LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (HARDTH00530023) on TOWN HIGHWAY 53, crossing HAYNESVILLE BROOK, HARDWICK, VERMONT

U.S. Geological Survey
Open-File Report 96-638

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

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By SCOTT A. OLSON

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Pembroke, New Hampshire

1996

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

U.S. GEOLOGICAL SURVEY
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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 23 (HARDTH00530023) ON TOWN HIGHWAY 53, CROSSING HAYNESVILLE BROOK, HARDWICK, VERMONT

By **Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure HARDTH00530023 on Town Highway 53 crossing Haynesville Brook, Hardwick, 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 New England Upland section of the New England physiographic province in north-central Vermont. The 14.2-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the predominate surface cover consists of field grasses except for the upstream left bank with is brush covered.

In the study area, Haynesville Brook has a sinuous channel with a slope of approximately 0.004 ft/ft, an average channel top width of 39 ft and an average channel depth of 2 ft. Stream-bed material at the site ranged from silt to gravel with a median grain size (D_{50}) of 49.9 mm (0.164ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 27, 1995, indicated that the reach was laterally unstable. Channel scour in both the upstream and downstream reaches as well as irregular point bars and cut banks and upstream anabranching led to this assessment.

The Town Highway 53 crossing of Haynesville Brook is a 33-ft-long, one-lane bridge consisting of one 26-foot steel-beam span (Vermont Agency of Transportation, written communication, March 24, 1994). The bridge is supported by vertical, concrete abutments with no wingwalls. The concrete may be facing over the original stone abutments. Sheet piling has been driven around the base of each abutment and is filled with concrete. The channel is skewed approximately 10 degrees to the opening; the opening-skew-to-roadway is also 10 degrees. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and 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 ranged from 0.0 to 2.0 ft. The worst-case contraction scour occurred at the 100-year discharge. Abutment scour ranged from 7.0 to 12.9 ft. 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.

Cabot, VT. Quadrangle, 1:24,000, 1986

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 HARDTH00530023 ***Stream*** Haynesville Brook

County Caledonia ***Road*** TH53 ***District*** 7

Description of Bridge

Bridge length 33 ***ft*** ***Bridge width*** 16.2 ***ft*** ***Max span length*** 26 ***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*** 7/27/95

Description of stone fill --

Brief description of piers/abutments Abutments are concrete. The concrete may be facing of a stone abutment. Sheet piling has been driven around the abutments and filled with concrete and is acting as a subfooting.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 10

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

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	7/27/95	0	0
Level II	7/27/95	0	0

Potential for debris High. The banks in the reach are unstable which may cause debris problems.

Describe any features near or at the bridge that may affect flow (include observation date) There are two breached beaver dams downstream of the structure. July 27, 1995.

Description of the Geomorphic Setting

General topography The channel is located within an upland moderate relief valley with irregular flood plains.

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

Date of inspection 7/27/95

DS left: Irregular flood plain.

DS right: Irregular flood plain.

US left: Irregular flood plain.

US right: Irregular flood plain.

Description of the Channel

Average top width 39 ft ***Average depth*** 2 ft

Predominant bed material Sand/Gravel ***Bank material*** Sand

Sinuous with alluvial channel boundaries. Some anabranching occurring upstream of the bridge.

Vegetative co 7/27/95

Grass

DS left: Grass

DS right: Brush

US left: Grass

US right: Grass

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

July 27, 1995. There is channel scour in the upstream and downstream reach as well as cut banks and point bars. There is an anabranch just upstream of the bridge and the channel, in general, varies in width.

Describe any obstructions in channel and date of observation.

July 27, 1995. There are the remains of two breached beaver dams downstream of the bridge. Several logs are lying in the upstream channel.

Hydrology

Drainage area 14.2 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/New England Upland	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 2,700 ***ft³/s*** ***Q500*** 4,100 ***ft³/s***

The 100- and 500-year discharges were selected from a range defined by several empirical methods for determining flood discharges on a stream with basin characteristics such as this one (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 of the upstream, streamward corner of the left abutment (elev. 497.35 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream, streamward corner or the right abutment (elev. 497.67 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	-29	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	42	1	Approach section

[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 0.035 to 0.040, and overbank "n" values ranged from 0.055 to 0.065.

Normal depth at the exit section (EXITX) 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 0.0041 ft/ft which determined from surveyed thalweg points.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 500.1 *ft*
Average low steel elevation 498.2 *ft*

100-year discharge 2,700 *ft³/s*
Water-surface elevation in bridge opening 498.3 *ft*
Road overtopping? Y *Discharge over road* 1,170
Area of flow in bridge opening 144 *ft²*
Average velocity in bridge opening 10.6 *ft/s*
Maximum WSPRO tube velocity at bridge 12.8 *ft/s*

Water-surface elevation at Approach section with bridge 501.5
Water-surface elevation at Approach section without bridge 498.8
Amount of backwater caused by bridge 2.7

500-year discharge 4,100 *ft³/s*
Water-surface elevation in bridge opening 498.3 *ft*
Road overtopping? Y *Discharge over road* 2,620
Area of flow in bridge opening 144 *ft²*
Average velocity in bridge opening 10.5 *ft/s*
Maximum WSPRO tube velocity at bridge 12.6

Water-surface elevation at Approach section with bridge 502.3
Water-surface elevation at Approach section without bridge 499.7
Amount of backwater caused by bridge 2.6

Incipient overtopping discharge 1,140 *ft³/s*
Water-surface elevation in bridge opening 498.3 *ft*
Area of flow in bridge opening 144 *ft²*
Average velocity in bridge opening 7.8 *ft/s*
Maximum WSPRO tube velocity at bridge 9.6 *ft/s*

Water-surface elevation at Approach section with bridge 499.7
Water-surface elevation at Approach section without bridge 497.2
Amount of backwater caused by bridge 2.5

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 was computed by use of the Chang pressure-flow scour equation (Richardson and others, 1995, p. 145-146). For each of the modelled discharges, there was orifice flow at the bridge. 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). The results of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) were also computed and can be found in appendix F.

Since less than five percent of the bed sample's distribution was coarser than the incipient motion size, armoring will not occur (U.S. Department of Transportation, 1993).

