

Preliminary Design Report

Dunn Brook Bridge #5837
over
Dunn Brook

Smyrna, Maine

STP-1787(800)X
PIN 17878.00



Maine Department of Transportation



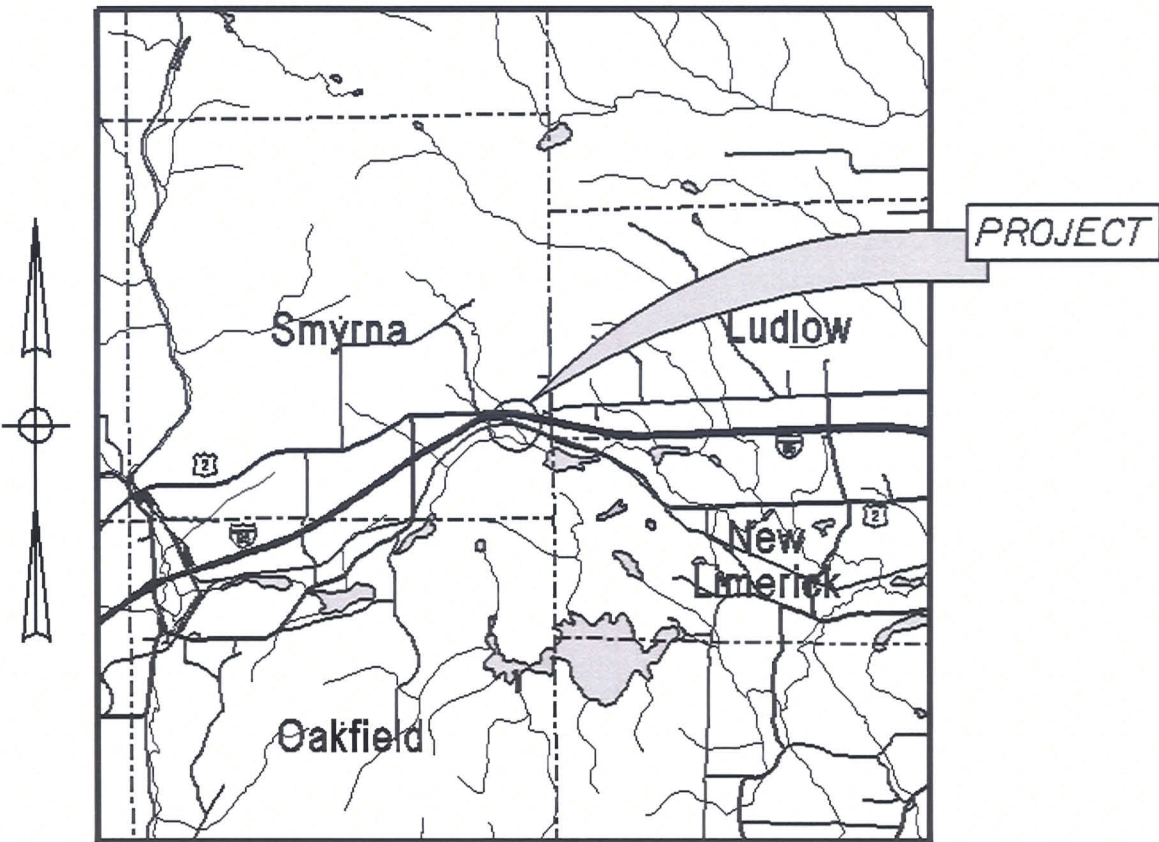
Bridge Program



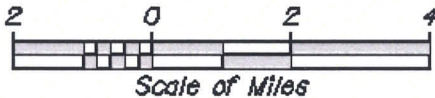
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Location Map



LOCATION MAP



HYDROLOGY REPORT

The Drainage Basin Characteristics for [Dunn Brook Bridge #5837 in Smyrna on U.S. Route 2 over Dunn Brook](#) was provided by the Maine Department of Transportation Office of the Environment-Hydrology Section. The flows were computed using the 1999 USGS full regression equation. No other flow data is available such as gage data, existing studies, or reports from local residents. Therefore the hydrology data was used as provided and as follows:

Summary

Drainage Area = [4.08](#) square miles
Fish passage flow (low) = [0.78](#) cfs
Fish passage flow (high) = [11.62](#) cfs
Ordinary High Water ($Q_{1.1}$) = [86.4](#) cfs
10 Year Flood (Q_{10}) = [410.6](#) cfs
 Q_{25} = [543.6](#) cfs
Design Discharge (Q_{50}) = [650.7](#) cfs
Check Discharge (Q_{100}) = [766.7](#) cfs

Reported By: [David Sullivan](#)
Date: [April 29, 2011](#)

HYDRAULICS SUMMARY

Background

The culvert was analyzed using the HY-8 (version 7.2) program. The tailwater conditions in HY8 are modeled as an irregular channel that is located downstream from the outlet. The flows as shown in the Hydrology Report were used. The road itself will overtop at elevation 525' and greater.

Existing Culvert

Discussions during the Initial Team Meeting which included Region 5 Maintenance & Operations personnel revealed that there is no known history of flooding at the site. This is consistent with a site visit, which showed no signs of major flooding having occurred and reports from the Town Manager and one Selectman. 100' downstream from the bridge is an 8'+/- span culvert under the railroad. The Bank Full Width (BFW) has been estimated to be 16ft by Charlie Hebson thus the 1.2 BFW dimension is 19.2ft. The HW/D ratio of 1.35 is greater than 0.90 used for the design of new structures. At Q100, the water is just on the verge of overtopping the road.

Culvert Rehabilitation Options

Invert lining -The invert lining can be either 5" thick concrete (shotcrete or cast in place) or 2" thick FRP. The concrete and/or FRP invert lining would extend up the side of the pipe arch about 6" above the limits of the rust line. The concrete option will start to overtop at Q50 but if the thinner FRP is used the overtopping should start after Q50. In order to maintain minimum flow depths for fish passage; three interior weirs spaced evenly, and two exterior weirs at the downstream end will be needed. The HW/D ratio of 1.77 is greater than the 1.35 of the existing structure. Hydraulically this is not an improvement from the existing structure, but it is still the best global option.

