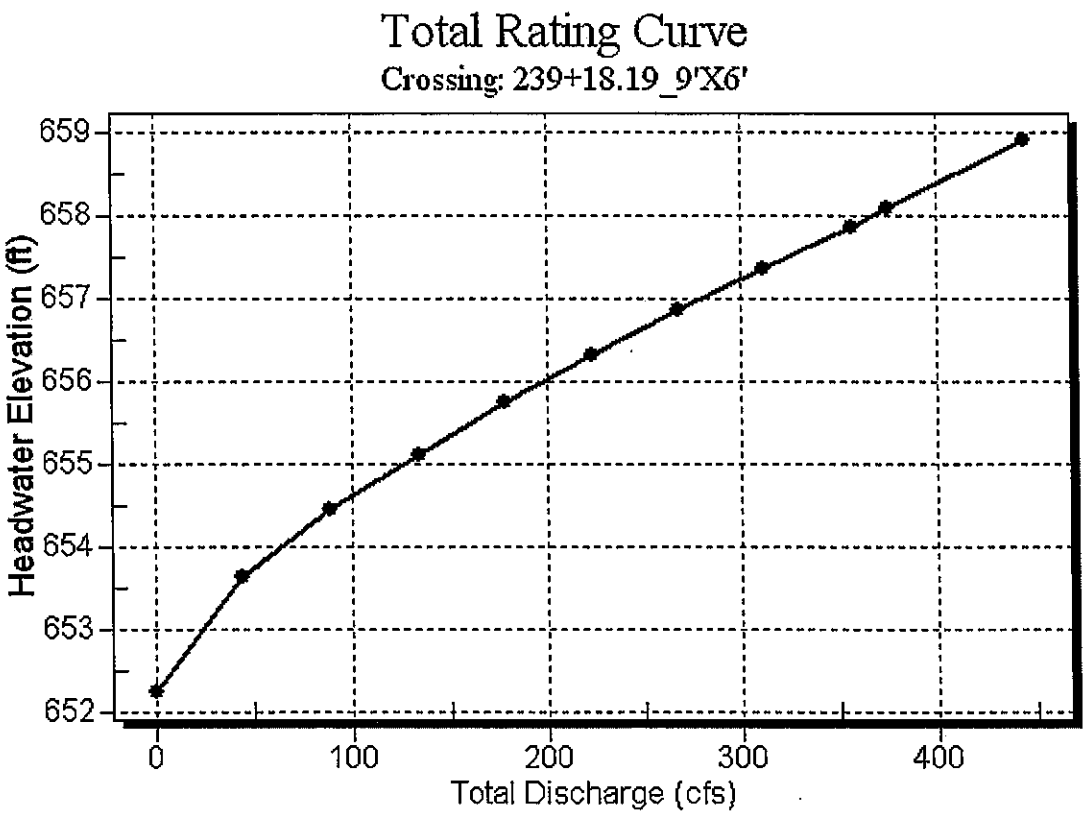


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	652.25	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
44.50	44.50	653.63	1.384	1.384	1-S2n	0.495	0.914	0.504	0.790	9.806	3.863
89.00	89.00	654.44	2.195	2.195	1-S2n	0.800	1.451	0.841	1.183	11.755	4.897
133.50	133.50	655.13	2.875	2.875	1-S2n	1.054	1.902	1.062	1.494	13.972	5.589
178.00	178.00	655.75	3.503	3.503	1-S2n	1.285	2.304	1.294	1.759	15.288	6.125
222.50	222.50	656.33	4.078	4.078	1-S2n	1.486	2.673	1.493	1.994	16.556	6.570
267.00	267.00	656.86	4.612	4.612	1-S2n	1.686	3.019	1.689	2.206	17.568	6.949
311.50	311.50	657.37	5.125	5.125	1-S2n	1.875	3.345	1.884	2.404	18.367	7.277
356.00	356.00	657.88	5.629	5.629	1-S2n	2.051	3.657	2.056	2.587	19.240	7.573
375.00	375.00	658.10	5.846	5.846	1-S2n	2.126	3.786	2.135	2.661	19.517	7.693
445.00	445.00	658.92	6.666	6.666	5-S2n	2.402	4.243	2.402	2.920	20.581	8.089

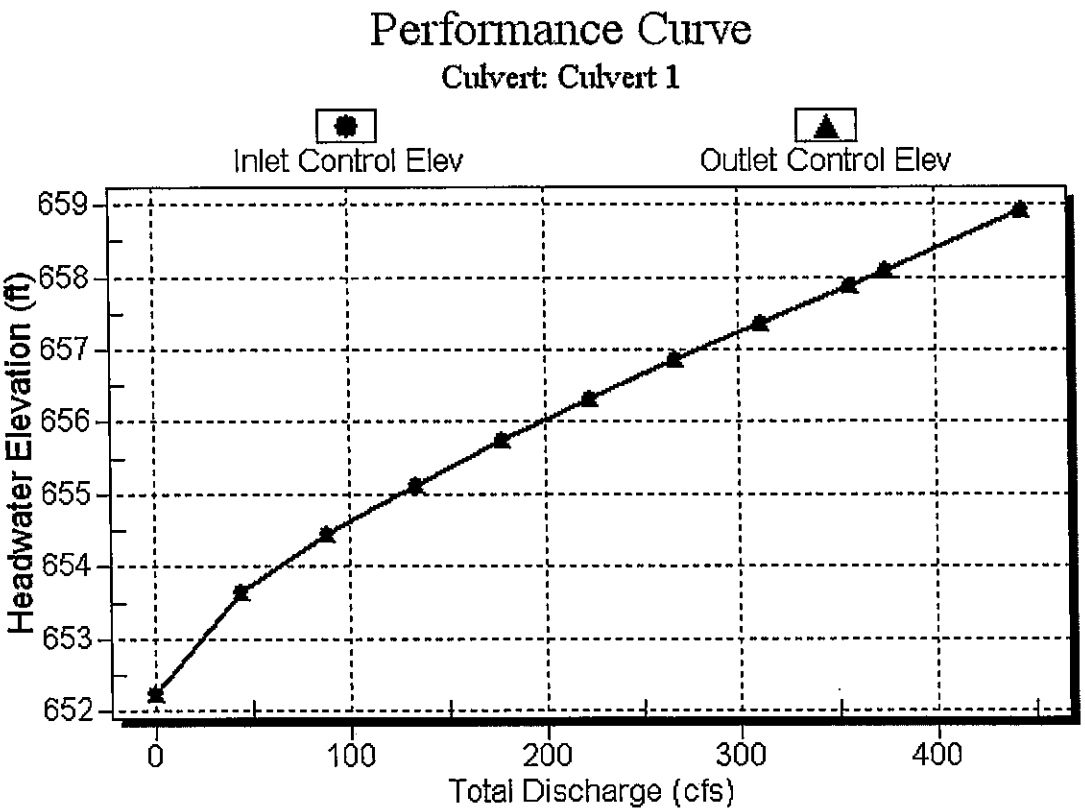
****

Inlet Elevation (invert): 652.25 ft, Outlet Elevation (invert): 639.63 ft

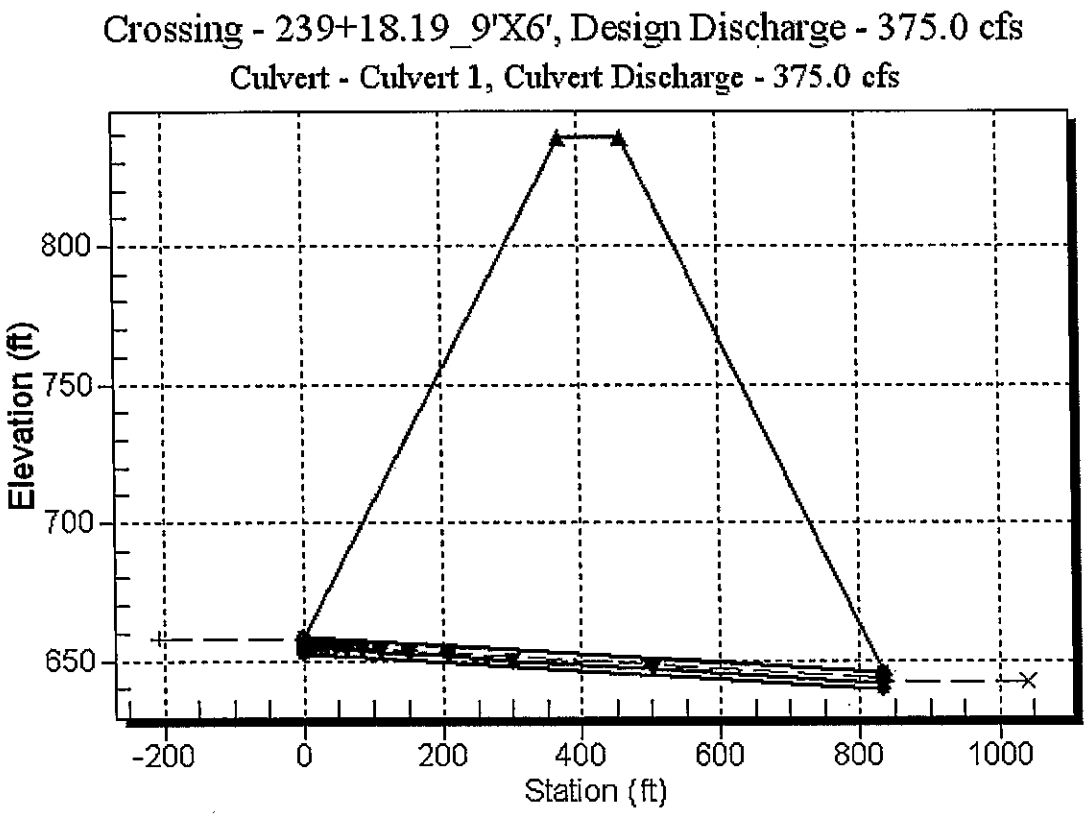
Culvert Length: 834.10 ft, Culvert Slope: 0.0151

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 652.25 ft

Outlet Station: 834.00 ft

Outlet Elevation: 639.63 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 9.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (30-75º flare) Wingwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 239+18.19_9'X6')

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	639.63	0.00	0.00	0.00	0.00
44.50	640.42	0.79	3.86	0.86	0.81
89.00	640.81	1.18	4.90	1.29	0.85
133.50	641.12	1.49	5.59	1.63	0.88
178.00	641.39	1.76	6.12	1.92	0.90
222.50	641.62	1.99	6.57	2.18	0.91
267.00	641.84	2.21	6.95	2.41	0.92
311.50	642.03	2.40	7.28	2.62	0.93
356.00	642.22	2.59	7.57	2.82	0.94
375.00	642.29	2.66	7.69	2.91	0.94
445.00	642.55	2.92	8.09	3.19	0.95

Tailwater Channel Data - 239+18.19_9'X6'

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0175

Channel Manning's n: 0.0400

Channel Invert Elevation: 639.63 ft

Roadway Data for Crossing: 239+18.19_9'X6'

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 838.62 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 - STA. 297+56.24

6' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 297+56.24

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
576.06	0.00	0.00	0.00	1
578.71	66.62	66.62	0.00	1
580.23	133.24	133.24	0.00	1
581.52	199.86	199.86	0.00	1
582.77	266.48	266.48	0.00	1
584.12	333.10	333.10	0.00	1
585.66	399.72	399.72	0.00	1
587.45	466.34	466.34	0.00	1
589.54	532.96	532.96	0.00	1
590.62	564.30	564.30	0.00	1
594.68	666.20	666.20	0.00	1

Rating Curve Plot for Crossing: 297+56.24

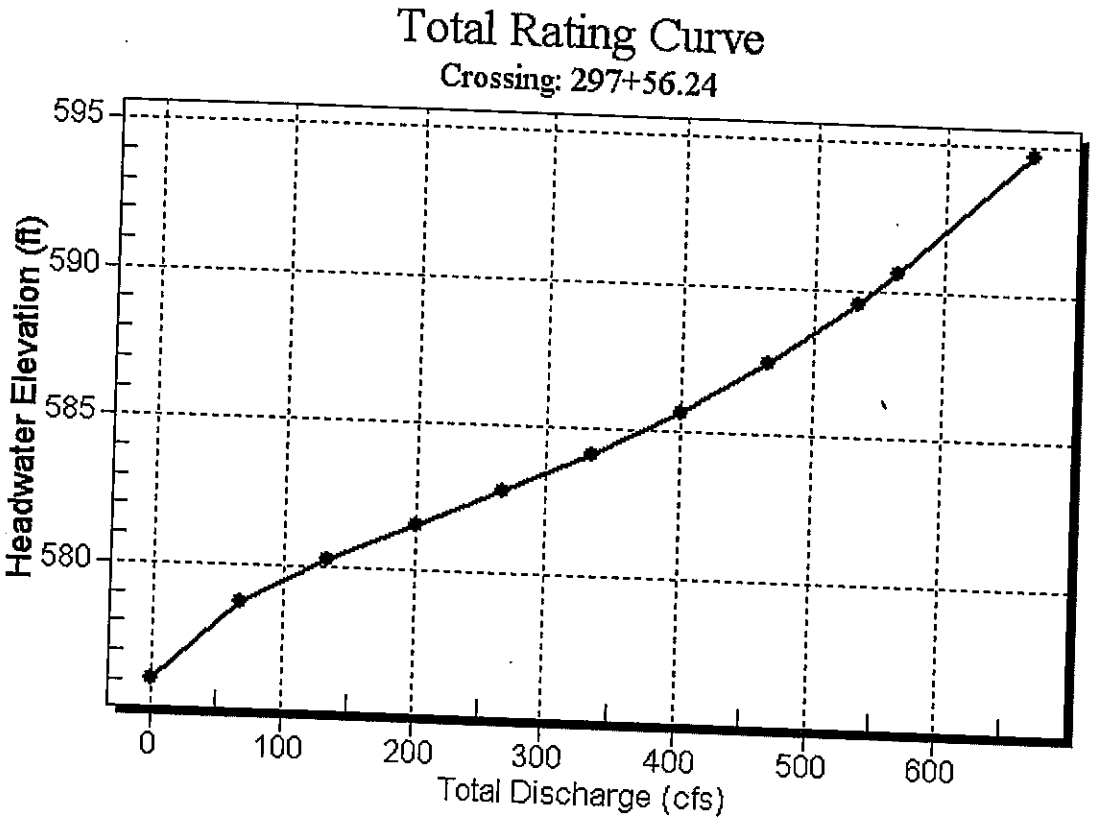


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	576.06	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
66.62	66.62	578.71	2.655	0.000	1-S2n	0.914	1.568	0.958	0.451	11.593	4.778
133.24	133.24	580.23	4.174	0.000	1-S2n	1.486	2.489	1.488	0.682	14.927	6.225
199.86	199.86	581.52	5.465	0.000	1-S2n	1.984	3.261	1.990	0.869	16.738	7.246
266.48	266.48	582.77	6.715	0.000	5-S2n	2.448	3.951	2.450	1.031	18.132	8.062
333.10	333.10	584.12	8.060	0.000	5-S2n	2.886	4.584	2.893	1.178	19.189	8.740
399.72	399.72	585.66	9.598	0.000	5-S2n	3.310	5.177	3.316	1.312	20.093	9.341
466.34	466.34	587.45	11.392	0.000	5-S2n	3.726	5.737	3.727	1.436	20.855	9.880
532.96	532.96	589.54	13.476	1.998	5-S2n	4.134	6.000	4.139	1.554	21.461	10.362
564.30	564.30	590.62	14.562	4.121	5-S2n	4.323	6.000	4.329	1.608	21.726	10.567
666.20	666.20	594.68	18.617	11.863	5-S2n	4.931	6.000	4.939	1.772	22.481	11.206