Abutment scour was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE 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	2.0	1.7	0.0
Depth to armoring	N/A	N/A	1.3
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	9.2	9.7	7.0
Right abutment	12.3	12.9	10.1
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.7	1.7	0.9
Right abutment	1.7	1.7	0.9
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

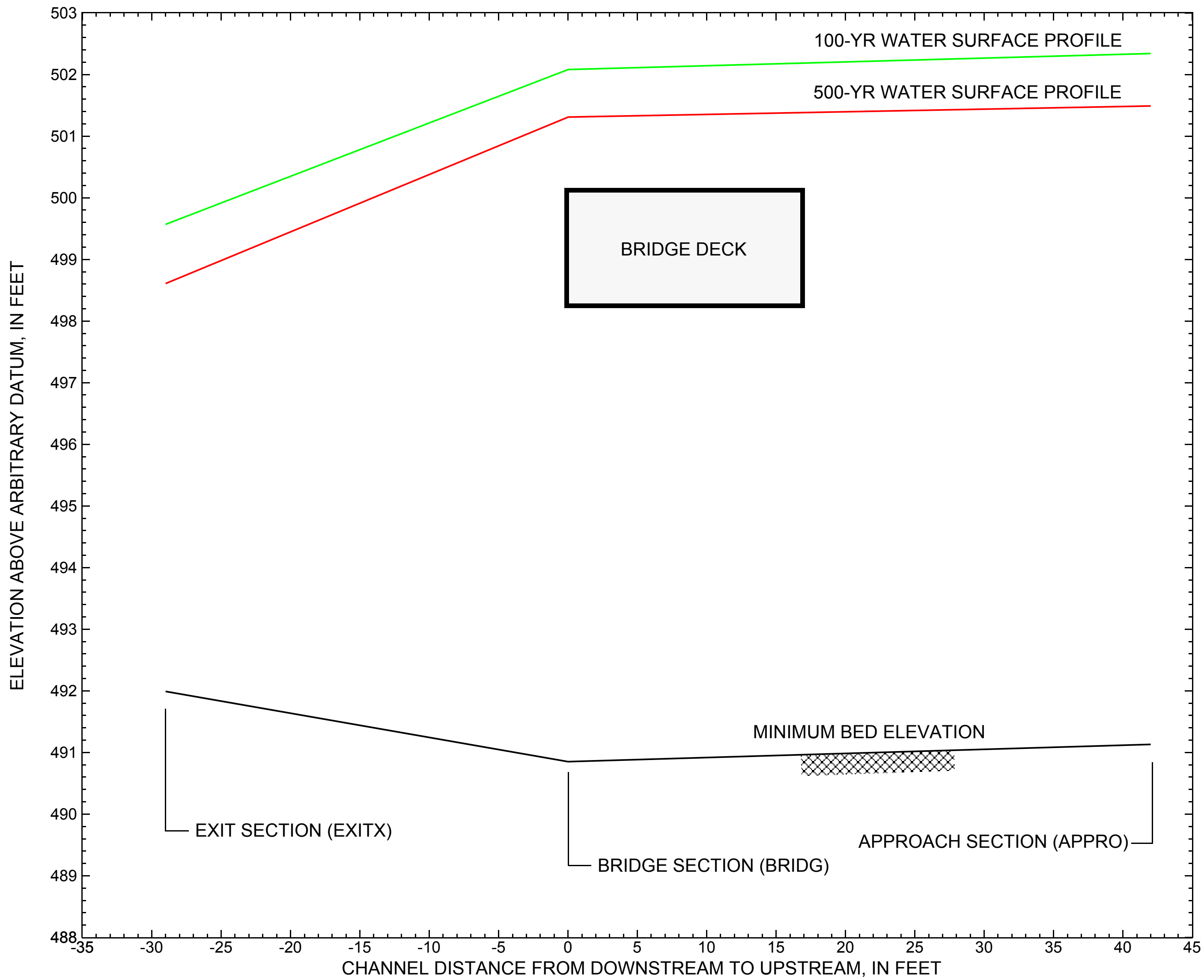

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure HARDTH00530023 on Town Highway 53, crossing Haynesville Brook, Hardwick, Vermont.

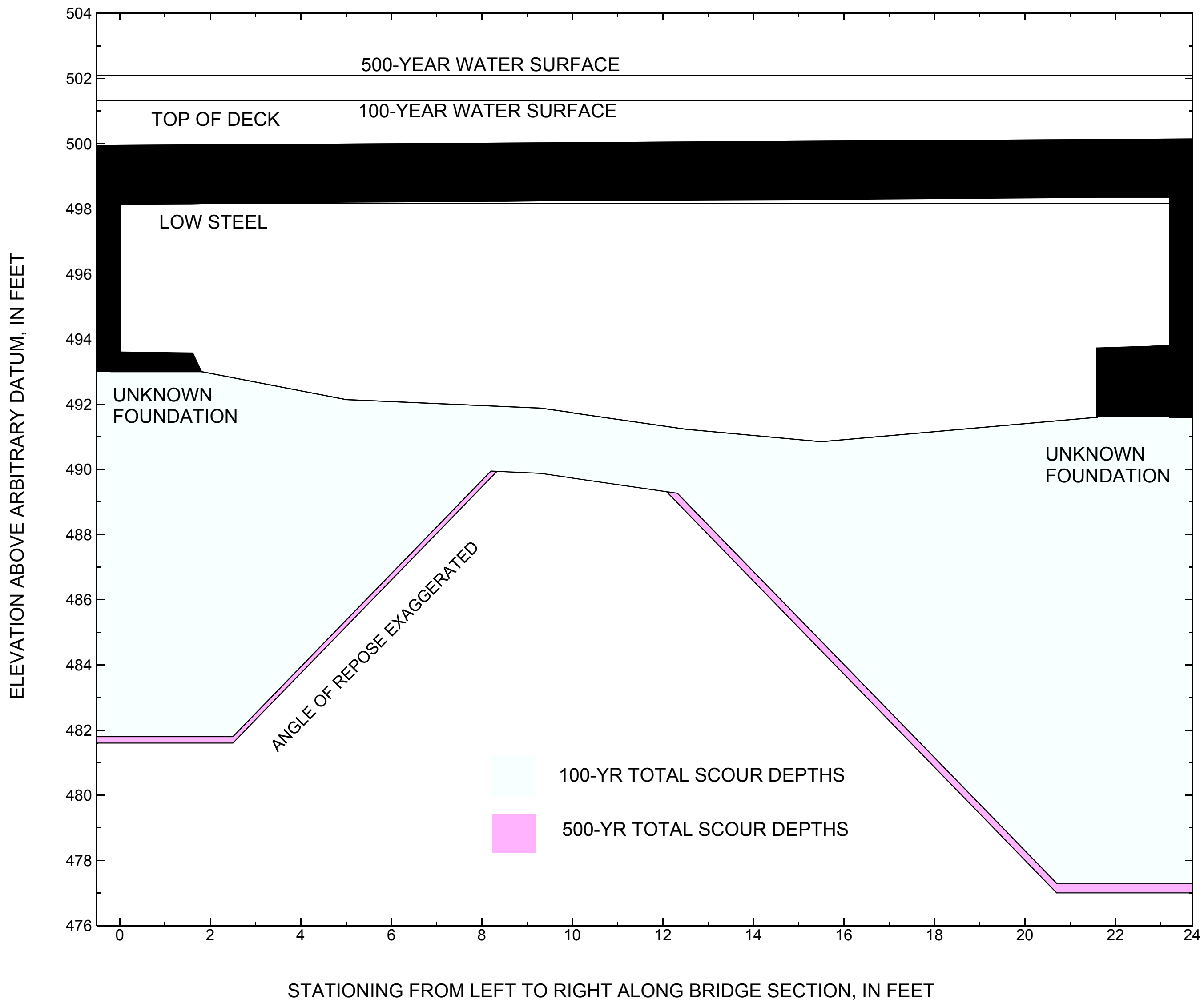

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure HARDTH00530023 on Town Highway 53, crossing Haynesville Brook, Hardwick, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure HARDTH00530023 on Town Highway 53, crossing Haynesville Brook, Hardwick, Vermont.