Sliplining – A 7'-8" span by 5'-5" is the largest pipe that can be sliplined into the existing pipe which has a bow in the top as shown in the cross section. This size pipe allows a minimum of 6 inches around the sliplining. So the inlet will be 6 inches higher than the existing pipes bottom. The sliplining will overtop the roadway before Q25. The HW/D ratio of 1.93 is greater than the 1.35 of the existing structure and hydraulically this is not an improvement from the existing structure. Therefore the sliplining option is not a feasible solution.

Culvert Replacement Options

Bankfull width option

16' span by 10' rise by 82' long precast concrete box culvert embedded 2' with sediment traps

1.2 bankfull width option

20' span by 10' rise by 86' long precast concrete box culvert embedded 2' with sediment traps

A formal hydraulic analysis was not performed on these replacement options. Both replacement options will clearly have better hydraulic performance than the existing pipe arch.

Recommendation

Due to the high velocities at Q100, the use of heavy riprap is recommended for the sideslopes and the aprons. From a hydraulic standpoint, the preferred alternative is a

large single opening such a large concrete box culvert, however, the final decision on what alternative to use will be based on other factors such as constructability, initial cost and life cycle cost. Please refer to the summary of preliminary engineering.

	Existing 11'-4" x 6'-9" Steel Pipe Arch	Invert Lining	Sliplining 7'-8" x 5'-5" Steel Pipe Arch
Total Area of Waterway Opening	60.5 ft ²	54.3 ft ²	33.0 ft ²
Headwater Elevation @ low fish passage flow	514.38 ft	514.76 ft	514.85 ft
Headwater Elevation @ high fish passage flow	515.00 ft	515.36 ft	515.74 ft
Headwater Elevation @ Q _{1.1}	516.64 ft	517.15 ft	517.84 ft
Headwater Elevation @ Q ₂₅	522.32 ft	524.19 ft	Overtop
Headwater Elevation @ Q ₅₀	523.40 ft	Overtop	Overtop
Headwater Elevation @ Q ₁₀₀	524.94 ft	Overtop	Overtop
HW/D @ Q ₅₀	1.38	1.77	1.93
Outlet Velocity @ low fish passage flow	0.35 ft/s	3.00 ft/s	1.90 ft/s
Outlet Velocity @ high fish passage flow	2.23 ft/s	4.44 ft/s	3.65 ft/s
Outlet Velocity @ Q _{1.1}	6.12 ft/s	11.17 ft/s	7.12 ft/s
Outlet Velocity @ Q ₂₅	11.97 ft/s	16.16 ft/s	12.51 ft/s
Outlet Velocity @ Q ₅₀	12.96 ft/s	16.34 ft/s	12.59 ft/s
Outlet Velocity @ Q ₁₀₀	14.08 ft/s	16.31 ft/s	12.67 ft/s
Outlet Depth @ low fish passage flow	0.44 ft	0.02 ft	0.17 ft
Outlet Depth @ high fish passage flow	0.80 ft	0.24 ft	0.67 ft

Reported By: [David Sullivan](#)

Date: [May 9, 2011](#)

Note: All elevations based on North American Vertical Datum (NAVD) of 1988

STATE OF MAINE DEPARTMENT OF TRANSPORTATION



SMYRNA AROOSTOOK DUNN BROOK BRIDGE OVER DUNN BROOK U. S. ROUTE 2 PROJECT NO. STP-1787(800)X CULVERT INVERT LINING BRIDGE NO. 5837

TRAFFIC DATA

Current (2011) AADT	1,420
Future (2031) AADT	1,700
DHV - % of AADT	11
Design Hour Volume	187
Heavy Trucks (% of AADT)	10
Heavy Trucks (% of DHV)	9
Directional Distribution (% of DHV)	56
18 kip Equivalent P 2.0	189
18 kip Equivalent P 2.5	180
Design Speed (mph)	50

HYDROLOGIC DATA

Drainage Area	4.08 sq mi
Design Discharge (Q50)	650.7 cfs
Check Discharge (Q100)	766.7 cfs
Headwater Elevation (Q50)	525.22 ft
Headwater Elevation (Q100)	525.42 ft
Discharge Velocity (Q50)	16.34 fps
Discharge Velocity (Q100)	16.31 fps
Headwater Elevation (Q1.1)	517.15 ft
Discharge Velocity (Q1.1)	11.17 fps
Headwater Elevation (Q25)	524.19 ft

MATERIALS

Concrete	Modified "LP" or Shotcrete
Reinforcing Steel	ASTM A 615/A 615M, Grade 60

BASIC DESIGN STRESSES

Concrete	f'c = 5,000 psi
Reinforcing Steel	f _y = 60,000 psi

UTILITIES

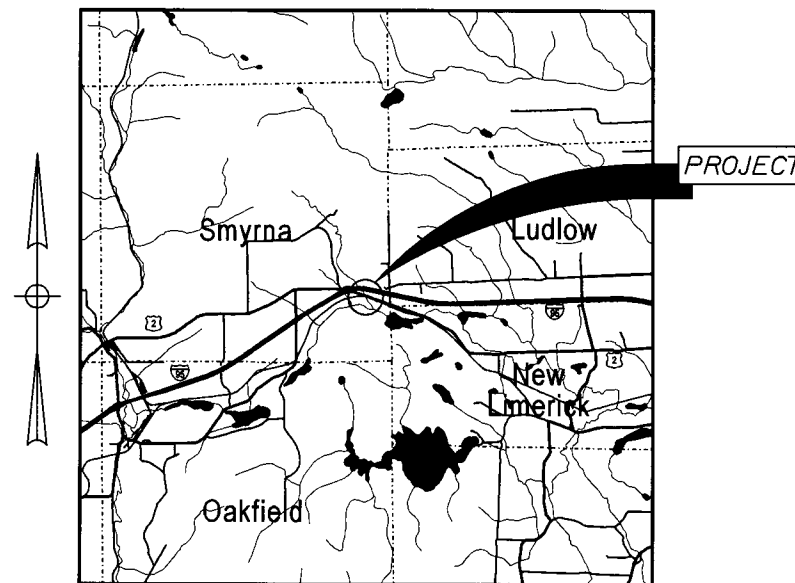
Maine Public Service Company
Northland Telephone (Fairpoint Classic)

MAINTENANCE OF TRAFFIC

Maintain two - way traffic during construction. When needed, single lane closures will be maintained by flaggers.

