LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (HUNTTH00290029) on TOWN HIGHWAY 29, crossing COBB BROOK, HUNTINGTON, VERMONT

U.S. Geological Survey
Open-File Report 97-652

Prepared in cooperation with
VERMONT AGENCY OF TRANSPORTATION
and
FEDERAL HIGHWAY ADMINISTRATION

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By ROBERT H. FLYNN

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Pembroke, New Hampshire

1997

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

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

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 29 (HUNTTH00290029) ON TOWN HIGHWAY 29, CROSSING COBB BROOK, HUNTINGTON, VERMONT

By **Robert H. Flynn**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure HUNTTH00290029 on Town Highway 29 crossing Cobb Brook, Huntington, 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 (U.S. Department of Transportation, 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, gleaned 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 northwestern Vermont. The 4.16-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream and downstream of the bridge.

In the study area, Cobb Brook has an incised, straight channel with a slope of approximately 0.024 ft/ft, an average channel top width of 53 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to bedrock with a median grain size (D_{50}) of 112.0 mm (0.367 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 25, 1996, indicated that the reach was stable.

The Town Highway 29 crossing of Cobb Brook is a 36-ft-long, one-lane bridge consisting of one 30-foot steel-beam span (Vermont Agency of Transportation, written communication, December 11, 1995) and a wooden deck. The opening length of the structure parallel to the bridge face is 27 ft.The bridge is supported by vertical, concrete abutments. The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway was measured to be 20 degrees. VTAOT records indicate an opening-skew-to-roadway of zero degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed extending from 12 ft upstream of the upstream end of the left abutment to 10 ft under the bridge in the center of the channel during the Level I assessment. Another scour hole approximately 1.2 ft deeper than the mean thalweg depth was observed along the downstream end of the right abutment during the Level I assessment. The scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the upstream end of the right abutment and type-3 stone fill (less than 48 inches diameter) along the upstream end of the upstream left retaining wall. 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 others, 1995). 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 was computed to be zero ft. Abutment scour ranged from 9.9 to 12.5 ft along the left abutment and from 6.2 to 8.6 ft along the right abutment. The worst-case abutment scour occurred at the 500-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 others, 1995, p. 47). 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.

Huntington, VT. Quadrangle, 1:24,000, 1948
Photorevised 1980

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 HUNTTH00290029 ***Stream*** Cobb Brook

County Chittenden ***Road*** TH29 ***District*** 5

Description of Bridge

Bridge length 36 ***ft*** ***Bridge width*** 13.4 ***ft*** ***Max span length*** 30 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 6/25/96

Description of stone fill Type-2 stone fill along the upstream end of the right abutment and type-3 stone fill along the upstream end of the upstream left retaining wall.

Brief description of piers/abutments Abutments are concrete. There is a 1.5 ft deep scour hole extending from the upstream end of the left abutment to 10 ft under the bridge at the center of the channel and a 1.2 ft deep scour hole along the downstream end of the right abutment.

Is bridge skewed to flood flow according to Level I survey? Y ***Angle*** 25

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

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	6/25/96	0	0
Level II	6/25/96	0	0

Potential for debris Moderate. There are some trees and debris caught on boulders and banks upstream and trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) Bedrock outcropping, downed trees, and boulders in the upstream and downstream channel will affect flow at lower flows. Noted 6/25/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley setting with steep valley walls on both sides.

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

Date of inspection 6/25/96

DS left: Steep channel bank to a steep valley wall.

DS right: Steep channel bank to a narrow flood plain.

US left: Steep channel bank to a steep valley wall.

US right: Steep channel bank to a narrow flood plain.

Description of the Channel

Average top width 53 ft ***Average depth*** 4 ft

Predominant bed material Bedrock / Boulder ***Bank material*** Gravel/Cobbles

Sinuous and straight with non-alluvial channel boundaries and no flood plain.

Vegetative co 6/25/96

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right: Trees and brush

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

Describe any obstructions in channel and date of observation. The assessment of 6/25/96 noted flow conditions up to bank-full level are influenced by boulders and bedrock outcroppings in the upstream and downstream channel. In addition, a tree is caught on boulders in the channel 50 ft upstream.

Hydrology

Drainage area 4.16 ***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***: None.

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 1,190 ***ft³/s*** ***Q500*** 2,190 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(4.2/4.16) exp 0.67] with bridge number 7h in Huntington. Bridge number 7h crosses Cobb Brook downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 7h is 4.2 square miles (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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 and 4 ft from the upstream end of the upstream left abutment (elev. 499.16 ft, arbitrary survey datum). RM2 is a chiseled X inside a chisled square in bedrock, 90 ft downstream on the left bank (elev. 492.40 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-28	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	43	1	Modelled Approach section (As surveyed)

[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 0.050 to 0.075, and overbank "n" values were 0.060.

Normal depth at the exit section (EXITX) was assumed as the starting water surface for the 100-year and incipient-overtopping discharges while critical depth at the exit section (EXITX) was assumed as the starting water surface for the 500-year discharge. 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 0.024 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1948). This slope resulted in a normal depth 0.13 ft less than critical depth for the 500-year discharge and WSPRO defaulted to critical depth. Critical depth in the downstream reach for the 500-year discharge is considered to be a satisfactory solution.

The surveyed approach section (APPRO) was located one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.3 ***ft***
Average low steel elevation 498.7 ***ft***

100-year discharge 1,190 ***ft³/s***
Water-surface elevation in bridge opening 496.1 ***ft***
Road overtopping? Y ***Discharge over road*** 50 ***ft³/s***
Area of flow in bridge opening 109 ***ft²***
Average velocity in bridge opening 10.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.9 ***ft/s***

Water-surface elevation at Approach section with bridge 498.2
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 0.6 ***ft***

500-year discharge 2,190 ***ft³/s***
Water-surface elevation in bridge opening 498.9 ***ft***
Road overtopping? Y ***Discharge over road*** 901 ***ft³/s***
Area of flow in bridge opening 175 ***ft²***
Average velocity in bridge opening 7.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.6 ***/s***

Water-surface elevation at Approach section with bridge 500.0
Water-surface elevation at Approach section without bridge 499.0
Amount of backwater caused by bridge 1.0 ***ft***

Incipient overtopping discharge 1,080 ***ft³/s***
Water-surface elevation in bridge opening 495.8 ***ft***
Area of flow in bridge opening 102 ***ft²***
Average velocity in bridge opening 10.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.0 ***ft/s***

Water-surface elevation at Approach section with bridge 498.1
Water-surface elevation at Approach section without bridge 497.3
Amount of backwater caused by bridge 0.8 ***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 others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the 100-year and incipient roadway-overtopping discharges were computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 500-year discharge 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 this discharge was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146).