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

Description	Station[a]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[b] (feet)	Bottom of footing 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 2,700 cubic-feet per second											
Left abutment	0.0	--	498.14	--	493.0	2.0	9.2	--	11.2	481.8	--
Right abutment	23.2	--	498.34	--	491.6	2.0	12.3	--	14.3	477.3	--

a.Measured along the face of the most constricting side of the bridge.
b.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure HARDTH00530023 on Town Highway 53, crossing Haynesville Brook, Hardwick, Vermont.

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

Description	Station[a]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[b] (feet)	Bottom of footing 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 4,100 cubic-feet per second											
Left abutment	0.0	--	498.14	--	493.0	1.7	9.7	--	11.4	481.6	--
Right abutment	23.2	--	498.34	--	491.6	1.7	12.9	--	14.6	477.0	--

a.Measured along the face of the most constricting side of the bridge.
b.Arbitrary datum for this study.

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U.S. Geological Survey, 1986, Cabot, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1         U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard023.wsp
T2         CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00530023 USING FILE hard023.dca
T3         HYDRAULIC ANALYSIS OF HARD023     SAO
*
J3          6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2700 4100 1140
SK          0.0041 0.0041 0.0041
*
XS   EXITX    -29
GR          -179.5, 507.27   -173.7, 503.17   -143.0, 504.61   -109.4, 503.06
GR           -93.8, 498.15    -64.8, 496.78    -40.0, 495.87     -7.5, 496.16
GR            -1.9, 494.82      0.0, 492.85      4.5, 492.63     10.4, 492.26
GR            16.1, 492.20     20.9, 491.99     27.1, 492.05     30.8, 492.87
GR            41.0, 495.49     60.7, 497.23    110.8, 497.19    224.7, 503.49
GR           286.6, 507.59
N            0.055        0.040        0.055
SA                   -7.5        41.0
*
XS   FULLV    0
*
BR   BRIDG    0     498.24      10.0
GR             0.0, 498.14      0.1, 493.60      1.6, 493.56      1.8, 492.95
GR             5.0, 492.14      9.3, 491.88     12.5, 491.23     15.5, 490.85
GR            19.0, 491.29     21.6, 491.57     21.6, 493.71     23.1, 493.79
GR            23.2, 498.34      0.0, 498.14
N             0.035
CD            1 20.3
*
XR   RDWAY   10      16.2   2
GR          -148.5, 505.03   -144.4, 504.15   -138.7, 504.71   -125.0, 504.39
GR          -108.2, 503.08    -75.5, 501.23    -53.8, 500.31    -18.1, 500.02
GR            -4.0, 499.98     -3.9, 500.39     29.2, 500.53     29.2, 499.92
GR            39.5, 499.96     74.6, 499.70    109.2, 499.95    175.5, 501.49
GR           229.6, 504.40    274.1, 507.97    341.9, 510.16    364.6, 517.79
*
AS   APPRO   42
GR          -227.4, 511.48   -218.6, 509.27   -169.9, 506.49   -135.4, 504.58
GR           -93.4, 502.39    -66.6, 498.99    -32.3, 498.28    -18.2, 496.21
GR             0.0, 494.97      7.9, 492.89     11.0, 491.36     16.5, 491.80
GR            20.9, 491.13     25.2, 491.62     29.9, 492.06     32.9, 492.80
GR            35.0, 495.80     42.5, 497.73    132.4, 497.05    221.7, 503.75
N            0.065        0.039        0.055
SA                     0         42.5
*
HP 1 BRIDG  498.34 1 498.34
HP 2 BRIDG  498.34 * * 1523
HP 2 RDWAY  501.31 * * 1169
HP 1 APPRO  501.49 1 501.49
HP 2 APPRO  501.49 * * 2700
*
HP 1 BRIDG  498.34 1 498.34
HP 2 BRIDG  498.34 * * 1502
HP 2 RDWAY  502.08 * * 2619
HP 1 APPRO  502.34 1 502.34
HP 2 APPRO  502.34 * * 4100
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard023.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00530023 USING FILE hard023.dca
        HYDRAULIC ANALYSIS OF HARD023     SAO
           *** RUN DATE & TIME: 08-01-96  07:44
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     144.  11285.     0.    57.                           0.
   498.34          144.  11285.     0.    57.  1.00     0.    23.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.34     0.0    23.2   143.8  11285.    1523.  10.59
 X STA.         0.0         2.6         4.1         5.3         6.5         7.6
  A(I)             12.0         8.1         7.3         7.1         6.6
  V(I)             6.33        9.39       10.38       10.75       11.60

 X STA.         7.6         8.6         9.7        10.7        11.6        12.5
  A(I)              6.6         6.4         6.4         6.3         6.0
  V(I)            11.48       11.94       11.94       12.17       12.60

 X STA.        12.5        13.3        14.2        15.0        15.9        16.7
  A(I)              6.0         6.1         6.0         6.0         6.2
  V(I)            12.72       12.51       12.61       12.79       12.26

 X STA.        16.7        17.6        18.5        19.6        20.7        23.2
  A(I)              6.3         6.6         7.1         7.9        12.8
  V(I)            12.17       11.46       10.77        9.66        5.94

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.31   -76.9   167.8   256.6    7672.    1169.   4.56
 X STA.       -76.9       -46.5       -33.3       -22.7       -12.6        -4.7
  A(I)             19.3        14.6        12.9        12.9        10.4
  V(I)             3.02        4.00        4.54        4.52        5.62

 X STA.        -4.7         7.8        21.5        32.8        39.2        46.9
  A(I)             11.5        11.6        11.1         8.7        10.6
  V(I)             5.07        5.05        5.27        6.73        5.52

 X STA.        46.9        54.8        62.3        69.5        76.5        83.9
  A(I)             11.4        11.1        11.2        11.1        11.6
  V(I)             5.13        5.25        5.20        5.28        5.05

 X STA.        83.9        91.7       100.3       110.2       123.4       167.8
  A(I)             12.0        12.5        13.7        15.6        22.9
  V(I)             4.89        4.69        4.26        3.75        2.55