LIST OF DRAWINGS

Preliminary Title Sheet	1
Preliminary Invert Lining Plan	2



LOCATION MAP



STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
APPROVED
DATE
COMMISSIONER
CHIEF ENGINEER

PROJECT INFORMATION
PROGRAM: BRIDGE
PROJECT MANAGER: STEPHEN BOOGE
DESIGNER: DAVID SULLIVAN
CONSULTANT:
PROJECT RESIDENT:
CONTRACTOR:
PROJECT COMPLETION DATE:
SIGNATURE:
P. E. NUMBER:
DATE:

STP-1787(800)X
SMYRNA
DUNN BROOK BRIDGE
PRELIMINARY TITLE SHEET

SHEET NUMBER
1
OF 2

Date: 5/10/2011

name: david.sullivan

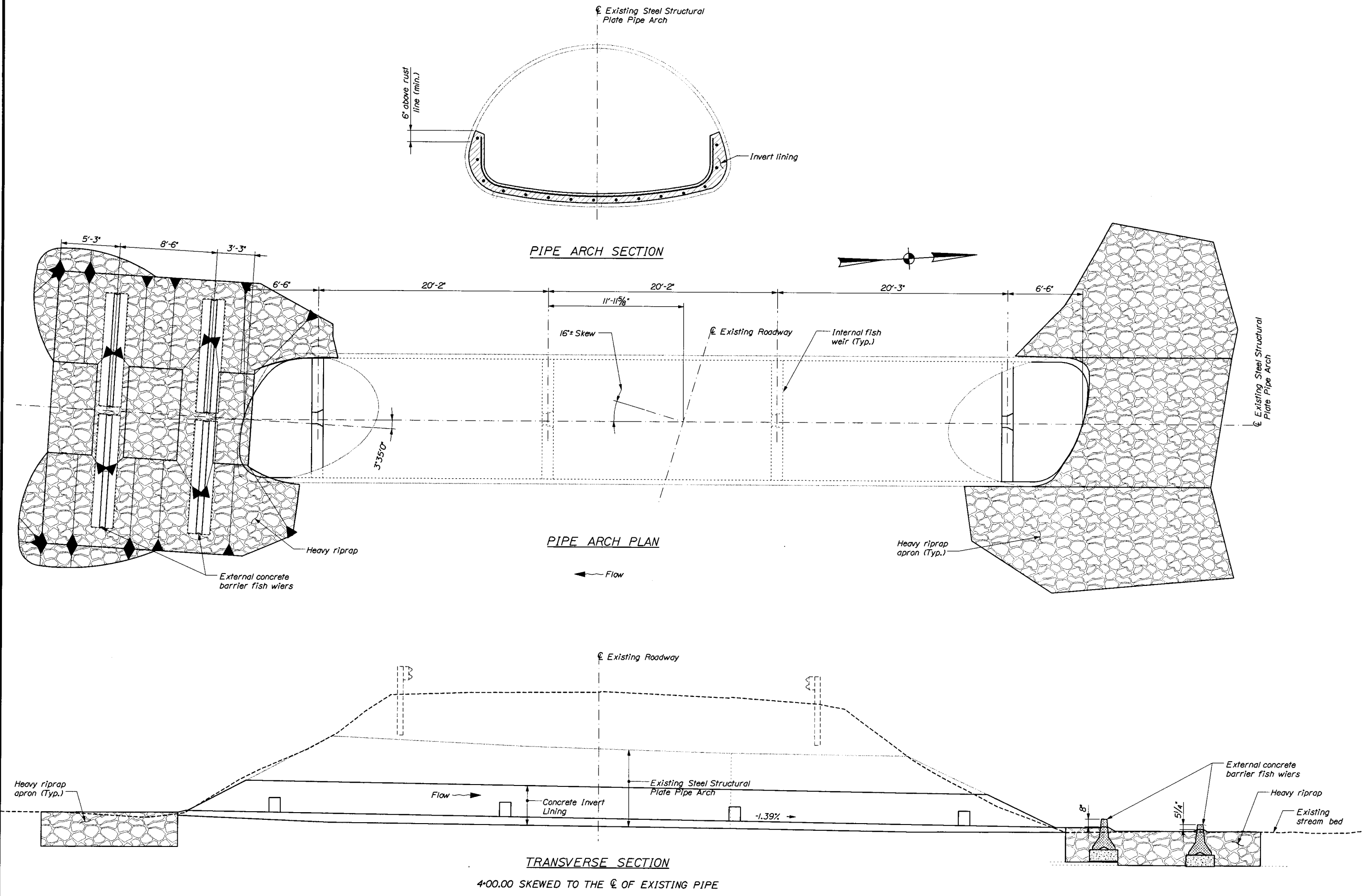
Division: BRIDGE

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PIN 17878.00

STP-1787(800)X

Filename: ...Ansta\002_Preliminary_Pipe.dgn Division: BRIDGE Isurname: david.sullivan Date: 5/10/2011



STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
STP-1787(800)X
BRIDGE NO. 5837 PIN 17878.00
BRIDGE PLANS

PROJ. MANAGER	STEPHEN BODGE	BY	DATE
DESIGN-DETAILED	D. Sullivan		
CHECKED-REVIEWED	M. Wright		
DESIGN-DETAILED			
REVISIONS	1		
REVISIONS	2		
REVISIONS	3		
REVISIONS	4		
FIELD CHANGES			