For the 500-year discharge, which resulted in orifice flow, estimates of contraction scour were also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, since the 500-year discharge resulted in unsubmerged orifice flow, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution is provided in Appendix F.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 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 Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	8.6 1.0	9.9	--
Left overbank	--	--	--
Right overbank	--	--	10.4

Local scour:			
Abutment scour			
Left abutment	12.5	9.9	6.2
Right abutment	8.6	8.4	---
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	1.8

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.1	1.7	1.8
Right abutment	1.1	1.7	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--
	--	--	

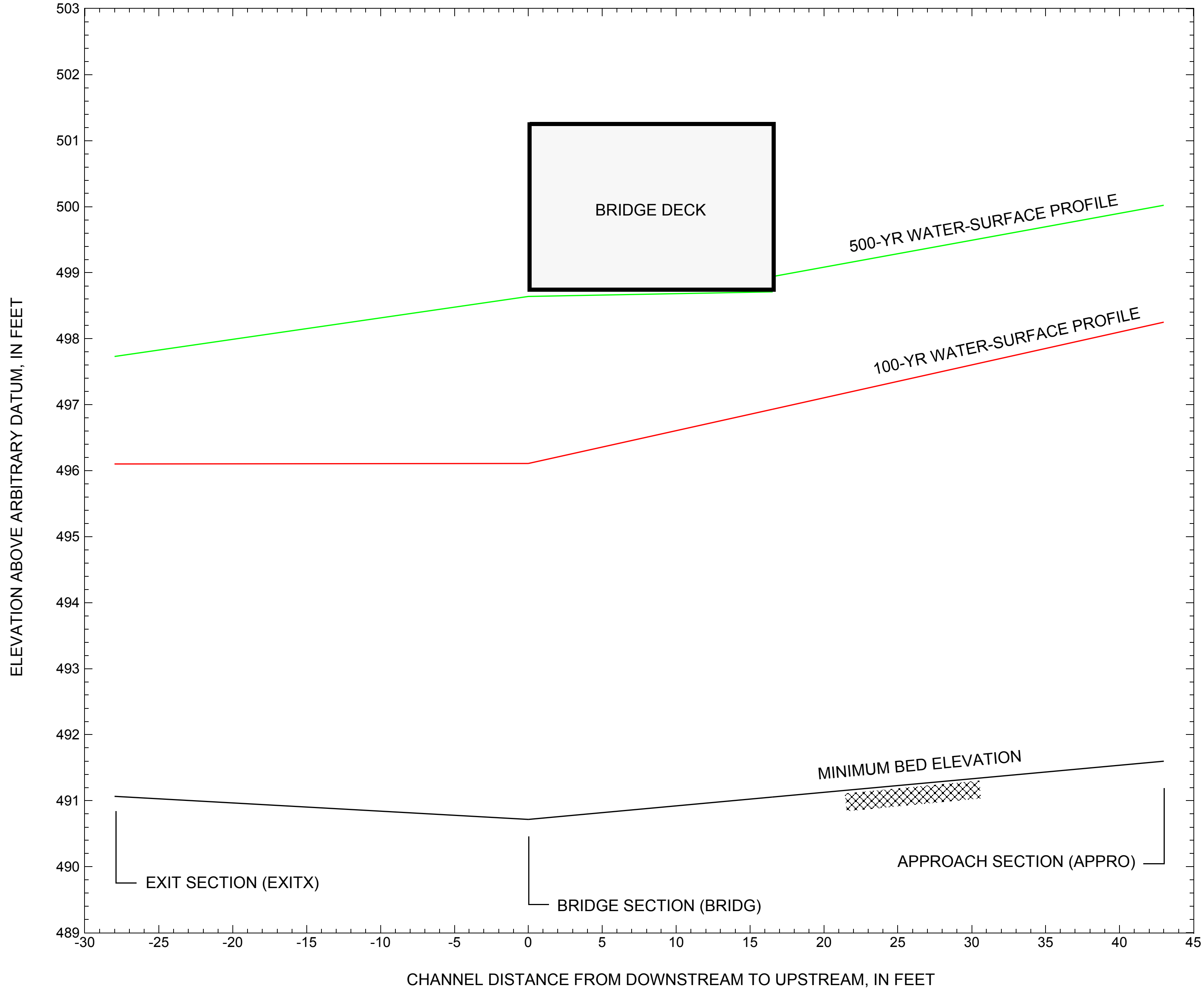

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure HUNTTH00290029 on Town Highway 29, crossing Cobb Brook, Huntington, Vermont.