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     290.  14854.    86.    87.                        3013.
             2     354.  53370.    43.    45.                        5796.
             3     500.  30324.   149.   149.                        5196.
   501.49         1144.  98548.   278.   281.  1.86   -86.   192.   9643.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.49   -86.3   191.6  1143.7  98548.    2700.   2.36
 X STA.       -86.3       -31.5       -12.6        -0.3         4.9         8.8
  A(I)            125.3        87.7        75.2        36.9        32.5
  V(I)             1.08        1.54        1.79        3.66        4.15

 X STA.         8.8        11.9        14.7        17.7        20.6        23.4
  A(I)             29.9        28.6        28.9        29.0        28.5
  V(I)             4.52        4.73        4.67        4.66        4.74

 X STA.        23.4        26.4        29.6        33.4        45.5        65.0
  A(I)             29.7        30.7        34.6        57.7        75.3
  V(I)             4.54        4.40        3.91        2.34        1.79

 X STA.        65.0        83.3       100.8       118.7       136.4       191.6
  A(I)             73.0        72.6        76.3        77.1       114.3
  V(I)             1.85        1.86        1.77        1.75        1.18
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard023.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00530023 USING FILE hard023.dca
        HYDRAULIC ANALYSIS OF HARD023      SAO
           *** RUN DATE & TIME: 08-01-96  07:44
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     144.   11285.     0.    57.                           0.
   498.34          144.   11285.     0.    57.  1.00     0.    23.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.34     0.0    23.2   143.8   11285.    1502.  10.45
X STA.         0.0        2.6        4.1        5.3        6.5        7.6
  A(I)            12.0        8.1        7.3        7.1        6.6
  V(I)            6.24       9.26      10.24      10.61      11.44

X STA.         7.6        8.6        9.7       10.7       11.6       12.5
  A(I)             6.6        6.4        6.4        6.3        6.0
  V(I)           11.32      11.78      11.78      12.01      12.42

X STA.        12.5       13.3       14.2       15.0       15.9       16.7
  A(I)             6.0        6.1        6.0        6.0        6.2
  V(I)           12.54      12.34      12.44      12.61      12.09

X STA.        16.7       17.6       18.5       19.6       20.7       23.2
  A(I)             6.3        6.6        7.1        7.9       12.8
  V(I)           12.00      11.30      10.62       9.53       5.86

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.
         WSEL     LEW     REW    AREA        K        Q    VEL
       502.08   -90.5   186.5   458.8   18660.    2619.   5.71
X STA.       -90.5      -52.9      -39.1      -26.9      -15.7       -5.8
  A(I)            36.3       25.4       23.7       22.8       20.5
  V(I)            3.60       5.15       5.54       5.75       6.38

X STA.        -5.8        4.1       15.4       27.1       35.3       43.1
  A(I)            17.4       18.4       18.5       16.5       16.5
  V(I)            7.53       7.12       7.08       7.94       7.92

X STA.        43.1       52.8       61.9       70.7       79.4       88.6
  A(I)            21.1       20.5       20.5       20.4       21.4
  V(I)            6.20       6.39       6.38       6.41       6.13

X STA.        88.6       98.6      109.1      121.7      139.4      186.5
  A(I)            22.4       22.9       25.0       28.9       39.6
  V(I)            5.86       5.71       5.24       4.53       3.30

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     366.   20851.    93.    93.                        4120.
             2     390.   62754.    43.    45.                        6706.
             3     631.   42618.   160.   161.                        7110.
   502.34         1388.  126223.   296.   299.  1.81   -93.   203.  12688.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
         WSEL     LEW     REW    AREA        K        Q    VEL
       502.34   -93.0   202.9  1387.6  126223.    4100.   2.95
X STA.       -93.0      -38.8      -17.0       -3.4        3.8        8.2
  A(I)           145.3      105.0       91.1       54.6       39.1
  V(I)            1.41       1.95       2.25       3.76       5.24

X STA.         8.2       11.8       14.9       18.2       21.3       24.5
  A(I)            37.3       34.5       35.1       34.2       35.1
  V(I)            5.50       5.94       5.85       6.00       5.85

X STA.        24.5       27.9       31.6       39.4       56.2       73.4
  A(I)            35.9       37.9       55.6       79.6       82.1
  V(I)            5.72       5.40       3.69       2.58       2.50

X STA.        73.4       90.4      107.2      123.9      142.3      202.9
  A(I)            83.4       84.6       86.2       93.4      137.8
  V(I)            2.46       2.42       2.38       2.20       1.49
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard023.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00530023 USING FILE hard023.dca
        HYDRAULIC ANALYSIS OF HARD023     SAO
           *** RUN DATE & TIME: 08-01-96  07:44
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     144.   11285.     0.    57.                           0.
  498.34           144.   11285.     0.    57.  1.00     0.    23.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.34     0.0    23.2   143.8   11285.    1140.   7.93
X STA.         0.0        2.6        4.1        5.3        6.5        7.6
  A(I)            12.0        8.1        7.3        7.1        6.6
  V(I)            4.74       7.03       7.77       8.05       8.68

X STA.         7.6        8.6        9.7       10.7       11.6       12.5
  A(I)             6.6        6.4        6.4        6.3        6.0
  V(I)            8.59       8.94       8.94       9.11       9.43

X STA.        12.5       13.3       14.2       15.0       15.9       16.7
  A(I)             6.0        6.1        6.0        6.0        6.2
  V(I)            9.52       9.37       9.44       9.57       9.18

X STA.        16.7       17.6       18.5       19.6       20.7       23.2
  A(I)             6.3        6.6        7.1        7.9       12.8
  V(I)            9.11       8.58       8.06       7.23       4.45

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     147.    5418.    72.    72.                        1194.
             2     277.   35565.    43.    45.                        4022.
             3     253.   10971.   125.   125.                        2044.
  499.69           678.   51955.   240.   243.  2.01   -72.   168.    4567.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.69   -72.1   167.6   677.9   51955.    1140.   1.68
X STA.       -72.1      -14.0       -1.0        4.0        7.4       10.1
  A(I)            87.7       55.0       25.3       21.3       19.3
  V(I)            0.65       1.04       2.25       2.68       2.95

X STA.        10.1       12.2       14.4       16.6       18.8       20.8
  A(I)            17.9       17.4       17.6       17.5       17.1
  V(I)            3.18       3.27       3.24       3.25       3.33

X STA.        20.8       22.9       25.1       27.5       30.0       33.0
  A(I)            17.4       18.0       19.0       19.4       22.1
  V(I)            3.27       3.16       2.99       2.94       2.58

X STA.        33.0       49.7       76.9      100.5      122.9      167.6
  A(I)            46.9       57.5       54.7       55.4       71.3
  V(I)            1.22       0.99       1.04       1.03       0.80
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard023.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00530023 USING FILE hard023.dca
        HYDRAULIC ANALYSIS OF HARD023     SAO
           *** RUN DATE & TIME: 08-01-96  07:44