DUNN BROOK BRIDGE
DUNN BROOK
SMYRNA
AROOSTOOK
PRELIMINARY INVERT LINING PLANS

SHEET NUMBER
2
OF 2

PHOTOGRAPHS

17878.00 – Smyrna, Dunn Brook Bridge #5837



Figure 1: Approach - U.S. Rt. 2 looking East



Figure 2: Approach - U.S. Rt. 2 looking West



Figure 3: Looking upstream



Figure 4: Railroad bridge downstream



Figure 5: Looking downstream through the pipe



Figure 6: Looking upstream through pipe



Figure 7: Upstream rust line



Figure 8: Downstream rust line



Figure 9: Good condition of top plates

Structure Inventory and Appraisal Sheet (English Units)

Bridge Key:	5837	Agency ID:	5837	SR: 71.2	SD/FO: N
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IDENTIFICATION	
State 1:	23 Maine
Facility Carried 7:	US #2
Rte.(On/Under)5A:	Route On Structure
Level of Service 5C:	1 Mainline
Directional Suffix 5E:	0 N/A (NBI)
SHD District 2:	05 Northern
Place Code 4:	03590 Smyrna
Feature Intersected 6:	DUNN BROOK
Latitude 16:	46d 08' 34"
Border Bridge Code 98:	Not Applicable (P)
Border Bridge Number 99:	n/a

INSPECTION	
Frequency 91:	24 months
FC Frequency 92A:	NA
UW Frequency 92B:	NA
SI Frequency 92C:	NA
Element Frequency:	24 months
Inspection Date 90:	10/27/2009
FC Inspection Date 93A:	NA
UW Inspection Date 93B:	NA
SI Date 93C:	NA
Element Inspection Date:	10/27/2009
Next Inspection:	10/27/2011
Next FC Inspection:	NA
Next UW Inspection:	NA
Next SI:	NA
Next Elem. Insp. Due:	10/27/2011

STRUCTURE TYPE AND MATERIALS	
Number of Approach Spans 46:	0
Main Span Material/Design 43A/B:	3 Steel
Deck Type 107:	0
Wearing Surface 108A:	N N/A (no deck (NBI))
Membrane 108B:	N N/A (no deck (NBI))
Deck Protection 108C:	N N/A (no deck (NBI))

CLASSIFICATION	
Defense Highway 100:	0 Not a STRAHNET hwy
Highway System 104:	0 Not on NHS
Defense Hwy 110:	0 Not a STRAHNET
Owner 22:	01 State Highway Agency
Custodian 21:	01 State Highway Agency
Parallel Structure 101:	No bridge exists
Temporary Structure 103:	Not Applicable (P)
NBIS Length 112:	Too Short
Functional Class 26:	07 Rural Mjr Collector
Historical Significance 37:	5 Not eligible for NRHP

AGE AND SERVICE	
Year Built 27:	1954
Type of Service on 42A:	1 Highway
Type of Service under 42B:	5 Waterway
Lanes on 28A:	2
ADT 29:	1,420
Year Reconstructed 106:	0
Detour Length 19:	11.2 mi
Year of ADT 30:	2009

CONDITION	
Deck 58:	N N/A (NBI)
Culvert 62:	4 Considerable Damage
Super 59:	N N/A (NBI)
Channel/Channel Protection 61:	7 Minor Damage
Sub 60:	N N/A (NBI)

LOAD RATING AND POSTING	
Inventory Rating Method 65:	2 AS Allowable Stress
Inventory Rating 66:	HS20.0
Design Load 31:	0 Other or Unknown
Posting status 41:	A Open, no restriction
Operating Rating Method 63:	2 AS Allowable Stress
Operating Rating 64:	HS30.0
Posting 70:	5 At/Above Legal Loads

GEOMETRIC DATA	
Length Max Span 48:	12.0 ft
Curb/Sdwlk Width L 50A:	0.0 ft
Width Curb to Curb 51:	0.0 ft
Approach Roadway Width 32:	30.0 ft
Deck Area:	384. sq. ft
Skew 34:	0.00 °
Vertical Clearance 10:	99.99 ft
Minimum Vertical Clearance Over Bridge 53:	327.8 ft
Minimum Vertical Underclearance Reference 54A:	N Feature not hwy or RR
Minimum Vertical Underclearance 54B:	0.0 ft
Minimum Lateral Underclearance Reference R 55A:	N Feature not hwy or RR
Minimum Lateral Underclearance R 55:	327.8 ft
Minimum Lateral Underclearance L 56:	327.8 ft

APPRAISAL	
Bridge Rail 36A:	N N/A or not required
Transition 36B:	N N/A or not required
Str. Evaluation 67:	4
Underclearance, Vertical and Horizontal 69:	N Not applicable (NBI)
Waterway Adequacy 71:	8 Equal Desirable
Scour Critical 113:	6 Calcs not made
Approach Rail 36C:	1 Meets Standards
Approach Rail Ends 36D:	1 Meets Standards
Deck Geometry 68:	N Not applicable (NBI)
Approach Alignment 72:	8 Equal Desirable Crit

PROPOSED IMPROVEMENTS	
Bridge Cost 94:	NA
Roadway Cost 95:	Unknown
Total Cost 96:	Unknown
Year of Cost Estimate 97:	Unknown
Type of Work 75:	Unknown (P)
Length of Improvement 76:	
Future ADT 114:	2,130
Year of Future ADT 115:	2029

NAVIGATION DATA	
Navigation Control 38:	0 Permit Not Required
Vertical Clearance 39:	0.0 ft
Pier Protection 111:	Not Applicable (P)
Horizontal Clearance 40:	0.0 ft
Lift Bridge Vertical Clearance 116:	0.0 ft

ELEMENT CONDITION STATE DATA

Str Unit	Elm/Env	Description	Units	Total Qty	% in 1	Qty. St. 1	% in 2	Qty. St. 2	% in 3	Qty. St. 3	% in 4	Qty. St. 4	% in 5	Qty. St. 5
1	240/2	Steel Culvert	(LF)	78	0 %	0	45 %	35	35 %	27	20 %	16	0 %	0

Structure in Fair and Serviceable condition.

GPS coordinates off. Updated coordinates.

Large elongated holes were found and could be made with probe across ribs up to 4' into upstream end of pipe. Appears to be getting worse.

90% of the pipe invert is covered with rocks and sandy gravel which did not allow for accurate probing beyond the first 6' of upstream invert.

upstream end of pipe is distorted upward slightly.

Previous reports:

2001 inspection noted pin holes in arch below normal water level. Higher water level this time, pin holes still exist, but hammer soundings did not produce any holes.

2007: No holes could be made with hammer. Shiny steel in invert from abrasive scour.

Channel:

Alignment - Poor

Gradient - Moderately Severe

Opening - Satisfactory

Composition - Sand and gravel with Pervasive head size stones.



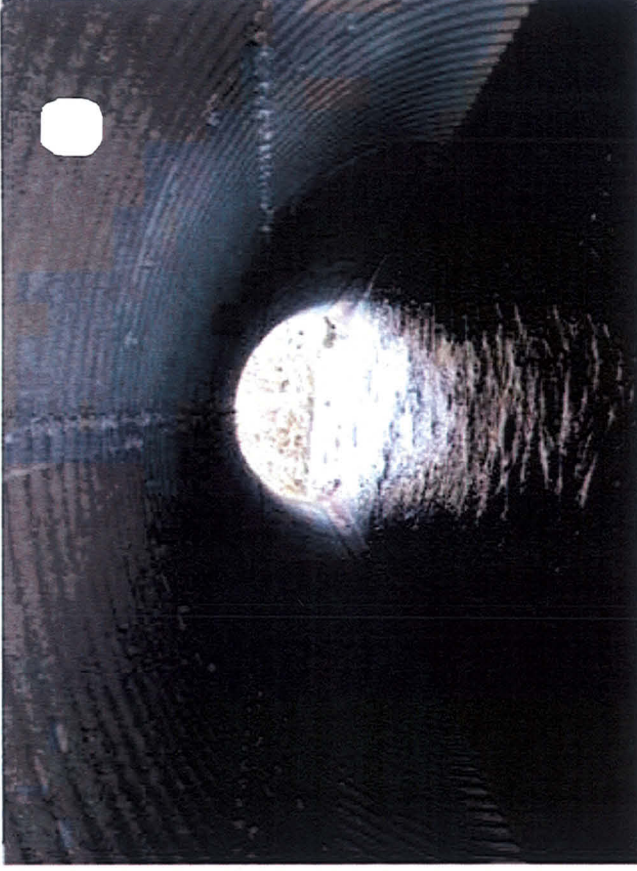
Roadway looking West



Looking upstream

5837

Smyrna



General view looking upstream - Note pipe bolt line indicates pipe is lifted at inlet



Looking downstream

Dunn Brook

10/27/09



Large elongated holes were found and could be made with probe across bottoms of ribs at upstream end up to 4' into pipe



Upstream East side banking from stream to roadway is heavily eroded

HYDROLOGY/HYDRAULICS/SCOUR DATA

Project Name: <u>Smyrna</u>	PIN: <u>17878.00</u>
Stream Name: _____	Town: <u>Smyrna</u>
Bridge Name: <u>Dunn Brook Bridge</u>	Bridge No. <u>5837</u>
Route No. <u>2</u>	USGS Quad: _____
Analysis by: <u>AWMann</u>	Date: <u>9/28/2010</u>

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999)

Enter data in blue cells only!

	km ²	mi ²	ac
A	10.58	4.08	2614.3
W	0.86	0.28	183.3
P _c	572204	5113182	
County	Arroostook S		
pptA	39.0		
SG	0.00		
A (km ²)	10.58		
W (%)	6.24		

Enter data in [mi²]
 Watershed Area
 Wetlands area (by NWI)

watershed centroid (E, N; UTM 19N; meters)
 choose county from drop-down menu
 mean annual precipitation (inches; by look-up)
 sand & gravel aquifer as decimal fraction of watershed A

Worksheet prepared by:
 Charles S. Hebson, PE
 Environmental Office
 Maine Dept. Transportation
 Augusta, ME 04333-0018
 207-557-1052
Charles.Hebson@maine.gov

Conf Lvl

Ret Pd T (yr)	Peak Flow Estimate		
	Lower	Q _T (m ³ /s)	Upper
1.1		2.45	
2	3.85	5.42	7.63
5	6.30	8.93	12.64
10	8.13	11.63	16.64
25	10.59	15.39	22.37
50	12.52	18.43	27.13
100	14.56	21.71	32.39
500	19.49	30.08	46.44

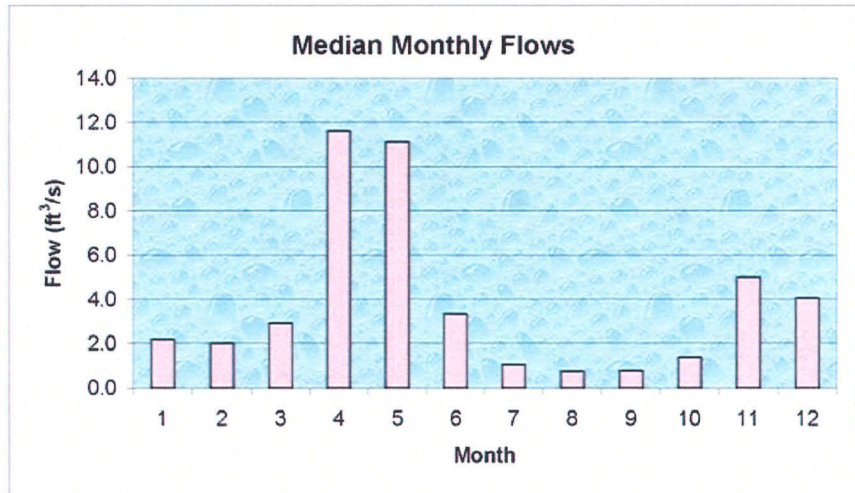
Q _T (ft ³ /s)
86.4
191.4
315.2
410.8
543.6
650.7
766.7
1062.2

Reference:

Hodgkins, G., 1999.
 Estimating the magnitude of peak flows for streams
 in Maine for selected recurrence intervals
Water-Resources Investigations Report 99-4008
 US Geological Survey, Augusta, Maine

$$Q_T = b \times A^3 \times 10^{pptA}$$

Month	Q _{median}	
	(ft ³ /s)	(m ³ /s)
Jan	2.19	0.0620
Feb	2.02	0.0572
Mar	2.91	0.0823
Apr	11.62	0.3294
May	11.11	0.3148
Jun	3.34	0.0946
Jul	1.06	0.0300
Aug	0.74	0.0208
Sep	0.79	0.0223
Oct	1.39	0.0394
Nov	5.02	0.1423
Dec	4.05	0.1147



HY-8 Analysis Results

Culvert Summary Table - Existing

Culvert Crossing: Smyrna Dunn Brook-All Flows

	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)
Q _{1.1}	86.40	86.40	516.64	2.35	0.15	1-S2n	1.57	1.59	1.58	1.21	6.12	5.97
	154.43	154.43	517.63	3.34	0.46	1-S2n	2.13	2.17	2.13	1.52	7.71	6.00
	222.46	222.46	518.43	4.14	0.68	1-S2n	2.62	2.64	2.63	1.74	8.65	5.59
	290.49	290.49	519.70	4.82	5.41	2-M2c	3.08	3.08	3.09	1.91	9.39	5.63
	358.52	358.52	520.43	5.46	6.14	2-M2c	3.53	3.47	3.48	2.06	10.14	5.53
	426.55	426.55	521.16	6.12	6.87	2-M2c	3.98	3.84	3.84	2.18	10.84	5.30
	494.58	494.58	521.82	6.84	7.53	2-M2c	4.44	4.18	4.19	2.29	11.50	5.21
	562.61	562.61	522.51	7.64	8.22	2-M2c	4.95	4.51	4.51	2.39	12.14	5.19
	630.64	630.64	523.20	8.55	8.91	2-M2c	5.54	4.80	4.82	2.49	12.78	5.21
Q ₅₀	650.70	650.70	523.40	8.83	9.11	2-M2c	5.73	4.89	4.90	2.51	12.96	5.21
Q ₁₀₀	766.70	766.70	524.94	10.65	10.39	2-M2c	7.42	5.36	5.37	2.66	14.08	5.28
Low Fish Passage Flow	0.74	0.74	514.38	0.05	0.09	3-M1t	0.03	0.03	0.44	0.15	0.35	1.42
High Fish Passage Flow	11.62	11.62	515	0.66	0.71	3-M1t	0.51	0.46	0.8	0.51	2.23	3.03
Q ₂₅	543.6	543.6	522.32	7.41	8.03	2-M2c	4.81	4.42	4.42	2.36	11.97	5.2

HY-8 Analysis Results

Culvert Summary Table - Invert Lining

Culvert Crossing: Smyrna Dunn Brook-All Flows

	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)
Q _{1.1}	86.40	86.40	517.15	2.44	0.0*	1-S2n	0.86	1.53	0.99	1.21	11.17	5.97
	154.43	154.43	518.17	3.46	0.0*	1-S2n	1.20	2.16	1.43	1.52	12.80	6.00
	222.46	222.46	519.08	4.37	0.0*	1-S2n	1.47	2.71	1.83	1.74	13.90	5.59
	290.49	290.49	519.98	5.27	0.0*	1-S2n	1.72	3.20	2.21	1.91	14.67	5.63
	358.52	358.52	520.85	6.14	0.58	1-S2n	1.96	3.59	2.62	2.06	15.02	5.53
	426.55	426.55	521.89	7.18	0.70	5-S2n	2.17	3.96	2.96	2.18	15.51	5.30
	494.58	494.58	523.22	8.51	0.81	5-S2n	2.38	4.29	3.33	2.29	15.81	5.21
	562.61	562.61	524.61	9.90	0.91	5-S2n	2.62	4.60	3.67	2.39	16.25	5.19
	630.64	588.21	525.17	10.46	1.01	5-S2n	2.76	4.71	3.81	2.49	16.35	5.21
Q ₅₀	650.70	590.28	525.22	10.51	1.03	5-S2n	2.78	4.71	3.82	2.51	16.34	5.21
Q ₁₀₀	766.70	599.75	525.42	10.71	1.18	5-S2n	2.83	4.75	3.89	2.66	16.31	5.28
Low Fish Passage Flow	0.74	0.74	514.38	0.05	0.09	3-M1t	0.03	0.03	0.44	0.15	0.35	1.42
High Fish Passage Flow	11.62	11.62	515	0.66	0.71	3-M1t	0.51	0.46	0.8	0.51	2.23	3.03
Q ₂₅	543.6	543.6	522.32	7.41	8.03	2-M2c	4.81	4.42	4.42	2.36	11.97	5.2

HY-8 Analysis Results

Culvert Summary Table - Sliplining

Culvert Crossing: Smyrna Dunn Brook-All Flows

	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)
Q _{1.1}	86.40	86.40	517.84	2.93	3.12	2-M2c	2.06	1.86	1.90	1.21	7.12	5.97
	154.43	154.43	519.24	4.10	4.52	2-M2c	3.04	2.62	2.63	1.52	8.74	6.00
	222.46	222.46	520.51	5.37	5.79	2-M2c	4.14	3.24	3.24	1.74	10.09	5.59
	290.49	290.49	521.91	7.03	7.19	2-M2c	5.42	3.76	3.76	1.91	11.38	5.63
	358.52	339.24	525.98	8.47	11.26	7-M2c	5.42	4.07	4.09	2.06	12.32	5.53
	426.55	343.43	525.33	8.60	10.61	7-M2c	5.42	4.10	4.11	2.18	12.40	5.30
	494.58	346.66	525.44	8.70	10.72	7-M2c	5.42	4.12	4.13	2.29	12.47	5.21
	562.61	349.31	525.54	8.78	10.82	7-M2c	5.42	4.13	4.15	2.39	12.52	5.19
	630.64	351.90	525.63	8.87	10.91	7-M2c	5.42	4.15	4.17	2.49	12.57	5.21
Q ₅₀	650.70	352.62	523.95	8.89	9.23	7-M2c	5.42	4.16	4.17	2.51	12.59	5.21
Q ₁₀₀	766.70	356.65	525.83	9.02	11.11	7-M2c	5.42	4.18	4.19	2.66	12.67	5.28
Fish Passage Flow	0.74	0.74	514.85	0.08	0.13	2-M2c	0.07	0.05	0.17	0.15	1.90	1.42
High Fish Passage Flow	11.62	11.62	515.74	1.02	0.99	2-M2c	0.70	0.63	0.67	0.51	3.65	3.03
Q ₂₅	543.60	348.58	525.36	8.76	10.64	7-M2c	5.42	4.13	4.15	2.36	12.51	5.20

HY-8 Culvert Analysis Report - Existing

Site Data - Existing culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 514.29 ft

Outlet Station: 74.91 ft

Outlet Elevation: 512.94 ft

Number of Barrels: 1

Culvert Data Summary - Existing culvert

Barrel Shape: Pipe Arch

Barrel Span: 139.40 in

Barrel Rise: 89.10 in

Barrel Material: Steel Structural Plate

Embedment: 0.00 in

Barrel Manning's n: 0.0340

Inlet Type: Conventional

Inlet Edge Condition: Mitered

Inlet Depression: None

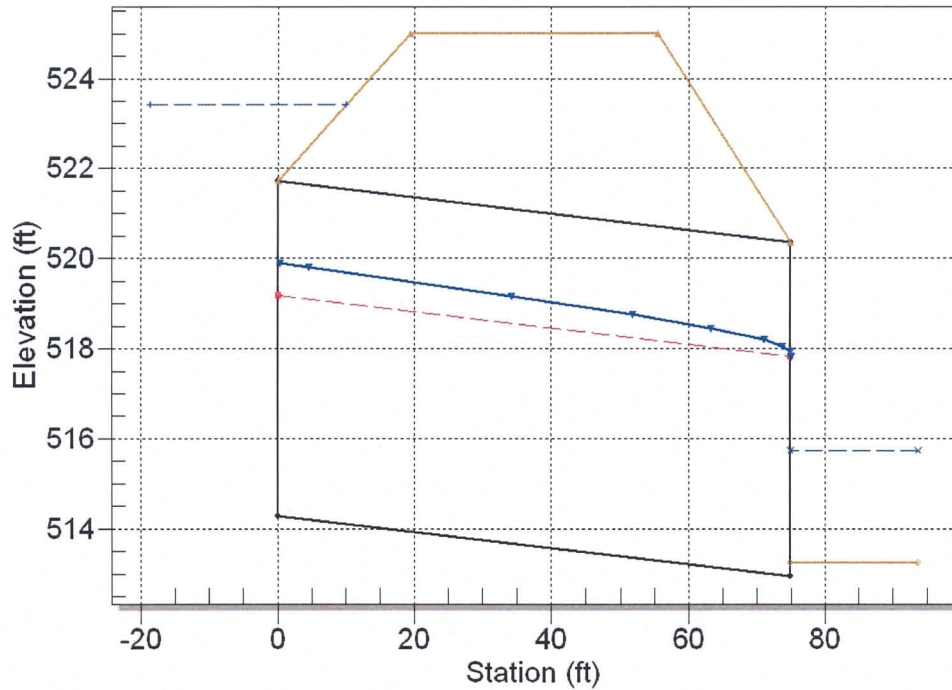
Table 1 - Culvert Summary Table: Existing culvert

 Inlet Elevation (invert): 514.29 ft, Outlet Elevation (invert): 512.94 ft
 Culvert Length: 74.92 ft, Culvert Slope: 0.0180

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)
86.40	86.40	516.64	2.346	0.150	1-S2n	1.574	1.587	1.577	1.210	6.120	5.971
154.43	154.43	517.63	3.342	0.460	1-S2n	2.129	2.170	2.130	1.520	7.705	6.000
222.46	222.46	518.43	4.143	0.681	1-S2n	2.615	2.640	2.630	1.741	8.650	5.589
290.49	290.49	519.70	4.820	5.412	2-M2c	3.081	3.078	3.086	1.911	9.387	5.626
358.52	358.52	520.43	5.459	6.143	2-M2c	3.530	3.467	3.479	2.055	10.142	5.526
426.55	426.55	521.16	6.119	6.866	2-M2c	3.985	3.838	3.845	2.179	10.841	5.298
494.58	494.58	521.82	6.839	7.531	2-M2c	4.444	4.177	4.189	2.289	11.502	5.214
562.61	562.61	522.51	7.645	8.219	2-M2c	4.954	4.509	4.512	2.391	12.144	5.194
630.64	630.64	523.20	8.548	8.907	2-M2c	5.536	4.803	4.817	2.486	12.777	5.207
650.70	650.70	523.40	8.833	9.115	2-M2c	5.726	4.890	4.903	2.512	12.964	5.214
766.70	766.70	524.94	10.647	10.395	2-M2c	7.425	5.360	5.374	2.660	14.077	5.278

Table 2 - Downstream Channel Rating Curve (Crossing: Smyrna Dunn Brook-Existing)

Crossing - Smyrna Dunn Brook-Existing, Design Discharge - 650.7 cfs
 Culvert - Existing culvert, Culvert Discharge - 650.7 cfs



Tailwater Channel Data - Smyrna Dunn Brook-Existing

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0250

User Defined Channel Cross-Section:

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
86.40	514.44	1.21	5.97	1.89	1.14
154.43	514.75	1.52	6.00	2.37	1.55
222.46	514.97	1.74	5.59	2.72	1.27
290.49	515.14	1.91	5.63	2.98	1.19
358.52	515.29	2.06	5.53	3.21	1.33
426.55	515.41	2.18	5.30	3.40	1.18
494.58	515.52	2.29	5.21	3.57	1.08
562.61	515.62	2.39	5.19	3.73	1.02
630.64	515.72	2.49	5.21	3.88	0.97
650.70	515.74	2.51	5.21	3.92	0.96
766.70	515.89	2.66	5.28	4.15	0.92

HY-8 Culvert Analysis Report – Invert Lining

Site Data - Invert Lining

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 514.71 ft

Outlet Station: 74.91 ft

Outlet Elevation: 513.36 ft

Number of Barrels: 1

Culvert Data Summary - Invert Lining

Barrel Shape: User Defined

Barrel Span: 10.73 ft

Barrel Rise: 6.38 ft

Barrel Material: Corrugated Metal Riveted or Welded

Embedment: 0.00 in

Barrel Manning's n: 0.0340 (top and sides)

Manning's n: 0.0120 (bottom)

Inlet Type: Conventional

Inlet Edge Condition: Mitered to Conform to Slope

Inlet Depression: None

Table 3 - Culvert Summary Table: Invert Lining

* theoretical depth is impractical. Depth reported is corrected.

Inlet Elevation (invert): 514.71 ft, Outlet Elevation (invert): 513.36 ft

Culvert Length: 74.92 ft, Culvert Slope: 0.0180

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)
86.40	32.57	516.10	1.388	0.0*	1-S2n	0.498	0.868	0.498	1.210	8.063	5.971
154.43	62.80	516.72	2.011	0.0*	1-S2n	0.744	1.291	0.828	1.520	10.285	6.000
222.46	93.88	517.28	2.567	0.0*	1-S2n	0.900	1.605	1.045	1.741	11.395	5.589
290.49	125.48	517.77	3.061	0.0*	1-S2n	1.058	1.923	1.253	1.911	12.206	5.626
358.52	156.91	518.21	3.495	0.0*	1-S2n	1.216	2.185	1.448	2.055	12.843	5.526
426.55	187.17	518.61	3.898	0.0*	1-S2n	1.342	2.437	1.626	2.179	13.379	5.298
494.58	216.13	518.99	4.284	0.0*	1-S2n	1.447	2.663	1.793	2.289	13.816	5.214
562.61	270.55	519.72	5.008	0.0*	1-S2n	1.644	3.058	2.101	2.391	14.461	5.194
630.64	302.15	520.12	5.414	0.0*	1-S2n	1.759	3.267	2.277	2.486	14.770	5.207
650.70	310.39	520.23	5.520	0.0*	1-S2n	1.789	3.313	2.330	2.512	14.786	5.214
766.70	363.62	520.91	6.204	0.0*	1-S2n	1.972	3.616	2.643	2.660	15.059	5.278

Crossing - Smyrna Dunn Brook-Existing, Design Discharge - 650.7 cfs

Culvert - Invert Lining, Culvert Discharge - 310.4 cfs

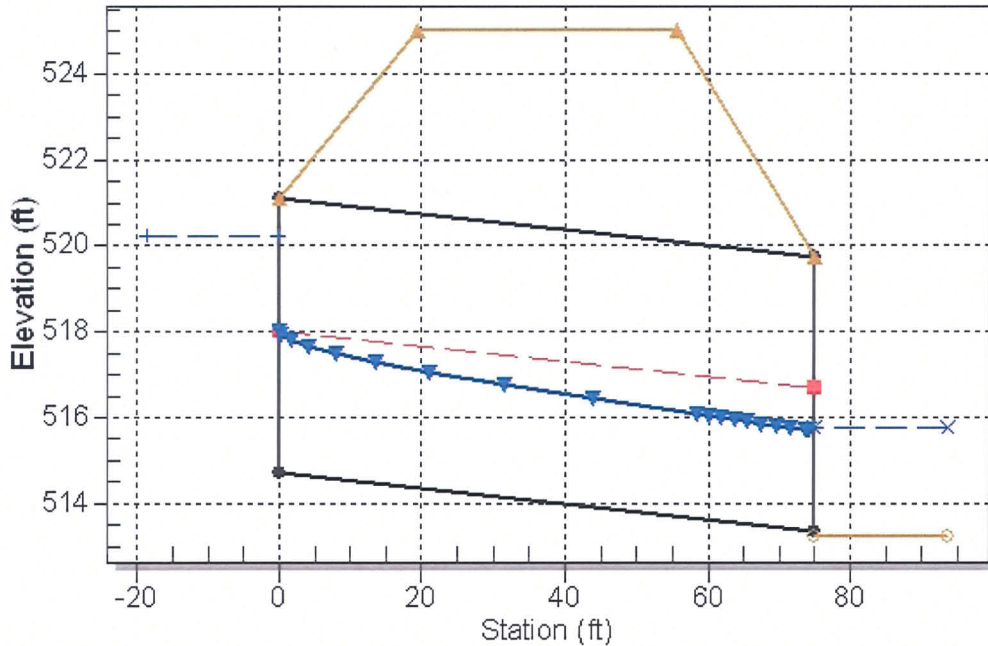


Table 4 - Downstream Channel Rating Curve (Crossing: Smyrna Dunn Brook-Existing)

Tailwater Channel Data - Smyrna Dunn Brook-Existing

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0250

Channel Slope: 0.0

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
86.40	514.44	1.21	5.97	1.89	1.14
154.43	514.75	1.52	6.00	2.37	1.55
222.46	514.97	1.74	5.59	2.72	1.27
290.49	515.14	1.91	5.63	2.98	1.19
358.52	515.29	2.06	5.53	3.21	1.33
426.55	515.41	2.18	5.30	3.40	1.18
494.58	515.52	2.29	5.21	3.57	1.08
562.61	515.62	2.39	5.19	3.73	1.02
630.64	515.72	2.49	5.21	3.88	0.97
650.70	515.74	2.51	5.21	3.92	0.96
766.70	515.89	2.66	5.28	4.15	0.92