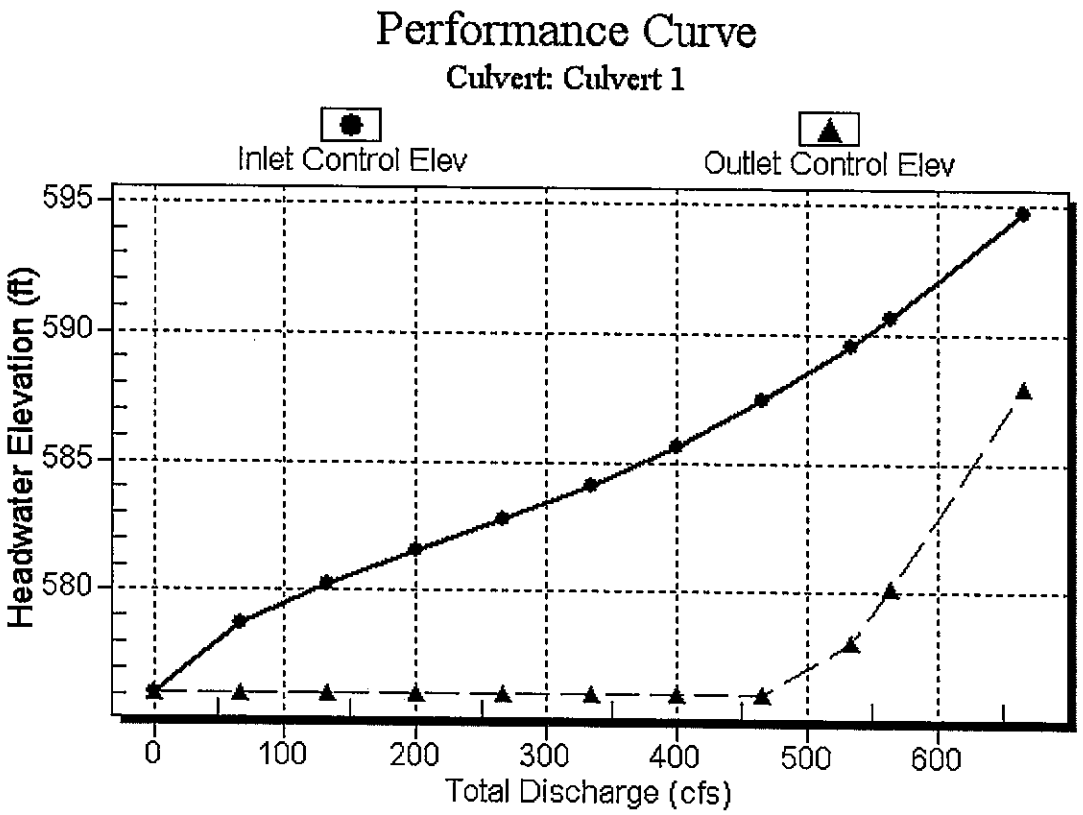
****

Inlet Elevation (invert): 576.06 ft, Outlet Elevation (invert): 554.52 ft

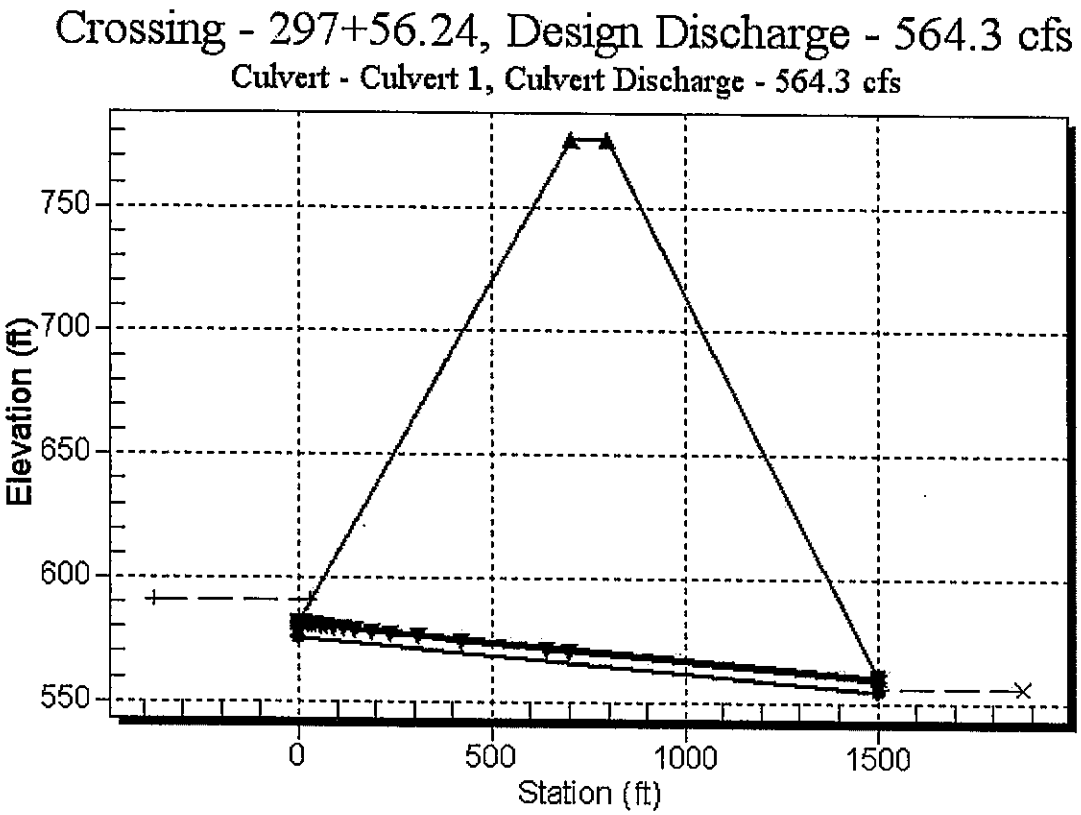
Culvert Length: 1502.15 ft, Culvert Slope: 0.0143

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 576.06 ft

Outlet Station: 1502.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 6.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 297+56.24)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
66.62	554.97	0.45	4.78	1.41	1.27
133.24	555.20	0.68	6.23	2.13	1.36
199.86	555.39	0.87	7.25	2.71	1.41
266.48	555.55	1.03	8.06	3.22	1.44
333.10	555.70	1.18	8.74	3.67	1.47
399.72	555.83	1.31	9.34	4.09	1.49
466.34	555.96	1.44	9.88	4.48	1.52
532.96	556.07	1.55	10.36	4.85	1.53
564.30	556.13	1.61	10.57	5.02	1.54
666.20	556.29	1.77	11.21	5.53	1.56

Tailwater Channel Data - 297+56.24

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 30.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 297+56.24

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 777.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 297+56.24

7' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 297+56.24

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
576.06	0.00	0.00	0.00	1
578.46	66.62	66.62	0.00	1
579.83	133.24	133.24	0.00	1
580.99	199.86	199.86	0.00	1
582.06	266.48	266.48	0.00	1
583.14	333.10	333.10	0.00	1
584.33	399.72	399.72	0.00	1
585.66	466.34	466.34	0.00	1
587.18	532.96	532.96	0.00	1
587.97	564.30	564.30	0.00	1
590.86	666.20	666.20	0.00	1

Rating Curve Plot for Crossing: 297+56.24

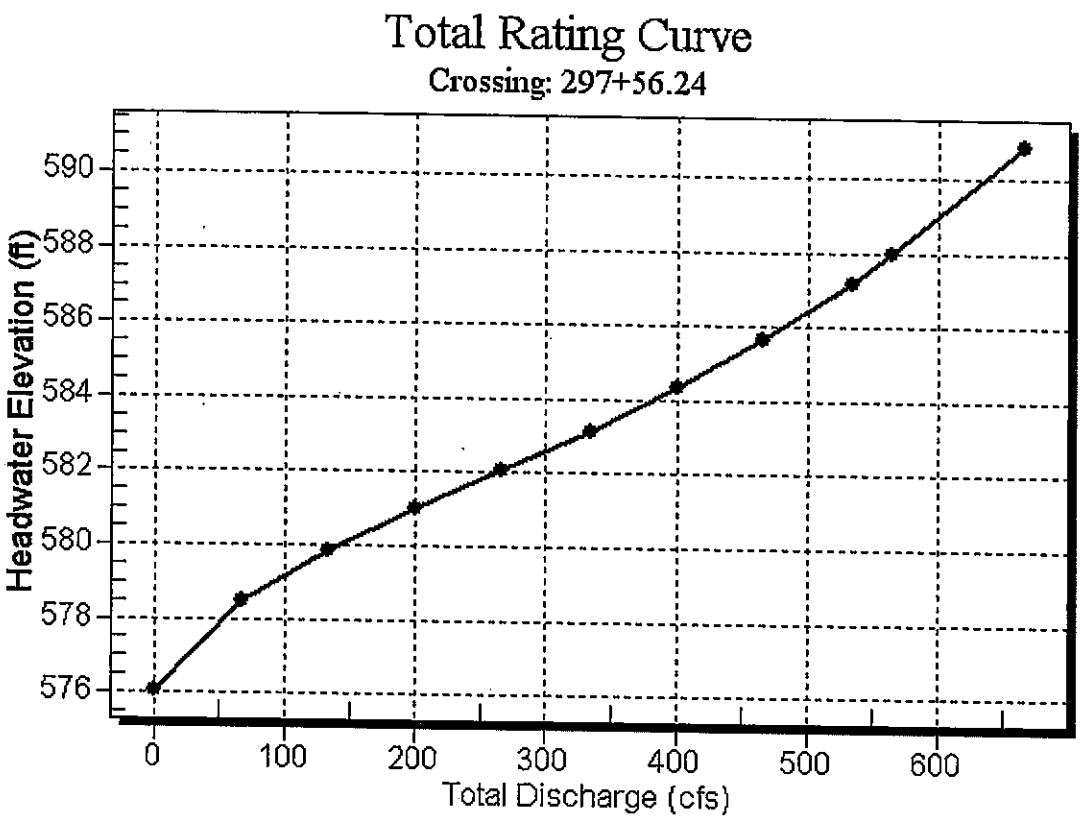


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	576.06	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
66.62	66.62	578.46	2.396	0.000	1-S2n	0.811	1.415	0.814	0.451	11.697	4.778
133.24	133.24	579.83	3.773	0.000	1-S2n	1.311	2.246	1.315	0.682	14.479	6.225
199.86	199.86	580.99	4.926	0.000	1-S2n	1.735	2.943	1.742	0.869	16.394	7.246
266.48	266.48	582.06	5.996	0.000	1-S2n	2.120	3.565	2.124	1.031	17.926	8.062
333.10	333.10	583.14	7.084	0.000	5-S2n	2.491	4.136	2.495	1.178	19.069	8.740
399.72	399.72	584.33	8.266	0.000	5-S2n	2.842	4.671	2.850	1.312	20.036	9.341
466.34	466.34	585.66	9.598	0.000	5-S2n	3.185	5.177	3.191	1.436	20.880	9.880
532.96	532.96	587.18	11.118	0.000	5-S2n	3.520	5.659	3.528	1.554	21.583	10.362
564.30	564.30	587.97	11.905	0.000	5-S2n	3.675	5.878	3.677	1.608	21.922	10.567
666.20	666.20	590.86	14.804	3.250	5-S2n	4.170	6.000	4.179	1.772	22.774	11.206

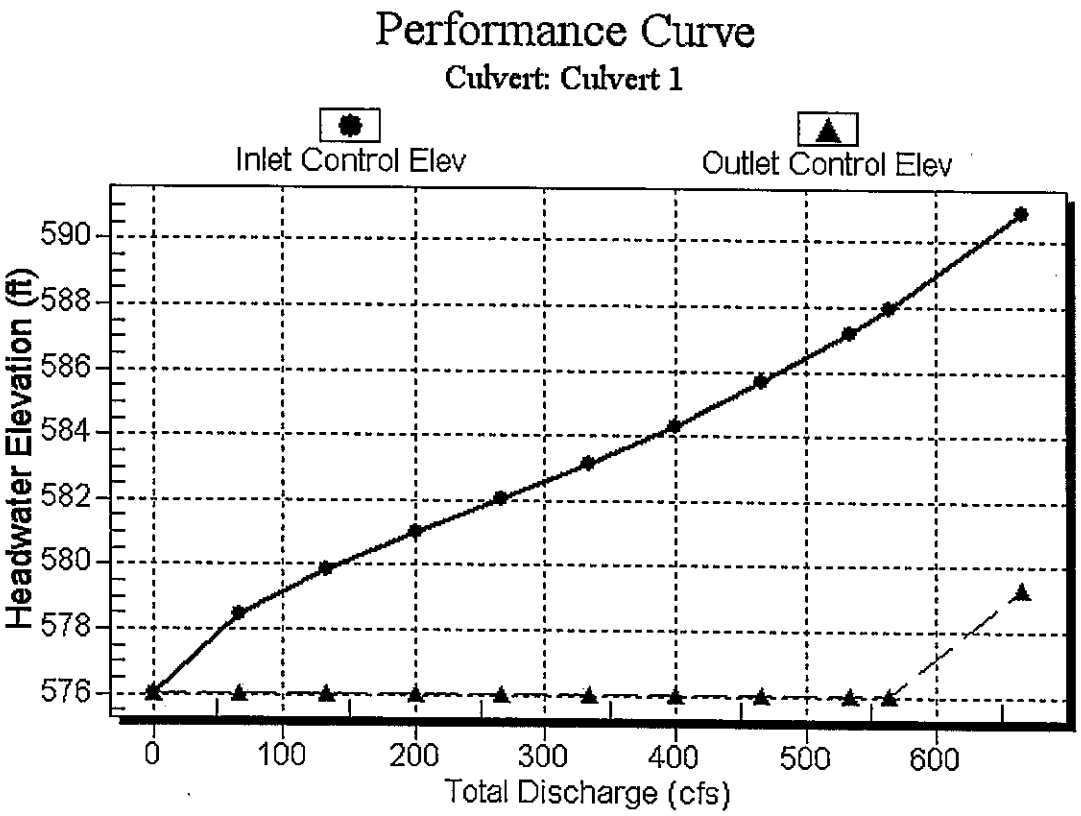
****

Inlet Elevation (invert): 576.06 ft, Outlet Elevation (invert): 554.52 ft

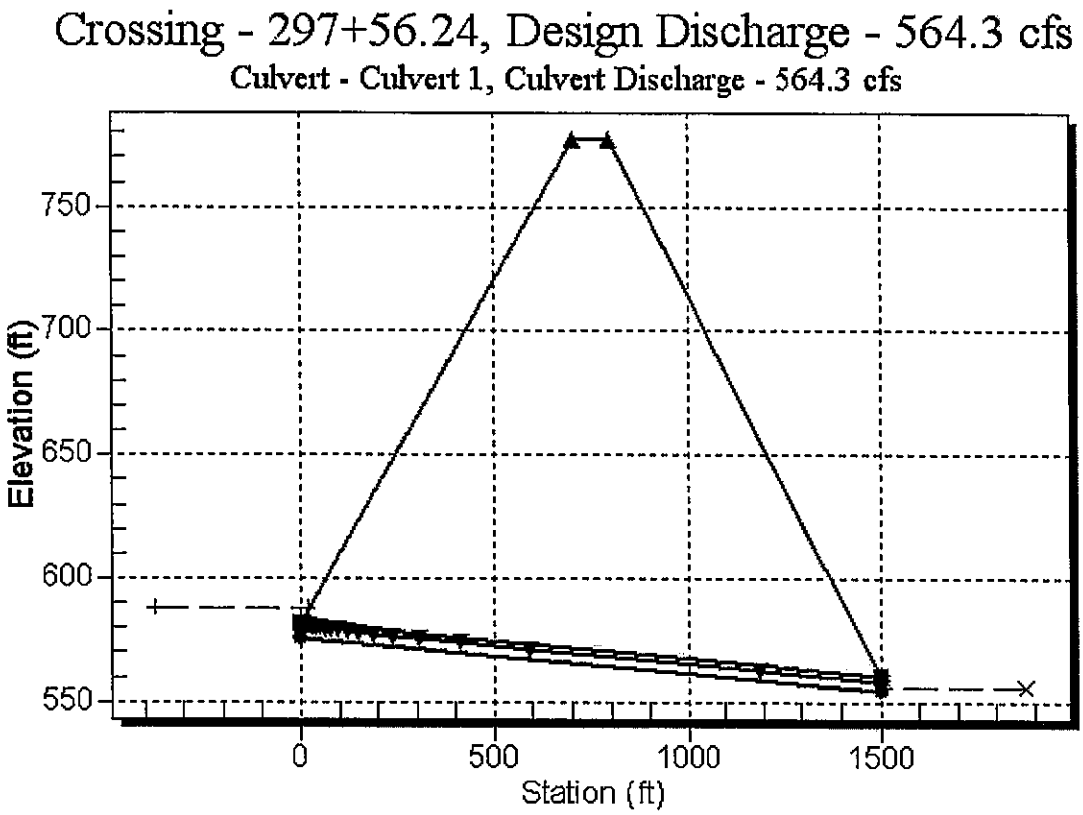
Culvert Length: 1502.15 ft, Culvert Slope: 0.0143

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 576.06 ft

Outlet Station: 1502.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 7.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 297+56.24)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
66.62	554.97	0.45	4.78	1.41	1.27
133.24	555.20	0.68	6.23	2.13	1.36
199.86	555.39	0.87	7.25	2.71	1.41
266.48	555.55	1.03	8.06	3.22	1.44
333.10	555.70	1.18	8.74	3.67	1.47
399.72	555.83	1.31	9.34	4.09	1.49
466.34	555.96	1.44	9.88	4.48	1.52
532.96	556.07	1.55	10.36	4.85	1.53
564.30	556.13	1.61	10.57	5.02	1.54
666.20	556.29	1.77	11.21	5.53	1.56

Tailwater Channel Data - 297+56.24

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 30.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 297+56.24

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 777.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 - STA. 297+56.24

8' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 297+56.24

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
576.06	0.00	0.00	0.00	1
578.25	66.62	66.62	0.00	1
579.52	133.24	133.24	0.00	1
580.57	199.86	199.86	0.00	1
581.52	266.48	266.48	0.00	1
582.46	333.10	333.10	0.00	1
583.43	399.72	399.72	0.00	1
584.48	466.34	466.34	0.00	1
585.66	532.96	532.96	0.00	1
586.26	564.30	564.30	0.00	1
588.46	666.20	666.20	0.00	1

Rating Curve Plot for Crossing: 297+56.24

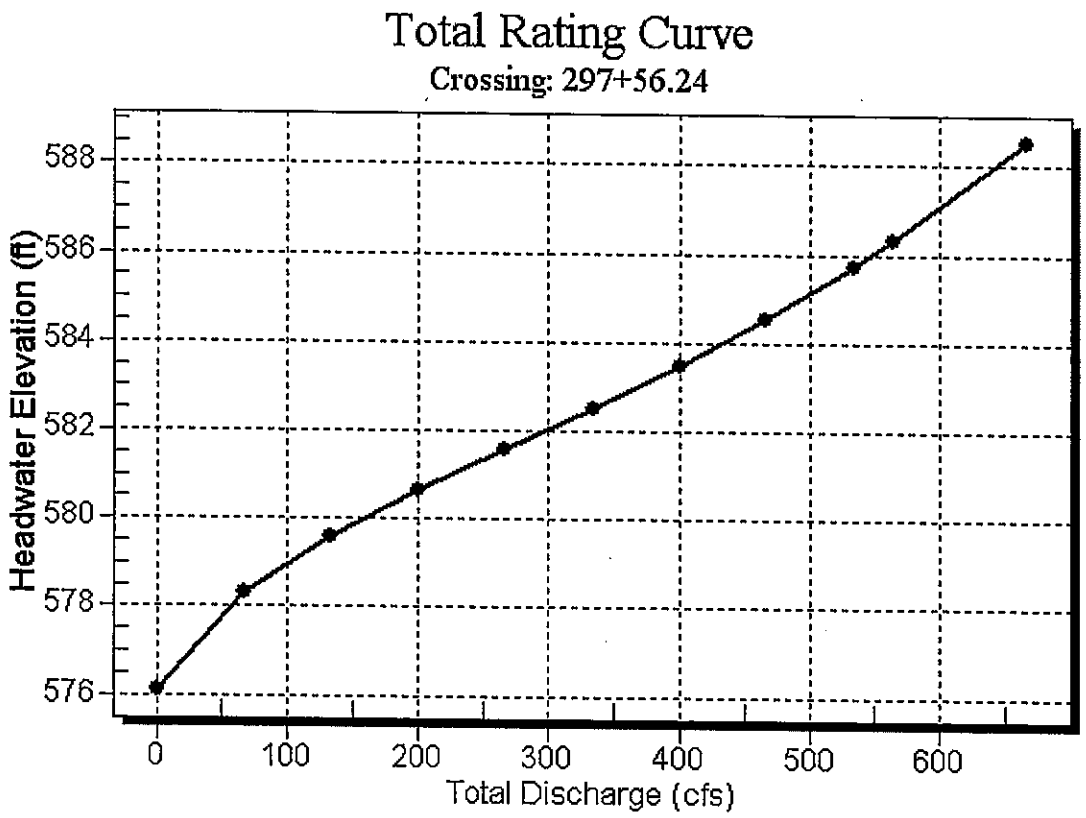


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	576.06	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
66.62	66.62	578.25	2.190	0.000	1-S2n	0.737	1.294	0.744	0.451	11.191	4.778
133.24	133.24	579.52	3.458	0.000	1-S2n	1.187	2.054	1.188	0.682	14.015	6.225
199.86	199.86	580.57	4.509	0.000	1-S2n	1.546	2.692	1.552	0.869	16.097	7.246
266.48	266.48	581.52	5.465	0.000	1-S2n	1.892	3.261	1.900	1.031	17.531	8.062
333.10	333.10	582.46	6.398	0.000	5-S2n	2.207	3.784	2.213	1.178	18.814	8.740
399.72	399.72	583.43	7.369	0.000	5-S2n	2.513	4.273	2.522	1.312	19.810	9.341
466.34	466.34	584.48	8.424	0.000	5-S2n	2.805	4.736	2.806	1.436	20.776	9.880
532.96	532.96	585.66	9.598	0.000	5-S2n	3.092	5.177	3.096	1.554	21.521	10.362
564.30	564.30	586.26	10.199	0.000	5-S2n	3.222	5.378	3.227	1.608	21.861	10.567
666.20	666.20	588.46	12.396	-1.908	5-S2n	3.644	6.000	3.649	1.772	22.821	11.206

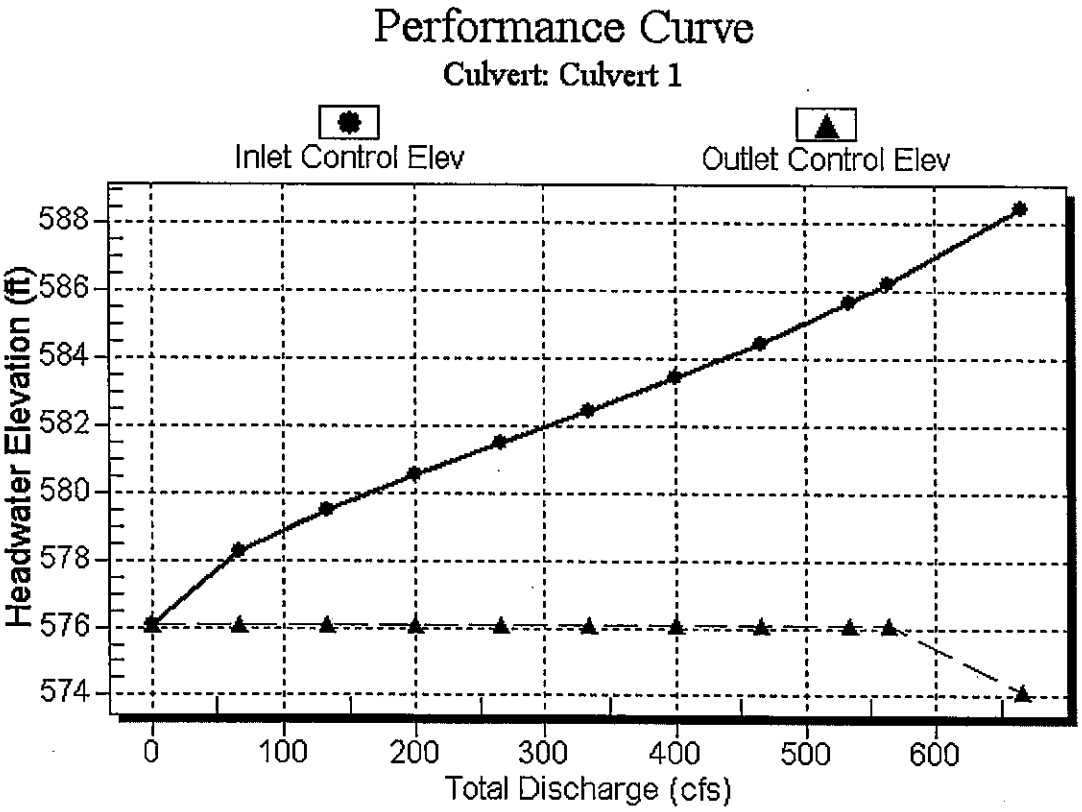
****

Inlet Elevation (invert): 576.06 ft, Outlet Elevation (invert): 554.52 ft

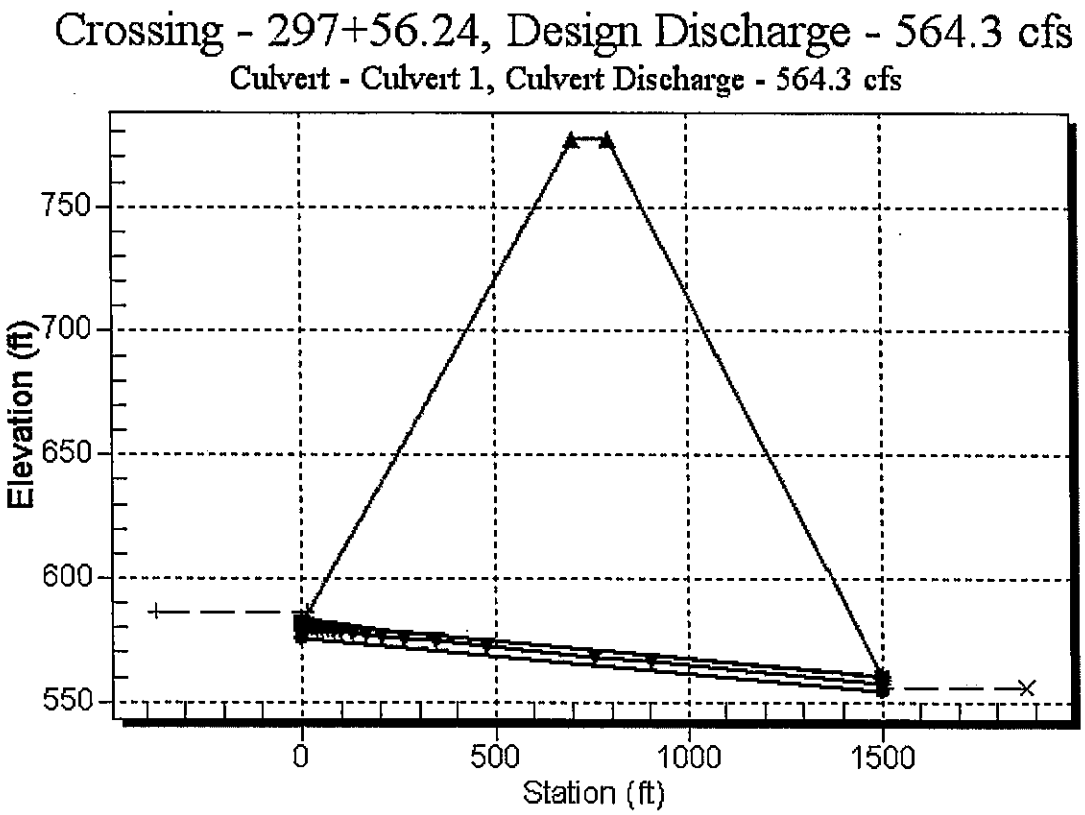
Culvert Length: 1502.15 ft, Culvert Slope: 0.0143

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 576.06 ft

Outlet Station: 1502.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 297+56.24)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
66.62	554.97	0.45	4.78	1.41	1.27
133.24	555.20	0.68	6.23	2.13	1.36
199.86	555.39	0.87	7.25	2.71	1.41
266.48	555.55	1.03	8.06	3.22	1.44
333.10	555.70	1.18	8.74	3.67	1.47
399.72	555.83	1.31	9.34	4.09	1.49
466.34	555.96	1.44	9.88	4.48	1.52
532.96	556.07	1.55	10.36	4.85	1.53
564.30	556.13	1.61	10.57	5.02	1.54
666.20	556.29	1.77	11.21	5.53	1.56

Tailwater Channel Data - 297+56.24

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 30.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 297+56.24

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 777.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 297+56.24

9' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 297+56.24

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
576.06	0.00	0.00	0.00	1
578.08	66.62	66.62	0.00	1
579.26	133.24	133.24	0.00	1
580.23	199.86	199.86	0.00	1
581.11	266.48	266.48	0.00	1
581.94	333.10	333.10	0.00	1
582.77	399.72	399.72	0.00	1
583.65	466.34	466.34	0.00	1
584.61	532.96	532.96	0.00	1
585.09	564.30	564.30	0.00	1
586.82	666.20	666.20	0.00	1

Rating Curve Plot for Crossing: 297+56.24

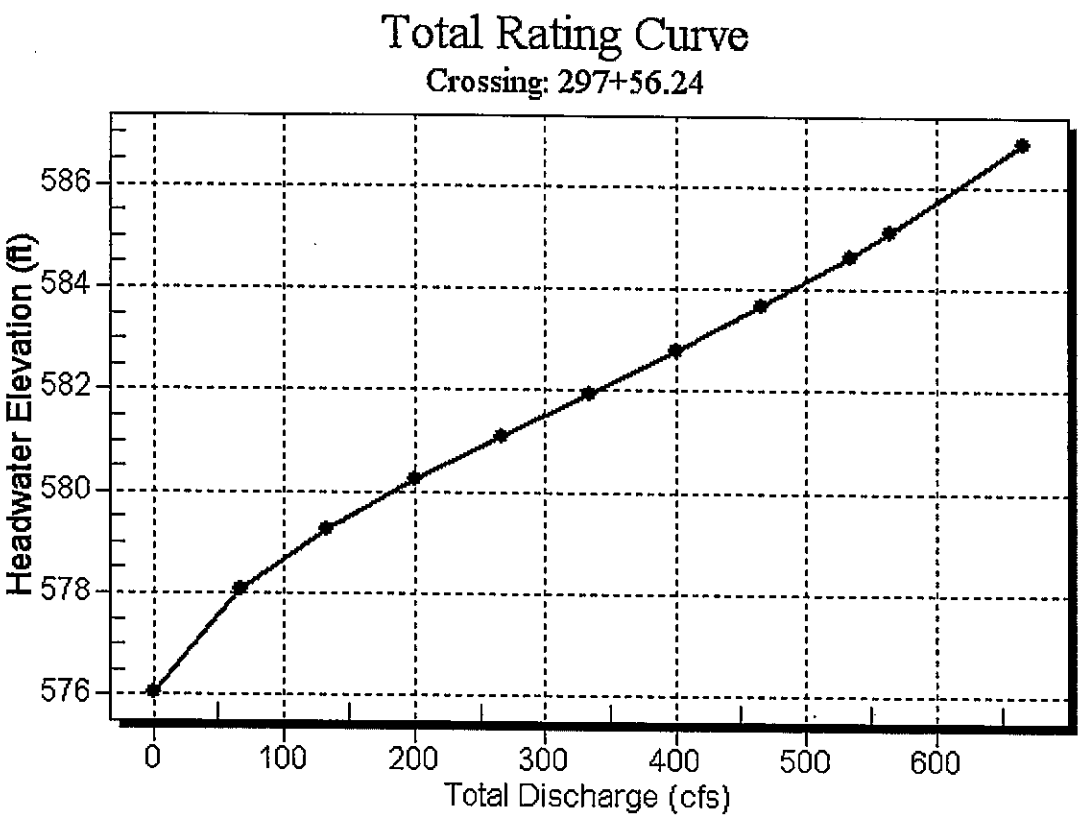


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	576.06	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
66.62	66.62	578.08	2.022	0.000	1-S2n	0.683	1.196	0.686	0.451	10.784	4.778
133.24	133.24	579.26	3.203	0.000	1-S2n	1.074	1.899	1.089	0.682	13.592	6.225
199.86	199.86	580.23	4.174	0.000	1-S2n	1.408	2.489	1.409	0.869	15.764	7.246
266.48	266.48	581.11	5.047	0.000	1-S2n	1.716	3.015	1.724	1.031	17.177	8.062
333.10	333.10	581.94	5.878	0.000	1-S2n	1.996	3.498	1.997	1.178	18.530	8.740
399.72	399.72	582.77	6.715	0.000	5-S2n	2.266	3.951	2.274	1.312	19.532	9.341
466.34	466.34	583.65	7.594	0.000	5-S2n	2.525	4.378	2.531	1.436	20.472	9.880
532.96	532.96	584.61	8.548	0.000	5-S2n	2.774	4.786	2.776	1.554	21.334	10.362
564.30	564.30	585.09	9.029	0.000	5-S2n	2.891	4.972	2.892	1.608	21.684	10.567
666.20	666.20	586.82	10.763	0.000	5-S2n	3.255	5.553	3.262	1.772	22.690	11.206

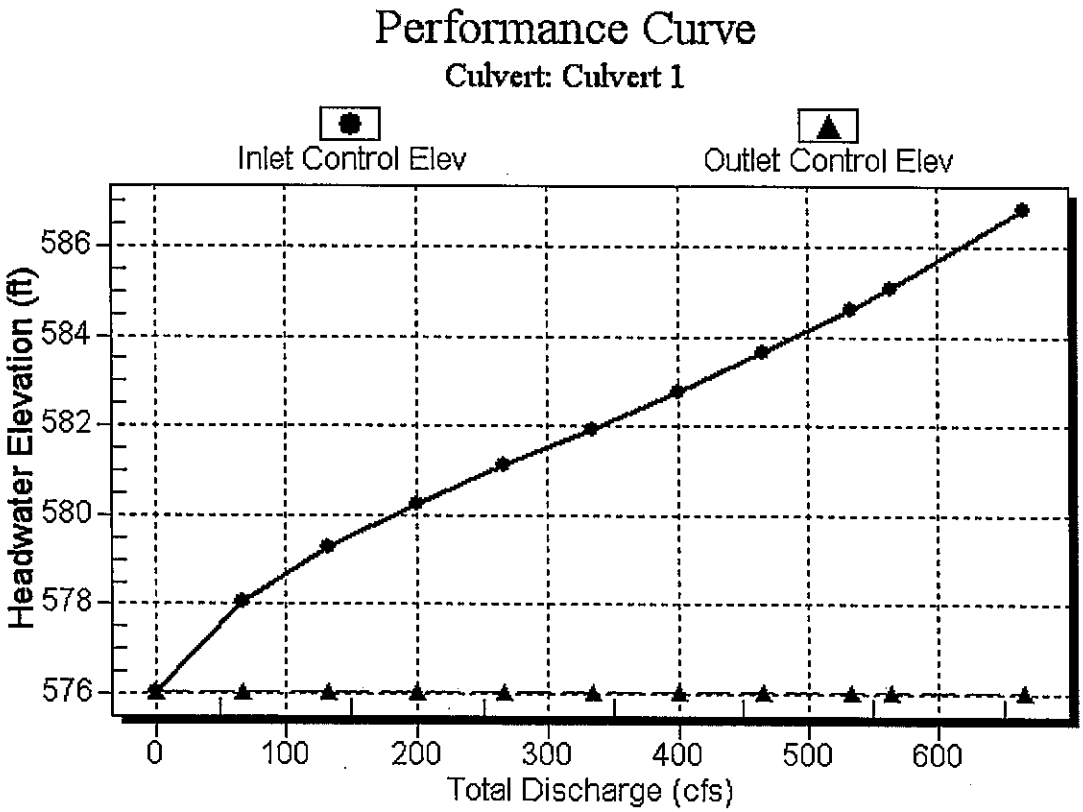
****

Inlet Elevation (invert): 576.06 ft, Outlet Elevation (invert): 554.52 ft

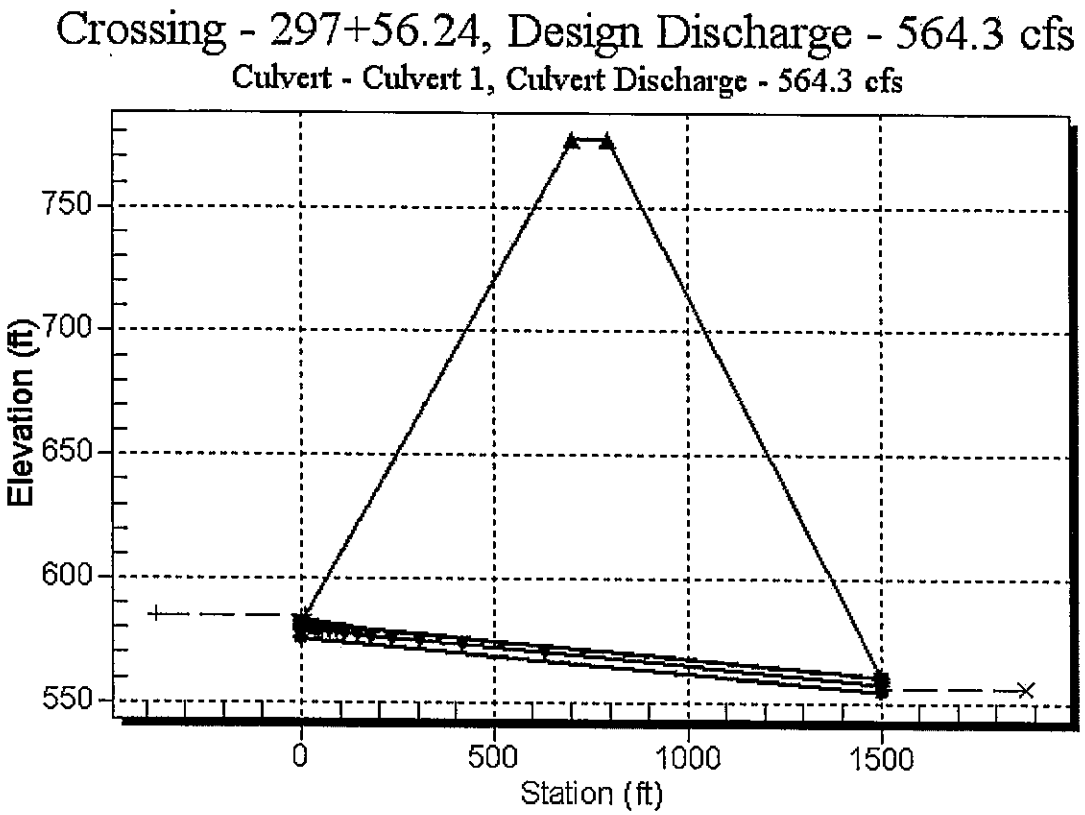
Culvert Length: 1502.15 ft, Culvert Slope: 0.0143

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 576.06 ft

Outlet Station: 1502.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 9.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 297+56.24)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
66.62	554.97	0.45	4.78	1.41	1.27
133.24	555.20	0.68	6.23	2.13	1.36
199.86	555.39	0.87	7.25	2.71	1.41
266.48	555.55	1.03	8.06	3.22	1.44
333.10	555.70	1.18	8.74	3.67	1.47
399.72	555.83	1.31	9.34	4.09	1.49
466.34	555.96	1.44	9.88	4.48	1.52
532.96	556.07	1.55	10.36	4.85	1.53
564.30	556.13	1.61	10.57	5.02	1.54
666.20	556.29	1.77	11.21	5.53	1.56

Tailwater Channel Data - 297+56.24

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 30.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 297+56.24

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 777.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 297+56.24

10' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 297+56.24

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
576.06	0.00	0.00	0.00	1
577.95	66.62	66.62	0.00	1
579.05	133.24	133.24	0.00	1
579.96	199.86	199.86	0.00	1
580.77	266.48	266.48	0.00	1
581.52	333.10	333.10	0.00	1
582.27	399.72	399.72	0.00	1
583.03	466.34	466.34	0.00	1
583.84	532.96	532.96	0.00	1
584.24	564.30	564.30	0.00	1
585.66	666.20	666.20	0.00	1

Rating Curve Plot for Crossing: 297+56.24

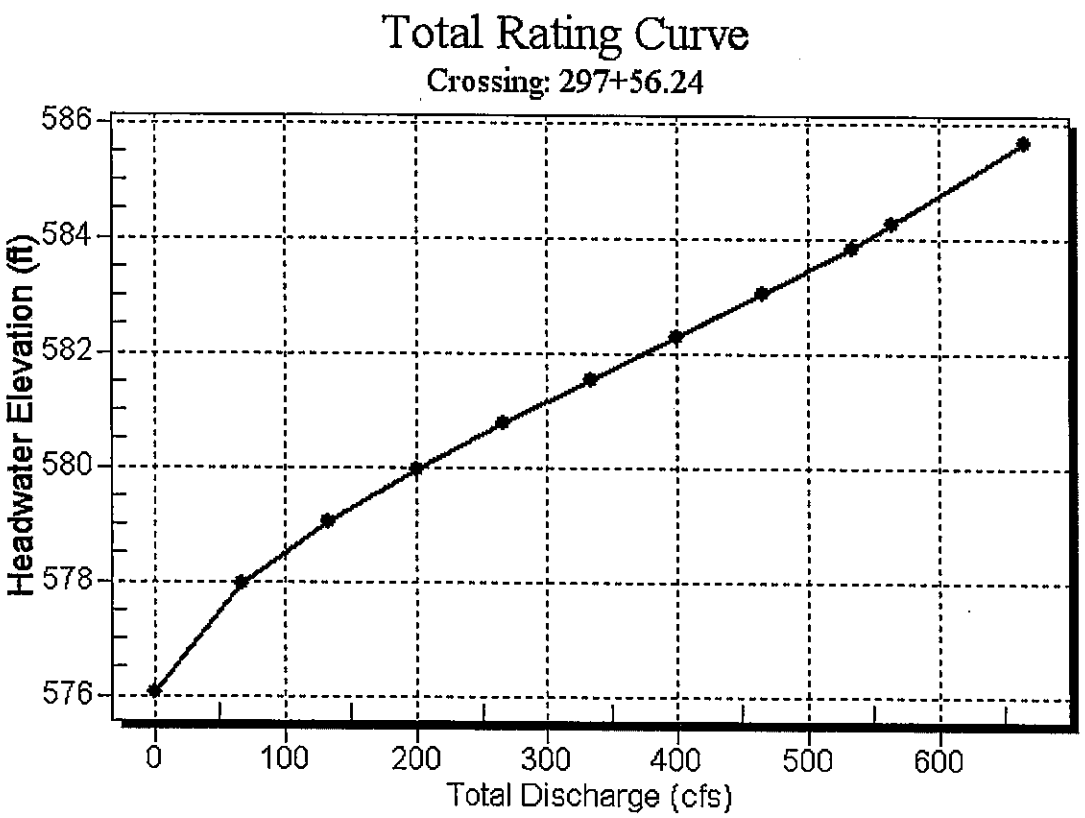


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	576.06	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
66.62	66.62	577.95	1.889	0.000	1-S2n	0.641	1.115	0.644	0.451	10.340	4.778
133.24	133.24	579.05	2.992	0.000	1-S2n	0.986	1.770	1.000	0.682	13.319	6.225
199.86	199.86	579.96	3.896	0.000	1-S2n	1.303	2.320	1.310	0.869	15.258	7.246
266.48	266.48	580.77	4.706	0.000	1-S2n	1.573	2.810	1.580	1.031	16.863	8.062
333.10	333.10	581.52	5.465	0.000	1-S2n	1.838	3.261	1.840	1.178	18.103	8.740
399.72	399.72	582.27	6.210	0.000	5-S2n	2.073	3.683	2.082	1.312	19.203	9.341
466.34	466.34	583.03	6.972	0.000	5-S2n	2.308	4.081	2.314	1.436	20.152	9.880
532.96	532.96	583.84	7.778	0.000	5-S2n	2.532	4.461	2.540	1.554	20.982	10.362
564.30	564.30	584.24	8.178	0.000	5-S2n	2.633	4.634	2.633	1.608	21.429	10.567
666.20	666.20	585.66	9.598	0.000	5-S2n	2.962	5.177	2.967	1.772	22.456	11.206

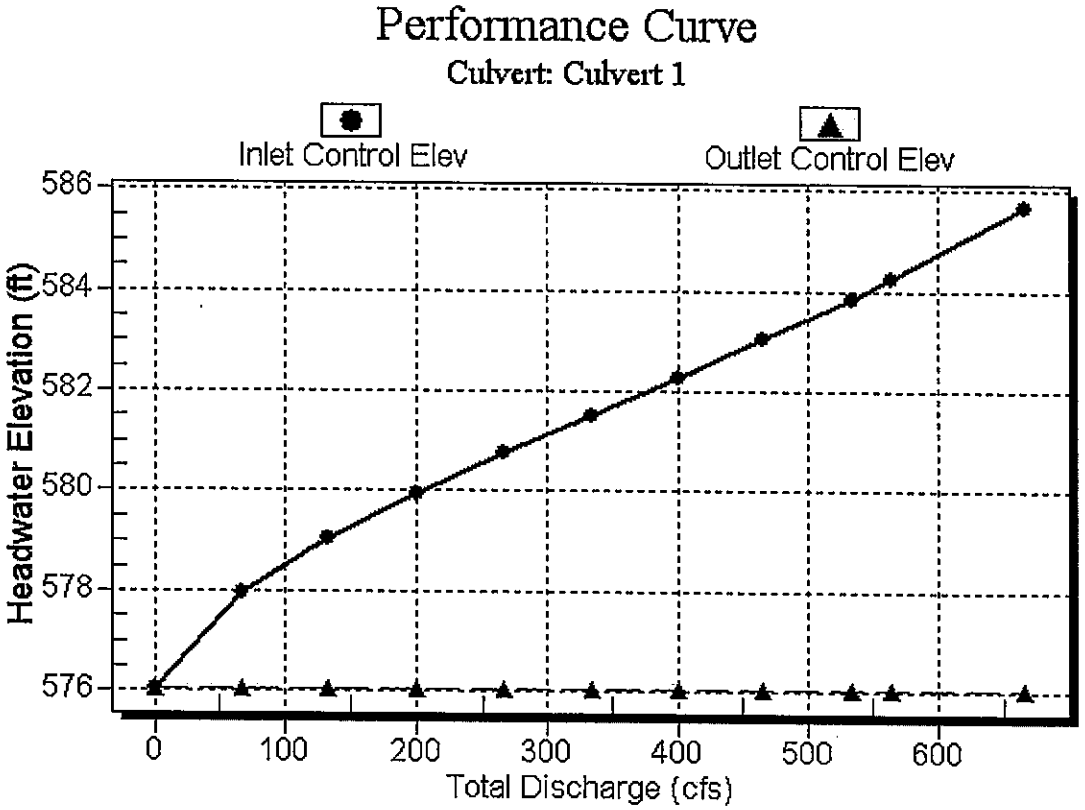
****

Inlet Elevation (invert): 576.06 ft, Outlet Elevation (invert): 554.52 ft

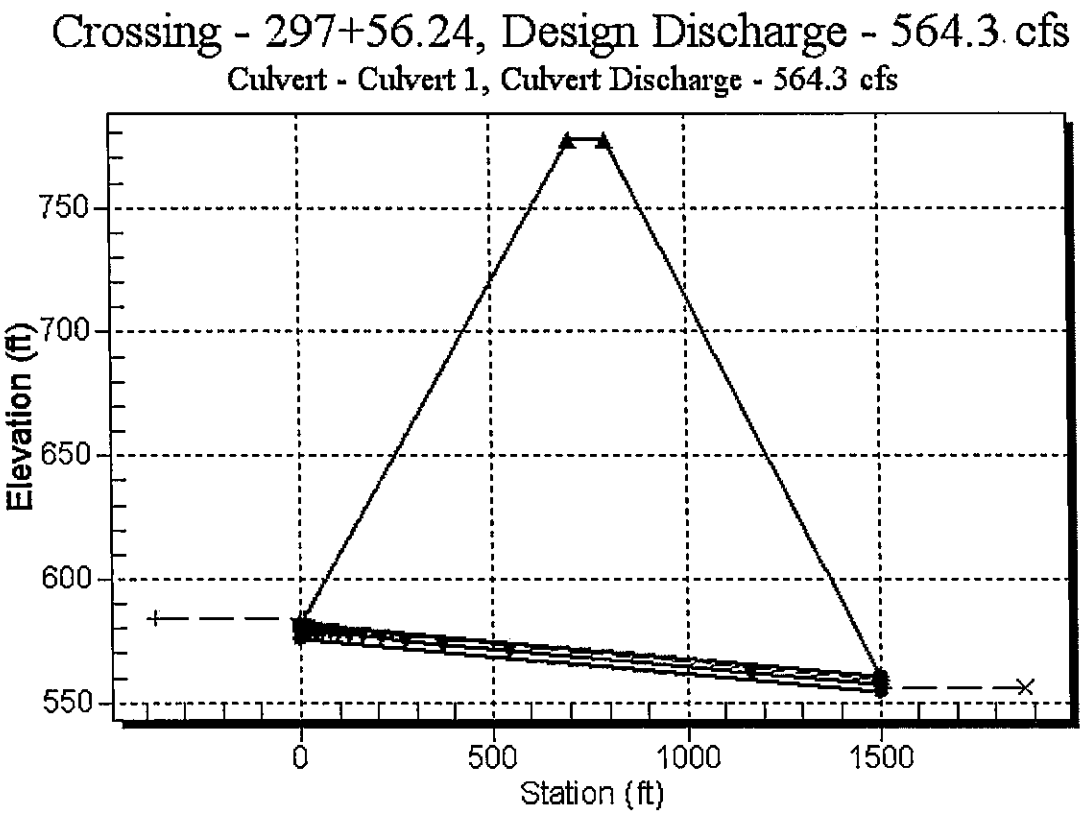
Culvert Length: 1502.15 ft, Culvert Slope: 0.0143

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 576.06 ft

Outlet Station: 1502.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 297+56.24)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
66.62	554.97	0.45	4.78	1.41	1.27
133.24	555.20	0.68	6.23	2.13	1.36
199.86	555.39	0.87	7.25	2.71	1.41
266.48	555.55	1.03	8.06	3.22	1.44
333.10	555.70	1.18	8.74	3.67	1.47
399.72	555.83	1.31	9.34	4.09	1.49
466.34	555.96	1.44	9.88	4.48	1.52
532.96	556.07	1.55	10.36	4.85	1.53
564.30	556.13	1.61	10.57	5.02	1.54
666.20	556.29	1.77	11.21	5.53	1.56

Tailwater Channel Data - 297+56.24

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 30.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 297+56.24

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 777.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 297+56.24

10' x 7' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 297+56.24

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
576.06	0.00	0.00	0.00	1
577.96	66.62	66.62	0.00	1
579.06	133.24	133.24	0.00	1
579.97	199.86	199.86	0.00	1
580.78	266.48	266.48	0.00	1
581.52	333.10	333.10	0.00	1
582.23	399.72	399.72	0.00	1
582.92	466.34	466.34	0.00	1
583.61	532.96	532.96	0.00	1
583.94	564.30	564.30	0.00	1
585.07	666.20	666.20	0.00	1

Rating Curve Plot for Crossing: 297+56.24

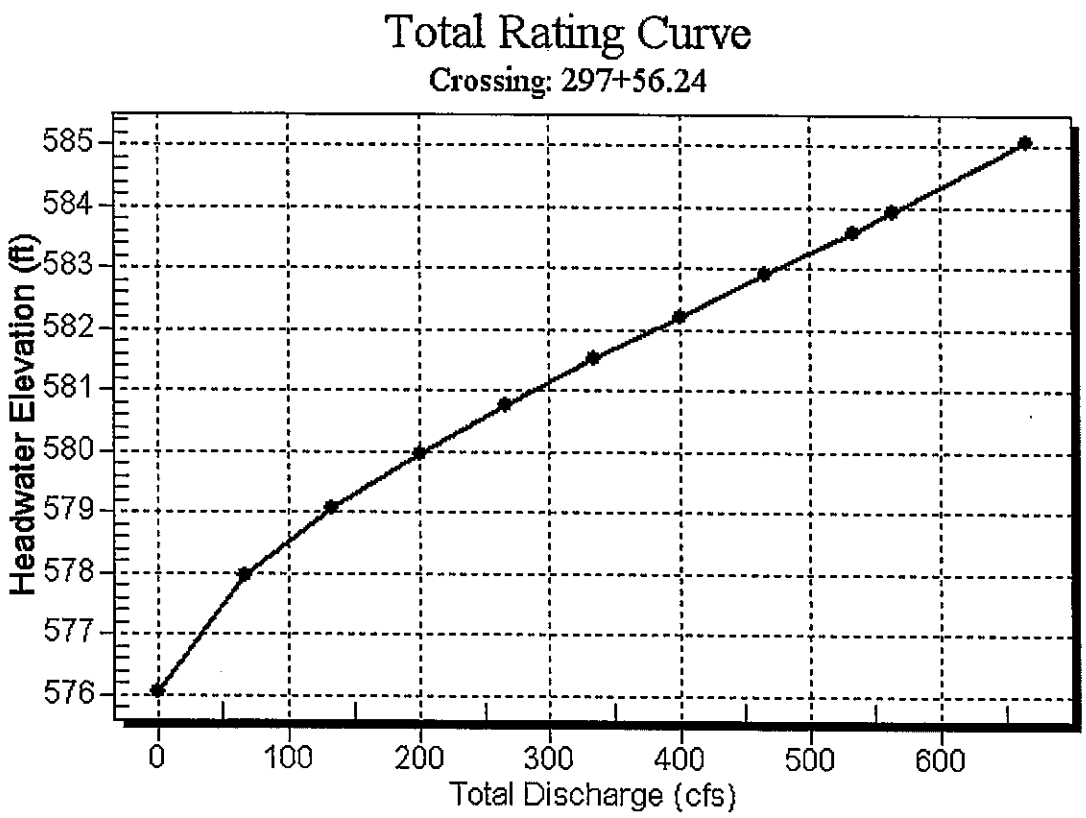


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	576.06	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
66.62	66.62	577.96	1.897	0.000	1-S2n	0.621	1.115	0.635	0.451	10.487	4.778
133.24	133.24	579.06	2.998	0.000	1-S2n	0.979	1.770	1.000	0.682	13.319	6.225
199.86	199.86	579.97	3.908	0.000	1-S2n	1.299	2.320	1.310	0.869	15.258	7.246
266.48	266.48	580.78	4.716	0.000	1-S2n	1.573	2.810	1.580	1.031	16.863	8.062
333.10	333.10	581.52	5.461	0.000	1-S2n	1.827	3.261	1.851	1.178	17.995	8.740
399.72	399.72	582.23	6.167	0.000	1-S2n	2.080	3.683	2.082	1.312	19.203	9.341
466.34	466.34	582.92	6.857	0.000	1-S2n	2.305	4.081	2.314	1.436	20.152	9.880
532.96	532.96	583.61	7.551	0.000	5-S2n	2.528	4.461	2.531	1.554	21.057	10.362
564.30	564.30	583.94	7.883	0.000	5-S2n	2.632	4.634	2.633	1.608	21.429	10.567
666.20	666.20	585.07	9.012	0.000	5-S2n	2.959	5.177	2.967	1.772	22.456	11.206

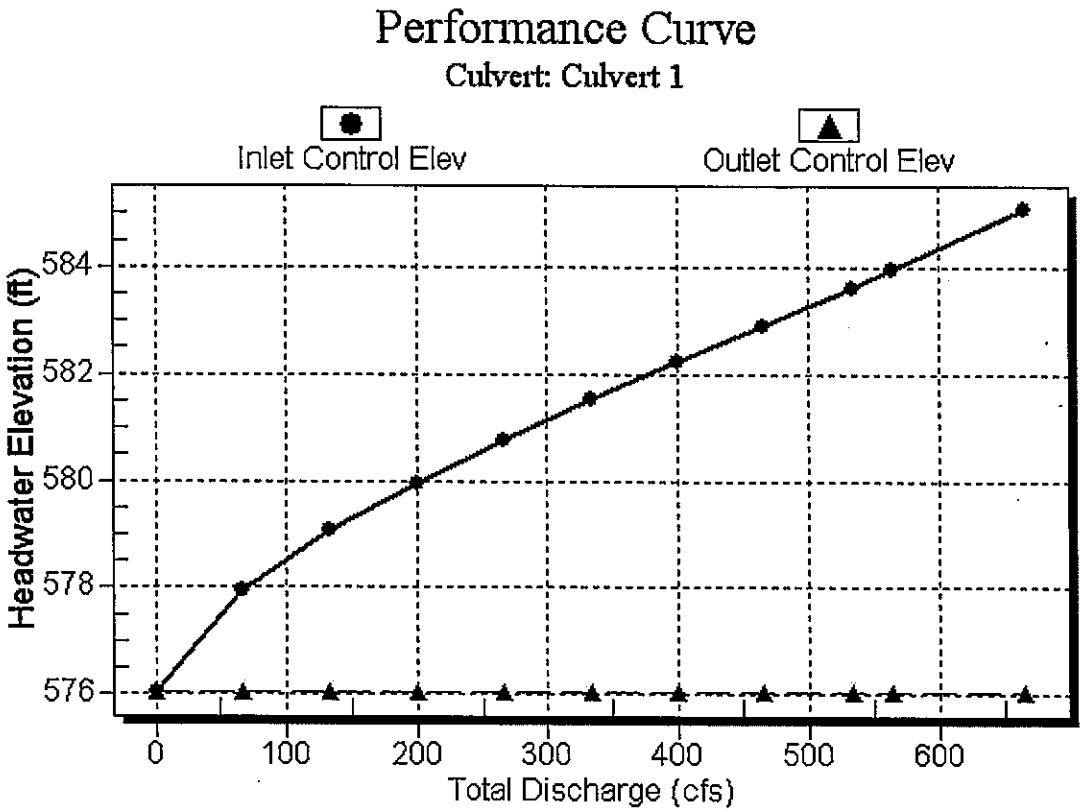
****

Inlet Elevation (invert): 576.06 ft, Outlet Elevation (invert): 554.52 ft

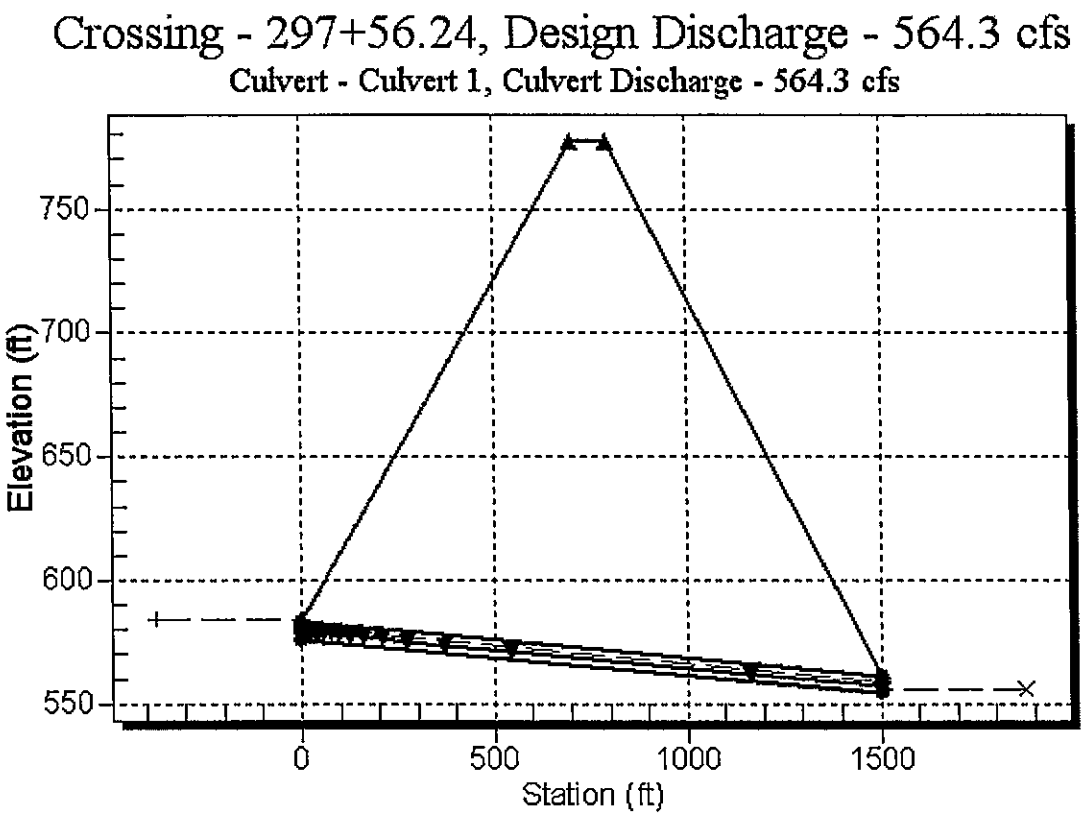
Culvert Length: 1502.15 ft, Culvert Slope: 0.0143

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 576.06 ft

Outlet Station: 1502.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 7.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 297+56.24)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
66.62	554.97	0.45	4.78	1.41	1.27
133.24	555.20	0.68	6.23	2.13	1.36
199.86	555.39	0.87	7.25	2.71	1.41
266.48	555.55	1.03	8.06	3.22	1.44
333.10	555.70	1.18	8.74	3.67	1.47
399.72	555.83	1.31	9.34	4.09	1.49
466.34	555.96	1.44	9.88	4.48	1.52
532.96	556.07	1.55	10.36	4.85	1.53
564.30	556.13	1.61	10.57	5.02	1.54
666.20	556.29	1.77	11.21	5.53	1.56

Tailwater Channel Data - 297+56.24

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 30.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 297+56.24

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 777.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 297+56.24

10' x 8' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 297+56.24

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
576.06	0.00	0.00	0.00	1
577.96	66.62	66.62	0.00	1
579.06	133.24	133.24	0.00	1
579.98	199.86	199.86	0.00	1
580.79	266.48	266.48	0.00	1
581.53	333.10	333.10	0.00	1
582.23	399.72	399.72	0.00	1
582.89	466.34	466.34	0.00	1
583.54	532.96	532.96	0.00	1
583.84	564.30	564.30	0.00	1
584.84	666.20	666.20	0.00	1

Rating Curve Plot for Crossing: 297+56.24

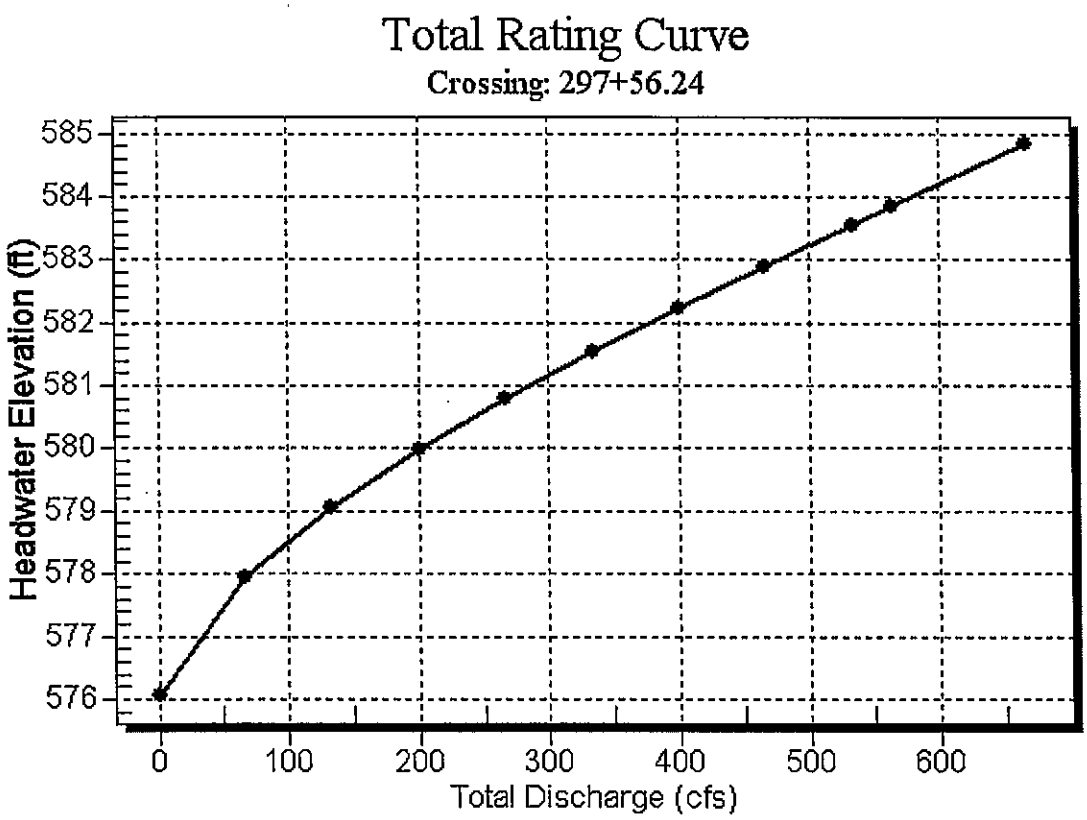


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	576.06	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
66.62	66.62	577.96	1.899	0.000	1-S2n	0.574	1.115	0.605	0.451	11.007	4.778
133.24	133.24	579.06	2.997	0.000	1-S2n	0.982	1.770	1.000	0.682	13.319	6.225
199.86	199.86	579.98	3.922	0.000	1-S2n	1.283	2.320	1.310	0.869	15.258	7.246
266.48	266.48	580.79	4.728	0.000	1-S2n	1.583	2.810	1.589	1.031	16.767	8.062
333.10	333.10	581.53	5.471	0.000	1-S2n	1.826	3.261	1.851	1.178	17.995	8.740
399.72	399.72	582.23	6.167	0.000	1-S2n	2.067	3.683	2.073	1.312	19.286	9.341
466.34	466.34	582.89	6.832	0.000	1-S2n	2.307	4.081	2.314	1.436	20.152	9.880
532.96	532.96	583.54	7.481	0.000	1-S2n	2.530	4.461	2.531	1.554	21.057	10.362
564.30	564.30	583.84	7.784	0.000	1-S2n	2.630	4.634	2.633	1.608	21.429	10.567
666.20	666.20	584.84	8.778	0.000	5-S2n	2.956	5.177	2.967	1.772	22.456	11.206

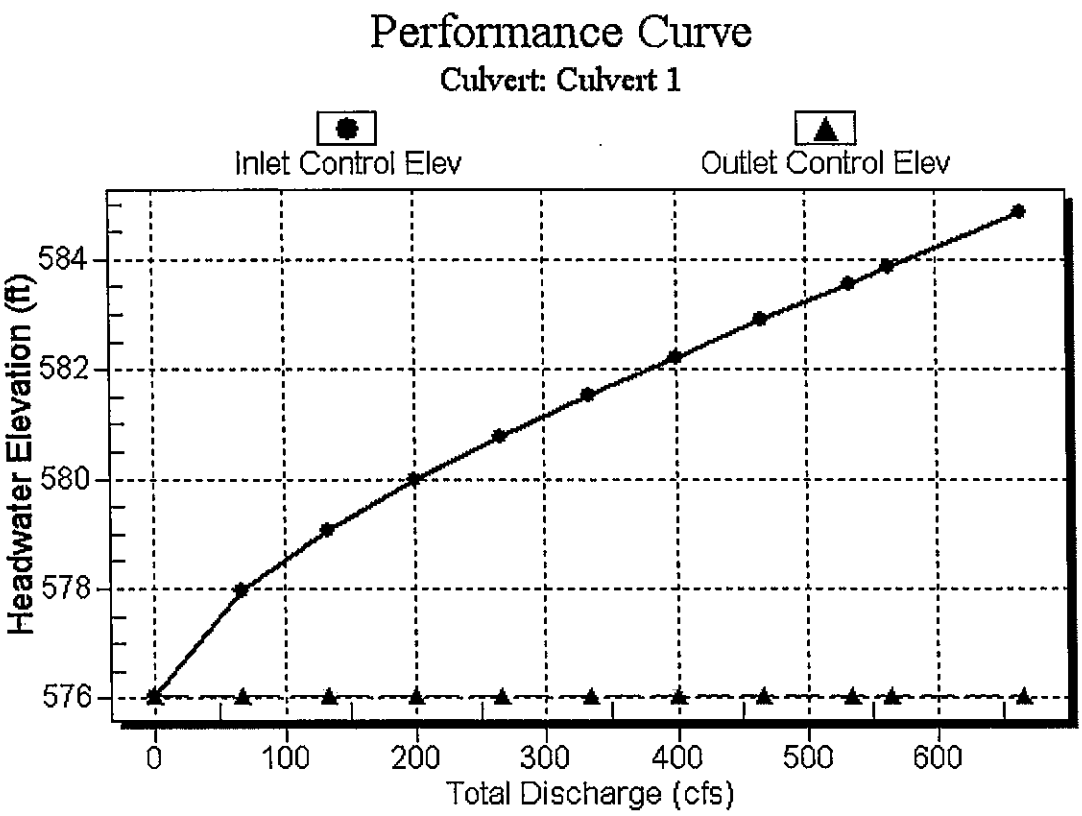
****

Inlet Elevation (invert): 576.06 ft, Outlet Elevation (invert): 554.52 ft

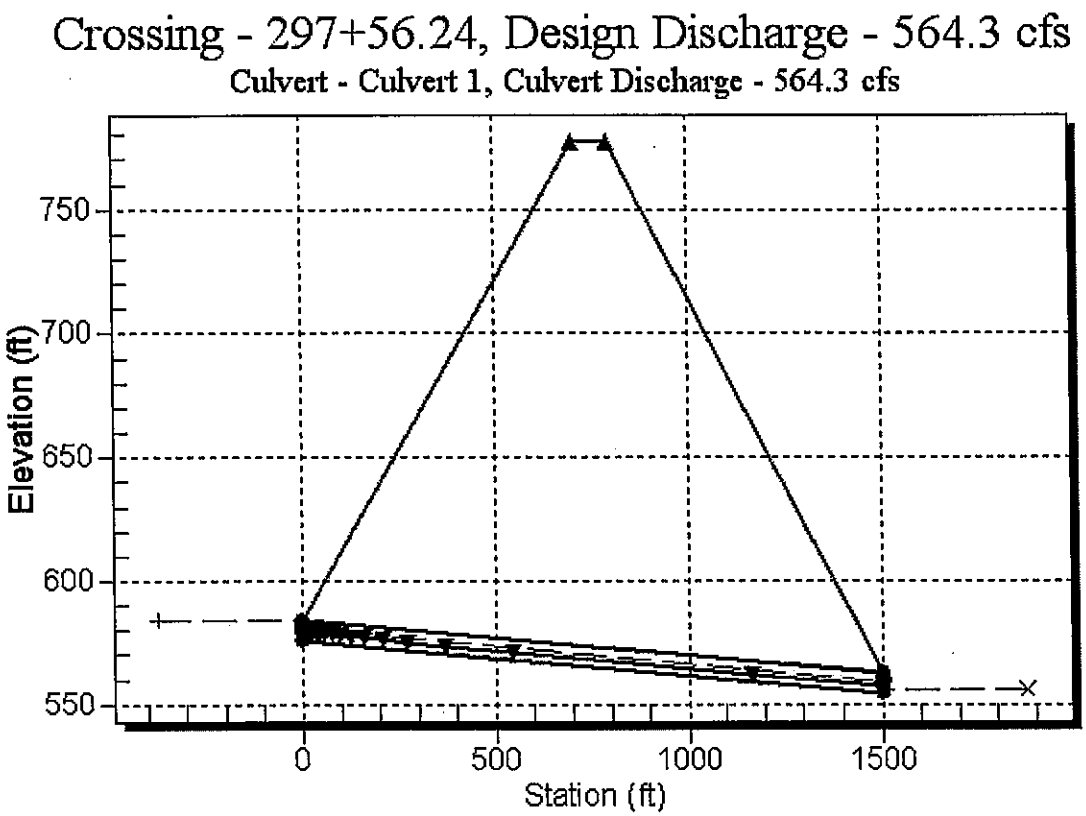
Culvert Length: 1502.15 ft, Culvert Slope: 0.0143

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 576.06 ft

Outlet Station: 1502.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 8.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 297+56.24)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
66.62	554.97	0.45	4.78	1.41	1.27
133.24	555.20	0.68	6.23	2.13	1.36
199.86	555.39	0.87	7.25	2.71	1.41
266.48	555.55	1.03	8.06	3.22	1.44
333.10	555.70	1.18	8.74	3.67	1.47
399.72	555.83	1.31	9.34	4.09	1.49
466.34	555.96	1.44	9.88	4.48	1.52
532.96	556.07	1.55	10.36	4.85	1.53
564.30	556.13	1.61	10.57	5.02	1.54
666.20	556.29	1.77	11.21	5.53	1.56

Tailwater Channel Data - 297+56.24

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 30.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 297+56.24

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 777.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 300+89.44

6' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 300+89.44

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
565.62	0.00	0.00	0.00	1
567.76	47.92	47.92	0.00	1
569.00	95.84	95.84	0.00	1
570.02	143.77	143.77	0.00	1
570.94	191.69	191.69	0.00	1
571.84	239.61	239.61	0.00	1
572.76	287.53	287.53	0.00	1
573.74	335.45	335.45	0.00	1
574.83	383.38	383.38	0.00	1
575.34	404.20	404.20	0.00	1
577.40	479.22	479.22	0.00	1

Size 6' + 6'

Allowable Head = 565.62 + 6 + 2

= 573.62

HWE_{50} = 575.34 > 573.62

HWE_{00} = 577.40 > 573.62

} Increase Size

Rating Curve Plot for Crossing: 300+89.44

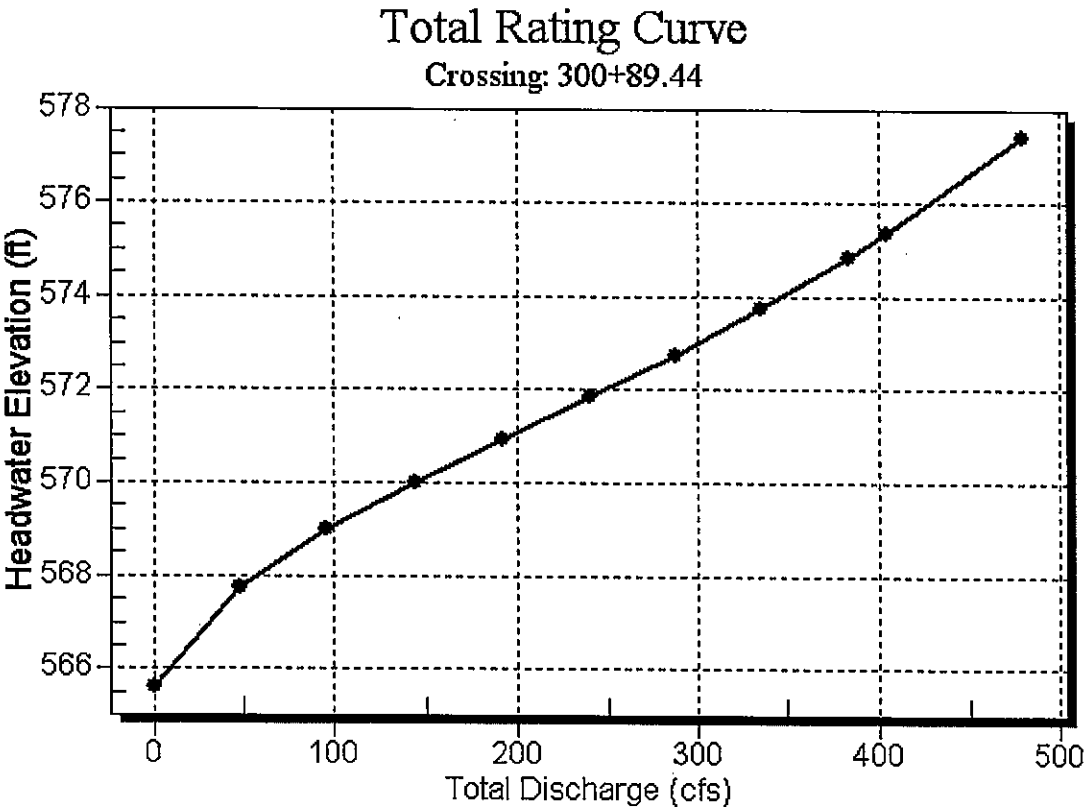


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	565.62	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
47.92	47.92	567.76	2.137	0.000	1-S2n	0.809	1.259	0.849	0.606	9.412	5.564
95.84	95.84	569.00	3.376	0.000	1-S2n	1.313	1.998	1.317	0.910	12.129	7.106
143.77	143.77	570.02	4.398	0.000	1-S2n	1.746	2.618	1.747	1.153	13.715	8.147
191.69	191.69	570.94	5.323	0.000	1-S2n	2.141	3.172	2.142	1.361	14.918	8.961
239.61	239.61	571.84	6.217	0.000	5-S2n	2.522	3.680	2.529	1.545	15.789	9.638
287.53	287.53	572.76	7.135	0.000	5-S2n	2.887	4.156	2.895	1.714	16.554	10.212
335.45	335.45	573.74	8.122	0.000	5-S2n	3.242	4.606	3.245	1.870	17.231	10.715
383.38	383.38	574.83	9.210	0.000	5-S2n	3.592	5.035	3.594	2.015	17.781	11.173
404.20	404.20	575.34	9.721	0.000	5-S2n	3.740	5.215	3.744	2.076	17.992	11.352
479.22	479.22	577.40	11.782	0.000	5-S2n	4.270	5.842	4.276	2.282	18.678	11.959

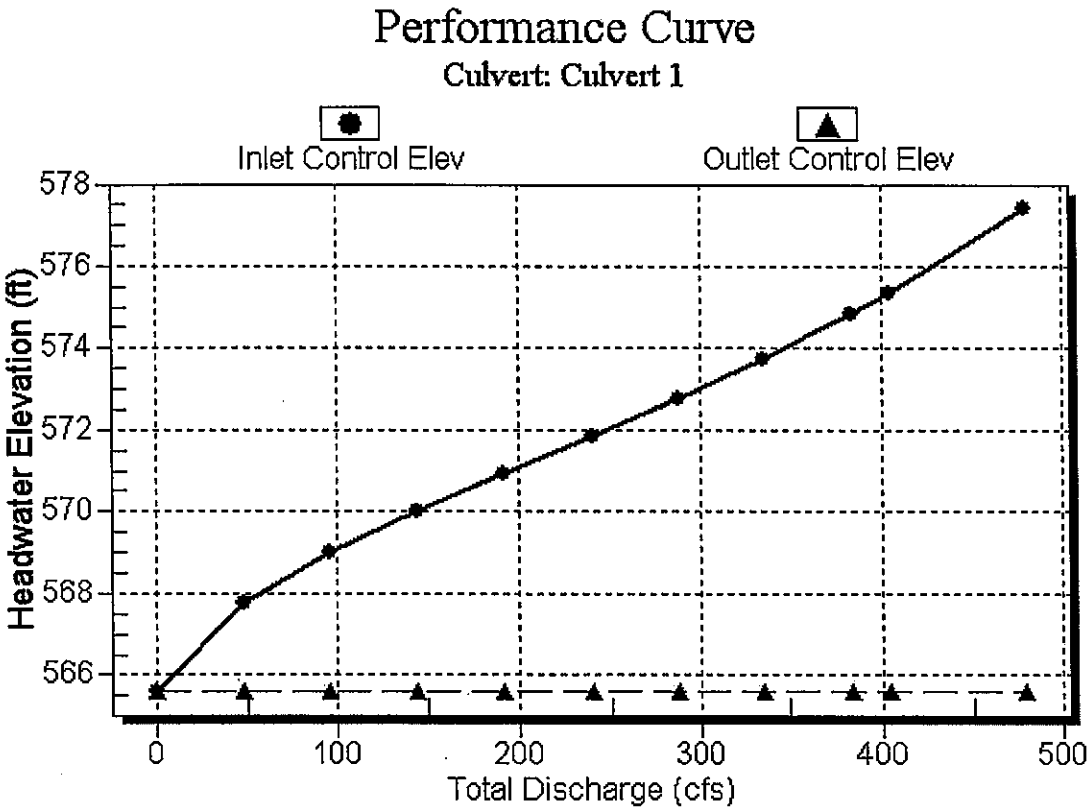
****

Inlet Elevation (invert): 565.62 ft, Outlet Elevation (invert): 554.52 ft

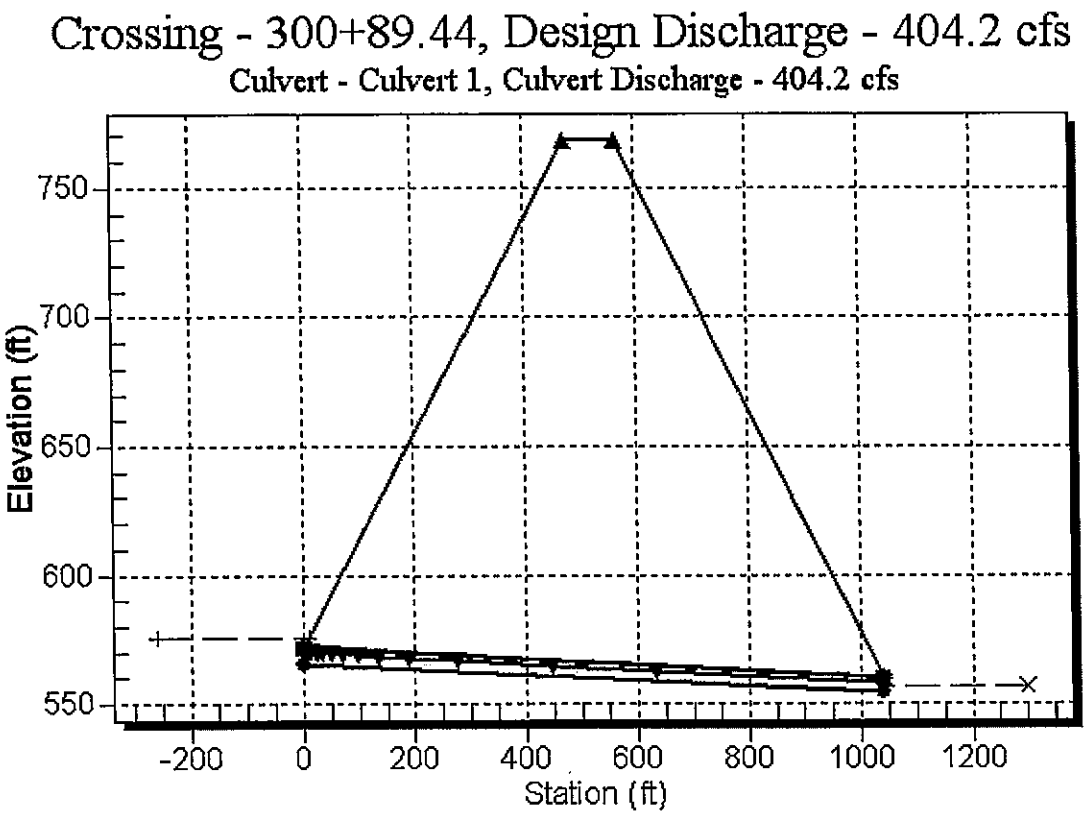
Culvert Length: 1040.06 ft, Culvert Slope: 0.0107

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 565.62 ft

Outlet Station: 1040.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 6.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 300+89.44)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
47.92	555.13	0.61	5.56	1.89	1.31
95.84	555.43	0.91	7.11	2.84	1.39
143.77	555.67	1.15	8.15	3.60	1.43
191.69	555.88	1.36	8.96	4.25	1.47
239.61	556.07	1.55	9.64	4.82	1.49
287.53	556.23	1.71	10.21	5.35	1.51
335.45	556.39	1.87	10.72	5.83	1.53
383.38	556.53	2.01	11.17	6.29	1.54
404.20	556.60	2.08	11.35	6.48	1.55
479.22	556.80	2.28	11.96	7.12	1.57

Tailwater Channel Data - 300+89.44

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 300+89.44

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 768.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 - STA. 300+89.44

7' x 6' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 300+89.44

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
565.62	0.00	0.00	0.00	1
567.55	47.92	47.92	0.00	1
568.68	95.84	95.84	0.00	1
569.60	143.77	143.77	0.00	1
570.42	191.69	191.69	0.00	1
571.20	239.61	239.61	0.00	1
571.97	287.53	287.53	0.00	1
572.76	335.45	335.45	0.00	1
573.60	383.38	383.38	0.00	1
573.98	404.20	404.20	0.00	1
575.51	479.22	479.22	0.00	1

Size 7' x 6'

Allowable head = 565.62 + 6 + 2 = 573.62

HW_{50} = 573.98 > 573.62

HW_{100} = 575.51 > 573.62

Increase the size

Rating Curve Plot for Crossing: 300+89.44

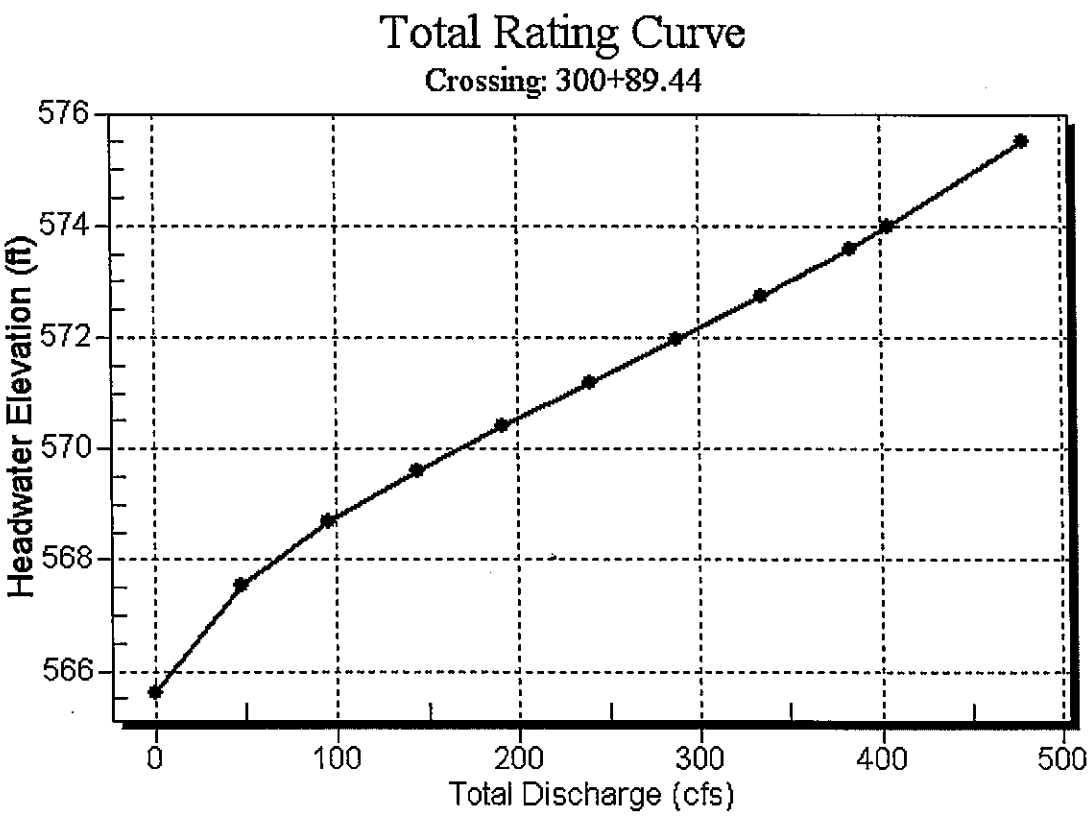


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	565.62	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
47.92	47.92	567.55	1.930	0.000	1-S2n	0.723	1.136	0.726	0.606	9.433	5.564
95.84	95.84	568.68	3.055	0.000	1-S2n	1.163	1.803	1.163	0.910	11.775	7.106
143.77	143.77	569.60	3.977	0.000	1-S2n	1.524	2.362	1.531	1.153	13.411	8.147
191.69	191.69	570.42	4.802	0.000	1-S2n	1.869	2.862	1.871	1.361	14.637	8.961
239.61	239.61	571.20	5.579	0.000	1-S2n	2.184	3.321	2.190	1.545	15.631	9.638
287.53	287.53	571.97	6.345	0.000	5-S2n	2.492	3.750	2.499	1.714	16.437	10.212
335.45	335.45	572.76	7.135	0.000	5-S2n	2.785	4.156	2.786	1.870	17.201	10.715
383.38	383.38	573.60	7.975	0.000	5-S2n	3.074	4.543	3.082	2.015	17.771	11.173
404.20	404.20	573.98	8.362	0.000	5-S2n	3.196	4.706	3.196	2.076	18.068	11.352
479.22	479.22	575.51	9.887	0.000	5-S2n	3.632	5.272	3.641	2.282	18.805	11.959

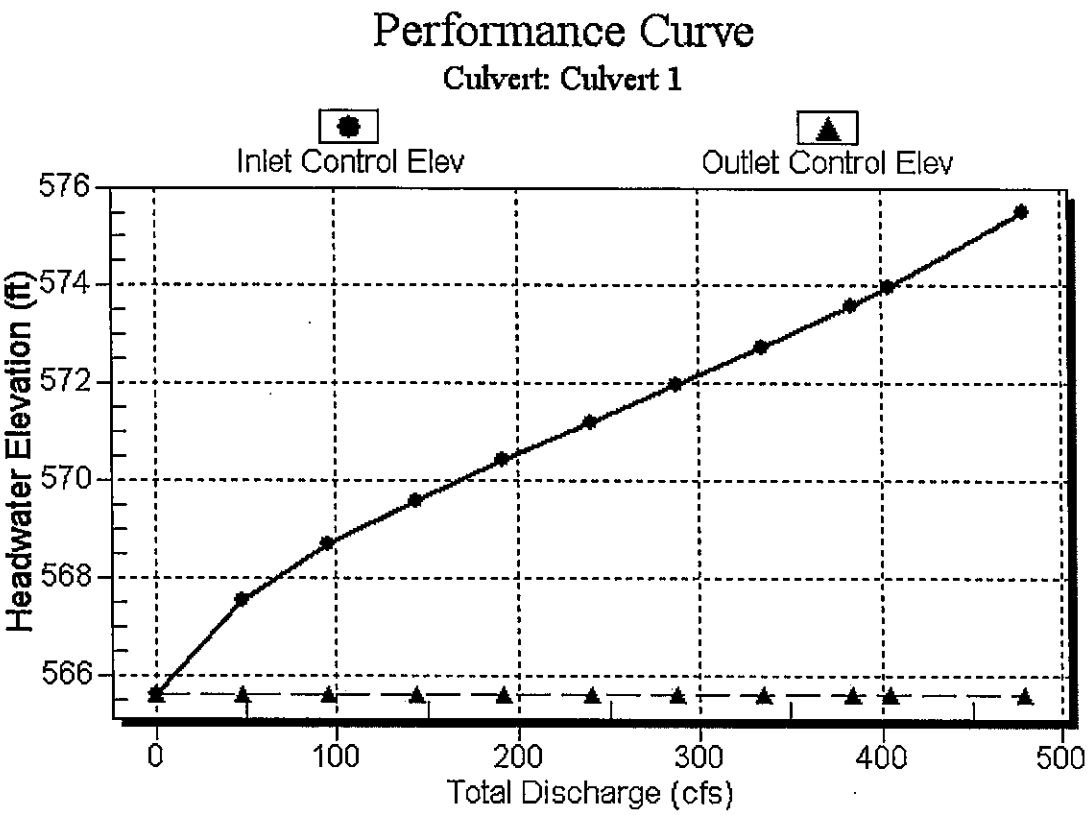
****

Inlet Elevation (invert): 565.62 ft, Outlet Elevation (invert): 554.52 ft

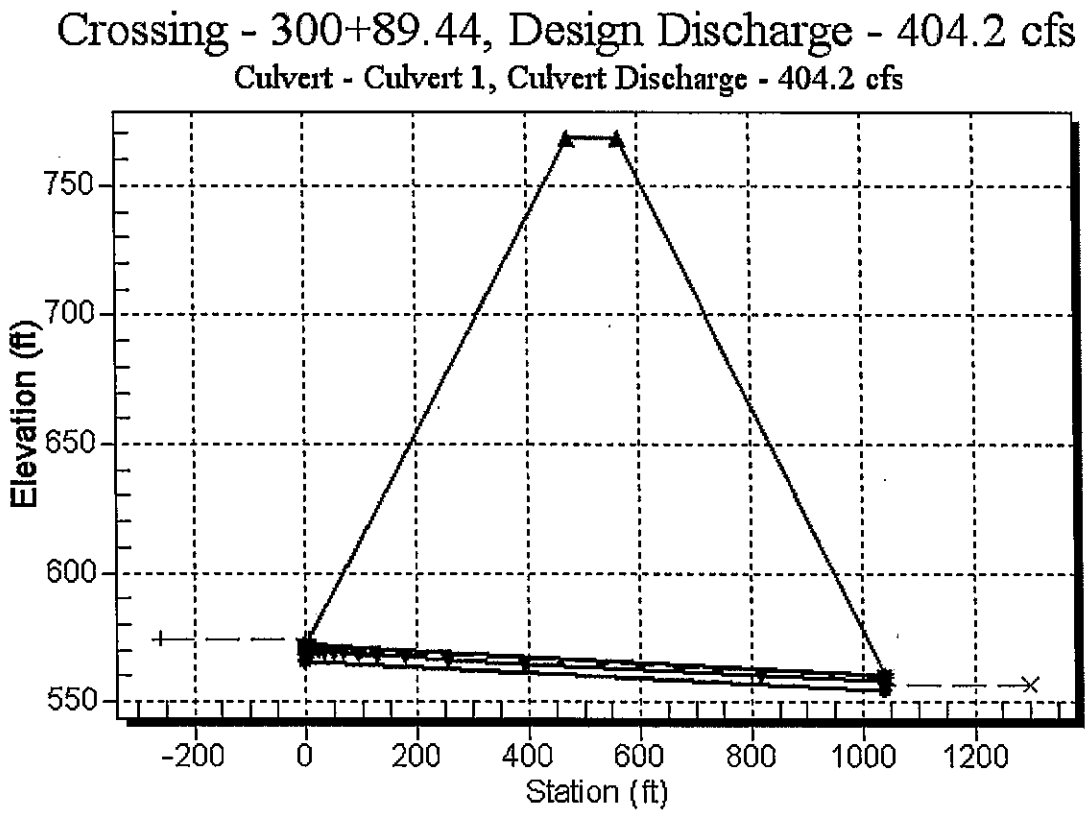
Culvert Length: 1040.06 ft, Culvert Slope: 0.0107

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 565.62 ft

Outlet Station: 1040.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 7.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 300+89.44)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
47.92	555.13	0.61	5.56	1.89	1.31
95.84	555.43	0.91	7.11	2.84	1.39
143.77	555.67	1.15	8.15	3.60	1.43
191.69	555.88	1.36	8.96	4.25	1.47
239.61	556.07	1.55	9.64	4.82	1.49
287.53	556.23	1.71	10.21	5.35	1.51
335.45	556.39	1.87	10.72	5.83	1.53
383.38	556.53	2.01	11.17	6.29	1.54
404.20	556.60	2.08	11.35	6.48	1.55
479.22	556.80	2.28	11.96	7.12	1.57

Tailwater Channel Data - 300+89.44

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 300+89.44

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 768.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

Table 1 - Summary of Culvert Flows at Crossing: 300+89.44

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
565.62	0.00	0.00	0.00	1
567.39	47.92	47.92	0.00	1
568.42	95.84	95.84	0.00	1
569.27	143.77	143.77	0.00	1
570.02	191.69	191.69	0.00	1
570.72	239.61	239.61	0.00	1
571.39	287.53	287.53	0.00	1
572.06	335.45	335.45	0.00	1
572.76	383.38	383.38	0.00	1
573.07	404.20	404.20	0.00	1
574.27	479.22	479.22	0.00	1

Allowable H-W = 565.62 + 6 + 2 = 573.62

HW_{TD} = 573.07 < 573.62 OK

HW_{LUD} = 574.27 > 573.62 Not OK

Try Bigger Size

HY-8 Culvert Analysis Report

SR823 – STA. 300+89.44

8' x 6' BOX CULVERT

Rating Curve Plot for Crossing: 300+89.44

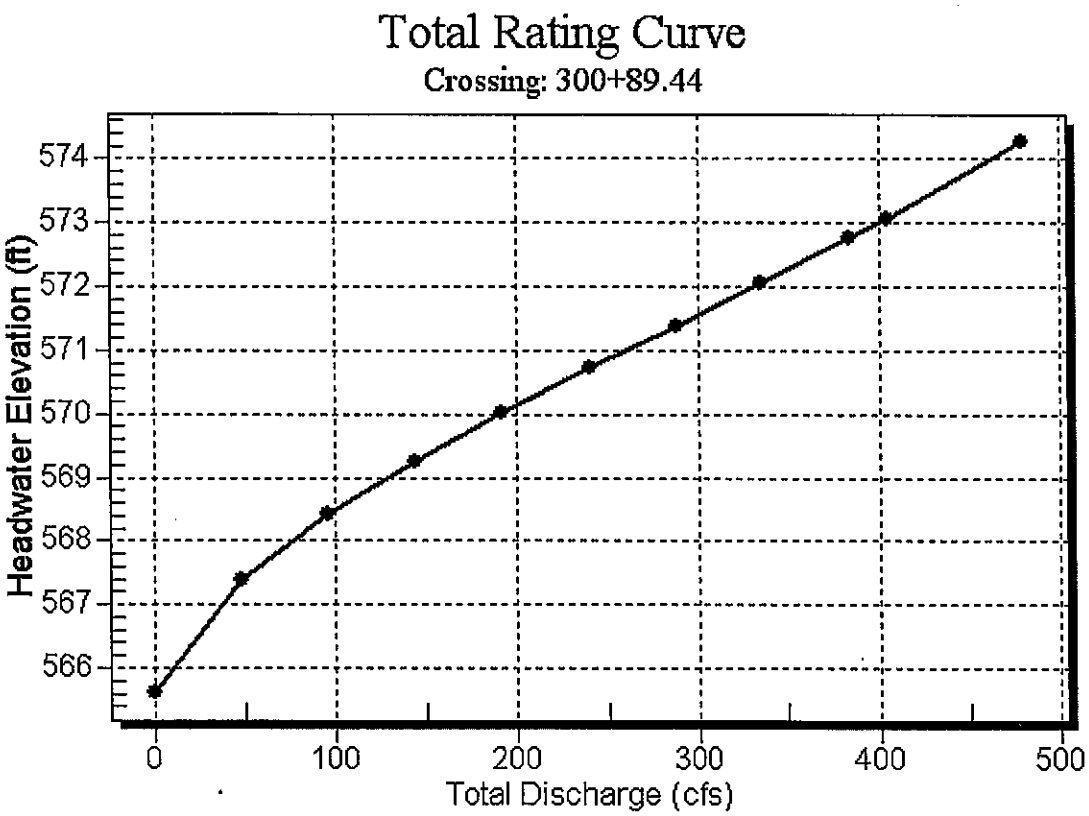


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	565.62	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
47.92	47.92	567.39	1.771	0.000	1-S2n	0.663	1.039	0.669	0.606	8.954	5.564
95.84	95.84	568.42	2.802	0.000	1-S2n	1.037	1.649	1.039	0.910	11.528	7.106
143.77	143.77	569.27	3.645	0.000	1-S2n	1.368	2.161	1.371	1.153	13.106	8.147
191.69	191.69	570.02	4.398	0.000	1-S2n	1.666	2.618	1.668	1.361	14.365	8.961
239.61	239.61	570.72	5.097	0.000	1-S2n	1.945	3.038	1.952	1.545	15.344	9.638
287.53	287.53	571.39	5.770	0.000	1-S2n	2.208	3.431	2.221	1.714	16.185	10.212
335.45	335.45	572.06	6.442	0.000	5-S2n	2.466	3.802	2.471	1.870	16.970	10.715
383.38	383.38	572.76	7.135	0.000	5-S2n	2.709	4.156	2.715	2.015	17.651	11.173
404.20	404.20	573.07	7.447	0.000	5-S2n	2.815	4.305	2.815	2.076	17.948	11.352
479.22	479.22	574.27	8.652	0.000	5-S2n	3.186	4.823	3.192	2.282	18.769	11.959

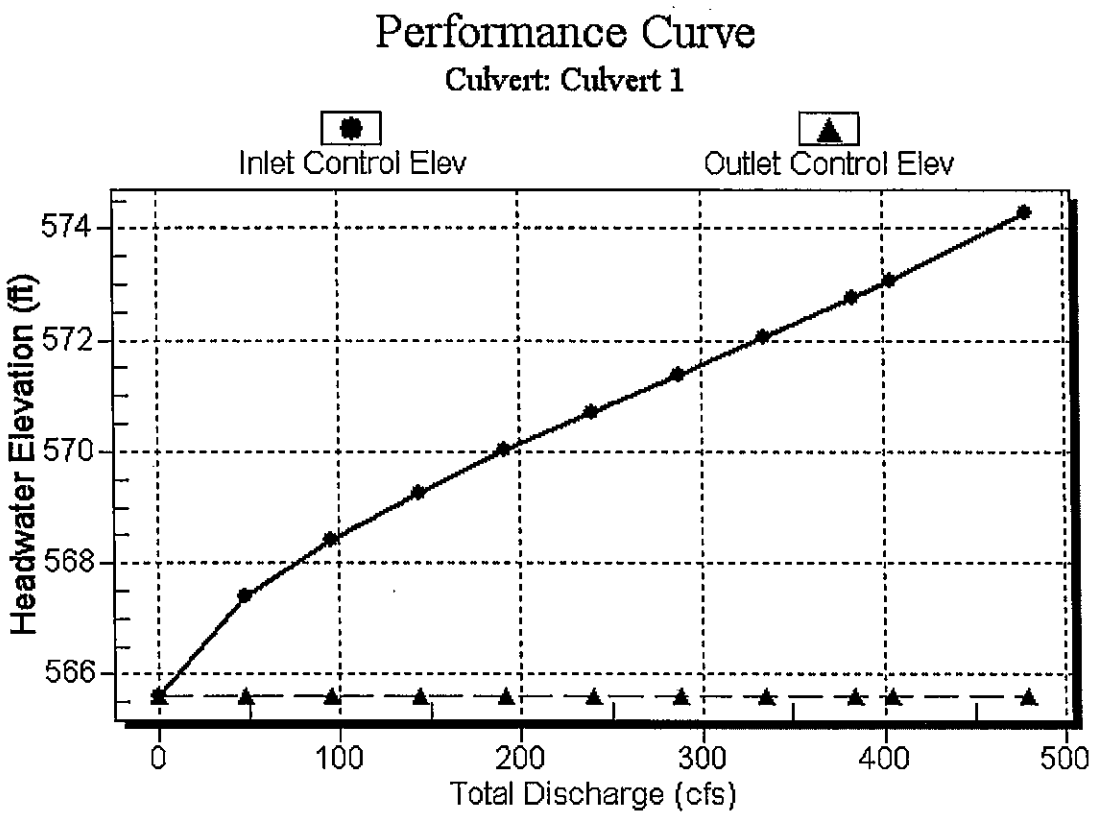
****

Inlet Elevation (invert): 565.62 ft, Outlet Elevation (invert): 554.52 ft

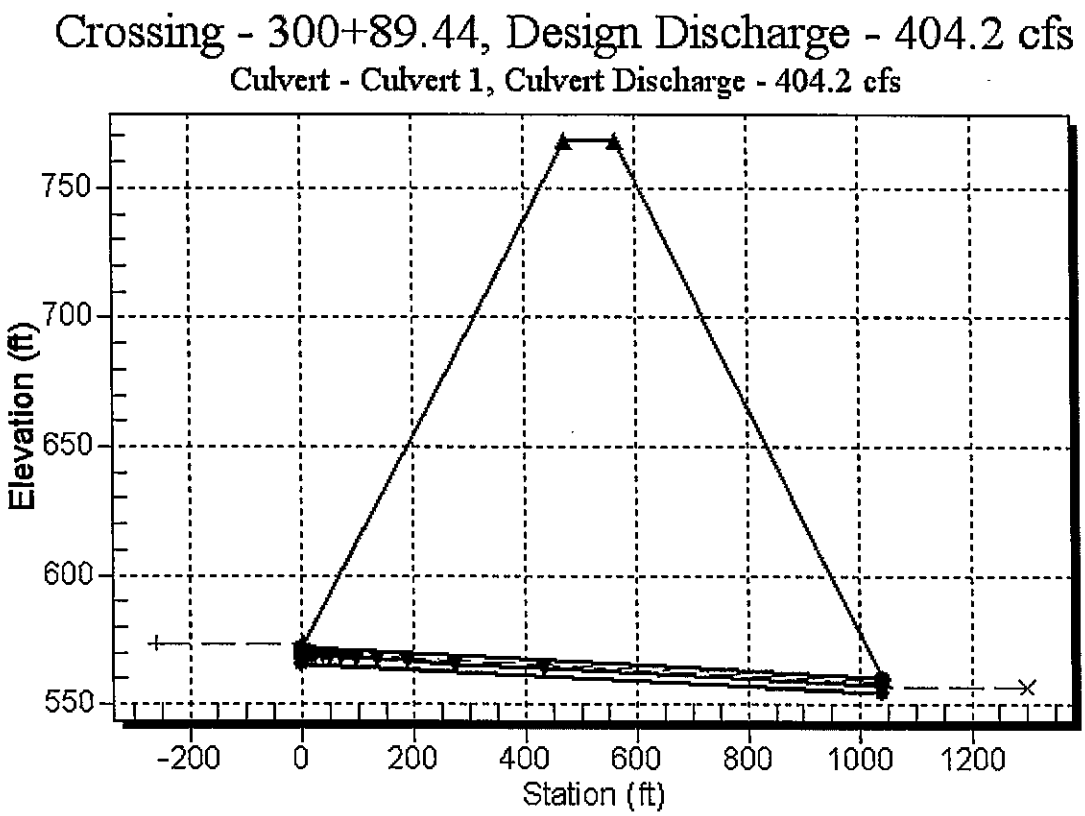
Culvert Length: 1040.06 ft, Culvert Slope: 0.0107

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 565.62 ft

Outlet Station: 1040.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 300+89.44)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
47.92	555.13	0.61	5.56	1.89	1.31
95.84	555.43	0.91	7.11	2.84	1.39
143.77	555.67	1.15	8.15	3.60	1.43
191.69	555.88	1.36	8.96	4.25	1.47
239.61	556.07	1.55	9.64	4.82	1.49
287.53	556.23	1.71	10.21	5.35	1.51
335.45	556.39	1.87	10.72	5.83	1.53
383.38	556.53	2.01	11.17	6.29	1.54
404.20	556.60	2.08	11.35	6.48	1.55
479.22	556.80	2.28	11.96	7.12	1.57

Tailwater Channel Data - 300+89.44

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 300+89.44

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 768.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft

HY-8 Culvert Analysis Report

SR823 – STA. 300+89.44

8' x 8' BOX CULVERT

Table 1 - Summary of Culvert Flows at Crossing: 300+89.44

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
565.62	0.00	0.00	0.00	1
567.40	47.92	47.92	0.00	1
568.42	95.84	95.84	0.00	1
569.29	143.77	143.77	0.00	1
570.05	191.69	191.69	0.00	1
570.74	239.61	239.61	0.00	1
571.39	287.53	287.53	0.00	1
572.00	335.45	335.45	0.00	1
572.59	383.38	383.38	0.00	1
572.85	404.20	404.20	0.00	1
573.76	479.22	479.22	0.00	1

Allowable Headwater = 565.62 + 8.72

= 575.62

HW_{50} = 572.85 < 575.62 Ok

HW_{100} = 573.78 < 575.62 Ok

Rating Curve Plot for Crossing: 300+89.44

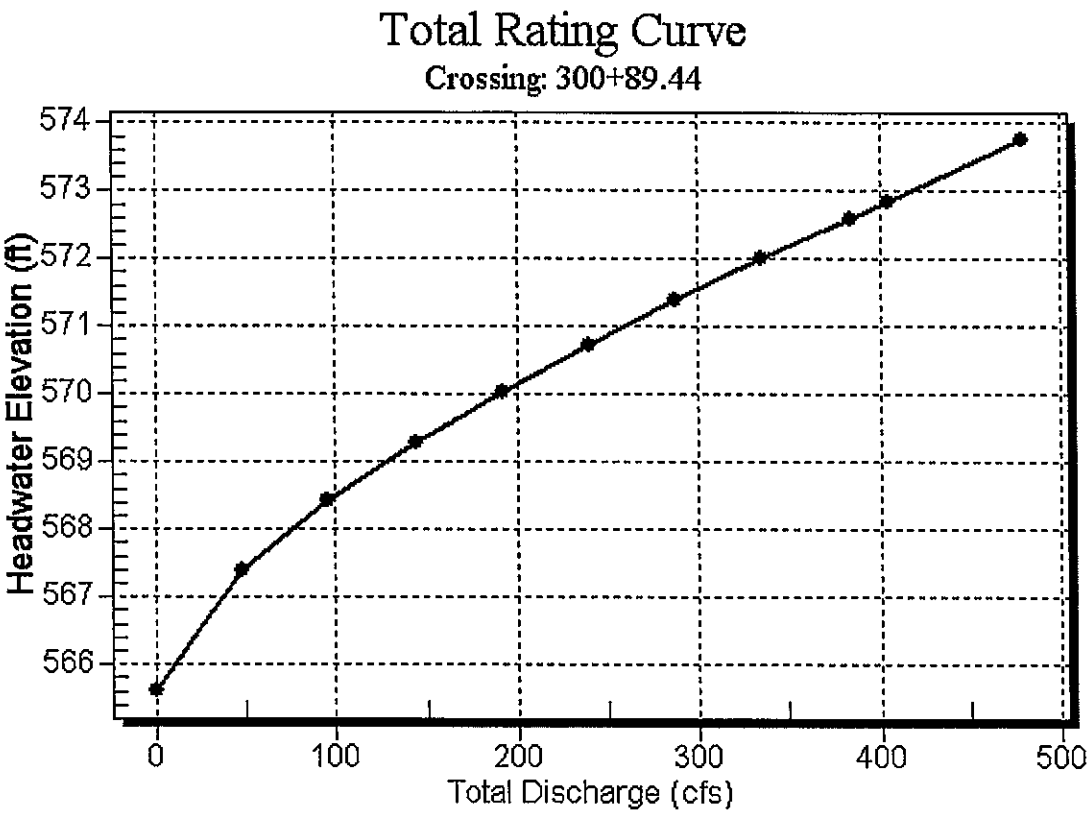


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	565.62	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
47.92	47.92	567.40	1.775	0.000	1-S2n	0.612	1.039	0.629	0.606	9.524	5.564
95.84	95.84	568.42	2.799	0.000	1-S2n	1.028	1.649	1.039	0.910	11.528	7.106
143.77	143.77	569.29	3.672	0.000	1-S2n	1.356	2.161	1.360	1.153	13.212	8.147
191.69	191.69	570.05	4.426	0.000	1-S2n	1.669	2.618	1.677	1.361	14.287	8.961
239.61	239.61	570.74	5.118	0.000	1-S2n	1.937	3.038	1.937	1.545	15.463	9.638
287.53	287.53	571.39	5.765	0.000	1-S2n	2.204	3.431	2.221	1.714	16.185	10.212
335.45	335.45	572.00	6.380	0.000	1-S2n	2.465	3.802	2.471	1.870	16.970	10.715
383.38	383.38	572.59	6.973	0.000	1-S2n	2.706	4.156	2.715	2.015	17.651	11.173
404.20	404.20	572.85	7.227	0.000	1-S2n	2.811	4.305	2.815	2.076	17.948	11.352
479.22	479.22	573.76	8.135	0.000	5-S2n	3.188	4.823	3.192	2.282	18.769	11.959

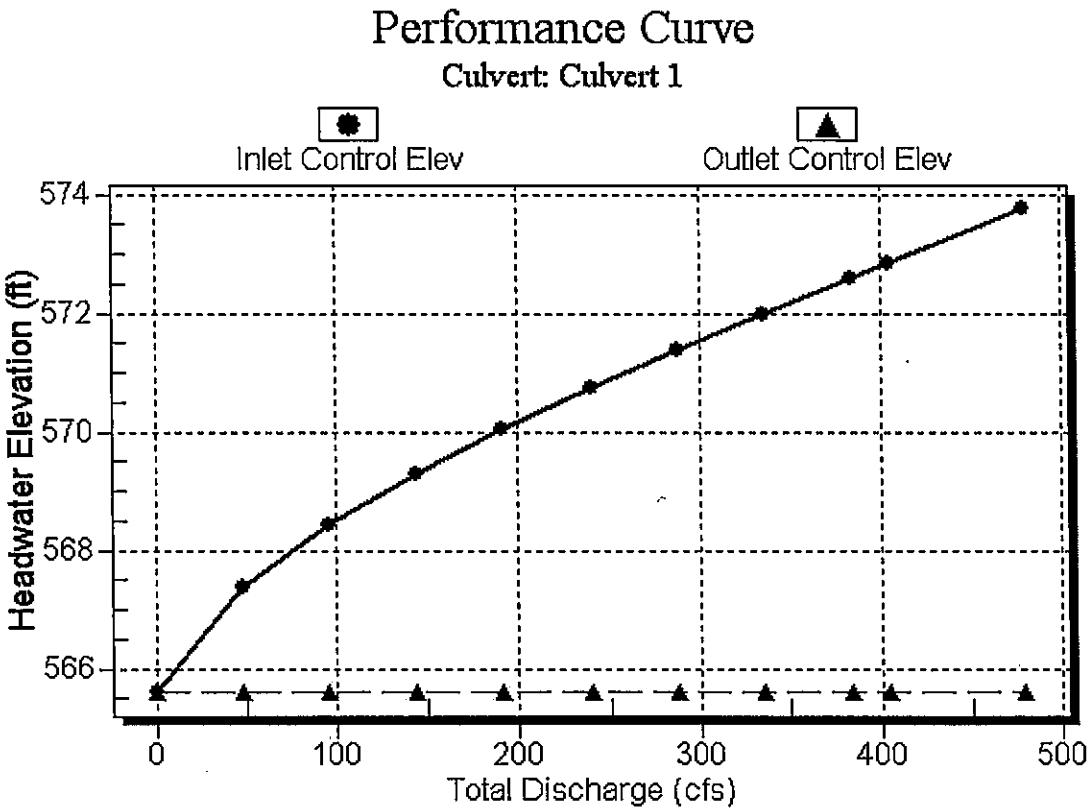
****

Inlet Elevation (invert): 565.62 ft, Outlet Elevation (invert): 554.52 ft

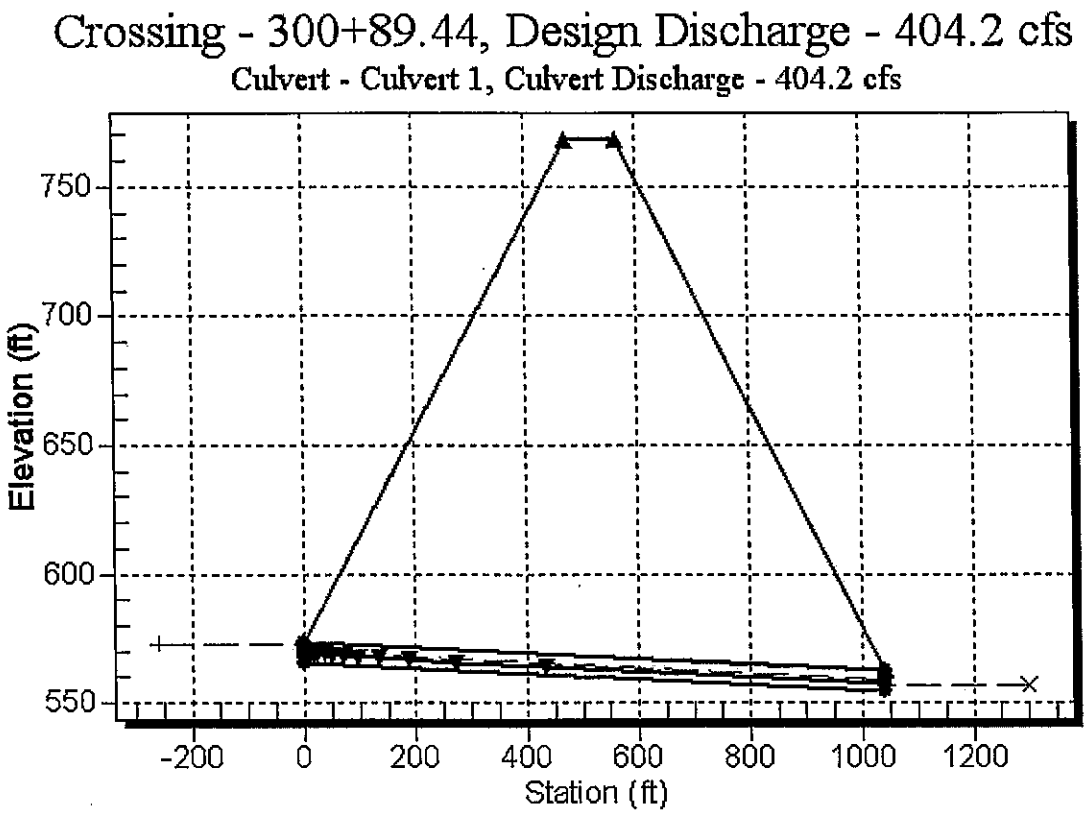
Culvert Length: 1040.06 ft, Culvert Slope: 0.0107

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 565.62 ft

Outlet Station: 1040.00 ft

Outlet Elevation: 554.52 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 8.00 ft

Barrel Material: Concrete

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 300+89.44)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	554.52	0.00	0.00	0.00	0.00
47.92	555.13	0.61	5.56	1.89	1.31
95.84	555.43	0.91	7.11	2.84	1.39
143.77	555.67	1.15	8.15	3.60	1.43
191.69	555.88	1.36	8.96	4.25	1.47
239.61	556.07	1.55	9.64	4.82	1.49
287.53	556.23	1.71	10.21	5.35	1.51
335.45	556.39	1.87	10.72	5.83	1.53
383.38	556.53	2.01	11.17	6.29	1.54
404.20	556.60	2.08	11.35	6.48	1.55
479.22	556.80	2.28	11.96	7.12	1.57

Tailwater Channel Data - 300+89.44

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 13.00 ft

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

Channel Slope: 0.0500

Channel Manning's n: 0.0400

Channel Invert Elevation: 554.52 ft

Roadway Data for Crossing: 300+89.44

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 768.00 ft

Roadway Surface: Paved

Roadway Top Width: 90.00 ft