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

EXITX:XS   ******   -95.     573.  0.62 *****  499.23  497.94   2700.  498.61
      -29. ******   137.   42160.  1.79 ***** *******    0.71    4.71

FULLV:FV      29.   -96.     621.  0.52  0.11  499.34 *******   2700.  498.81
        0.    29.   140.   46335.  1.78  0.00    0.00    0.63    4.35
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.97     498.75     498.28

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   498.31     511.48    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   498.31     511.48     498.28

APPRO:AS      42.   -55.     463.  1.04  0.19  499.78  498.28   2700.  498.75
       42.    42.   155.   34448.  1.96  0.26    0.00    0.97    5.83
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   498.81     498.24

            <<<<<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      29.     0.     144.  1.75 *****  500.09  497.11   1523.  498.34
        0. ******    23.   11285.  1.00 ***** *******    0.75   10.60

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.24 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    26.  0.02  0.16  501.63    0.00   1169.  501.31

           Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    382.    89.   -77.    12.   1.3   1.0   5.0   4.5   1.3   3.0
   RT:    787.   155.    12.   168.   1.6   1.1   5.4   4.6   1.4   3.0

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

APPRO:AS      22.   -86.    1143.  0.16  0.11  501.65  498.28   2700.  501.49
       42.    27.   192.   98427.  1.86  0.00    0.00    0.28    2.36

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K      AREA     VEL    WSEL
   EXITX:XS     -29.   -95.   137.   2700.   42160.     573.     4.71  498.61
   FULLV:FV       0.   -96.   140.   2700.   46335.     621.     4.35  498.81
   BRIDG:BR       0.     0.    23.   1523.   11285.     144.    10.60  498.34
   RDWAY:RG      10.*******   382.   1169.******************     2.00  501.31
   APPRO:AS      42.   -86.   192.   2700.   98427.    1143.     2.36  501.49

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    497.94    0.71  491.99  507.59************  0.62  499.23  498.61
   FULLV:FV  ********    0.63  491.99  507.59  0.11  0.00  0.52  499.34  498.81
   BRIDG:BR    497.11    0.75  490.85  498.34************  1.75  500.09  498.34
   RDWAY:RG  ****************  499.70  517.79  0.02******  0.16  501.63  501.31
   APPRO:AS    498.28    0.28  491.13  511.48  0.11  0.00  0.16  501.65  501.49
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WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard023.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00530023 USING FILE hard023.dca
        HYDRAULIC ANALYSIS OF HARD023     SAO
           *** RUN DATE & TIME: 08-01-96  07:44

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

EXITX:XS   ******   -98.     806.  0.69 *****  500.27  498.76   4100.  499.57
      -29. ******   154.   64013.  1.72 ***** *******    0.66    5.08

FULLV:FV      29.   -99.     858.  0.61  0.11  500.38 *******   4100.  499.78
        0.    29.   158.   69215.  1.71  0.00    0.01    0.60    4.78
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.89     499.71     499.51

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   499.28     511.48    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   499.28     511.48     499.51

APPRO:AS      42.   -72.     680.  1.14  0.20  500.83  499.51   4100.  499.70
       42.    42.   168.   52122.  2.01  0.26   -0.01    0.89    6.03
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   499.78     498.24

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =    2619.      2404.    1.09

             <<<<<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      29.     0.     144.  1.70 *****  500.04  497.07   1502.  498.34
        0. ******    23.   11285.  1.00 ***** *******    0.74   10.45

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.24 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    26.  0.03  0.25  502.55    0.01   2619.  502.08

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    909.   103.   -91.    12.   2.1   1.6   6.5   5.7   2.0   3.1
   RT:   1711.   174.    12.   186.   2.4   1.7   6.7   5.7   2.2   3.0

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

APPRO:AS      22.   -93.    1386.  0.25  0.16  502.58  499.51   4100.  502.34
       42.    29.   203.  126089.  1.81  0.00    0.01    0.32    2.96

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -29.   -98.   154.   4100.   64013.     806.    5.08  499.57
   FULLV:FV       0.   -99.   158.   4100.   69215.     858.    4.78  499.78
   BRIDG:BR       0.     0.    23.   1502.   11285.     144.   10.45  498.34
   RDWAY:RG      10.*******   909.   2619.******************    2.00  502.08
   APPRO:AS      42.   -93.   203.   4100.  126089.    1386.    2.96  502.34

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    498.76    0.66  491.99  507.59************  0.69  500.27  499.57
   FULLV:FV  ********    0.60  491.99  507.59  0.11  0.00  0.61  500.38  499.78
   BRIDG:BR    497.07    0.74  490.85  498.34************  1.70  500.04  498.34
   RDWAY:RG  ****************  499.70  517.79  0.03******  0.25  502.55  502.08
   APPRO:AS    499.51    0.32  491.13  511.48  0.16  0.00  0.25  502.58  502.34
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WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard023.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00530023 USING FILE hard023.dca
        HYDRAULIC ANALYSIS OF HARD023     SAO
           *** RUN DATE & TIME: 08-01-96  07:44

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

EXITX:XS   ******   -68.     243.  0.47 *****  497.42  495.68   1140.  496.94
      -29. ******    57.   17792.  1.38 ***** *******    0.70    4.69

FULLV:FV      29.   -72.     266.  0.41  0.11  497.53 *******   1140.  497.13
        0.    29.    60.   19607.  1.43  0.00    0.01    0.63    4.28
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      42.   -25.     205.  0.59  0.16  497.78 *******   1140.  497.19
       42.    42.   134.   17394.  1.23  0.09   -0.01    0.70    5.55
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.29     498.42     498.53     498.24

 ===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      29.     0.     144.  0.94 *****  499.28  496.16   1120.  498.34
        0. ******    23.   11285.  1.00 ***** *******    0.55    7.79

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.454  0.000  498.24 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      22.   -72.     677.  0.09  0.05  499.78  495.66   1140.  499.69
       42.    24.   168.   51914.  2.01  0.31   -0.02    0.25    1.68

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.68

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL   WSEL
   EXITX:XS     -29.   -68.    57.   1140.   17792.     243.    4.69  496.94
   FULLV:FV       0.   -72.    60.   1140.   19607.     266.    4.28  497.13
   BRIDG:BR       0.     0.    23.   1120.   11285.     144.    7.79  498.34
   RDWAY:RG      10.**************      0.       0.*********    2.00********
   APPRO:AS      42.   -72.   168.   1140.   51914.     677.    1.68  499.69