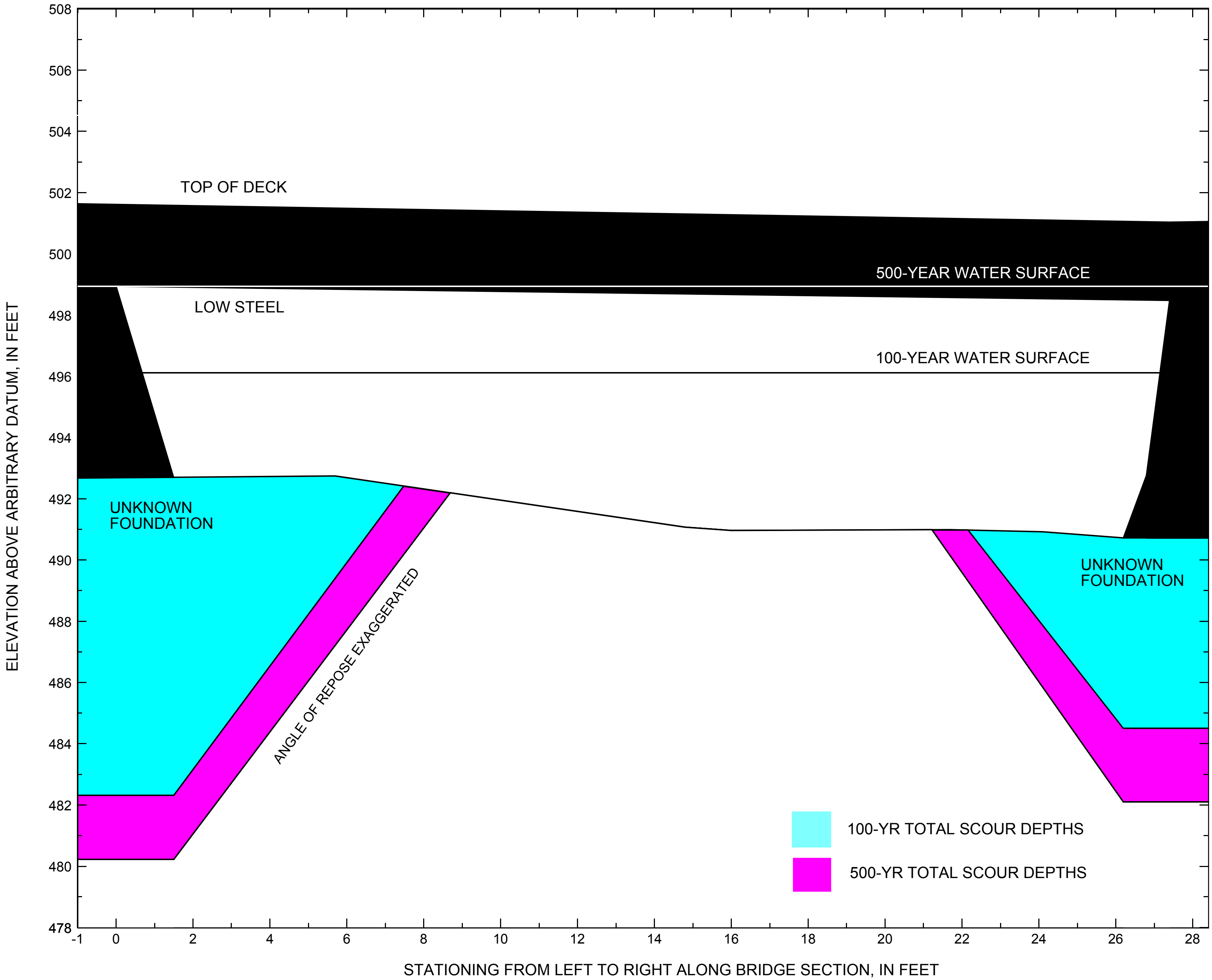

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure HUNTTH00290029 on Town Highway 29, crossing Cobb Brook, Huntington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure HUNTTH00290029 on Town Highway 29, crossing Cobb Brook, Huntington, 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 1,190 cubic-feet per second											
Left abutment	1.5	--	498.9	--	492.7	0.0	10.4	--	10.4	482.3	--
Right abutment	26.2	--	498.5	--	490.7	0.0	6.2	--	6.2	484.5	--

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-year discharge at structure HUNTTH00290029 on Town Highway 29, crossing Cobb Brook, Huntington, 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 2,190 cubic-feet per second											
Left abutment	1.5	--	498.9	--	492.7	0.0	12.5	--	12.5	480.2	--
Right abutment	26.2	--	498.5	--	490.7	0.0	8.6	--	8.6	482.1	--

