LEVEL II SCOUR ANALYSIS FOR BRIDGE 47 (PLYMTH00540047) on TOWN HIGHWAY 54, crossing PINNEY HOLLOW BROOK, PLYMOUTH, VERMONT

Open-File Report 98-196

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

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By EMILY C. WILD and MATTHEW A. WEBER

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Pembroke, New Hampshire

1998

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Thomas J. Casadevall, Acting Director

For additional information
write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Velocity and Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	Max	maximum
D_{50}	median diameter of bed material	MC	main channel
DS	downstream	RAB	right abutment
elev.	elevation	RABUT	face of right abutment
f/p	flood plain	RB	right bank
ft^2	square feet	ROB	right overbank
ft/ft	feet per foot	RWW	right wingwall
FEMA	Federal Emergency Management Agency	TH	town highway
FHWA	Federal Highway Administration	UB	under bridge
JCT	junction	US	upstream
LAB	left abutment	USGS	United States Geological Survey
LABUT	face of left abutment	VTAOT	Vermont Agency of Transportation
LB	left bank	WSPRO	water-surface profile model
LOB	left overbank	yr	year

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 47 (PLYMTH00540047) ON TOWN HIGHWAY 54, CROSSING PINNEY HOLLOW BROOK, PLYMOUTH, VERMONT

By **Emily C. Wild and Matthew A. Weber**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure PLYMTH00540047 on Town Highway 54 crossing Pinney Hollow Brook, Plymouth, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gathered from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in south-central Vermont. The 7.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream and downstream of the bridge while the immediate banks have dense woody vegetation.

In the study area, Pinney Hollow Brook has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 57 ft and an average bank height of 7 ft. The channel bed material ranges from sand to cobbles with a median grain size (D_{50}) of 45.7 mm (0.150 ft). The geomorphic assessment at the time of the Level I and Level II site visit on March 30, 1995 and Level II site visit on October 2, 1995, indicated that the reach was stable.

The Town Highway 54 crossing of Pinney Hollow Brook is a 30-ft-long, two-lane bridge consisting of a 27-foot steel-stringer span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 25.7 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is not skewed to the opening and the opening-skew-to-roadway is zero degrees.

Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the upstream left wingwall, the upstream right wingwall and the downstream end of the downstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 2.0 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Left abutment scour ranged from 3.4 to 6.7 ft. The worst-case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 8.9 to 9.6 ft. The worst-case right abutment scour occurred at the 100-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number PLYMTH00540047 ***Stream*** Pinney Hollow Brook

County Windsor ***Road*** TH 54 ***District*** 3

Description of Bridge

Bridge length 30 ***ft*** ***Bridge width*** 16.2 ***ft*** ***Max span length*** 27 ***ft***

Alignment of bridge to road (on curve or straight) Straight

Abutment type Vertical, concrete ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 3/30/95

Description of stone fill Type-1 stone fill extends along the upstream left wingwall, the upstream right wingwall and the downstream end of the downstream left wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete.

Is bridge located on a bend in channel? No ***If so, describe (mild, moderate, severe)*** --

Is bridge skewed to flood flow according to Level I survey? No ***Angle***

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	3/30/95	0	0
Level II	10/2/95	0	0

Potential for debris Moderate. There was some debris and leaning trees within the upstream channel.

Describe any features near or at the bridge that may affect flow (include observation date) No features were observed near or at the bridge during the 3/30/95 site visit.

Description of the Geomorphic Setting

General topography The channel is located within a narrow flood plain with moderately sloped valley walls.

Geomorphic conditions at bridge site: downstream (DS), upstream (US)

Date of inspection 3/30/95

DS left: Narrow flood plain to a moderately sloped overbank

DS right: Steep channel bank to a narrow flood plain

US left: Narrow flood plain to a moderately sloped overbank

US right: Steep channel bank to a narrow flood plain

Description of the Channel

Average top width 57 ***ft***

Average depth 7 ***ft***

Predominant bed material Gravel

Bank material Gravel

Straight, stable stream with semi-alluvial channel boundaries and a narrow flood plain.

3/30/95

Vegetative co

DS left: Pasture with brush and trees along the immediate bank

DS right: Pasture, some brush along the immediate bank and Vermont 100A

US left: Pasture with brush and trees along the immediate bank

US right: Pasture, some brush along the immediate bank and Vermont 100A

Do banks appear stable? Yes ***If not, describe location and type of instability and date of observation.***

Describe any obstructions in channel and date of observation. The assessment of 3/30/95 did not indicate there were any obstructions in the channel.

Hydrology

Drainage area 7.91 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/Green Mountain	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***:

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,700 ***ft³/s*** ***Q500*** 2,350 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(7.9/8.6)exp 0.67] with flood frequency estimates available from the VTAOT database (written communication, May 1995) for bridge number 8 in Plymouth. Bridge number 8 crosses Pinney Hollow Brook downstream of this site and the drainage area above it is 8.6 square miles. These area adjusted values were within a range defined by flood frequency curves derived from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

Description of the Water-Surface Profile Model (WSPRO) Analysis

Datum for WSPRO analysis (USGS survey, sea level, VTAOT plans) USGS survey

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the downstream right wingwall (elev. 498.33 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the upstream left wingwall (elev. 498.24 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-25	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPR1	42	2	Modelled Approach section (Templated from APTEM)
APTEM	49	1	Approach section as surveyed (Used as a template)

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.055, and an overbank "n" value of 0.045.

Normal depth at the exit section (EXIT1) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0133 ft/ft, which was estimated from thalweg points surveyed downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0132 ft/ft) to establish the modelled approach section (APPR1), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing the supercritical and subcritical profiles for the incipient-overtopping discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.1 ***ft***
Average low steel elevation 498.3 ***ft***

100-year discharge 1,700 ***ft³/s***
Water-surface elevation in bridge opening 498.3 ***ft***
Road overtopping? Yes ***Discharge over road*** 230 ***ft³/s***
Area of flow in bridge opening 211 ***ft²***
Average velocity in bridge opening 7.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.0 ***ft/s***

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 496.2
Amount of backwater caused by bridge 3.1 ***ft***

500-year discharge 2,350 ***ft³/s***
Water-surface elevation in bridge opening 498.3 ***ft***
Road overtopping? Yes ***Discharge over road*** 546 ***ft³/s***
Area of flow in bridge opening 211 ***ft²***
Average velocity in bridge opening 8.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.5 ***ft/s***

Water-surface elevation at Approach section with bridge 500.0
Water-surface elevation at Approach section without bridge 496.9
Amount of backwater caused by bridge 3.1 ***ft***

Incipient overtopping discharge 1,650 ***ft³/s***
Water-surface elevation in bridge opening 495.2 ***ft***
Area of flow in bridge opening 130 ***ft²***
Average velocity in bridge opening 12.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.1 ***ft/s***

Water-surface elevation at Approach section with bridge 497.8
Water-surface elevation at Approach section without bridge 496.1
Amount of backwater caused by bridge 1.7 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100-year and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). Variables for the Laursen clear-water contraction scour equation include the discharge through the bridge, the width of the channel at the bridge, and the median grain size of the channel bed material.

Contraction scour for the 100-year and 500-year discharges, which resulted in unsubmerged orifice flow, also was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Furthermore, contraction scour for the 100-year and 500-year discharges was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in appendix F.