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.68    0.70  491.99  507.59************  0.47  497.42  496.94
   FULLV:FV  ********    0.63  491.99  507.59  0.11  0.00  0.41  497.53  497.13
   BRIDG:BR    496.16    0.55  490.85  498.34************  0.94  499.28  498.34
   RDWAY:RG  ****************  499.70  517.79************  0.08  499.96********
   APPRO:AS    495.66    0.25  491.13  511.48  0.05  0.31  0.09  499.78  499.69
```
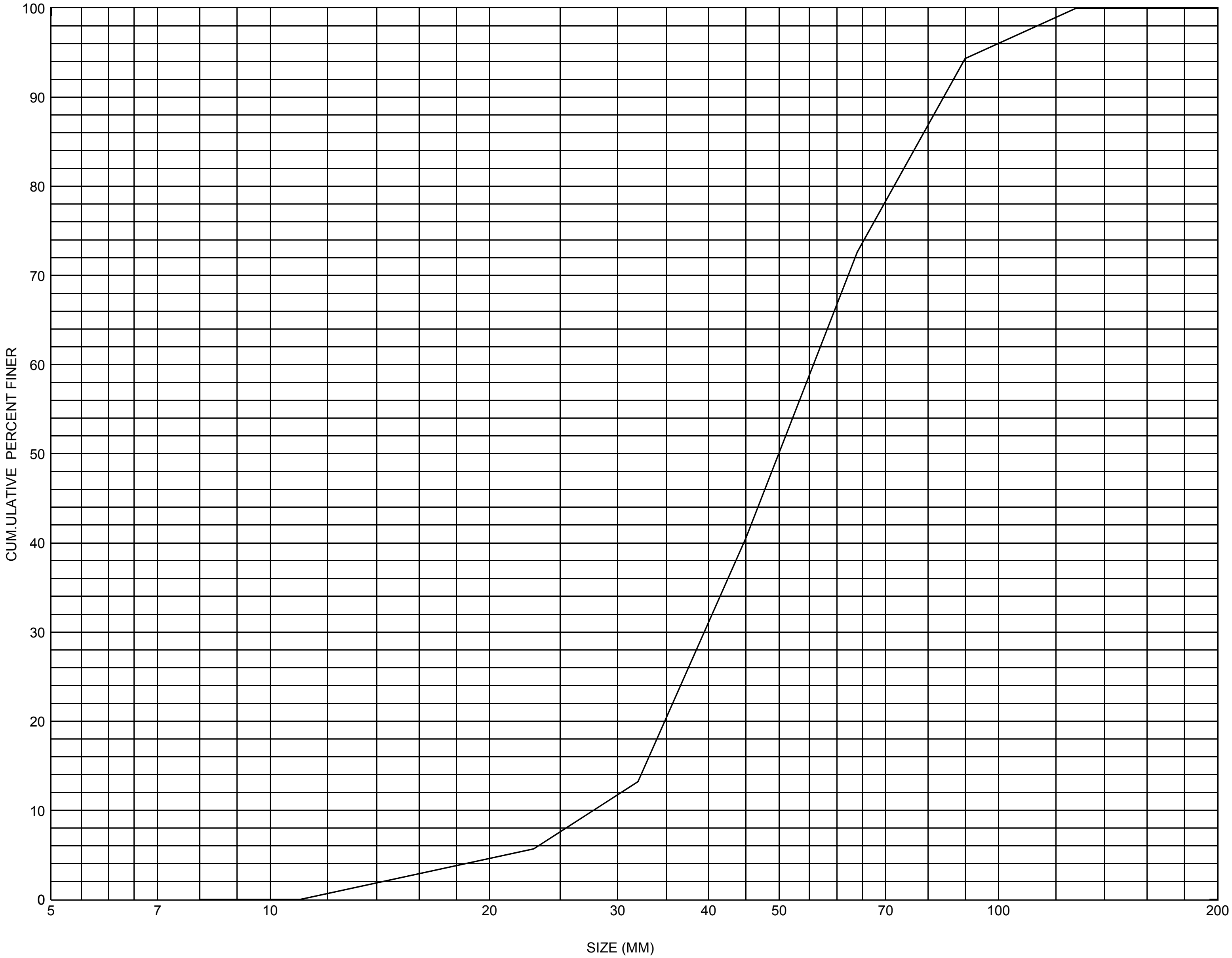

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one pebble count transect in the channel approach of structure HARDTH00530023, in Hardwick, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number HARDTH00530023

General Location Descriptive

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

Date (MM/DD/YY) 03 / 24 / 95

Highway District Number (I - 2; nn) 07

County (FIPS county code; I - 3; nnn) 005

Town (FIPS place code; I - 4; nnnnn) 31825

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

Waterway (I - 6) HAYNESVILLE BROOK

Road Name (I - 7): -

Route Number TH053

Vicinity (I - 9) AT JCT TH 53 + VT 15

Topographic Map Cabot

Hydrologic Unit Code: 02010005

Latitude (I - 16; nnnn.n) 44296

Longitude (i - 17; nnnnn.n) 72191

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10030500230305

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0026

Year built (I - 27; YYYY) 1954

Structure length (I - 49; nnnnnn) 000033

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

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

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) 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) 006.8

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

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

Comments:

The structural inspection report of 6/1/93 indicates the structure is a steel stringer type bridge with a timber deck. Abutments and wingwalls are grouted "laid up" stone blocks with some stone chinking and concrete facing. Large areas of grouting have broken or spalled out. Some of the stone chinking is also missing. An eight foot section at the downstream end of the right abutment is undermined 2-3 feet with a penetration of 3-12 inches. The greatest penetration is noted at the abutment end. A couple 2.5-3 foot deep scour holes are in the channel near the downstream end of the left and right abutments. Some erosion can be seen along the up- and downstream banks from past flooding. **(Continued, page 33)**

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area (*mi²*): -

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*): ____ *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:

Some possible settlement has been noted over the years. Minor gravel point bars are reported. There are beaver dams noted downstream. Not much stone fill protection is noted. Comments were made to repair the 8 ft. undermined section and the scour holes at both abutments in the report.
(Evidently, repairs were made before the 7/27/95 Level I assessment.)

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **14.23** mi^2 Lake and pond area **.095** mi^2

Watershed storage *(ST)* **.67** %

Bridge site elevation **961** ft Headwater elevation **2402** ft

Main channel length **6.8** mi

10% channel length elevation **1001** ft 85% channel length elevation **1933** ft

Main channel slope *(S)* **182.88** 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? N *If no, type ctrl-n xs*

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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: 04/11/96
Computerized by: EW Date: 04/15/96
Reviewd by: SAO Date: 8/21/96

Structure Number HARDTH00530023

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 07 / 27 / 1995

2. Highway District Number 07 Mile marker 0000000

County CALENDONIA Town HARDWICK 31825

Waterway *(I - 6)* HAYNESVILLE BROOK Road Name -

Route Number TH 53 Hydrologic Unit Code: 02010005

3. Descriptive comments:

AT JUNCTION BETWEEN TOWN HIGHWAY 53 AND VT 15.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 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 1 UB 1 DS 1 *(**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 33 *(feet)* Span length 26 *(feet)* Bridge width 16.2 *(feet)*

Road approach to bridge:

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

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

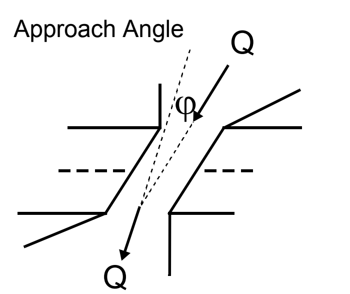
10. Embankment slope (*run / rise in feet / foot*):
US left --:1 US right --:1

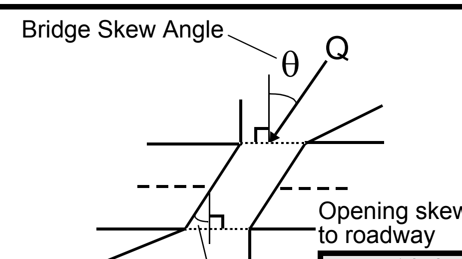
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	2	0	-
RBUS	2	2	0	-
RBDS	2	2	0	-
LBDS	2	2	0	-

*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: 10





α= 10.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 38 feet US *(US, UB, DS)* to 7 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 15 feet US *(US, UB, DS)* to 14 feet DS

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

18. Bridge Type: **1b**

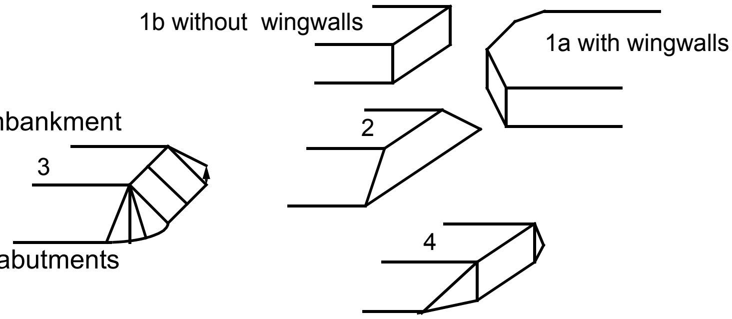
1a- Vertical abutments with wingwalls

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.)

#7: values from VTAOT; measured values: bridge length = 33 feet; bridge span = 23 feet; bridge width = 16.2 feet

#8: RB road approach is even with bridge for 30 feet, then the road rises.