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, 1948, Huntington, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1980, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE (continued)

```
T1        U.S. Geological Survey WSPRO Input File hunt029.wsp
T2        Hydraulic analysis for structure HUNTTH00290029   Date: 02-JUN-97
T3        Bridge #29 over Cobb Brook in Huntington, Vt.  RHF
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1190.0   2190.0   1080.0
SK          0.024    0.024    0.024
*
XS   EXITX    -28
GR          -72.4, 509.21    -21.2, 500.36    -16.0, 498.27     -6.2, 494.66
GR           -1.2, 492.60      0.0, 492.30      9.2, 492.28     13.8, 492.36
GR           18.6, 491.66     26.6, 491.07     30.5, 491.61     32.7, 493.04
GR           37.7, 497.50     60.8, 497.20     83.4, 497.01    120.8, 497.02
GR          160.3, 497.08    209.2, 504.77
*
N           0.060        0.070        0.060
SA                 -21.2         37.7
*
*
XS   FULLV      0  * * *  0.004
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.71      20.0
GR            0.0, 498.94      1.5, 492.67      5.7, 492.74     14.8, 491.07
GR           16.0, 490.96     21.7, 490.99     24.1, 490.92     26.2, 490.72
GR           26.8, 492.77     27.4, 498.48      0.0, 498.94
*
*         BRTYPE  BRWDTH
CD           1      16.5
N           0.050
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      13.4     2
GR         -126.8, 514.45    -77.9, 508.02    -34.2, 502.67      0.0, 501.61
GR           29.1, 501.03     46.8, 499.80     66.2, 498.02     87.5, 497.39
GR           99.0, 497.92    142.8, 498.21    209.2, 504.77
*
*
AS   APPRO     43
GR          -22.5, 502.61    -16.9, 500.07    -10.5, 494.45      0.0, 494.14
GR           15.1, 492.38     19.1, 491.60     24.4, 492.04     25.4, 492.87
GR           30.2, 496.24     81.5, 499.11    100.7, 498.70    142.8, 498.21
GR          154.5, 499.48    159.2, 503.27    176.2, 506.33
*
N           0.060        0.075        0.060
SA                 -16.9         30.2
*
HP 1 BRIDG   496.12 1 496.12
HP 2 BRIDG   496.12 * * 1140
HP 2 RDWAY   498.20 * * 50
HP 1 APPRO   498.23 1 498.23
HP 2 APPRO   498.23 * * 1190
*
HP 1 BRIDG   498.94 1 498.94
HP 2 BRIDG   498.94 * * 1269
HP 1 BRIDG   498.64 1 498.64
HP 2 RDWAY   499.70 * * 901
HP 1 APPRO   500.02 1 500.02
HP 2 APPRO   500.02 * * 2190
*
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
        U.S. Geological Survey WSPRO Input File hunt029.wsp
        Hydraulic analysis for structure HUNTTH00290029   Date: 02-JUN-97
        Bridge #29 over Cobb Brook in Huntington, Vt.  RHF

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      109      7324     25     32                         1300
   496.12           109      7324     25     32  1.00      1     27     1300

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.12     0.7    27.2   109.3    7324.    1140.  10.43

X STA.         0.7        4.0        6.0        7.8        9.3       10.6
  A(I)             9.4        6.4        6.0        5.5        5.3
  V(I)             6.07       8.95       9.50      10.46      10.85

X STA.        10.6       11.8       12.9       14.0       14.9       15.9
  A(I)             4.9        4.8        4.7        4.6        4.5
  V(I)            11.56      11.82      12.13      12.28      12.76

X STA.        15.9       16.8       17.7       18.6       19.6       20.5
  A(I)             4.4        4.4        4.5        4.5        4.5
  V(I)            12.86      12.87      12.73      12.58      12.54

X STA.        20.5       21.5       22.5       23.6       24.8       27.2
  A(I)             4.8        4.9        5.3        6.0        9.9
  V(I)            11.96      11.68      10.81       9.51       5.73


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.20    64.2   141.3    22.9     253.      50.   2.18

X STA.        64.2       71.3       74.1       76.3       78.0       79.6
  A(I)             1.5        1.0        1.0        0.9        0.9
  V(I)             1.70       2.39       2.58       2.81       2.91

X STA.        79.6       81.0       82.3       83.5       84.6       85.7
  A(I)             0.8        0.8        0.8        0.8        0.8
  V(I)             3.03       3.05       3.08       3.13       3.09

X STA.        85.7       86.8       87.8       89.0       90.3       92.0
  A(I)             0.8        0.9        0.9        1.0        1.1
  V(I)             3.02       2.92       2.80       2.62       2.37

X STA.        92.0       94.1       97.2      103.3      112.2      141.3
  A(I)             1.2        1.4        1.7        2.0        2.8
  V(I)             2.15       1.82       1.47       1.26       0.89


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      43.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      207     10883     45     48                         2516
             3       35       875     36     36                          200
   498.23           242     11758     81     84  1.11    -14     66     2265

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      43.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.23   -14.8    65.8   242.2   11758.    1190.   4.91

X STA.       -14.8       -7.9       -4.5       -1.3        1.6        4.3
  A(I)            18.2       13.2       12.7       12.1       11.9
  V(I)             3.27       4.50       4.70       4.91       5.00

X STA.         4.3        6.6        8.8       10.7       12.6       14.3
  A(I)            11.1       10.8       10.2       10.1        9.8
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  V(I)             5.35       5.52       5.86       5.91       6.06

X STA.        14.3       15.9       17.5       18.9       20.3       21.7
  A(I)              9.5        9.4        9.0        9.2        9.1
  V(I)             6.25       6.34       6.58       6.49       6.54

X STA.        21.7       23.2       24.8       27.4       35.2       65.8
  A(I)              9.4       10.1       12.7       17.7       26.1
  V(I)             6.32       5.88       4.68       3.37       2.28

WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
        U.S. Geological Survey WSPRO Input File hunt029.wsp
        Hydraulic analysis for structure HUNTTH00290029   Date: 02-JUN-97
        Bridge #29 over Cobb Brook in Huntington, Vt.  RHF

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      175     10241      0     63                            0
   498.94           175     10241      0     63  1.00      0     27        0

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
       498.94     0.0    27.4   174.8   10241.    1269.   7.26
X STA.         0.0        3.3        5.0        6.5        8.0        9.4
  A(I)             14.9        9.6        9.1        8.8        8.4
  V(I)             4.26       6.63       6.95       7.23       7.56

X STA.         9.4       10.6       11.8       12.9       14.0       15.1
  A(I)              8.0        7.9        7.6        7.7        7.4
  V(I)             7.92       7.99       8.35       8.27       8.60

X STA.        15.1       16.1       17.1       18.1       19.2       20.2
  A(I)              7.4        7.4        7.4        7.4        7.7
  V(I)             8.62       8.60       8.52       8.62       8.27

X STA.        20.2       21.3       22.4       23.6       24.9       27.4
  A(I)              7.7        8.0        8.3        9.4       14.9
  V(I)             8.28       7.94       7.62       6.78       4.26

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      172     12326     17     46                         3139
   498.64           172     12326     17     46  1.00      0     27     3139

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.
          WSEL     LEW     REW    AREA        K        Q    VEL
       499.70    47.9   157.9   164.2    5323.     901.   5.49
X STA.        47.9       64.8       69.9       74.3       78.1       81.6
  A(I)             13.1        8.7        8.0        7.6        7.2
  V(I)             3.43       5.15       5.61       5.94       6.29

X STA.        81.6       84.7       87.6       90.7       94.0       97.7
  A(I)              6.9        6.7        6.8        6.8        7.1
  V(I)             6.56       6.75       6.60       6.60       6.31

X STA.        97.7      101.8      106.1      110.6      115.2      120.1
  A(I)              7.4        7.5        7.6        7.9        8.0
  V(I)             6.06       6.00       5.91       5.72       5.66

X STA.       120.1      125.0      130.2      135.6      141.7      157.9
  A(I)              8.0        8.3        8.5        9.1       12.9
  V(I)             5.66       5.44       5.28       4.94       3.48