Abutment scour for the right abutment was computed by use of the Froehlich equation (Richardson and Davis, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour at the left abutment was computed by use of the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.9	2.0
Depth to armoring	N/A N/	A N/	A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	5.4 6.7	3.4	9.6
Right abutment	9.0–	8.9-	---
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	2.0

Riprap Sizing

	100-year discharge	500-year discharge (D_{50} in feet)	Incipient overtopping discharge
Abutments:			
Left abutment	2.5	2.1	2.0
Right abutment	2.5	2.1	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	

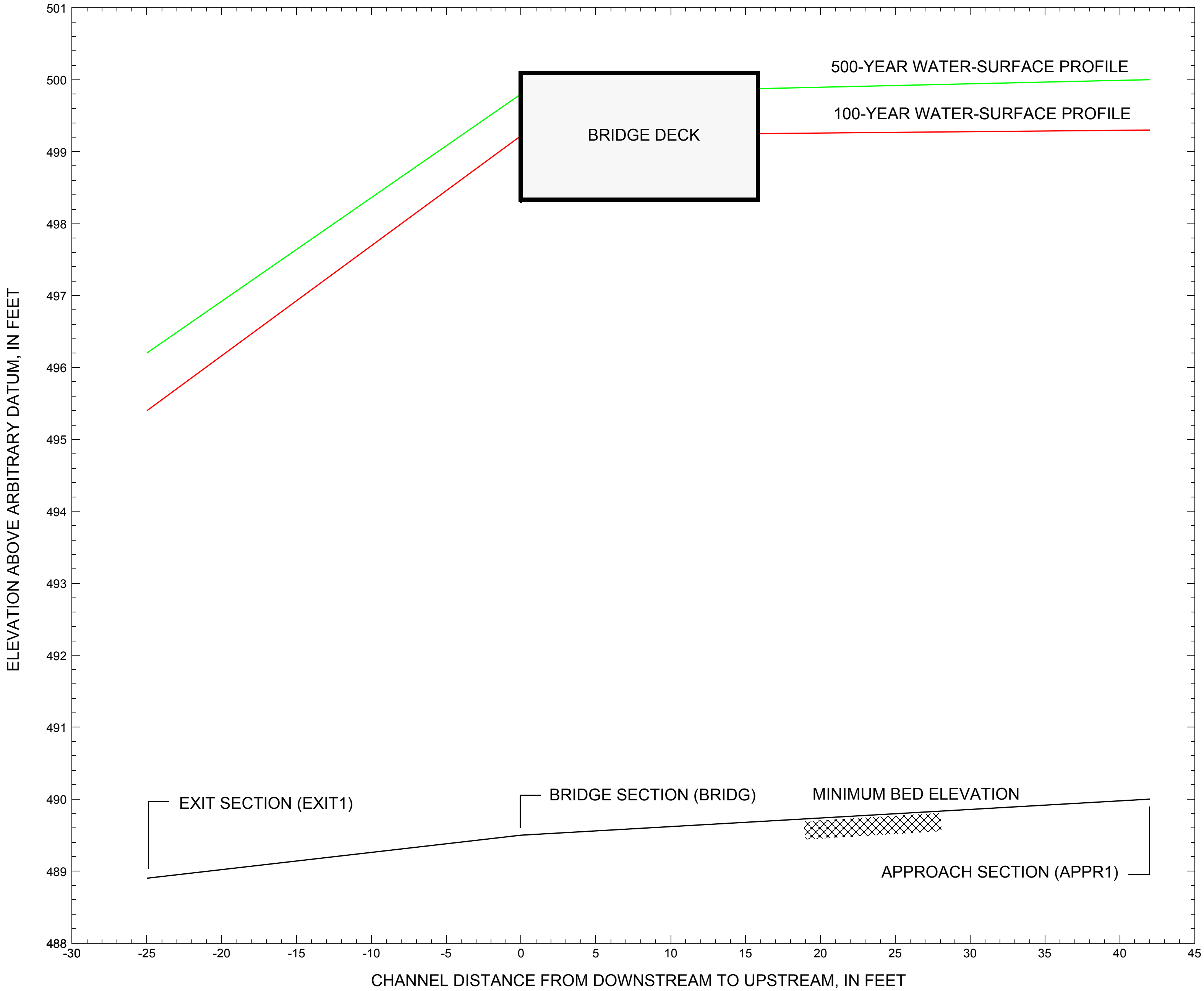

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure PLYMTH00540047 on Town Highway 54, crossing Pinney Hollow Brook, Plymouth, Vermont.

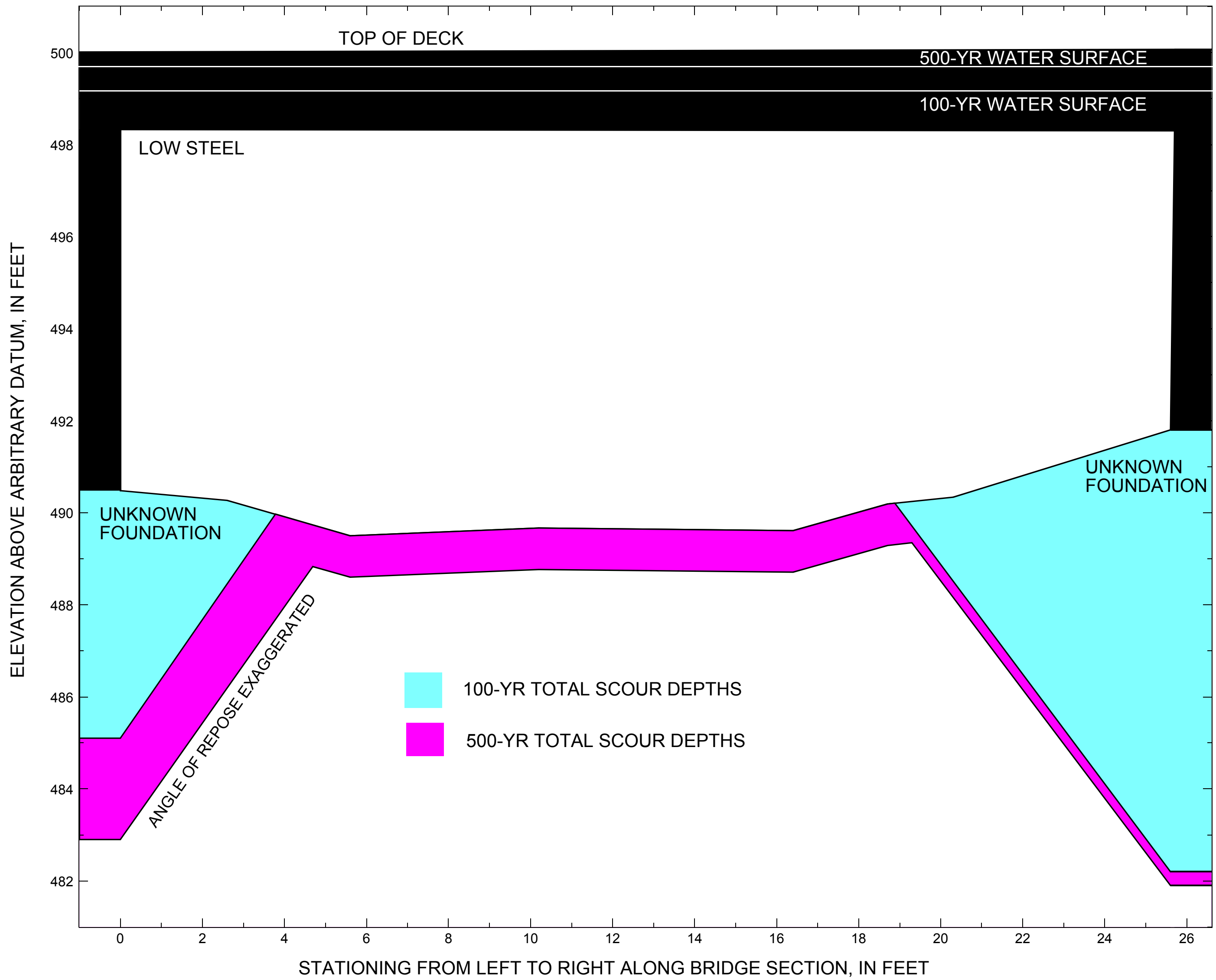

Figure 8. Scour elevations for the 100- and 500-yr discharges at structure PLYMTH00540047 on Town Highway 54, crossing Pinney Hollow Brook, Plymouth, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure PLYMTH00540047 on Town Highway 54, crossing Pinney Hollow Brook, Plymouth, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr discharge is 1,700 cfs											
Left abutment	0.0	--	498.3	--	490.5	0.0	5.4	--	5.4	485.1	--
Right abutment	25.7	--	498.3	--	491.8	0.0	9.6	--	9.6	482.2	--

1.Measured along the face of the most constricting side of the bridge.
2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-yr discharge at structure PLYMTH00540047 on Town Highway 54, crossing Pinney Hollow Brook, Plymouth, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr discharge is 2,350 cfs											
Left abutment	0.0	--	498.3	--	490.5	0.9	6.7	--	7.6	482.9	--
Right abutment	25.7	--	498.3	--	491.8	0.9	9.0	--	9.9	481.9	--

1.Measured along the face of the most constricting side of the bridge.
2.Arbitrary datum for this study.