#11-12: Protection is composed of granite blocks, probably of the previous abutment, slightly slumped at all four corners.

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
21.5	**2.0**			**3.0**	**1**	**2**	**23**	**23**	**1**	**1**

23. Bank width **15.0** 24. Channel width **50.0** 25. Thalweg depth **35.0** 29. Bed Material **123**

30 .Bank protection type: LB **0** RB **2** 31. Bank protection condition: LB **-** RB **2**

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.):

#26: Vegetation cover on RB is comprised of three trees within one bridge length.

#30: Right bank protection is from 10 ft. to 30 ft. US.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **92** 35. Mid-bar width: **27**

36. Point bar extent: **54** feet **US** (US, UB) to **122** feet **US** (US, UB, DS) positioned **25** %LB to **85** %RB

37. Material: **324**

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

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: **95** 42. Cut bank extent: **38** feet **US** (US, UB) to **140** 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.):

Another cut-bank present on RB from 17 feet US to 0 feet US. Bank is eroded and tree roots are exposed.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **16**

47. Scour dimensions: Length **35** Width **8** Depth : **1.75** Position **55** %LB to **85** %RB

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

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
Minor confluence on LB at 23 feet US from bridge (width = 4 feet; height = 5 feet). Currently it is dry.

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
25.5		1.5		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.):

213
#63: The bed material is gravel and sand in the middle of the channel, whereas sand and silt constitute the bed material up to five feet adjacent to both abutments.

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 3 ____ (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

A few logs and twigs in stream.

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**	**0**	**2**	**1.6**	**2.8**	**90.0**
RABUT	**1**	**10**	**90**			**0**	**2**	**23.0**

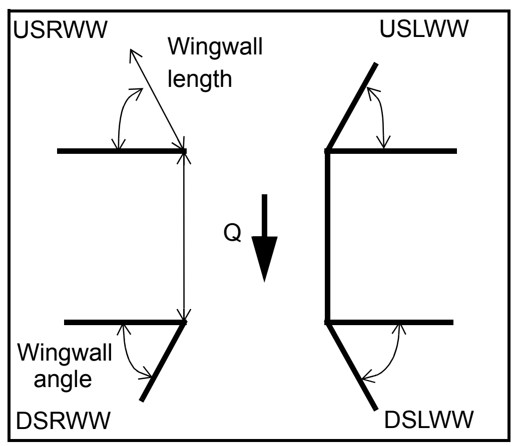
Pushed: LB or RB *Toe Location (Loc.): **0**- even, **1**- set back, **2**- protrudes*
*Scour cond.: **0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**-undermined footing; **4**- piling exposed; **5**- settled; **6**- failed*
Materials: **1**- Concrete; **2**- Stone masonry or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

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

0.9
2.1
1
#76: LABUT - maximum of 2.8 feet at DS end.
RABUT - maximum of 2.1 feet at US end.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**23.0**	
USRWW:	**N**		**-**		**-**	**1.5**	
DSLWW:	**-**		**-**		**N**	**21.0**	
DSRWW:	**-**		**-**		**-**	**19.5**	



*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	-	-	**N**	-	-	-	-	-
Condition	**N**	-	-	-	-	-	-	-
Extent	-	-	-	-	-	-	-	-

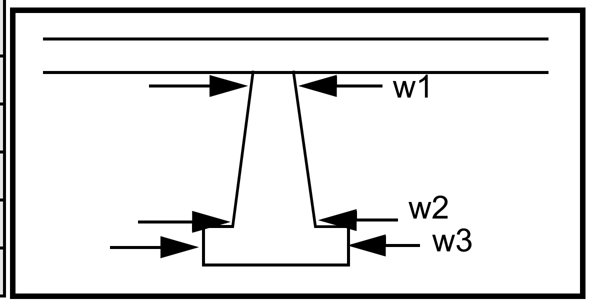
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? _____ *(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	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)		-	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		-	-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material		-	-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		-	-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		-	-	-	*Y- yes; N- no*
91. Attack ∠ (BF)		-	-	-	
92. Pushed		-	-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		-	-	-	
95. Cross-members		-	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition		-	-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**N**	-	-	-	
98. Exposure depth	-	-	-	-	

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

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
-	-			-	-	NO	PIE	RS		

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.):

1
1
213
21
1
1
231
0
2
-
******

Channel is slightly enlarged on RB from 26 feet DS to 95 feet DS, as a result of pooling and redirection of flow by breached beaver dams. The remains of the first old beaver dam is 42 feet to 51 feet downstream on the

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

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

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

bank. It blocks nearly half the channel from the right bank. The remains of a second old beaver dam (breached) exists at 95 feet DS.

****The right bank about five feet from bridge has some granite blocks placed on a cut bank. The protection is sparsely placed.**

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 **N** %LB to **-** %RB

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **76** feet **8** *(US, UB, DS)* to **64** feet **DS** *(US, UB, DS)*

Bank damage: **88** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
50
85
23

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

Scour dimensions: Length ______ Width ______ Depth: **N** Positioned **-** %LB to **-** %RB

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

-
-
-
-

Are there major confluences? **-** *(Y or if N type ctrl-n mc)* How many? **NO**

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

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

Confluence comments (eg. confluence name):

Y

F. Geomorphic Channel Assessment