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      43.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      289     18344     47     51                         4070
             3      222      8042    125    125                         1674
   500.02           511     26386    172    176  1.20    -16    155     4562
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    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      43.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.02   -16.8   155.2   510.7   26386.    2190.   4.29
X STA.       -16.8       -7.7       -3.6        0.2        3.7        6.8
  A(I)            33.3       23.3       22.3       21.2       20.4
  V(I)            3.29       4.69       4.92       5.17       5.38

X STA.         6.8        9.6       12.3       14.7       17.0       19.1
  A(I)            19.4       19.1       18.2       17.5       17.4
  V(I)            5.65       5.74       6.00       6.25       6.31

X STA.        19.1       21.2       23.3       25.9       30.8       38.3
  A(I)            17.1       17.8       19.4       25.2       26.5
  V(I)            6.42       6.16       5.64       4.34       4.13

X STA.        38.3       47.7       61.6       98.0      126.5      155.2
  A(I)            28.7       33.7       47.0       41.4       41.9
  V(I)            3.81       3.25       2.33       2.64       2.61

        U.S. Geological Survey WSPRO Input File hunt029.wsp
        Hydraulic analysis for structure HUNTTH00290029   Date: 02-JUN-97
        Bridge #29 over Cobb Brook in Huntington, Vt.  RHF

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      102      6594     25     32                          1172
   495.82           102      6594     25     32  1.00      1     27     1172

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.82     0.7    27.1   101.9    6594.    1080.  10.60

X STA.         0.7        4.1        6.1        7.9        9.4       10.8
  A(I)             8.7        6.0        5.5        5.2        4.9
  V(I)            6.19       9.04       9.74      10.43      11.05

X STA.        10.8       12.0       13.1       14.1       15.1       16.0
  A(I)             4.8        4.5        4.4        4.3        4.2
  V(I)           11.33      12.06      12.35      12.49      13.00

X STA.        16.0       16.9       17.8       18.8       19.7       20.6
  A(I)             4.2        4.1        4.2        4.2        4.3
  V(I)           13.00      13.02      12.88      12.99      12.45

X STA.        20.6       21.6       22.6       23.7       24.9       27.1
  A(I)             4.3        4.5        4.9        5.6        9.1
  V(I)           12.44      11.87      10.98       9.66       5.95


   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      43.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      200     10331     45     48                          2399
             3       30       710     33     33                           165
   498.08           230     11041     78     81  1.10    -14     63     2145

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      43.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.08   -14.6    63.1   230.4   11041.    1080.   4.69

X STA.       -14.6       -7.9       -4.4       -1.3        1.7        4.3
  A(I)            17.2       13.0       12.1       11.8       11.1
  V(I)            3.14       4.16       4.47       4.56       4.85

X STA.         4.3        6.6        8.8       10.7       12.5       14.2
  A(I)            10.7       10.4        9.8        9.7        9.5
  V(I)            5.06       5.21       5.53       5.57       5.71

X STA.        14.2       15.8       17.3       18.7       20.1       21.4
```

```
  A(I)            9.1       8.9       8.8       8.6       8.7
  V(I)           5.97      6.05      6.16      6.26      6.19

X STA.      21.4      22.9      24.4      26.6      33.3      63.1
  A(I)            9.0       9.2      11.5      16.6      24.8
  V(I)           5.98      5.87      4.70      3.26      2.18
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        U.S. Geological Survey WSPRO Input File hunt029.wsp
        Hydraulic analysis for structure HUNTTH00290029   Date: 02-JUN-97
        Bridge #29 over Cobb Brook in Huntington, Vt.  RHF

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

EXITX:XS   ******     -9      162  0.84 *****  496.95  495.25    1190  496.10
       -27 ******     36     7675  1.00 ***** *******    0.69    7.35

FULLV:FV       28    -11      193  0.59  0.52  497.47 *******    1190  496.88
         0     28     37     9925  1.00  0.00    0.00    0.55    6.16
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       43    -13      192  0.64  0.70  498.19 *******    1190  497.55
        43     43     54     8769  1.07  0.03    0.00    0.67    6.20
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.52       0.00     495.94     497.39
 ===260 ATTEMPTING FLOW CLASS 4 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       28      1      109  1.70  0.68  497.81  495.75    1140  496.12
         0     28     27     7312  1.00  0.19    0.00    0.88   10.44

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  498.71 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    30.  0.30  0.41  498.36    0.00     50.  498.20

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0. ****** ****** ****** ***** ***** ***** ***** ***** *****
   RT:     50.    33.    66.    99.   0.8   0.5   3.4   3.0   0.7   2.7

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
```
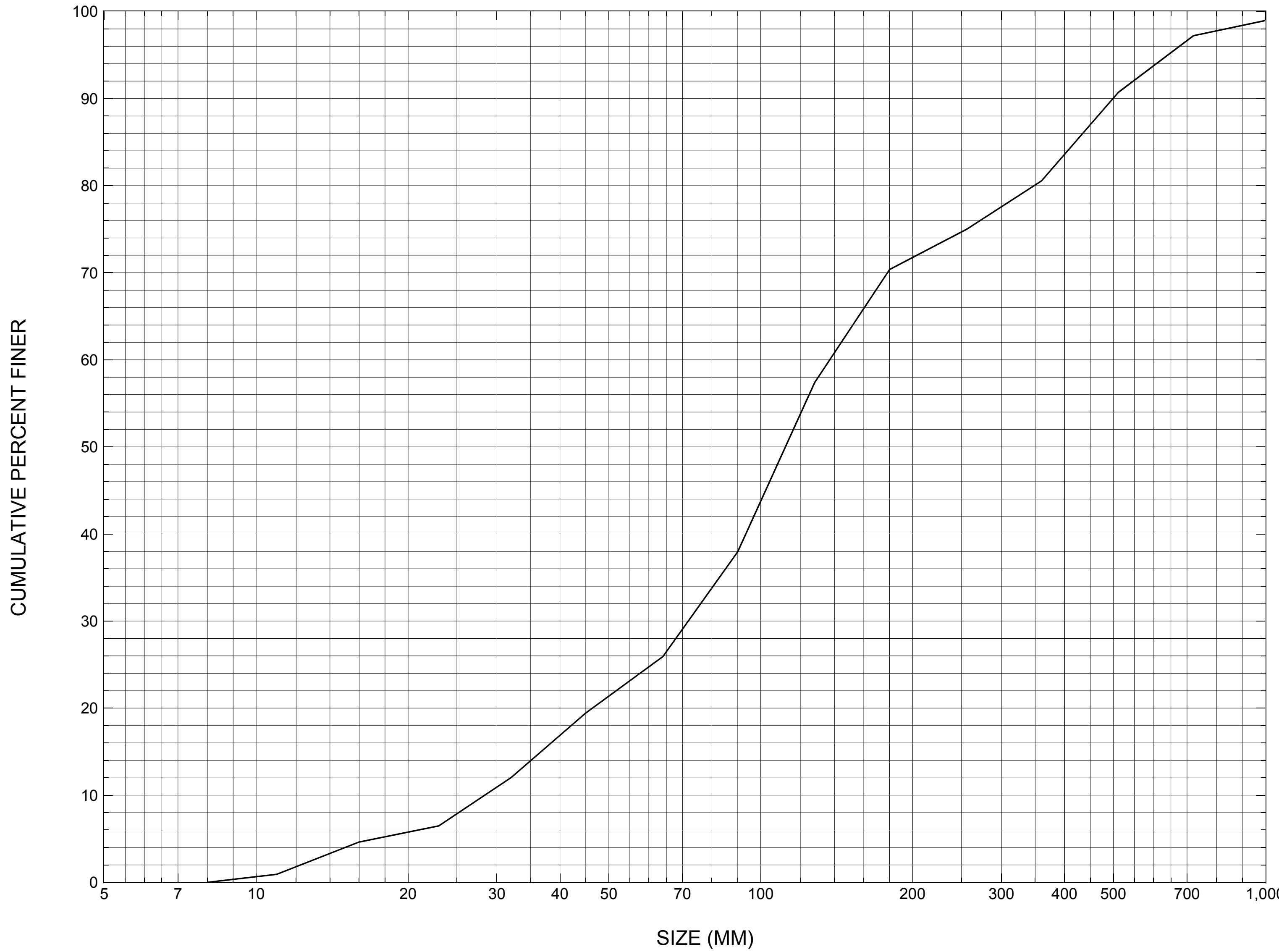

```
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS       27    -14      243  0.41  0.44  498.65  496.35    1190  498.23
       43      28     66    11777  1.11  0.40    0.01    0.52    4.91

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.605  0.254    8757.    -1.    26. ********

    A vertical “wall” was placed at station 81.5 of the Approach cross-section
    for the 100-year discharge due to a high point in the approach which yielded
    split flow.
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

        U.S. Geological Survey WSPRO Input File hunt029.wsp
        Hydraulic analysis for structure HUNTTH00290029   Date: 02-JUN-97
        Bridge #29 over Cobb Brook in Huntington, Vt.  RHF
           *** RUN DATE & TIME: 06-27-97  10:45
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -28.    -10.    36.   1190.    7675.     162.    7.35  496.10
   FULLV:FV       0.    -12.    37.   1190.    9925.     193.    6.16  496.88
   BRIDG:BR       0.     1.     27.   1140.    7312.     109.   10.44  496.12
   RDWAY:RG       8.*******     0.     50.       0.       0.    2.00  498.20
   APPRO:AS      43.    -15.    66.   1190.   11777.     243.    4.91  498.23

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    26.    8757.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.25    0.69  491.07  509.21************  0.84  496.95  496.10
   FULLV:FV  ********    0.55  491.18  509.32  0.52  0.00  0.59  497.47  496.88
   BRIDG:BR    495.75    0.88  490.72  498.94  0.68  0.19  1.70  497.81  496.12
   RDWAY:RG  ****************  497.39  514.45  0.30******  0.41  498.36  498.20
   APPRO:AS    496.35    0.52  491.60  505.00  0.44  0.40  0.41  498.65  498.23


        U.S. Geological Survey WSPRO Input File hunt029.wsp
        Hydraulic analysis for structure HUNTTH00290029   Date: 02-JUN-97
        Bridge #29 over Cobb Brook in Huntington, Vt.  RHF
 ===015 WSI IN WRONG FLOW REGIME AT SECID “EXITX”:  USED WSI = CRWS.
                             WSI,CRWS =   497.60     497.73

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******    -14      320  0.96 *****  498.69  497.73    2190  497.73
      -27 ******    164    15145  1.32 ***** *******    1.04    6.85

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             “FULLV”     KRATIO =  1.52

FULLV:FV       28    -16      465  0.44  0.38  499.07 *******    2190  498.64
        0      28    169    23059  1.27  0.00    0.00    0.59    4.71
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.90     498.99     498.06
 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   498.14     506.33    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   498.14     506.33     498.06
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             “APPRO”     KRATIO =  0.69

APPRO:AS       43    -15      336  0.86  0.56  499.84  498.06    2190  498.99
       43      43    150    15929  1.30  0.21    0.00    0.90    6.53
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   502.11       0.00     497.98     497.39
```

WSPRO OUTPUT FILE (continued)

```
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   498.39     499.58     499.87     498.71
 ===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       28      0      175  0.82 *****  499.76  496.05    1269  498.94
         0 ******     27    10241  1.00 ***** *******    0.51    7.26

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.426  0.000  498.71 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    30.  0.20  0.34  500.16   -0.01    901.  499.70

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    17.    -3.    14.   0.4   0.2   4.4  15.5   1.1   2.8
   RT:    901.   110.    48.   158.   2.3   1.5   6.3   5.5   2.0   3.0

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

APPRO:AS       27    -16      511  0.34  0.33  500.36  498.06    2190  500.02
        43     30    155    26382  1.20  0.17   -0.01    0.48    4.29

        U.S. Geological Survey WSPRO Input File hunt029.wsp
        Hydraulic analysis for structure HUNTTH00290029   Date: 02-JUN-97
        Bridge #29 over Cobb Brook in Huntington, Vt.  RHF
   FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -28.   -15.   164.   2190.   15145.     320.    6.85  497.73
   FULLV:FV       0.   -17.   169.   2190.   23059.     465.    4.71  498.64
   BRIDG:BR       0.     0.    27.   1269.   10241.     175.    7.26  498.94
   RDWAY:RG       8.*******     0.    901.       0.*********    2.00  499.70
   APPRO:AS      43.   -17.   155.   2190.   26382.     511.    4.29  500.02

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

 SECOND USER DEFINED TABLE.
   XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    497.73    1.04  491.07  509.21************  0.96  498.69  497.73
   FULLV:FV  ********    0.59  491.18  509.32  0.38  0.00  0.44  499.07  498.64
   BRIDG:BR    496.05    0.51  490.72  498.94************  0.82  499.76  498.94
   RDWAY:RG  ****************  497.39  514.45  0.20******  0.34  500.16  499.70
   APPRO:AS    498.06    0.48  491.60  506.33  0.33  0.17  0.34  500.36  500.02
        U.S. Geological Survey WSPRO Input File hunt029.wsp
        Hydraulic analysis for structure HUNTTH00290029   Date: 02-JUN-97
        Bridge #29 over Cobb Brook in Huntington, Vt.  RHF

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

EXITX:XS   ******     -9      151  0.79 *****  496.67  495.05    1080  495.88
       -27 ******     36     6966  1.00 ***** *******    0.69    7.13

FULLV:FV       28    -10      181  0.55  0.52  497.18 *******    1080  496.63
         0     28     37     9049  1.00  0.00    0.00    0.54    5.96
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       43    -13      176  0.62  0.71  497.93 *******    1080  497.30
        43     43     49     7829  1.06  0.04    0.00    0.67    6.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   498.08       0.00     495.82     497.39
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure HUNTTH00290029, in Huntington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **HUNTTH00290029**

General Location Descriptive

Data collected by *(First Initial, Full last name)* **L**. **Medalie**

Date *(MM/DD/YY)* **12** / **11** / **95**

Highway District Number *(I - 2; nn)* **05**

County *(FIPS county code; I - 3; nnn)* **007**

Town *(FIPS place code; I - 4; nnnnn)* **34600**

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

Waterway *(I - 6)* **COBB BROOK**

Road Name *(I - 7)*: **CHARLES SMITH**

Route Number **C3029**

Vicinity *(I - 9)* **0.2 MI TO JCT W CL2 TH1**

Topographic Map **Huntington**

Hydrologic Unit Code: **-**

Latitude *(I - 16; nnnn.n)* **44164**

Longitude *(i - 17; nnnnn.n)* **72575**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10040800290408**

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

Maximum span length *(I - 48; nnnn)* **0030**

Year built *(I - 27; YYYY)* **1914**

Structure length *(I - 49; nnnnnn)* **000036**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000010**

Deck Width *(I - 52; nn.n)* **134**

Year of ADT *(I - 30; YY)* **93**

Channel & Protection *(I - 61; n)* **5**

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

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

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

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

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

Year Reconstructed *(I - 106)* **1938**

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*) **7.5**

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

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

Comments:

According to the structural inspection report dated 7/3/95, the deck consists of 2x6's on edge with wood plank runners. Abutments and wing/retainer walls are concrete, or possibly concrete faced laid up stone. The right abutment has a 1' to 1.5' by 2" to 3" deep undermined area in its bottom DS corner where a large boulder has been encased in the concrete. There are minor cracks and spalls overall. Each abutment has a treated timber plank backwall. Numerous large boulders are present in the US and DS channel, with large areas of erosion showing along the US and DS embankments. Ledge outcrops are showing in both US and DS channel.

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: **Sand and gravel with few boulders**

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*): - Frequency: -

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

Are there other structures nearby? (*Yes, No, Unknown*): - *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)* **4.16** mi^2
Lake/pond/swamp area **0.01** mi^2
Watershed storage *(ST)* **0.24** %
Bridge site elevation **790** ft
Headwater elevation **3160** ft
Main channel length **3.94** mi
10% channel length elevation **950** ft
85% channel length elevation **2690** ft
Main channel slope *(S)* **588.83** 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:

-

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

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

Foundation Type: - (*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? - *If no, type ctrl-n bi* Number of borings taken: -

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

Briefly describe material at foundation bottom elevation or around piles:

-

Comments:

-

Cross-sectional Data

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

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

Comments: **This cross-section is at the upstream face. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 7/03/95. The sketch was done on 10/27/93. There is no accurate low chord elevation data available.**

Station	0	8	13	21	27.4	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	7.0	8.1	7.7	6.8	5.0	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **10/8/96**

Computerized by: **EW** Date: **10/10/96**

Reviewd by: **RF** Date: **6/24/97**

Structure Number **HUNTTH00290029**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **06** / **25** / 19**96**

2. Highway District Number **05** Mile marker **000000**

County **WASHINGTON 007** Town **HUNTINGTON 34600**

Waterway *(I - 6)* **COBB BROOK** Road Name **CHARLES SMITH**

Route Number **TH029** Hydrologic Unit Code: ____

3. Descriptive comments:

The structure is located 0.2 miles from the junction with Town Highway 1.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **6** Overall **6**
*(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 **1** 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 **36** *(feet)* Span length **30** *(feet)* Bridge width **13.4** *(feet)*

Road approach to bridge:

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

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

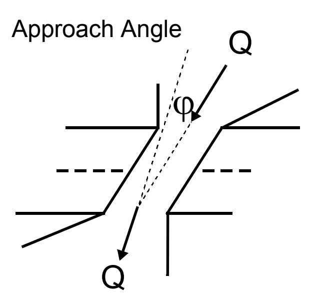
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

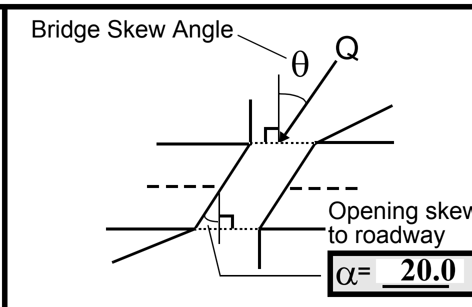
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	-
RBUS	0	-	0	-
RBDS	5	1	0	-
LBDS	0	-	2	1

*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: **10** 16. Bridge skew: **25**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **90** feet **US** *(US, UB, DS)* to **25** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **10** feet **UB** *(US, UB, DS)* to **0** feet **DS**

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

18. Bridge Type: **1b**

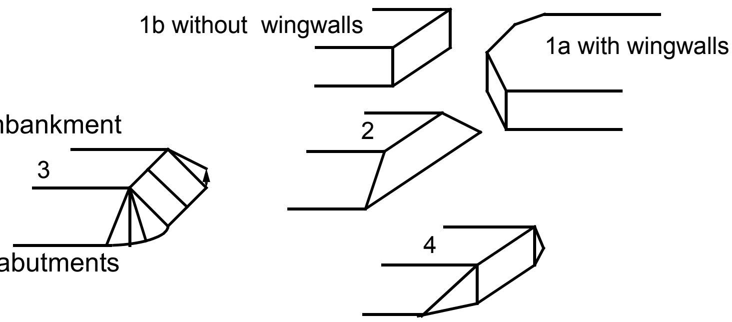
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular 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 downstream right bank surface cover is forest with TH29 along the downstream right bank.

#7: All measured values correspond with VTAOT values on the historical form.

#11: The downstream right bank road approach protection is a wood plank retaining wall for road gravel extending eight feet.

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
27.0	**5.5**			**3.5**	**4**	**3**	**34**	**56**	**2**	**1**

23. Bank width **40.0** 24. Channel width **30.0** 25. Thalweg depth **47.0** 29. Bed Material **654**

30 .Bank protection type: LB **5** RB **4** 31. Bank protection condition: LB **1** RB **1**

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 right bank consists of large boulders and some bedrock.

#29: The bed material consists of boulders, bedrock and cobble.

#30: The left bank protection extends from the end of the wingwall to 20 feet upstream.

At 60 feet upstream, a large group of boulders exists in the channel bed.

At 85 feet upstream, bedrock is exposed and extends further upstream.

Channel widens from the upstream bridge face to 94 feet upstream.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **40** 35. Mid-bar width: **30**

36. Point bar extent: **94** feet **US** (US, UB) to **10** feet **US** (US, UB, DS) positioned **0** %LB to **70** %RB

37. Material: **43**

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

Side bar is located in a widened channel zone with a cut-bank consisting of cobble and gravel.

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

41. Mid-bank distance: **55** 42. Cut bank extent: **94** feet **US** (US, UB) to **15** feet **US** (US, UB, DS)

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

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

Cut-bank begins at bedrock outcrop where channel widens and a side bar forms.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **2 US**

47. Scour dimensions: Length **22** Width **10** Depth : **1.5** Position **0** %LB to **50** %RB

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

Bridge scour extends from 12 feet upstream to 10 feet under bridge.

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)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
35.5		2.0		2	7	7	-

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **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.):

543

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? **2**___ (Y or N) Ice Blockage Potential **N**____ (1- Low; 2- Moderate; 3- High)

70. Debris and Ice Comments:

2

At 50 feet upstream, logs are across the channel and trees are leaning into the stream. There are also dead trees along both upstream banks.

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**	**83**	**2**	**1**	**1.5**	**0**	**90.0**
RABUT	**1**	**15**	**90**			**2**	**3**	**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

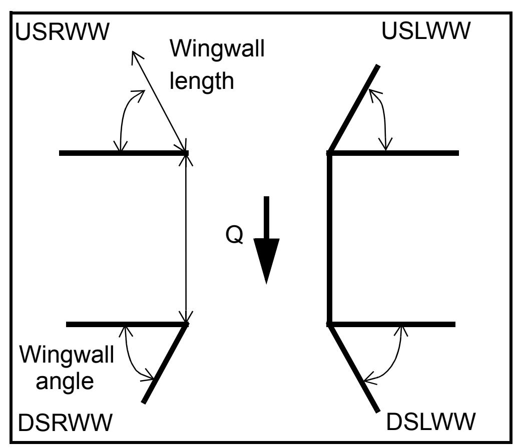
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

1.2
0.4
1

The right abutment is undermined along three feet of the downstream end, below the boulder and concrete of the abutment. Penetration depth is a maximum of 1 foot. Scour depth is 1.2 feet at the downstream corner of the right abutment. Undermining depth is 0.4 feet below the concrete base of the abutment at the upstream end of the boulder in the wall. This is also described in historical form.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**25.5**	
USRWW:	**Y**		**1**		**0**	**-**	
DSLWW:	**-**		**-**		**N**	**18.0**	
DSRWW:	**-**		**-**		**-**	**15.0**	



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**	**N**	**-**	**1**	**-**	**-**	**3**
Condition	**Y**	**-**	**-**	**-**	**2**	**-**	**-**	**2**
Extent	**1**	**-**	**-**	**3**	**-**	**0**	**2**	**-**

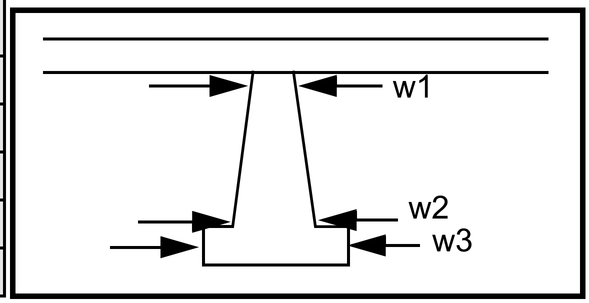
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **#82** *(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	**180.0**	**-**	**5.0**	**13.5**	**-**	**3.0**
Pier 2		**4.5**	**-**	**175.0**	**-**	**-**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**: At**	**ders**	**a few**	**areas**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**the**	**are**	**have**	**wher**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**upst**	**emb**	**been**	**e**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**ream**	**edde**	**place**	**these**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**end**	**d**	**d in**	**boul-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**of**	**into**	**front**	**ders**	
92. Pushed	**the**	**the**	**of**	**do**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**right**	**con-**	**the**	**not**	
95. Cross-members	**abut**	**crete**	**abut**	**exist,**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**ment**	**abut**	**ment**	**scou**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**,**	**ment**	**. In**	**r,**	
98. Exposure depth	**boul-**	**and**	**those**	**foot-**	

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

ing exposure and penetration are evident.

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 (Amb) - Thalweg depth (Amb) - 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.):

-
-
-
-

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

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

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

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

Is channel scour present? _____ (Y or if N type ctrl-n cs) Mid-scour distance: 4______

Scour dimensions: Length 4_____ Width 346___ Depth: 45___ Positioned 2___ %LB to 1___ %RB

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

635
0
0
-

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

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

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

Confluence comments (eg. confluence name):

sists of gravel and cobble with bedrock beginning at 70 feet downstream and extending farther downstream.

F. Geomorphic Channel Assessment

107. Stage of reach evolution Th___

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)*:

e right bank material consists of cobbles and boulders.

A bedrock outcrop extends across channel creating a drop of 4 feet at 86 feet downstream from bridge.

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: HUNTTH00290029 Town: HUNTINGTON
Road Number: TH29 County: CHITTENDEN
Stream: Cobb Brook

Initials RHF Date: 6/9/97 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 others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q	other Q
Total discharge, cfs	1190	2190	1080	1740
Main Channel Area, ft2	207	289	200	245
Left overbank area, ft2	0	0	0	0
Right overbank area, ft2	35	222	30	72
Top width main channel, ft	45	47	45	46
Top width L overbank, ft	0	0	0	0
Top width R overbank, ft	36	125	33	51
D50 of channel, ft	0.3672	0.3672	0.3672	0.3672
D50 left overbank, ft	--	--	--	--
D50 right overbank, ft	--	--	--	--
y1, average depth, MC, ft	4.6	6.1	4.4	5.3
y1, average depth, LOB, ft	ERR	ERR	ERR	ERR
y1, average depth, ROB, ft	1.0	1.8	0.9	1.4
Total conveyance, approach	11758	26386	11041	16424
Conveyance, main channel	10883	18344	10331	14186
Conveyance, LOB	0	0	0	0
Conveyance, ROB	875	8042	710	2238
Percent discrepancy, conveyance	0.0000	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1101.4	1522.5	1010.5	1502.9
Ql, discharge, LOB, cfs	0.0	0.0	0.0	0.0
Qr, discharge, ROB, cfs	88.6	667.5	69.5	237.1
Vm, mean velocity MC, ft/s	5.3	5.3	5.1	6.1
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.5	3.0	2.3	3.3
Vc-m, crit. velocity, MC, ft/s	10.4	10.9	10.3	10.6
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

Main Channel	0	0	0	0
Left Overbank	N/A	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A	N/A

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	1140	1269	1080

Main channel area (DS), ft2	109.3	172	101.9
Main channel width (normal), ft	24.9	25.7	24.8
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	24.9	25.7	24.8
D90, ft	1.6373	1.6373	1.6373
D95, ft	2.1016	2.1016	2.1016
Dc, critical grain size, ft	0.9010	0.3589	0.9666
Pc, Decimal percent coarser than Dc	0.239	0.513	0.227
Depth to armoring, ft	8.63	1.02	9.87

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 others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q	Other Q
(Q) total discharge, cfs	1190	2190	1080	1740
(Q) discharge thru bridge, cfs	1140	1269	1080	1347
Main channel conveyance	7324	10241	6594	10882
Total conveyance	7324	10241	6594	10882
Q2, bridge MC discharge,cfs	1140	1269	1080	1347
Main channel area, ft2	109	175	102	143
Main channel width (normal), ft	24.9	25.7	24.8	25.3
Cum. width of piers in MC, ft	0.0	0.0	0.0	0.0
W, adjusted width, ft	24.9	25.7	24.8	25.3
y_bridge (avg. depth at br.), ft	4.39	6.80	4.11	5.66
Dm, median (1.25*D50), ft	0.459	0.459	0.459	0.459
y2, depth in contraction,ft	4.10	4.37	3.93	4.67
ys, scour depth (y2-ybridge), ft	-0.29	-2.43	-0.18	-0.99

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 other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1190	2190	1080
Q, thru bridge MC, cfs	1140	1269	1080
Vc, critical velocity, ft/s	10.35	10.87	10.29
Va, velocity MC approach, ft/s	5.32	5.27	5.05
Main channel width (normal), ft	24.9	25.7	24.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.9	25.7	24.8
qbr, unit discharge, ft2/s	45.8	49.4	43.5
Area of full opening, ft2	109.3	174.8	101.9
Hb, depth of full opening, ft	4.39	6.80	4.11
Fr, Froude number, bridge MC	0	0.51	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	172	N/A
**Hb, depth at downstream face, ft	N/A	6.69	N/A
**Fr, Froude number at DS face	ERR	0.50	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	498.71	0
Elevation of Bed, ft	-4.39	491.91	-4.11
Elevation of Approach, ft	0	500.02	0
Friction loss, approach, ft	0	0.33	0
Elevation of WS immediately US, ft	0.00	499.69	0.00
ya, depth immediately US, ft	4.39	7.78	4.11
Mean elevation of deck, ft	0	503.32	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00

Cc, vert contrac correction (<=1.0)	1.00	0.97	1.00
**Cc, for downstream face (<=1.0)	ERR	0.963222	ERR
Ys, scour w/Chang equation, ft	N/A	-2.10	N/A
Ys, scour w/Umbrell equation, ft	N/A	-1.26	N/A

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

**Ys, scour w/Chang equation, ft	N/A	-1.97	N/A
**Ys, scour w/Umbrell equation, ft	ERR	-1.15	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	4.10	4.37	3.93
WSEL at downstream face, ft	--	498.64	--
Depth at downstream face, ft	N/A	6.69	N/A
Ys, depth of scour (Laursen), ft	N/A	-2.32	N/A

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 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	1190	2190	1080	1190	2190	1080
a', abut.length blocking flow, ft	16.3	17.6	16.1	39.4	128.6	36.8
Ae, area of blocked flow ft2	55.8	82.5	53.3	25.8	76.6	43
Qe, discharge blocked abut.,cfs	235.95	347.27	212.4	_	_	115.36
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.23	4.21	3.98	2.91	3.12	2.68
ya, depth of f/p flow, ft	3.42	4.69	3.31	0.65	0.60	1.17
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	70	70	70	110	110	110
K2	0.97	0.97	0.97	1.03	1.03	1.03
Fr, froude number f/p flow	0.403	0.343	0.386	0.462	0.402	0.437
ys, scour depth, ft	10.35	12.45	9.90	6.20	8.62	8.42

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	16.3	17.6	16.1	39.4	128.6	36.8
y1 (depth f/p flow, ft)	3.42	4.69	3.31	0.65	0.60	1.17
a'/y1	4.76	3.75	4.86	60.17	215.90	31.49
Skew correction (p. 49, fig. 16)	0.93	0.93	0.93	1.04	1.04	1.04
Froude no. f/p flow	0.40	0.34	0.39	0.46	0.40	0.44
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	3.84	3.34	6.73
vertical w/ ww's	ERR	ERR	ERR	3.15	2.73	5.52
spill-through	ERR	ERR	ERR	2.11	1.83	3.70

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.88	0.51	0.92	0.88	0.51	0.92
y, depth of flow in bridge, ft	4.39	6.68	4.11	4.39	6.68	4.11
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	1.07	ERR	ERR	1.07	ERR
Fr>0.8 (vertical abut.)	1.77	ERR	1.68	1.77	ERR	1.68
Fr<=0.8 (spillthrough abut.)	ERR	0.94	ERR	ERR	0.94	ERR
Fr>0.8 (spillthrough abut.)	1.57	ERR	1.48	1.57	ERR	1.48