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U.S. Geological Survey, 1966, Plymouth, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File plym047.wsp
T2        Hydraulic analysis for structure PLYMTH00540047   Date: 16-MAR-98
T3        TH 54, PINNEY HOLLOW BROOK, PLYMOUTH, VERMONT                  ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1700.0   2350.0   1650.0
SK          0.0133   0.0133   0.0133
*
XS   EXIT1    -25          0.
GR         -154.4, 515.94   -129.8, 500.57   -119.8, 496.83    -79.5, 495.12
GR          -58.1, 496.01    -28.5, 495.31    -11.4, 494.08      0.0, 492.23
GR            8.7, 490.02     11.3, 489.58     13.5, 489.14     18.8, 489.12
GR           20.8, 488.89     23.2, 489.40     24.3, 489.62     30.7, 490.63
GR           37.9, 494.63     41.2, 495.36     52.2, 499.10     79.2, 499.18
*
N           0.045        0.055        0.045
SA                 -11.4         52.2
*
*
XS   FULLV      0  * * *   0.0188
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    498.31       0.0
GR            0.0, 498.33      0.0, 490.48      2.6, 490.27      5.6, 489.50
GR           10.2, 489.67     16.4, 489.61     18.7, 490.19     20.3, 490.34
GR           25.6, 491.80     25.7, 498.30      0.0, 498.33
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      19.9 * *     43.5      4.0
N           0.045
*
*            SRD    EMBWID   IPAVE
XR   RDWAY      8      16.2     2
GR         -161.7, 512.31    -99.8, 500.39    -53.5, 497.83    -37.3, 497.86
GR            0.0, 500.01     25.3, 500.07     46.0, 499.62     62.0, 500.09
GR           72.6, 499.71    120.1, 500.46    150.8, 500.17    246.8, 504.99
GR          292.2, 504.92    333.5, 511.47    355.3, 521.79
*
XT   APTEM     49          0.
GR         -143.2, 518.38   -135.2, 511.02   -124.8, 507.47   -108.5, 500.11
GR          -86.5, 497.97    -15.6, 496.95      0.0, 495.43      4.4, 490.93
GR           11.5, 491.04     14.1, 490.71     16.3, 490.40     22.2, 490.11
GR           23.8, 490.35     26.3, 490.73     33.9, 495.34     39.1, 495.86
GR           50.4, 500.24     77.3, 500.11
*
AS   APPR1     42 * * * 0.0132
GT
N           0.045         0.050          0.045
SA                0.0            50.4
*
HP 1 BRIDG 498.31 1 498.31
HP 2 BRIDG 498.31 * * 1493
HP 1 BRIDG 495.74 1 495.74
HP 2 RDWAY 499.22 * * 230
HP 1 APPR1 499.32 1 499.32
HP 2 APPR1 499.32 * * 1700
*
HP 1 BRIDG 498.31 1 498.31
HP 2 BRIDG 498.31 * * 1833
HP 1 BRIDG 496.46 1 496.46
HP 2 RDWAY 499.84 * * 546
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. Geological Survey WSPRO Input File plym047.wsp
        Hydraulic analysis for structure PLYMTH00540047   Date: 16-MAR-98
        TH 54, PINNEY HOLLOW BROOK, PLYMOUTH, VERMONT                    ECW
           *** RUN DATE & TIME: 03-24-98  15:33
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     211.   18470.    17.    49.                        4193.
   498.31          211.   18470.    17.    49.  1.00     0.    26.   4193.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA         K        Q    VEL
       498.31     0.0    25.7   210.7   18470.    1493.   7.09

X STA.         0.0         3.3         4.3         5.1         6.0         6.9
  A(I)            26.7         7.6         7.7         7.7         7.6
  V(I)            2.80        9.79        9.74        9.67        9.88

X STA.         6.9         7.8         8.7         9.6        10.5        11.4
  A(I)             7.7         7.9         7.9         8.1         7.6
  V(I)            9.68        9.44        9.40        9.25        9.85

X STA.        11.4        12.2        13.0        13.9        14.7        15.5
  A(I)             6.8         7.2         7.4         7.1         7.1
  V(I)           10.98       10.31       10.14       10.44       10.48

X STA.        15.5        16.3        17.2        18.6        20.1        25.7
  A(I)             7.2         7.4        11.7        12.1        40.1
  V(I)           10.34       10.07        6.37        6.19        1.86

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     145.   12299.    26.    35.                        1950.
   495.74          145.   12299.    26.    35.  1.00     0.    26.   1950.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA         K        Q    VEL
       499.22   -78.6   -13.7    55.8     1668.     230.   4.12

X STA.       -78.6       -61.9       -59.3       -57.2       -55.4       -53.8
  A(I)             7.8         2.6         2.4         2.2         2.2
  V(I)            1.48        4.50        4.87        5.13        5.29

X STA.       -53.8       -52.2       -50.7       -49.1       -47.5       -45.9
  A(I)             2.1         2.2         2.2         2.2         2.2
  V(I)            5.38        5.32        5.30        5.19        5.20

X STA.       -45.9       -44.3       -42.7       -41.1       -39.5       -37.9
  A(I)             2.2         2.2         2.2         2.2         2.2
  V(I)            5.17        5.18        5.32        5.25        5.29

X STA.       -37.9       -36.3       -34.5       -32.4       -29.9       -13.7
  A(I)             2.2         2.2         2.3         2.5         7.6
  V(I)            5.30        5.16        4.93        4.58        1.52

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     199.   10357.   101.   101.                        1587.
             2     304.   29378.    48.    52.                        4338.
   499.32          504.   39734.   150.   154.  1.22  -101.    48.   4750.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

         WSEL     LEW     REW    AREA         K        Q    VEL
       499.32  -101.3    48.3   503.8   39734.    1700.   3.37

X STA.      -101.3       -56.2       -37.0       -21.3        -8.8        -1.4
  A(I)            61.0        38.7        35.6        32.7        26.1
  V(I)            1.39        2.20        2.39        2.60        3.26

X STA.        -1.4         3.8         5.9         8.0        10.0        12.0
  A(I)            27.8        17.7        17.2        16.9        16.9
  V(I)            3.05        4.81        4.94        5.01        5.03

X STA.        12.0        13.9        15.7        17.5        19.2        20.9
  A(I)            16.2        16.1        15.8        15.6        15.6
  V(I)            5.26        5.27        5.38        5.45        5.43

X STA.        20.9        22.5        24.2        26.1        28.3        48.3
  A(I)            15.3        15.7        16.1        18.2        68.6
  V(I)            5.57        5.40        5.29        4.68        1.24
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        U.S. Geological Survey WSPRO Input File plym047.wsp
        Hydraulic analysis for structure PLYMTH00540047   Date: 16-MAR-98
        TH 54, PINNEY HOLLOW BROOK, PLYMOUTH, VERMONT                    ECW
           *** RUN DATE & TIME: 03-24-98  15:33

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     211.   18470.    17.    49.                        4193.
   498.31          211.   18470.    17.    49.  1.00     0.    26.   4193.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.31     0.0    25.7   210.7   18470.    1833.   8.70

X STA.         0.0        3.3        4.3        5.1        6.0        6.9
  A(I)            26.7        7.6        7.7        7.7        7.6
  V(I)            3.44      12.02      11.96      11.87      12.13

X STA.         6.9        7.8        8.7        9.6       10.5       11.4
  A(I)             7.7        7.9        7.9        8.1        7.6
  V(I)           11.89      11.58      11.54      11.36      12.10

X STA.        11.4       12.2       13.0       13.9       14.7       15.5
  A(I)             6.8        7.2        7.4        7.1        7.1
  V(I)           13.48      12.65      12.44      12.82      12.87

X STA.        15.5       16.3       17.2       18.6       20.1       25.7
  A(I)             7.2        7.4       11.7       12.1       40.1
  V(I)           12.69      12.36       7.82       7.60       2.28

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     163.   14631.    26.    37.                        2335.
   496.46          163.   14631.    26.    37.  1.00     0.    26.   2335.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.84   -89.9    80.8   105.6    3977.     546.   5.17

X STA.       -89.9      -65.2      -62.0      -59.3      -56.9      -54.8
  A(I)            16.8        4.7        4.3        4.2        4.0
  V(I)            1.63       5.80       6.36       6.46       6.77

X STA.       -54.8      -52.8      -50.9      -48.9      -46.9      -45.0
  A(I)             3.9        3.9        4.0        3.9        3.9
  V(I)            7.04       6.94       6.90       6.99       7.00

X STA.       -45.0      -42.9      -40.9      -38.8      -36.7      -34.5
  A(I)             4.0        4.2        4.1        4.1        4.2
  V(I)            6.76       6.57       6.60       6.68       6.56

X STA.       -34.5      -32.1      -29.3      -25.9      -21.4       80.8
  A(I)             4.2        4.5        4.8        5.4       12.5
  V(I)            6.46       6.05       5.74       5.07       2.18

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     274.   16794.   109.   109.                        2469.
             2     339.   34350.    50.    54.                        5011.
             3       0.       0.     3.     3.                           0.
   500.03          613.   51144.   161.   165.  1.17  -109.    77.   6283.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.03  -108.5    77.3   613.3   51144.    2350.   3.83

X STA.      -108.5      -65.9      -49.9      -35.4      -22.6      -11.4
  A(I)            71.1       41.1       40.4       38.0       36.1
  V(I)            1.65       2.86       2.91       3.09       3.26

X STA.       -11.4       -3.6        2.7        5.4        7.7       10.0
  A(I)            31.2       32.4       23.7       20.9       20.8
  V(I)            3.77       3.63       4.96       5.62       5.64

X STA.        10.0       12.2       14.3       16.4       18.3       20.3
  A(I)            20.1       19.9       19.6       19.1       19.0
  V(I)            5.85       5.91       5.99       6.15       6.18

X STA.        20.3       22.2       24.1       26.1       28.7       77.3
  A(I)            19.0       19.0       19.3       22.3       80.3
  V(I)            6.20       6.17       6.09       5.27       1.46
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U.S. Geological Survey WSPRO Input File plym047.wsp
Hydraulic analysis for structure PLYMTH00540047   Date: 16-MAR-98
TH 54, PINNEY HOLLOW BROOK, PLYMOUTH, VERMONT                  ECW
   *** RUN DATE & TIME: 03-24-98  15:33

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     130.   10466.    26.    34.                        1652.
495.15          130.   10466.    26.    34.  1.00     0.    26.   1652.

 VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL     LEW     REW    AREA        K        Q    VEL
    495.15     0.0    25.7   129.6   10466.    1650.  12.73

X STA.        0.0        3.6        4.6        5.5        6.5        7.4
  A(I)           17.2        5.3        5.4        5.1        5.2
  V(I)           4.81      15.49      15.21      16.10      16.02

X STA.        7.4        8.3        9.3       10.2       11.2       12.2
  A(I)            5.2        5.3        5.3        5.4        5.4
  V(I)          15.73      15.62      15.64      15.30      15.28

X STA.       12.2       13.2       14.1       15.1       16.0       17.0
  A(I)            5.3        5.3        5.2        5.2        5.4
  V(I)          15.46      15.44      15.78      15.83      15.40

X STA.       17.0       18.0       19.1       20.3       21.6       25.7
  A(I)            5.4        5.6        5.5        5.9       15.9
  V(I)          15.31      14.84      14.93      13.90       5.19

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1      59.    1564.    82.    83.                         284.
          2     235.   20156.    44.    48.                        3066.
497.82          294.   21720.   127.   131.  1.26   -82.    44.   2261.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      42.

      WSEL     LEW     REW    AREA        K        Q    VEL
    497.82   -82.5    44.4   294.0   21720.    1650.   5.61

X STA.      -82.5       -3.6        3.2        5.1        6.6        8.1
  A(I)           50.8       21.6       12.1       10.6       10.5
  V(I)           1.62       3.82       6.82       7.80       7.87

X STA.        8.1        9.6       11.2       12.7       14.2       15.6
  A(I)           10.5       10.9       10.7       10.6        9.9
  V(I)           7.85       7.56       7.73       7.79       8.33

X STA.       15.6       16.8       18.1       19.4       20.6       21.8
  A(I)            9.1        9.8        9.7        9.7        9.5
  V(I)           9.06       8.42       8.51       8.51       8.70

X STA.       21.8       23.1       24.3       25.7       27.2       44.4
  A(I)            9.5        9.6        9.9       10.5       48.5
  V(I)           8.66       8.60       8.33       7.83       1.70
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        U.S. Geological Survey WSPRO Input File plym047.wsp
        Hydraulic analysis for structure PLYMTH00540047   Date: 16-MAR-98
        TH 54, PINNEY HOLLOW BROOK, PLYMOUTH, VERMONT                    ECW
           *** RUN DATE & TIME: 03-24-98  15:33
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT1:XS   ******   -87.     229.  0.93 *****  496.35  494.46   1700.  495.42
      -25. ******    41.   14735.  1.08 ***** *******    0.85    7.41
 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.84     495.73     494.93
 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   494.92     516.41    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   494.92     516.41     494.93

FULLV:FV      25.   -83.     216.  1.01  0.35  496.75  494.93   1700.  495.74
        0.    25.    41.   13850.  1.06  0.04    0.00    0.84    7.85
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID “APPR1”:  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.97     496.15     495.91
 ===110 WSEL NOT FOUND AT SECID “APPR1”:  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   495.24     518.29    0.50
 ===115 WSEL NOT FOUND AT SECID “APPR1”:  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   495.24     518.29     495.91

APPR1:AS      42.    -8.     168.  1.63  0.73  497.79  495.91   1700.  496.15
       42.    42.    40.   11974.  1.03  0.31    0.00    0.97   10.12
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.01       0.00     495.26     497.83
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                 WS,QBO,QRD =   501.17         0.      1700.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR      25.     0.     211.  0.78 *****  499.09  494.83   1493.  498.31
        0. ******    26.   18470.  1.00 ***** *******    0.44    7.09

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.386  0.000  498.31 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG       8.    26.  0.05  0.22  499.49    0.01    230.  499.22

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    230.    65.   -79.   -14.   1.4   0.9   4.7   4.1   1.1   2.9
   RT:      0.   128.    12.   155.   0.8   0.4   3.9   6.4   0.9   2.8

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPR1:AS      22.  -101.     504.  0.22  0.08  499.54  495.91   1700.  499.32
       42.    23.    48.   39801.  1.22  0.00    0.01    0.36    3.37

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS      -25.   -87.    41.   1700.   14735.     229.    7.41  495.42
   FULLV:FV        0.   -83.    41.   1700.   13850.     216.    7.85  495.74
   BRIDG:BR        0.     0.    26.   1493.   18470.     211.    7.09  498.31
   RDWAY:RG        8.*******   230.    230.*********       0.    2.00  499.22
   APPR1:AS       42.  -101.    48.   1700.   39801.     504.    3.37  499.32

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  ***********************

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS      FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS     494.46     0.85  488.89  515.94************  0.93  496.35  495.42
   FULLV:FV     494.93     0.84  489.36  516.41  0.35  0.04  1.01  496.75  495.74
   BRIDG:BR     494.83     0.44  489.50  498.33************  0.78  499.09  498.31
   RDWAY:RG  ***************  497.83  521.79  0.05******  0.22  499.49  499.22
   APPR1:AS     495.91     0.36  490.02  518.29  0.08  0.00  0.22  499.54  499.32
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        U.S. Geological Survey WSPRO Input File plym047.wsp
        Hydraulic analysis for structure PLYMTH00540047   Date: 16-MAR-98
        TH 54, PINNEY HOLLOW BROOK, PLYMOUTH, VERMONT                    ECW
           *** RUN DATE & TIME: 03-24-98  15:33
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT1:XS   ******  -104.     319.  1.04 *****  497.19  495.78   2350.  496.16
      -25. ******    44.   20364.  1.23 ***** *******    0.98    7.36

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.08     496.44     496.25
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   495.66     516.41    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   495.66     516.41     496.25

FULLV:FV      25.  -100.     294.  1.20  0.36  497.66  496.25   2350.  496.46
        0.    25.    43.   18765.  1.21  0.08    0.02    1.07    7.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.14     496.74     496.86
 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   495.96     518.29    0.50
 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   495.96     518.29     496.86
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPR1"
                   WSBEG,WSEND,CRWS =   496.86     518.29     496.86
APPR1:AS      42.   -16.     206.  2.16 *****  499.02  496.86   2350.  496.86
       42.    42.    42.   15486.  1.06 ***** *******    1.10   11.44
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   500.10       0.00     496.48     497.83
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   501.54         1.      2349.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR      25.     0.     211.  1.18 *****  499.49  495.52   1833.  498.31
        0. ******    26.   18470.  1.00 ***** *******    0.54    8.70
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.444  0.000  498.31 ****** ****** ******
    XSID:CODE     SRD   FLEN     HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG        8.    26.  0.05  0.27  500.24    0.01    546.  499.84
             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    520.    87.   -90.    -3.   2.0   1.2   5.7   5.1   1.6   3.0
   RT:     27.    29.    36.    81.   0.2   0.1   2.8  10.2   0.5   2.7

===140 AT SECID "APPR1":  END OF CROSS SECTION EXTENDED VERTICALLY.
                             WSEL,YLT,YRT =   500.03      518.3      500.0

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPR1:AS      22.  -109.     613.  0.27  0.11  500.29  496.86   2350.  500.03
       42.    23.    77.   51086.  1.17  0.00    0.01    0.37    3.84

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS      -25.  -104.    44.   2350.   20364.     319.    7.36  496.16
   FULLV:FV        0.  -100.    43.   2350.   18765.     294.    7.99  496.46
   BRIDG:BR        0.     0.    26.   1833.   18470.     211.    8.70  498.31
   RDWAY:RG        8.*******   520.    546.*********       0.    2.00  499.84
   APPR1:AS       42.  -109.    77.   2350.   51086.     613.    3.84  500.03

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  ***********************

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    495.78    0.98  488.89  515.94************  1.04  497.19  496.16
   FULLV:FV    496.25    1.07  489.36  516.41  0.36  0.08  1.20  497.66  496.46
   BRIDG:BR    495.52    0.54  489.50  498.33************  1.18  499.49  498.31
   RDWAY:RG  ***************  497.83  521.79  0.05******  0.27  500.24  499.84
   APPR1:AS    496.86    0.37  490.02  518.29  0.11  0.00  0.27  500.29  500.03
```

```
        U.S. Geological Survey WSPRO Input File plym047.wsp
        Hydraulic analysis for structure PLYMTH00540047   Date: 16-MAR-98
        TH 54, PINNEY HOLLOW BROOK, PLYMOUTH, VERMONT                   ECW
           *** RUN DATE & TIME: 03-24-98  15:33

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT1:XS   ******   -85.     223.  0.91 *****  496.26  494.39   1650.  495.35
      -25. ******    41.   14293.  1.07 ***** *******    0.82    7.40
 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.82     495.65     494.86
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   494.85     516.41    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   494.85     516.41     494.86

FULLV:FV      25.   -81.     211.  1.00  0.35  496.66  494.86   1650.  495.66
        0.    25.    40.   13463.  1.05  0.04    0.00    0.82    7.82
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.96     496.08     495.81
 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   495.16     518.29    0.50
 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   495.16     518.29     495.81

APPR1:AS      42.    -8.     165.  1.60  0.73  497.68  495.81   1650.  496.09
       42.    42.    40.   11672.  1.02  0.30    0.00    0.96   10.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                 SECID "BRIDG"     Q,CRWS =    1650.     495.15
            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
BRIDG:BR      25.     0.     130.  2.52 *****  497.67  495.15   1650.  495.15
        0.    25.    26.   10467.  1.00 ***** *******    1.00   12.73
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.31 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPR1:AS      22.   -82.     294.  0.62  0.28  498.44  495.81   1650.  497.82
       42.    23.    44.   21714.  1.26  0.49    0.01    0.73    5.61
      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.461  0.087   19720.     4.    30.   497.67

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -25.   -85.    41.   1650.   14293.     223.    7.40  495.35
   FULLV:FV       0.   -81.    40.   1650.   13463.     211.    7.82  495.66
   BRIDG:BR       0.     0.    26.   1650.   10467.     130.   12.73  495.15
   RDWAY:RG       8.**************      0.******************    2.00********
   APPR1:AS      42.   -82.    44.   1650.   21714.     294.    5.61  497.82

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       4.    30.   19720.

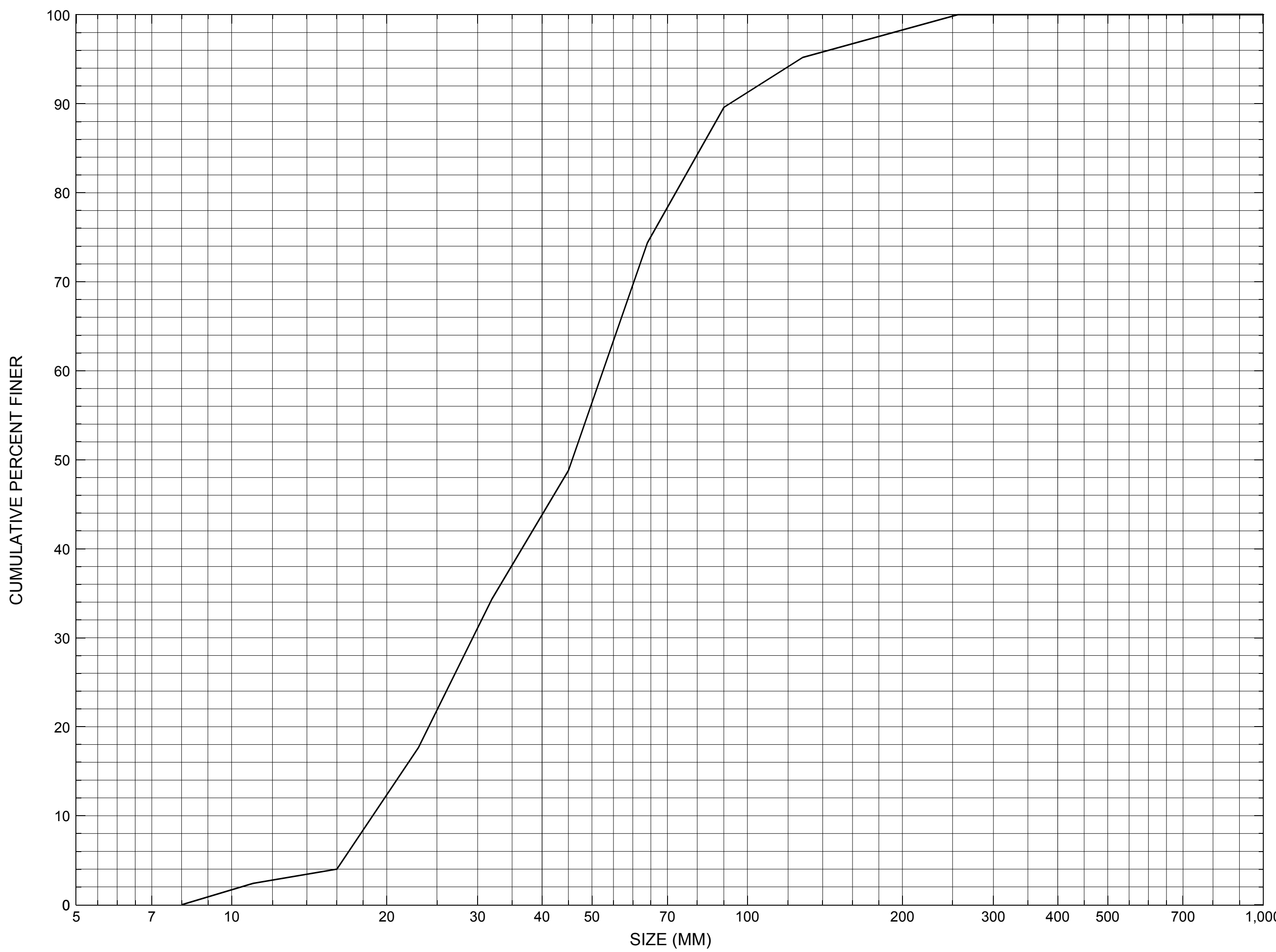
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    494.39    0.82  488.89  515.94************  0.91  496.26  495.35
   FULLV:FV    494.86    0.82  489.36  516.41  0.35  0.04  1.00  496.66  495.66
   BRIDG:BR    495.15    1.00  489.50  498.33************  2.52  497.67  495.15
   RDWAY:RG  ****************  497.83  521.79**********************************
   APPR1:AS    495.81    0.73  490.02  518.29  0.28  0.49  0.62  498.44  497.82
  ER

NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure PLYMTH00540047, in Plymouth, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number PLYMTH00540047

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 03 / 22 / 95

Highway District Number *(I - 2; nn)* 03

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 56050

Mile marker *(I - 11; nnn.nnn)* 000000

Waterway *(I - 6)* PINNEY HOLLOW BROOK

Road Name *(I - 7)*: -

Route Number TH054

Vicinity *(I - 9)* 0.01 MI TO JCT W VT100A

Topographic Map Plymouth

Hydrologic Unit Code: 01080106

Latitude *(I - 16; nnnn.n)* 43337

Longitude *(i - 17; nnnnn.n)* 72421

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10141200471412

Maintenance responsibility *(I - 21; nn)* 03

Maximum span length *(I - 48; nnnn)* 0027

Year built *(I - 27; YYYY)* 1974

Structure length *(I - 49; nnnnnn)* 000030

Average daily traffic, ADT *(I - 29; nnnnnn)* 000020

Deck Width *(I - 52; nn.n)* 162

Year of ADT *(I - 30; YY)* 91

Channel & Protection *(I - 61; n)* 6

Opening skew to Roadway *(I - 34; nn)* 00

Waterway adequacy *(I - 71; n)* 6

Operational status *(I - 41; X)* A

Underwater Inspection Frequency *(I - 92B; XYY)* N

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 0000

Approach span structure type *(I - 44; nnn)* 000

Clear span (*nnn.n ft*) -

Number of spans *(I - 45; nnn)* 001

Vertical clearance from streambed (*nnn.n ft*) 008.0

Number of approach spans *(I - 46; nnnn)* 0000

Waterway of full opening (*nnn.n ft*^{2}) -

Comments:

The structural inspection report of 6/14/93 indicates the structure is a steel stringer type bridge with a timber deck. The abutment walls and wingwalls are concrete. A short section of the left abutment footing is reported as exposed. A few boulders are noted as present in front of the wingwalls on each abutment and also are evident on the streambanks up- and downstream of the bridge. While some footing exposure is noted, the report indicates no undermining or settling has occurred. There only are minor gravel bars and debris noted on the report.

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area (*mi^2*): -

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data (*cfs*): $Q_{2.33}$ - Q_{10} - Q_{25} -

Q_{50} - Q_{100} - Q_{500} -

Record flood date (*MM / DD / YY*): - / / Water surface elevation (*ft*): -

Estimated Discharge (*cfs*): - Velocity at Q - (*ft/s*): -

Ice conditions (*Heavy, Moderate, Light*) : - Debris (*Heavy, Moderate, Light*): -

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): -

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

Watershed storage area (*in percent*): - %

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*)	-	-	-	-	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): U Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft^3/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): U *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft^2*): -

Downstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 7.91 mi^2

Lake/pond/swamp area 0.01 mi^2

Watershed storage *(ST)* 0.1 %

Bridge site elevation 1080 ft

Headwater elevation 2618 ft

Main channel length 3.89 mi

10% channel length elevation 1120 ft

85% channel length elevation 2040 ft

Main channel slope *(S)* 315.33 ft / mi

Watershed Precipitation Data

Average site precipitation -- in

Average headwater precipitation -- in

Maximum 2yr-24hr precipitation event *(I24,2)* -- in

Average seasonal snowfall *(Sn)* -- ft

Bridge Plan Data

Are plans available? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY):* - / -

Project Number -

Minimum channel bed elevation: -

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:

NO BENCHMARK INFORMATION

-
-
-

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

Foundation Type: 4 (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness _______ Footing bottom elevation: ______

If 2: Pile Type: ____ (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: _______

If 3: Footing bottom elevation: ______

Is boring information available? N *If no, type ctrl-n bi* Number of borings taken: -

Foundation Material Type: 3 (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

Is cross-sectional data available? Yes *If no, type ctrl-n xs*

Source (*FEMA, VTAOT, Other*)? VTAOT

Comments: **This cross section was made from a sketch dated 6-16-93 of the US face, that was attached to a bridge inspection report. The sketch provided low chord to bed, and between station distances. The low chord elevation comes from the 10/2/95 survey done for this report.**

Station	0	13	20	27	-	-	-	-	-	-	-
Feature	LAB	-	-	RAB	-	-	-	-	-	-	-
Low chord elevation	498.3	498.3	498.3	498.3	-	-	-	-	-	-	-
Bed elevation	490.2	490.0	489.9	491.5	-	-	-	-	-	-	-
Low chord to bed	8.1	8.3	8.4	6.8	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Source (*FEMA, VTAOT, Other*)? -

Comments: -
-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

U. S. Geological Survey
Bridge Field Data Collection and Processing Form

Qa/Qc Check by: RB Date: 2/15/96
Computerized by: RB Date: 2/15/96
Reviewd by: EW Date: 4/10/98

Structure Number PLYMTH00540047

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M WEBER Date *(MM/DD/YY)* 03 / 30 / 1995

2. Highway District Number 03 Mile marker 00000

County Windsor (027) Town Plymouth (56050)

Waterway *(I - 6)* PINNEY HOLLOW BROOK Road Name -

Route Number TH054 Hydrologic Unit Code: 01080106

3. Descriptive comments:

Located 0.01 miles to the junction with VT 100A. The road is unmarked. The bridge deck is no longer timber as noted in the historical form, but is new concrete topped with asphalt.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 LBDS 4 RBDS 4 Overall 4
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US 2 UB 2 DS 2 *(**1**- pool; **2**- riffle)*

6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length 30 *(feet)* Span length 27 *(feet)* Bridge width 16.2 *(feet)*

Road approach to bridge:

8. LB 1 RB 0 *(**0** even, **1**- lower, **2**- higher)*

9. LB 2 RB 1 *(**1**- Paved, **2**- Not paved)*

10. Embankment slope (*run / rise in feet / foot*):
US left 0.0:1 US right 0.0:1

	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	1	0	0
RBUS	1	1	0	0
RBDS	1	1	0	0
LBDS	1	1	2	1

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

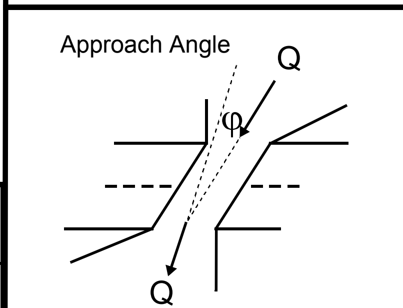
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

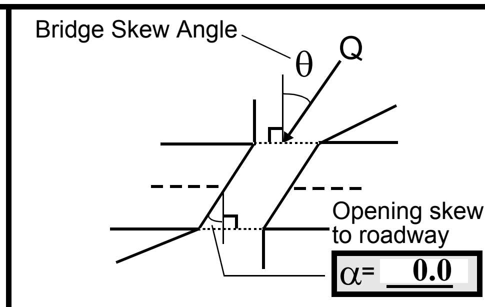
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 0





17. Channel impact zone 1: Exist? N *(Y or N)*
Where? - *(LB, RB)* Severity -
Range? - feet - *(US, UB, DS)* to - feet -

Channel impact zone 2: Exist? N *(Y or N)*
Where? - *(LB, RB)* Severity -
Range? - feet - *(US, UB, DS)* to - feet -

*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: **1a**

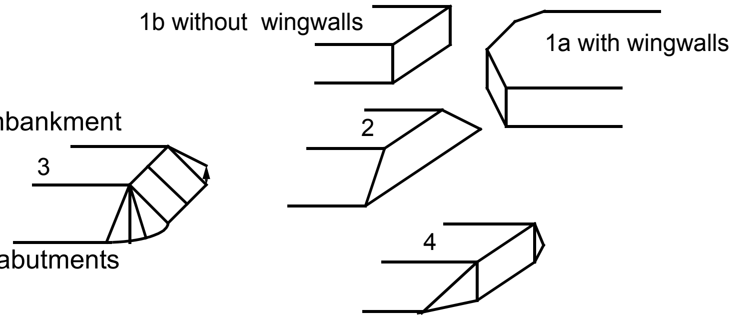
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



19. Bridge Deck Comments (surface cover variations, measured bridge and span lengths, bridge type variations, approach overflow width, etc.)

4. The right bank surface cover is generally pasture near the bridge, though there is a house and barn very close to the bridge and VT 100A parallels theright bank, passing 15 feet from the right end of the deck. Immediate banks on the right are shrubland. Immediate banks on the left are shrubland and young trees with pasture on the overbanks and forest on the hillside.
7. The values are from the VTAOT files.
9. The length of the right road approach is 15 feet. The left bank is a narrow floodplain and the left road approach is not significantly elevated off the floodplain level so no road overflow width was measured.
11. Sand and fine gravel have been dumped at all road approach corners. Minor erosion to some degree is occurring through this fine grained material at all road approaches.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
33.0	**4.5**			**9.5**	**3**	**1**	**234**	**342**	**2**	**1**

23. Bank width **45.0** 24. Channel width **20.0** 25. Thalweg depth **50.5** 29. Bed Material **3**

30 .Bank protection type: LB **0** RB **0** 31. Bank protection condition: LB **-** RB **-**

SRD - Section ref. dist. to US face *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*
*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*
*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*
*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

32. Comments (bank material variation, minor inflows, protection extent, etc.):

27. The left bank material is sand, gravel and cobble.
The right bank material is gravel, sand, cobble, and boulder.
29. The bed material is gravel and cobble.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 35 35. Mid-bar width: 10

36. Point bar extent: 85 feet US (US, UB) to 15 feet US (US, UB, DS) positioned 0 %LB to 30 %RB

37. Material: 324

38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):

This is a side bar with no vegetation. This bar is covered at higher flows. The bank above this bar is eroded and appears to have just fallen in.

39. Is a cut-bank present? N (Y or if N type ctrl-n cb) 40. Where? - (LB or RB)

41. Mid-bank distance: - 42. Cut bank extent: - feet - (US, UB) to - feet - (US, UB, DS)

43. Bank damage: - (1- eroded and/or creep; 2- slip failure; 3- block failure)

44. Cut bank comments (eg. additional cut banks, protection condition, etc.):

NO CUT BANKS

45. Is channel scour present? N (Y or if N type ctrl-n cs) 46. Mid-scour distance: -

47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB

48. Scour comments (eg. additional scour areas, local scouring process, etc.):

NO CHANNEL SCOUR

49. Are there major confluences? N (Y or if N type ctrl-n mc) 50. How many? -

51. Confluence 1: Distance - 52. Enters on - (LB or RB) 53. Type - (1- perennial; 2- ephemeral)

Confluence 2: Distance - Enters on - (LB or RB) Type - (1- perennial; 2- ephemeral)

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB 2 RB ____ (1- natural bank; 2- abutment; 3- artificial levee)

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
22.0		0.5		2	1	1	-

58. Bank width (BF) - 59. Channel width - 60. Thalweg depth 90.0 63. Bed Material -

*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*

*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*

64. Comments (bank material variation, minor inflows, protection extent, etc.):

3

The bed material is gravel and cobble and there is some sand on the sides of the channel.

65. **Debris and Ice** Is there debris accumulation? ____ *(Y or N)* 66. Where? **Y** ____ *(1- Upstream; 2- At bridge; 3- Both)*

67. Debris Potential **1** ____ *(1- Low; 2- Moderate; 3- High)* 68. Capture Efficiency **2** ____ *(1- Low; 2- Moderate; 3- High)*

69. Is there evidence of ice build-up? **1** ___ *(Y or N)* Ice Blockage Potential **N** ____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

Some trees are leaning into the channel on the left bank upstream above the side bar. There is some debris in the channel upstream. The bridge will not restrict much of the bank full flow.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**2**	**2**	**0**	**0.1**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**0**	**25.5**

Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1*- Concrete; *2*- Stone masonry or drywall; *3*- steel or metal; *4*- wood

79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

-

-

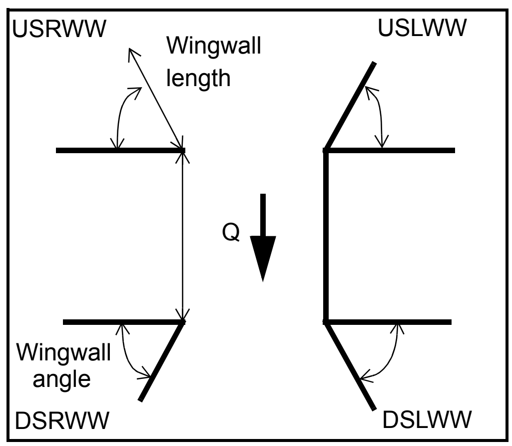
1

The US and DS ends of the left abutment footing are minimally exposed. The thalweg under the bridge is more to the left side of the channel.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**25.5**	
USRWW:	**Y**		**1**		**0**	**0.5**	
DSLWW:	**-**		**-**		**Y**	**16.0**	
DSRWW:	**1**		**0**		**-**	**16.0**	

Wingwall materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**0**	**Y**	**-**	**1**	**1**	**-**	**-**
Condition	**Y**	**-**	**1**	**-**	**1**	**1**	**-**	**-**
Extent	**1**	**-**	**0**	**1**	**1**	**0**	**0**	**-**

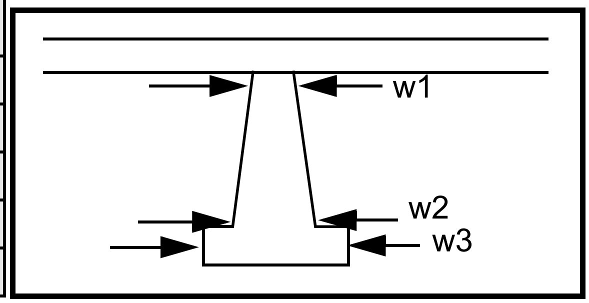
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
1
1
3
0
-
-

Piers:

84. Are there piers? **Th** *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**5.5**	**5.5**	**45.0**	**40.0**	**45.0**
Pier 2	**5.5**	**5.5**	**-**	**45.0**	**-**	**-**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e sand**	**es are**	**right**	**ily**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**and**	**also**	**wing**	**wash**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**fine**	**in**	**wall.**	**ed**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**grav**	**front**	**This**	**away**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**el**	**of all**	**fine**	**at**	*Y- yes; N- no*
91. Attack ∠ (BF)	**dum**	**the**	**grai**	**high**	
92. Pushed	**ped**	**wing**	**ned**	**flows**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**at all**	**walls**	**mate**	**.**	
95. Cross-members	**the**	**exce**	**rial**		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**road**	**pt**	**coul**		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**appr**	**the**	**d be**		
98. Exposure depth	**oach**	**DS**	**eas-**		

99. Pier comments (eg. undermined penetration, protection and protection extent, unusual scour processes, etc.):

N
-
-
-
-

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

Bank width (BF) - Channel width - Thalweg depth - Bed Material -

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB -

SRD - Section ref. dist. to US face *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*
*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*
*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*
*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

101. Is a drop structure present? - *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

103. Drop: - feet 104. Structure material: - *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
-
-
-
-
-
-

106. Point/Side bar present? - (Y or N. if N type ctrl-n pb) Mid-bar distance: - Mid-bar width: -

Point bar extent: - feet - (US, UB, DS) to - feet - (US, UB, DS) positioned - %LB to - %RB

Material: -

Point or side bar comments (Circle Point or Side; note additional bars, material variation, status, etc.):

NO PIERS

Is a cut-bank present? _____ (Y or if N type ctrl-n cb) Where? _____ (LB or RB) Mid-bank distance: _____

Cut bank extent: _____ feet _____ (US, UB, DS) to _____ feet 2 (US, UB, DS)

Bank damage: 1 (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)

Cut bank comments (eg. additional cut banks, protection condition, etc.):

3
3
0
0

Is channel scour present? 3 (Y or if N type ctrl-n cs) Mid-scour distance: 0

Scour dimensions: Length 0 Width - Depth: - Positioned The %LB to bed %RB

Scour comments (eg. additional scour areas, local scouring process, etc.):

material is gravel, cobble and sand. The bank material is gravel, cobble and sand.

Are there major confluences? _____ (Y or if N type ctrl-n mc) How many? _____

Confluence 1: Distance _____ Enters on _____ (LB or RB) Type _____ (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance _____ Enters on _____ (LB or RB) Type _____ (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

N

-

NO DROP STRUCTURE

N

-

-

-

-

109. G. Plan View Sketch - -

point bar (pb)	debris	flow (Q)	stone wall
cut-bank (cb)	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: PLYMTH00540047 Town: PLYMOUTH
Road Number: TH 54 County: WINDSOR
Stream: PINNEY HOLLOW BROOK

Initials ECW Date: 3/24/98 Checked: MAI

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1700	2350	1650
Main Channel Area, ft2	304	339	235
Left overbank area, ft2	199	274	59
Right overbank area, ft2	0	0	0
Top width main channel, ft	48	50	44
Top width L overbank, ft	101	109	82
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.15	0.15	0.15
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.3	6.8	5.3
y1, average depth, LOB, ft	2.0	2.5	0.7
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	39734	51144	21720
Conveyance, main channel	29378	34350	20156
Conveyance, LOB	10357	16794	1564
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	-0.0025	0.0000	0.0000
Qm, discharge, MC, cfs	1256.9	1578.3	1531.2
Ql, discharge, LOB, cfs	443.1	771.7	118.8
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	4.1	4.7	6.5
Vl, mean velocity, LOB, ft/s	2.2	2.8	2.0
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	8.1	8.2	7.9
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1700	2350	1650
(Q) discharge thru bridge, cfs	1493	1833	1650
Main channel conveyance	18470	18470	10466
Total conveyance	18470	18470	10466
Q2, bridge MC discharge,cfs	1493	1833	1650
Main channel area, ft2	211	211	130
Main channel width (normal), ft	25.7	25.7	25.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	25.7	25.7	25.7
y_bridge (avg. depth at br.), ft	8.21	8.21	5.06
Dm, median (1.25*D50), ft	0.1875	0.1875	0.1875
y2, depth in contraction,ft	6.49	7.74	7.07
ys, scour depth (y2-ybridge), ft	-1.72	-0.47	2.02

Armoring
Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1493	1833	1650
Main channel area (DS), ft2	145	163	130
Main channel width (normal), ft	25.7	25.7	25.7
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	25.7	25.7	25.7
D90, ft	0.3028	0.3028	0.3028
D95, ft	0.4147	0.4147	0.4147
Dc, critical grain size, ft	0.3631	0.4151	0.5747
Pc, Decimal percent coarser than Dc	0.071	0.050	0.026
Depth to armoring, ft	N/A	N/A	N/A

Pressure Flow Scour (contraction scour for orifice flow conditions)

```
Chang pressure flow equation        Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and Davis, 1995, p. 144-146)
```

	Q100	Q500	OtherQ
Q, total, cfs	1700	2350	1650
Q, thru bridge MC, cfs	1493	1833	1650
Vc, critical velocity, ft/s	8.10	8.19	7.87
Va, velocity MC approach, ft/s	4.13	4.66	6.52
Main channel width (normal), ft	25.7	25.7	25.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	25.7	25.7	25.7
qbr, unit discharge, ft2/s	58.1	71.3	64.2
Area of full opening, ft2	211.0	211.0	130.0
Hb, depth of full opening, ft	8.21	8.21	5.06
Fr, Froude number, bridge MC	0.44	0.54	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	145	163	N/A
**Hb, depth at downstream face, ft	5.64	6.34	N/A
**Fr, Froude number at DS face	0.76	0.79	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	498.31	498.31	498.31
Elevation of Bed, ft	490.10	490.10	493.25
Elevation of Approach, ft	499.32	500.03	0
Friction loss, approach, ft	0.08	0.11	0
Elevation of WS immediately US, ft	499.24	499.92	0.00
ya, depth immediately US, ft	9.14	9.82	-493.25
Mean elevation of deck, ft	500.04	500.04	500.04
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.96	ERR
**Cc, for downstream face (<=1.0)	0.865684	0.88266	ERR
Ys, scour w/Chang equation, ft	-0.85	0.89	N/A
Ys, scour w/Umbrell equation, ft	-1.50	-0.51	N/A

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

**Ys, scour w/Chang equation, ft	2.64	3.52	N/A
**Ys, scour w/Umbrell equation, ft	1.07	1.35	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	6.49	7.74	7.07
WSEL at downstream face, ft	495.74	496.46	--
Depth at downstream face, ft	5.64	6.34	N/A
Ys, depth of scour (Laursen), ft	0.85	1.40	N/A

Abutment Scour

Froehlich's Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1

(Richardson and Davis, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1700	2350	1650	1700	2350	1650
a', abut.length blocking flow, ft	101.3	108.5	82.5	22.6	51.6	18.7
Ae, area of blocked flow ft2	139.25	180.69	62.24	90.19	100.15	59
Qe, discharge blocked abut.,cfs	--	--	126.18	187.89	--	165
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.22	2.79	2.03	2.08	2.43	2.80
ya, depth of f/p flow, ft	1.37	1.67	0.75	3.99	1.94	3.16
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.278	0.308	0.411	0.184	0.298	0.277
ys, scour depth, ft	8.82	10.77	6.90	9.56	9.02	8.93

HIRE equation (a'/ya > 25)

ys = 4*Fr^0.33*y1*K/0.55

(Richardson and Davis, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	101.3	108.5	82.5	22.6	51.6	18.7
y1 (depth f/p flow, ft)	1.37	1.67	0.75	3.99	1.94	3.16
a'/y1	73.69	65.15	109.35	5.66	26.59	5.93
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.28	0.31	0.41	0.18	0.30	0.28
Ys w/ corr. factor K1/0.55:						
vertical	6.55	8.21	4.09	ERR	9.47	ERR
vertical w/ ww's	5.37	6.73	3.36	ERR	7.76	ERR
spill-through	3.60	4.52	2.25	ERR	5.21	ERR

Abutment riprap Sizing

Isbash Relationship

D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)

(Richardson and Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.76	0.79	1	0.76	0.79	1
y, depth of flow in bridge, ft	5.64	6.34	5.06	5.64	6.34	5.06
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.01	2.45	ERR	2.01	2.45	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	2.12	ERR	ERR	2.12