107. Stage of reach evolution **4**

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)*:

18
5
0.8
25
40
An additional scour hole exists behind breached beaver dam. The scour hole is about one foot below the mean thalweg depth and is located from 49 feet DS to 75 feet DS.

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: HARDTH00530023 Town: Hardwick
Road Number: TH53 County: Caledonia
Stream: Haynesville Brook

Initials SAO Date: 6/11/96 Checked: EMB 8/16/96

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
Total discharge, cfs	2700	4100	1140
Main Channel Area, ft2	354	390	277
Left overbank area, ft2	290	366	147
Right overbank area, ft2	500	631	253
Top width main channel, ft	43	43	43
Top width L overbank, ft	86	93	72
Top width R overbank, ft	149	160	125
D50 of channel, ft	0.164	0.164	0.164
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.2	9.1	6.4
y1, average depth, LOB, ft	3.4	3.9	2.0
y1, average depth, ROB, ft	3.4	3.9	2.0
Total conveyance, approach	98548	126223	51955
Conveyance, main channel	53370	62754	35565
Conveyance, LOB	14854	20851	5418
Conveyance, ROB	30324	42618	10971
Percent discrepancy, conveyance	0.0000	0.0000	0.0019
Qm, discharge, MC, cfs	1462.2	2038.4	780.4
Ql, discharge, LOB, cfs	407.0	677.3	118.9
Qr, discharge, ROB, cfs	830.8	1384.3	240.7
Vm, mean velocity MC, ft/s	4.1	5.2	2.8
Vl, mean velocity, LOB, ft/s	1.4	1.9	0.8
Vr, mean velocity, ROB, ft/s	1.7	2.2	1.0
Vc-m, crit. velocity, MC, ft/s	8.7	8.9	8.4
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 others, 1995, p. 32, eq. 20, 20a)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	354	390	277
Main channel width, ft	43	43	43
y1, main channel depth, ft	8.23	9.07	6.44
Bridge Section			
(Q) total discharge, cfs	2700	4100	1140
(Q) discharge thru bridge, cfs	1523	1502	1140
Main channel conveyance	11285	11285	11285
Total conveyance	11285	11285	11285
Q2, bridge MC discharge,cfs	1523	1502	1140
Main channel area, ft2	144	144	144
Main channel width (skewed), ft	22.8	22.8	22.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	22.8	22.8	22.8
y_bridge (avg. depth at br.), ft	6.32	6.32	6.32
Dm, median (1.25*D50), ft	0.205	0.205	0.205
y2, depth in contraction,ft	7.13	7.05	5.57
ys, scour depth (y2-ybridge), ft	0.82	0.73	-0.75
ys, scour depth (y2-yfullv), ft	--	--	0.37
ARMORING			
D90	0.2758	0.2758	0.2758
D95	0.3077	0.3077	0.3077
Critical grain size,Dc, ft	0.3556	0.3459	0.1993
Decimal-percent coarser than Dc	N/A	N/A	0.321
Depth to armoring,ft	ERR	ERR	1.26

PRESSURE FLOW SCOUR COMPUTATION (contraction scour for orifice flow conditions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10*(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richardson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	1523	1502	1140
Vc, critical velocity, ft/s	8.7	8.9	8.4
Vc, critical velocity, m/s	2.651631	2.712588	2.560195
Main channel width (skewed), ft	22.8	22.8	22.8
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	22.8	22.8	22.8

qbr, unit discharge, ft^2/s	66.79825	65.87719	50
qbr, unit discharge, m^2/s	6.205154	6.119594	4.644699
Area of full opening, ft^2	143.8	143.8	143.8
Hb, depth of full opening, ft	6.307018	6.307018	6.307018
Hb, depth of full opening, m	1.922285	1.922285	1.922285
Fr, Froude number MC	0.75	0.74	0.55
Cf, Fr correction factor (<=1.0)	1	1	1
Elevation of Low Steel, ft	498.24	498.24	498.24
Elevation of Bed, ft	491.933	491.933	491.933
Elevation of approach WS, ft	501.49	502.34	499.69
HF, bridge to approach, ft	0.11	0.16	0.05
Elevation of WS immediately US, ft	501.38	502.18	499.64
ya, depth immediately US, ft	9.447018	10.24702	7.707018
ya, depth immediately US, m	2.93568	3.184281	2.394971
Mean elev. of deck, ft	500.46	500.46	500.46
w, depth of overflow, ft (>=0)	0.92	1.72	0
Cc, vert contrac correction (<=1.0)	0.924034	0.924034	0.950732
Ys, depth of scour (chang), ft	2.002157	1.703437	-0.04618

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	2700	4100	1140	2700	4100	1140
a', abut.length blocking flow, ft	86.7	93.4	72.5	168.4	179.7	144.4
Ae, area of blocked flow ft2	217.7	229.2	149.8	482.3	510.2	361.9
Qe, discharge blocked abut.,cfs	--	--	130	--	--	505.2
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	1.44	1.95	0.87	2.11	2.70	1.40
ya, depth of f/p flow, ft	2.51	2.45	2.07	2.86	2.84	2.51
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	80	80	80	100	100	100
K2	0.98	0.98	0.98	1.01	1.01	1.01
Fr, froude number f/p flow	0.138	0.173	0.106	0.191	0.227	0.155
ys, scour depth, ft	10.20	11.45	7.50	16.71	18.58	13.09

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)	86.7	93.4	72.5	168.4	179.7	144.4
y1 (depth f/p flow, ft)	2.51	2.45	2.07	2.86	2.84	2.51
a'/y1	34.53	38.06	35.09	58.80	63.29	57.62
Skew correction (p. 49, fig. 16)	0.97	0.97	0.97	1.02	1.02	1.02
Froude no. f/p flow	0.14	0.17	0.11	0.19	0.23	0.16
Ys w/ corr. factor K1/0.55:						
vertical	9.21	9.70	6.96	12.30	12.91	10.06
vertical w/ ww's	7.56	7.96	5.71	10.09	10.59	8.25

spill-through	5.07	5.34	3.83	6.77	7.10	5.53

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)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.75	0.74	0.55	0.75	0.74	0.55
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.00	5.00	5.00	5.00	5.00	5.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.74	1.69	0.94	1.74	1.69	0.94
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.52	1.48	0.82	1.52	1.48	0.82
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR