LEVEL II SCOUR ANALYSIS FOR BRIDGE 8 (BARTTH00020008) on TOWN HIGHWAY 2, crossing ROARING BROOK, BARTON, VERMONT

U.S. Geological Survey
Open-File Report 96-404

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

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By Erick M. Boehmler and Michael A. Ivanoff

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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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Denver, CO 80225

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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 8 (BARTTH00020008) ON TOWN HIGHWAY 2, CROSSING ROARING BROOK, BARTON, VERMONT

By Erick M. Boehmler and Michael A. Ivanoff

INTRODUCTION

This report provides the results of a detailed Level II analysis of scour potential at structure BARTTH00020008 on town highway 2 crossing Roaring Brook, Barton, 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 VTAOT files, was compiled prior to conducting Level I and Level II analyses and can be found in Appendix D.

The site is in the New England Upland section of the New England physiographic province of North-central Vermont in the town of Barton. The 9.89-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the banks have woody vegetation coverage except for the downstream left bank, which has a few trees and grass and brush coverage.

In the study area, Roaring Brook has an incised, sinuous channel with a slope of approximately 0.019 ft/ft, an average channel top width of 35 ft and an average channel depth of 3 ft. The predominant channel bed material is gravel/cobble (D_{50} is 49.1 mm or 0.161 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 18, 1994 indicated that the reach was laterally unstable. A cut-bank on the downstream right bank and overall channel configuration in the valley are indications of the lateral instability at this site.

The town highway 2 crossing of Roaring Brook is a 30-ft-long, two-lane bridge consisting of one 26-foot span concrete T-beam type superstructure (Vermont Agency of Transportation, written communication, August 4, 1994). The bridge is supported by vertical, concrete abutments. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 2.5 ft deeper than the mean thalweg depth was observed near mid-channel downstream of the bridge during the Level I assessment. The only scour protection measure at the site was type-1 stone fill (less than 12 inches diameter) on the left upstream and downstream roadway embankments. 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 aggradation or degradation; 2) contraction scour (due to reduction in flow area caused by 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 scour depths for contraction and local scour and a summary of the results follows.

Contraction scour for all modelled flows ranged from 1.4 to 2.8 feet and the worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.5 to 16.5 feet and 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.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number BARTTH00020008 ***Stream*** Roaring Brook

County Orleans ***Road*** TH 2 ***District*** 09

Description of Bridge

Bridge length 30 ***ft*** ***Bridge width*** 23.6 ***ft*** ***Max span length*** 26 ***ft***

Alignment of bridge to road (on curve or straight) On a curve

Abutment type Vertical ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 10/18/94

Description of stone fill Type-1, on the left upstream and downstream roadway embankments.

Abutments are concrete. There is a scour hole about two and a half feet deep near mid-channel downstream of the bridge.

Y

Is bridge skewed to flood flow according to There ***survey?*** ***Angle*** 15 Y

is a mild channel bend in the upstream reach followed by a moderate bend immediately downstream of the bridge.

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
	10/18/94	0	0
Level I	10/18/94	--	--
Level II			

Potential for debris High. The channel is laterally unstable and the banks have significant vegetation coverage near the channel.

Describe any features near or at the bridge that may affect flow (include observation date) Large, apparently native, boulders scattered from right side to mid-channel downstream will partially block flood flow exiting the bridge as of 10/18/94.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting configured with a steep valley wall on the USRB but moderately sloped elsewhere.

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

Date of inspection 10/18/94

DS left: Moderate bank slope to a more gradual, irregular overbank slope.

DS right: Steep bank slope to a flat overbank.

US left: Moderate bank slope to a gradual, irregular overbank slope.

US right: Moderate bank slope to steep valley wall.

Description of the Channel

Average top width 35 ***ft*** ***Average depth*** 3.0 ***ft***

Predominant bed material Gravel / Cobbles ***Bank mate...*** Gravel/Sand

Sinuous and laterally unstable with semi-alluvial channel boundaries.

10/18/94

Vegetative co... Brush with a few trees

DS left: Trees

DS right: Trees

US left: Trees

US right: N

Do banks appear stable? ***...date of observation.*** On 10/18/94 a cut-bank with slumping bank material was evident on the right bank immediately downstream of the bridge. Additionally, a land-slide type bank failure was evident on the right bank about 200 feet upstream with a co-existing point bar on the left bank side.

Describe any obstructions in channel and date of observation. The assessment of 10/18/94 noted large, apparently native, boulders on the right bank downstream, which partially block the channel at the bridge outlet. In the vicinity of these boulders, a 2.5 foot deep scour hole has developed near mid-channel.

Hydrology

Drainage area 9.89 ***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:*** 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 1,180 ***ft³/s*** ***Q500*** 1,730 ***ft³/s***

The 100-year discharge is based on a drainage area relationship [Q100 = 1400(9.9/8.9)] with bridge number 32 in Barton, for which there were flood frequency estimates available in the VTAOT database (Written communication, VTAOT, May 4, 1995), and results from several empirical relationships (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957a & b; Talbot, 1887). Each flood frequency curve was extrapolated to obtain the 500-year discharge. Because bridge 32 in Barton may be visually observed upstream from this site, the difference in the 100-year discharge is assumed to result primarily due to the change in area.

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" in a chiseled square on top of the right abutment's US end (elev. 96.84 ft., arbitrary datum). RM2 is the high point of a chiseled square on top of a boulder located about 20 feet downstream of the downstream bridge face along the right bank edge of the channel (elev. 90.71 ft., arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-42	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPR1	48	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 0.040 to 0.055, and the exit left overbank "n" value was 0.065.

Normal depth at the exit section (EXIT1) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0188 ft/ft, which was estimated from surveyed channel points at and downstream of the EXIT1 section.

The surveyed approach section (APPR1) 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.

For the 100-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. Analyzing both the supercritical and subcritical profiles, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

The 100- and 500-year discharges modeled did not result in roadway overtopping.

Bridge Hydraulics Summary

Average bridge embankment elevation 99.6 *ft*
Average low steel elevation 96.2 *ft*

100-year discharge 1,180 *ft³/s*
Water-surface elevation in bridge opening 93.1 *ft*
Road overtopping? N *Discharge over road* 0 *s*
Area of flow in bridge opening 100 *ft²*
Average velocity in bridge opening 11.9 *ft/s*
Maximum WSPRO tube velocity at bridge 14.3 *ft/s*

Water-surface elevation at Approach section with bridge 95.7
Water-surface elevation at Approach section without bridge 93.9
Amount of backwater caused by bridge 1.8 *t*

500-year discharge 1,730 *ft³/s*
Water-surface elevation in bridge opening 96.2 *ft*
Road overtopping? N *Discharge over road* 0 */s*
Area of flow in bridge opening 169 *ft²*
Average velocity in bridge opening 10.4 *ft/s*
Maximum WSPRO tube velocity at bridge 12.2 */s*

Water-surface elevation at Approach section with bridge 99.4
Water-surface elevation at Approach section without bridge 94.9
Amount of backwater caused by bridge 4.5

Incipient overtopping discharge - *ft³/s*
Water-surface elevation in bridge opening - *ft*
Area of flow in bridge opening - *ft²*
Average velocity in bridge opening - *ft/s*
Maximum WSPRO tube velocity at bridge - *ft/s*

Water-surface elevation at Approach section with bridge -
Water-surface elevation at Approach section without bridge -
Amount of backwater caused by bridge - *t*

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.

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). Therefore, contraction scour for the 500-year discharge was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). For the 100-year discharge, contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations using the Laursen's equation, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The results of Laursen's clear-water contraction scour for the 500-year event were also computed and can be found in appendix F. The depths to streambed armoring computed suggest the contraction scour will not be limited by armoring.

Abutment scour for each discharge modeled 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	1.4	2.8	--
Depth to armoring	N/A	7.5	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	8.5	11.4	--
Right abutment	12.3	16.5	--
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	1.8	2.1	--
Right abutment	1.8	2.1	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

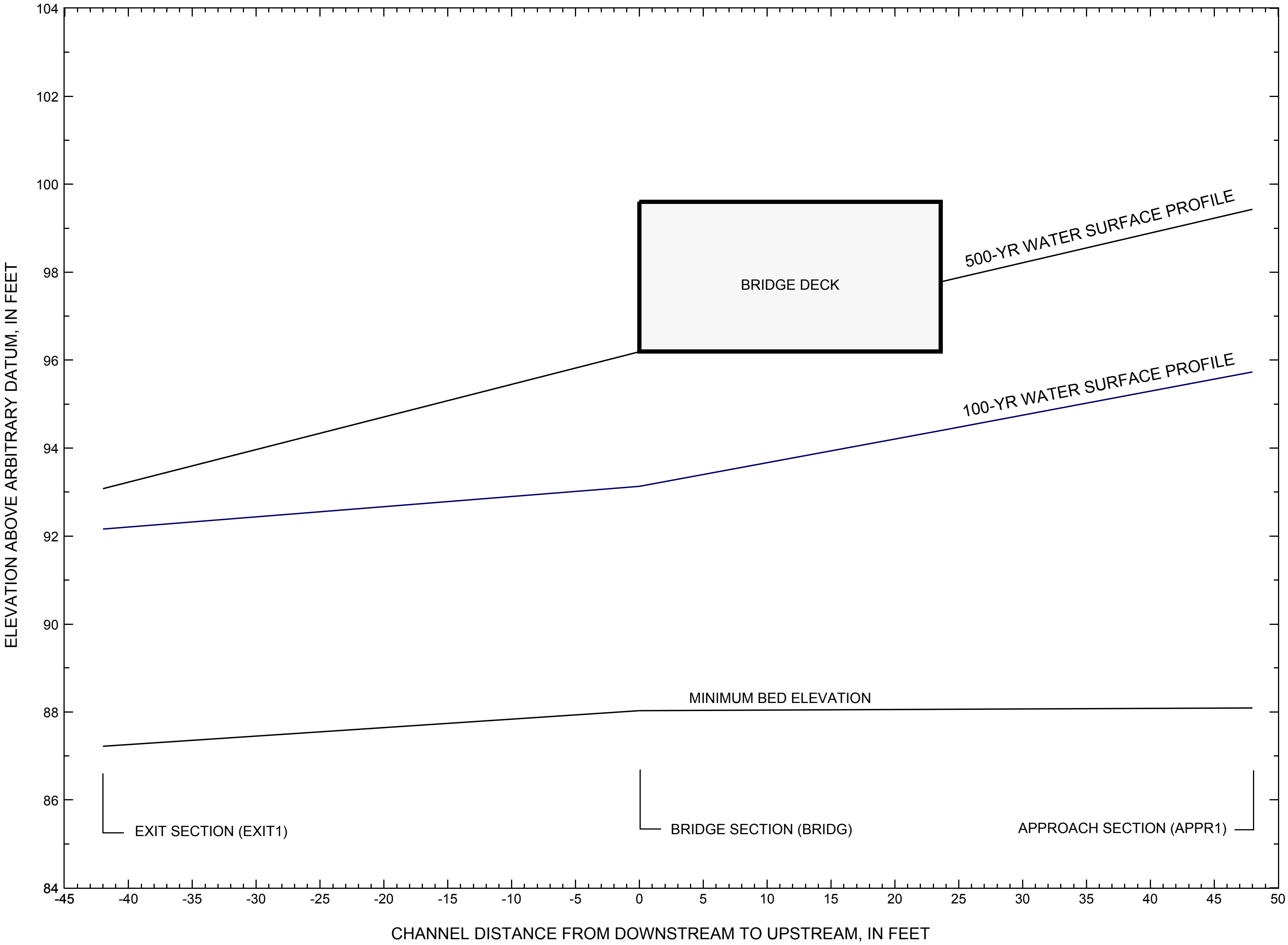

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BARTTH00020008 on town highway 2, crossing Roaring Brook, Barton, Vermont.

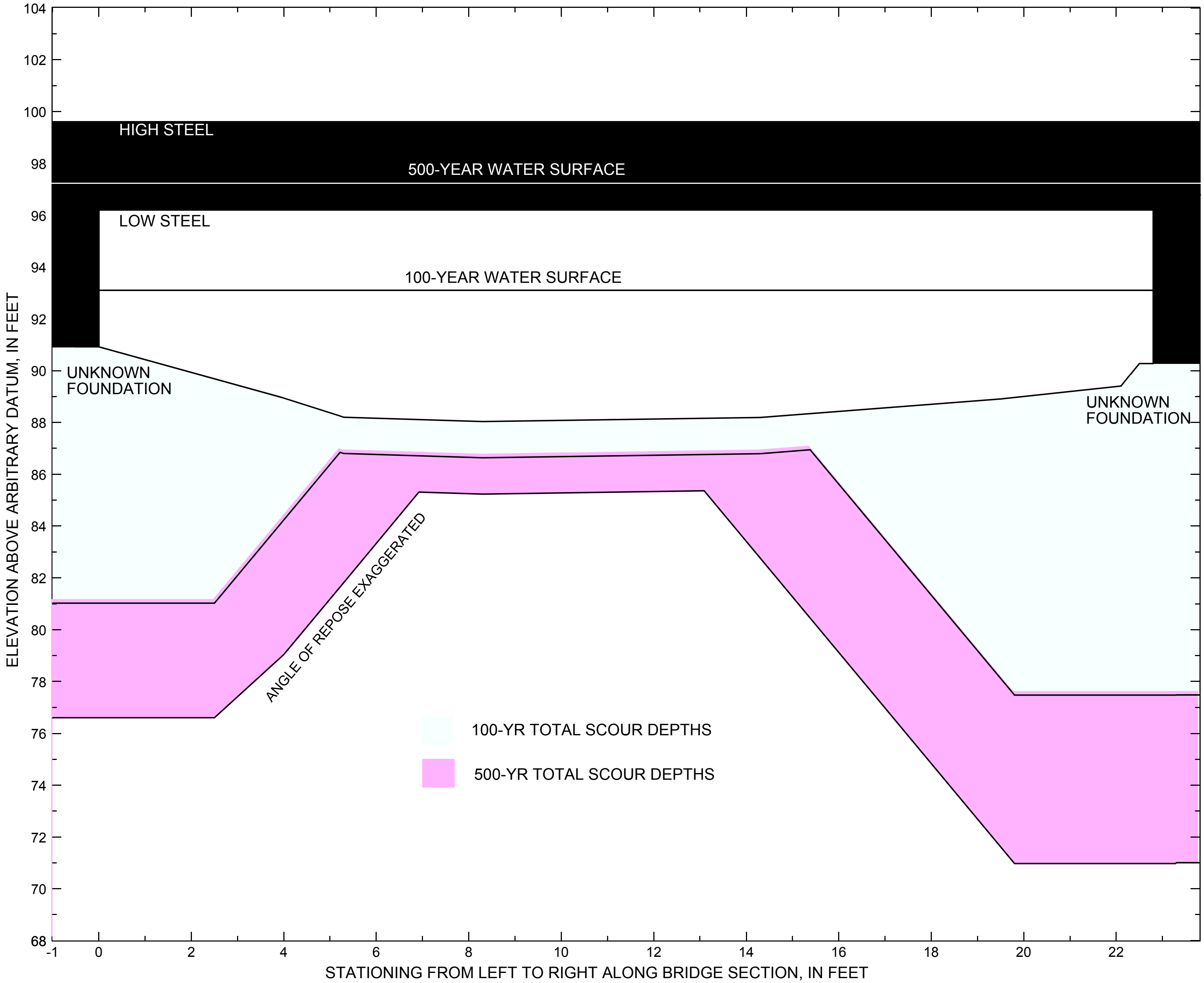

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BARTTH00020008 on town highway 2, crossing Roaring Brook, Barton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BARTTH00020008 on Town Highway 2, crossing Roaring Brook, Barton, 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 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 1,180 cubic-feet per second											
Left abutment	0.0	--	96.2	--	90.9	1.4	8.5	--	9.9	81.0	--
Right abutment	22.8	--	96.2	--	90.3	1.4	12.3	--	13.7	76.6	--

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 BARTTH00020008 on Town Highway 2, crossing Roaring Brook, Barton, 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 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 1,730 cubic-feet per second											
Left abutment	0.0	--	96.2	--	90.9	2.8	11.4	--	14.2	76.7	--
Right abutment	22.8	--	96.2	--	90.3	2.8	16.5	--	19.3	71.0	--

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. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1986, Crystal Lake, Vermont 7.5 Minute Series quadrangle map, Provisional edition: U.S. Geological Survey Topographic Maps, aerial photography, 1980, contour interval, 6 meters, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File bart008.wsp
T2        Hydraulic analysis for structure BARTTH00200008   Date: 12-MAR-96
T3        Town Highway 20 Bridge Crossing Roaring Brook, Barton, VT          EMB
Q           1180.0,  1730.0
SK           0.0188,  0.0188
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXIT1    -42
GR          -43.3,  99.63    -23.6,  90.77     -4.1,  90.12      0.0,  88.28
GR            1.4,  87.79      5.6,  87.93     11.2,  87.22     17.9,  87.31
GR           20.6,  88.34     23.3,  89.83     26.5,  97.79     35.4,  99.11
*
N            0.065         0.055
SA                   -4.1
*
XS   FULLV      0  * * *   0.0123
*
*              SRD     LSEL    XSSKEW
BR   BRIDG     0     96.19       0.0
GR            0.0,  96.19      0.0,  90.92      4.0,  88.94      5.3,  88.20
GR            8.3,  88.03     14.3,  88.19     19.5,  88.90     22.1,  89.40
GR           22.5,  90.27     22.5,  90.39     22.8,  96.18      0.0,  96.19
*
*         BRTYPE  BRWDTH
CD           1      24.3
N           0.040
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     12       23.6     1
GR         -271.5, 105.01   -193.0, 102.80   -126.1, 101.45    -86.4, 100.87
GR          -32.0, 100.12     -0.6,  99.75     -0.6, 103.32      0.0, 103.30
GR            0.0, 102.59      1.9, 102.53     26.3, 102.44     35.5, 102.41
GR           35.6, 103.23     38.0, 103.22     38.0,  99.51     63.8, 100.42
GR          138.2, 100.75    138.2, 105.00
BP          1.8
*
AS   APPR1     48           0.
GR          -55.3, 100.47    -32.9,  98.31    -13.7,  95.22     -4.8,  92.35
GR            0.0,  89.04      4.1,  88.14      9.3,  88.09     14.9,  88.24
GR           18.6,  88.36     21.1,  88.95     34.0,  92.03     47.1,  94.90
GR           71.8, 104.83
*
N           0.055
*
HP 1 BRIDG    93.13 1  93.13
HP 2 BRIDG    93.13 * * 1180
HP 1 APPR1    95.73 1  95.73
HP 2 APPR1    95.73 * * 1180
*
HP 1 BRIDG    96.19 1  96.19
HP 2 BRIDG    96.19 * * 1730
HP 1 APPR1    99.43 1  99.43
HP 2 APPR1    99.43 * * 1730
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      100      8466     23     29                         1185
   93.13            100      8466     23     29  1.00      0     23     1185

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

         WSEL     LEW     REW    AREA        K        Q    VEL
        93.13     0.0    22.6    99.6    8466.    1180.  11.85

X STA.        0.0        2.9        4.4        5.5        6.4        7.3
  A(I)            8.7        5.9        5.2        4.6        4.4
  V(I)           6.81      10.03      11.38      12.82      13.37

X STA.        7.3        8.1        9.0        9.8       10.6       11.4
  A(I)            4.2        4.2        4.2        4.1        4.1
  V(I)          13.90      14.11      14.06      14.28      14.34

X STA.       11.4       12.3       13.1       13.9       14.8       15.7
  A(I)            4.2        4.1        4.2        4.3        4.3
  V(I)          14.18      14.25      14.14      13.79      13.61

X STA.       15.7       16.7       17.7       18.9       20.2       22.6
  A(I)            4.6        4.7        5.1        5.5        9.0
  V(I)          12.78      12.58      11.53      10.77       6.56

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      48.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      297     21360     66     69                         3571
   95.73            297     21360     66     69  1.00    -16     49     3571

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      48.

         WSEL     LEW     REW    AREA        K        Q    VEL
        95.73   -16.9    49.2   296.8   21360.    1180.   3.98

X STA.      -16.9       -2.5        0.5        2.6        4.3        6.0
  A(I)           27.7       18.3       14.5       13.0       12.9
  V(I)           2.13       3.23       4.06       4.54       4.59

X STA.        6.0        7.6        9.1       10.7       12.2       13.8
  A(I)           11.9       11.7       11.8       11.6       11.6
  V(I)           4.94       5.03       4.99       5.08       5.11

X STA.       13.8       15.3       16.9       18.5       20.2       22.1
  A(I)           11.5       11.8       12.1       12.3       12.8
  V(I)           5.14       5.01       4.89       4.78       4.61
X STA.       22.1       24.3       26.9       30.2       34.8       49.2
  A(I)           14.0       14.6       16.4       18.7       27.7
  V(I)           4.21       4.03       3.61       3.16       2.13
```

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

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      169     12872     0     58                            0
   96.19           169     12872     0     58  1.00      0     23        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
       96.19     0.0    22.8   169.0   12872.    1730.  10.24

X STA.         0.0         2.4         3.8         5.0         6.0         6.9
  A(I)             14.4         9.5         8.8         7.9         7.4
  V(I)             6.01        9.06        9.78       10.89       11.62

X STA.         6.9         7.9         8.8         9.6        10.5        11.4
  A(I)              7.3         7.3         7.2         7.1         7.1
  V(I)            11.80       11.79       11.96       12.14       12.17

X STA.        11.4        12.3        13.2        14.1        15.0        16.0
  A(I)              7.2         7.2         7.2         7.3         7.5
  V(I)            12.04       12.08       11.97       11.90       11.48

X STA.        16.0        17.0        18.0        19.2        20.5        22.8
  A(I)              7.7         8.0         8.5         9.5        14.6
  V(I)            11.25       10.80       10.13        9.13        5.92

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      48.

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      603     51977   103    106                         8290
   99.43           603     51977   103    106  1.00    -44     58     8290

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      48.

        WSEL     LEW     REW    AREA        K        Q    VEL
       99.43   -44.5    58.4   603.3   51977.    1730.   2.87

X STA.       -44.5       -11.8        -4.6        -0.5         2.3         4.7
  A(I)             66.4        43.2        35.0        30.2        26.7
  V(I)             1.30        2.00        2.47        2.87        3.24

X STA.         4.7         7.0         9.1        11.2        13.3        15.4
  A(I)             25.4        24.5        23.7        23.3        23.2
  V(I)             3.41        3.53        3.65        3.71        3.73

X STA.        15.4        17.4        19.4        21.6        24.0        26.6
  A(I)             22.6        22.4        23.3        23.7        25.0
  V(I)             3.83        3.86        3.71        3.65        3.46

X STA.        26.6        29.5        32.9        37.1        42.6        58.4
  A(I)             25.3        27.6        29.8        33.9        48.2
  V(I)             3.42        3.13        2.90        2.55        1.79

  EX
```

```
+++ BEGINNING PROFILE CALCULATIONS --   2

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

EXIT1:XS   ******    -26      151  1.12 *****   93.27   91.88    1180   92.16
       -41 ******     24     8605  1.18 ***** *******    0.87    7.82

FULLV:FV       42    -27      172  0.86  0.66   93.93 *******    1180   93.07
         0     42     24    10267  1.17  0.00    0.00    0.72    6.88
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       48     -8      187  0.62  0.56   94.48 *******    1180   93.86
        48     48     42    11605  1.00  0.00   -0.01    0.59    6.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                    SECID "BRIDG"     Q,CRWS =    1180.      93.13

            <<<<<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       42      0      100  2.19 *****   95.31   93.13    1180   93.13
         0     42     23     8454  1.00 ***** *******    1.00   11.86

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******   96.19 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS       24    -16      297  0.25  0.19   95.98   92.44    1180   95.73
        48     25     49    21357  1.00  0.47    0.00    0.33    3.98

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.563  0.210   16859.     1.    24.    95.65

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -42.   -27.    24.   1180.    8605.     151.    7.82   92.16
   FULLV:FV       0.   -28.    24.   1180.   10267.     172.    6.88   93.07
   BRIDG:BR       0.     0.    23.   1180.    8454.     100.   11.86   93.13
   RDWAY:RG      12.**************      0.******************    1.00********
   APPR1:AS      48.   -17.    49.   1180.   21357.     297.    3.98   95.73

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       1.    24.   16859.
```

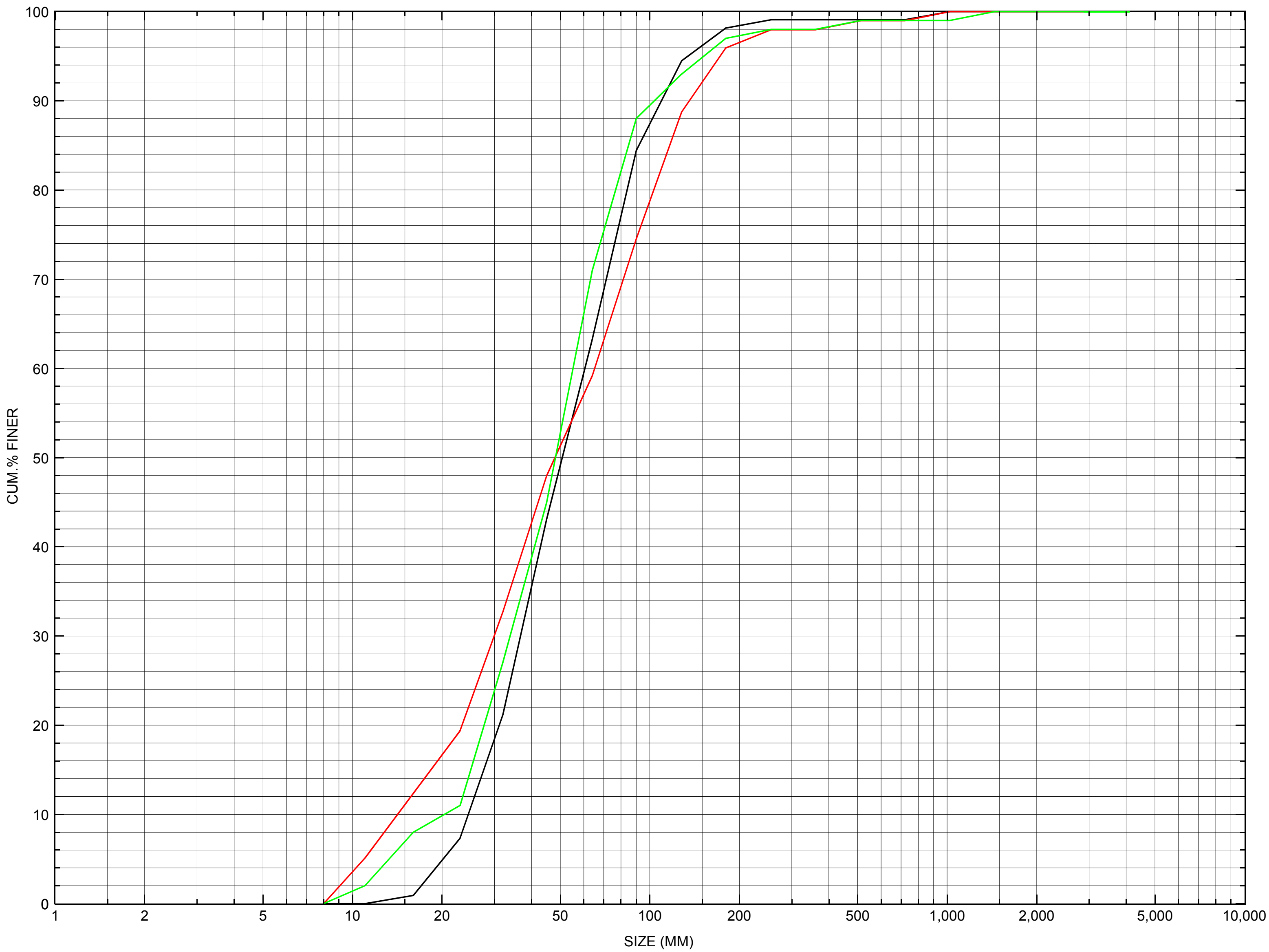
WSPRO OUTPUT FILE (continued)

```
 SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
  EXIT1:XS     91.88    0.87   87.22   99.63************  1.12    93.27   92.16
  FULLV:FV  ********    0.72   87.74  100.15  0.66  0.00  0.86    93.93   93.07
  BRIDG:BR     93.13    1.00   88.03   96.19************  2.19    95.31   93.13
  RDWAY:RG  ****************   99.51  105.01**********************************
  APPR1:AS     92.44    0.33   88.09  104.83  0.19  0.47  0.25    95.98   95.73

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

EXIT1:XS   ******    -28      199  1.36 *****   94.44   92.72    1730   93.08
       -41 ******     25    12614  1.16 ***** *******    0.85    8.70

FULLV:FV       42    -29      222  1.08  0.67   95.11 *******    1730   94.03
         0     42     25    14766  1.15  0.00    0.00    0.73    7.78
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       48    -12      245  0.77  0.59   95.68 *******    1730   94.91
        48     48     47    16591  1.00  0.00   -0.02    0.61    7.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =    94.40      97.47      97.64      96.19

 ===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       42      0      169  1.68 *****   97.87   94.46    1757   96.19
         0 ******     23    12872  1.00 ***** *******    0.67   10.39

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.491 ******   96.19 ****** ****** ******

   XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
  RDWAY:RG      12.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS       24    -44      603  0.13  0.11   99.56   93.43    1730   99.43
        48     25     58    51977  1.00  0.49    0.02    0.21    2.87

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******    99.40

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

  FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
  EXIT1:XS     -42.   -29.    25.   1730.   12614.     199.    8.70   93.08
  FULLV:FV       0.   -30.    25.   1730.   14766.     222.    7.78   94.03
  BRIDG:BR       0.     0.    23.   1757.   12872.     169.   10.39   96.19
  RDWAY:RG      12.**************      0.*****************    1.00********
  APPR1:AS      48.   -45.    58.   1730.   51977.     603.    2.87   99.43
```

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

SECOND USER DEFINED TABLE.

  XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
  EXIT1:XS    92.72    0.85   87.22   99.63************ 1.36   94.44   93.08
  FULLV:FV  ********   0.73   87.74  100.15  0.67  0.00 1.08   95.11   94.03
  BRIDG:BR    94.46    0.67   88.03   96.19************ 1.68   97.87   96.19
  RDWAY:RG  ****************  99.51  105.01************ 0.09  100.58********
  APPR1:AS    93.43    0.21   88.09  104.83  0.11  0.49 0.13   99.56   99.43
 ER

NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure BARTTH00020008, in Barton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BARTTH00020008

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. WEBER

Date *(MM/DD/YY)* 08 / 04 / 94

Highway District Number *(I - 2; nn)* 09

County *(FIPS county code; I - 3; nnn)* 019

Town *(FIPS place code; I - 4; nnnnn)* 03550

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

Waterway *(I - 6)* Roaring Brook

Road Name *(I - 7)*: Roaring Brook Road

Route Number TH002

Vicinity *(I - 9)* 0.05 MI TO JCT W C3 TH43

Topographic Map Crystal.Lake

Hydrologic Unit Code: 01110000

Latitude *(I - 16; nnnn.n)* 44443

Longitude *(i - 17; nnnnn.n)* 72128

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10100200081002

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

Maximum span length *(I - 48; nnnn)* 0026

Year built *(I - 27; YYYY)* 1928

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000730

Deck Width *(I - 52; nn.n)* 236

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 104

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*) 007.0

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

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

Comments:

Structural inspection report of 7/18/92 indicates settlement on the left abutment. The fascia T-beams have heavy section loss and exposed rebar spalling. Extensive spalling at the bottom left abutment with large aggregate exposed. Moderate channel turn upstream then sharp turn downstream with bank erosion. The bridge is in fair to poor condition. Photos with bridge record show large scour holes at unspecified wing walls above the ambient water surface. Also the photos show rail damage.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area (mi^2): 9.92

Terrain character: -

Stream character & type: -

Streambed material: Stones and gravel and random 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*): HEAVY

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 9.89 mi^2 Lake and pond area 0.47 mi^2
Watershed storage *(ST)* 4.8 %
Bridge site elevation 1147 ft Headwater elevation 2028 ft
Main channel length 6.01 mi
10% channel length elevation 1220 ft 85% channel length elevation 1750 ft
Main channel slope *(S)* 117.9 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: 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:

-

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 AVAILABLE.**

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: -

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: **EMB** Date: **2/9/95**
Computerized by: **MAI** Date: **3/17/95**
Reviewd by: **EMB** Date: **4/25/96**

Structure Number **BARTTH00020008**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **10** / **18** / 19**94**

2. Highway District Number **09** Mile marker **0**

County **Orleans (019)** Town **Barton (03550)**

Waterway *(I - 6)* **Roaring Brook** Road Name **Roaring Brook Road**

Route Number **TH002** Hydrologic Unit Code: **01110000**

3. Descriptive comments:

Located 0.005 miles from the junction of TH 2 and TH 43 and 1.5 miles west of the intersection of TH 2 and VT 16.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **5** 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 **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 **30** *(feet)* Span length **26** *(feet)* Bridge width **23.6** *(feet)*

Road approach to bridge:

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

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

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

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

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

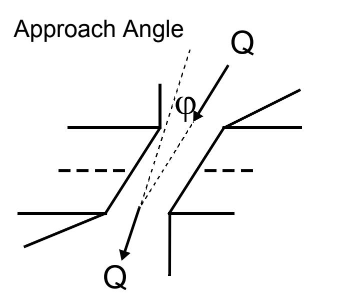
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

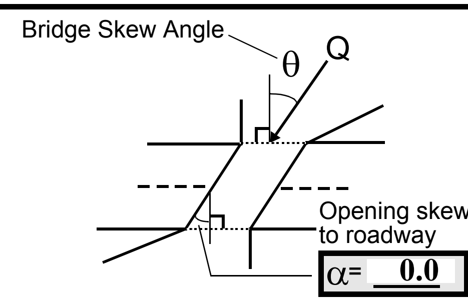
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

Channel approach to bridge (BF):

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





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **0**
Range? **30** feet **DS** *(US, UB, DS)* to **60** feet **DS**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **0** feet **US** *(US, UB, DS)* to **15** feet **UB**

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

18. Level II Bridge Type: **1b**

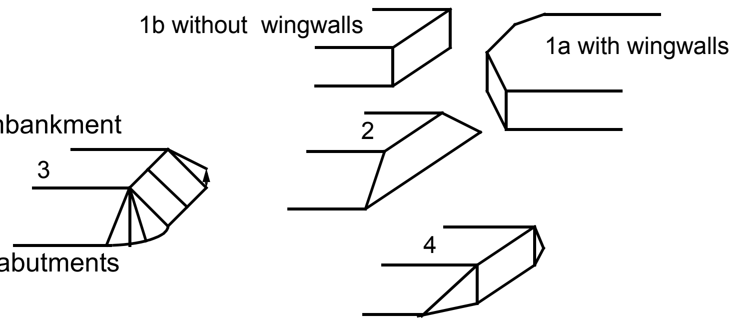
1a- Vertical abutments with wingwalls

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.)

Surface coverage on the right bank downstream is trees along banks (conifers) with a house and paved driveway 30 ft. from the channel. The measured bridge length was 30 feet, span length was 25 feet, and deck width was 23 ft. A road wash eroded gully is developing under the corner of the railing through holes in pavement and washing away material behind the downstream end of the right abutment.

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
23.5	3.5			3.0	4	4	325	325	0	0

23. Bank width **35.0** 24. Channel width **15.0** 25. Thalweg depth **39.0** 29. Bed Material **345**

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

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

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

Bank material is gravel mixed with sand and some boulders along the right and left banks while the bed material is gravel with cobbles and some boulders.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 200 35. Mid-bar width: 50

36. Point bar extent: 150 feet US (US, UB) to 250 feet US (US, UB, DS) positioned 0 %LB to 60 %RB

37. Material: 423

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

This point bar is well developed but also is far away from influencing flow near the bridge. The predominant bar materials are gravel and sand with some cobbles.

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

41. Mid-bank distance: 200 42. Cut bank extent: 150 feet US (US, UB) to 240 feet US (US, UB, DS)

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

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

Cut bank is located along a power line right of way which has been cleared of large vegetation (trees).

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 200

47. Scour dimensions: Length 40 Width 8 Depth : 1.5 Position 10 %LB to 70 %RB

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

Local scouring process due to a sharp channel bend within the cut bank zone.

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
21.0		1.0		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.):

345

Bed material is gravel with cobbles and some boulders.

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

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

1

Moderate accumulation of debris near the bridge. Trees are on the banks and the channel through the upstream reach, which is locally unstable laterally and meandering. Historical form notes heavy debris accumulation. Debris capture is moderate due to high channel gradient and the span length only 64% of the upstream bank width.

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		**-**	**85**	**2**	**2**	**0**	**1**	**90.0**
RABUT	**1**	**15**	**85**			**2**	**2**	**23.5**

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.):

0

1.5

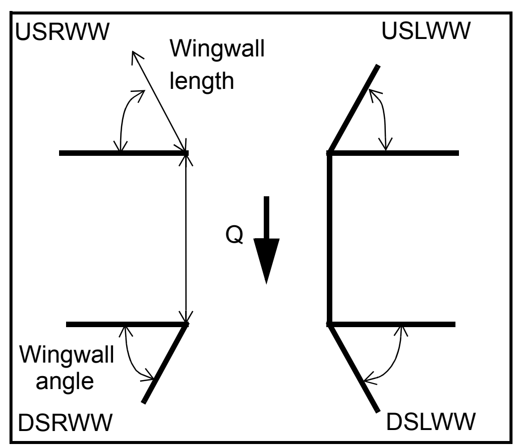
1

The right abutment has a sub-footing in front of the "original" footing with the entire height and length of the "original" footing exposed. The top of the sub-footing is exposed at the streambed elevation along the upstream half of the right abutment wall. Scour under the bridge is due to constriction of flow through the opening. The scour holes indicated in the structural inspection report (VTAOT, 7/18/92) were not observed at the time of this assessment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**23.5**	
USRWW:	**N**		**-**		**-**	**1.0**	
DSLWW:	**-**		**-**		**N**	**24.0**	
DSRWW:	**-**		**-**		**-**	**24.5**	

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	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

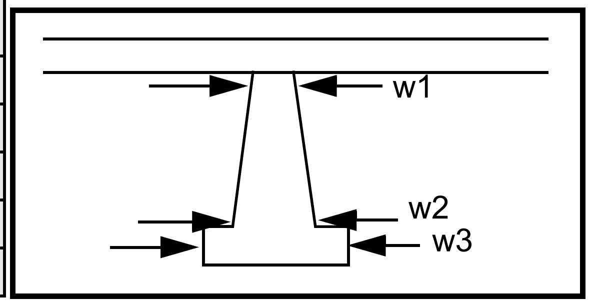
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? An (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)	addi-	ream	the	d on	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	tiona	right	sketc	the	1- Solid pier, 2- column, 3- bent
88. Material	l	appr	h on	right	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	wall	oach	the	bank	1- Round; 2- Square; 3- Pointed
90. Inclined?	and	to	field	dow	Y- yes; N- no
91. Attack ∠ (BF)	rail-	the	form	nstre	
92. Pushed	ing	brid	).	am	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	were	ge	Boul	to	
95. Cross-members	adde	(see	ders	pro-	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	d to	phot	have	tect	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	the	o #6	been	the	
98. Exposure depth	upst	and	place	bank	

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

and private drive above.

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: 2______

Scour dimensions: Length 2_____ Width 235____ Depth: 125__ Positioned 0___ %LB to 3___ %RB

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

345
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 is____ *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

mostly sands with gravel and some boulders while that of the right bank is silt/ clay, as revealed at the impact zone/cut bank, with sand and some boulders. The bed material is gravel with cobbles and some boulders.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

1- *Constructed*
2- *Stable*
3- *Aggraded*
4- *Degraded*
5- *Laterally unstable*
6- *Vertically and laterally unstable*

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

N

-

109. G. Plan View Sketch

N

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: BARTTH00020008 Town: BARTON
Road Number: TH 2 County: ORLEANS
Stream: ROARING BROOK

Initials EMB Date: 4/12/96 Checked: SAO Date: 4/15/96

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	1180	1730	0
Main Channel Area, ft2	296.8	603.3	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	66.1	102.9	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.161	0.161	0.161
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	4.5	5.9	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	21360	51977	0
Conveyance, main channel	21360	51977	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0	0	ERR
Qm, discharge, MC, cfs	1180	1730	ERR
Ql, discharge, LOB, cfs	0	0	ERR
Qr, discharge, ROB, cfs	0	0	ERR
Vm, mean velocity MC, ft/s	4.0	2.9	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	7.8	8.2	N/A
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	N/A	N/A

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	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	296.8	603.3	0
Main channel width, ft	66.1	102.9	0
y1, main channel depth, ft	4.490166	5.862974	ERR

Bridge Section			
(Q) total discharge, cfs	1180	1730	0
(Q) discharge thru bridge, cfs	1180	1730	
Main channel conveyance	8466	12872	
Total conveyance	8466	12872	
Q2, bridge MC discharge,cfs	1180	1730	ERR
Main channel area, ft2	100	169	0
Main channel width (skewed), ft	22.6	22.8	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	22.6	22.8	0
y_bridge (avg. depth at br.), ft	4.40708	7.412281	ERR
Dm, median (1.25*D50), ft	0.20125	0.20125	0.20125
y2, depth in contraction,ft	5.806414	7.999347	ERR
ys, scour depth (y2-ybridge), ft	1.40	0.59	N/A
ys, scour depth (y2-y1), ft	1.32	2.14	N/A
ys, scour depth (y2-yfullv), ft		2.75	

ARMORING			
D90	0.388	0.388	
D95	0.511	0.511	
Critical grain size,Dc, ft	0.582005	0.355658	ERR
Decimal-percent coarser than Dc	N/A	0.124	
Depth to armoring,ft	N/A	7.537653	ERR

Pressure Flow Scour (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	0	1730	0
Vc, critical velocity, ft/s	0	8.2	0
Vc, critical velocity, m/s	0	2.499238	0
Main channel width (skewed), ft	0	22.8	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	0	22.8	0
qbr, unit discharge, ft^2/s	ERR	75.87719	ERR
qbr, unit discharge, m^2/s	N/A	7.048534	N/A
Area of full opening, ft^2	0	169	0
Hb, depth of full opening, ft	ERR	7.412281	ERR
Hb, depth of full opening, m	N/A	2.259153	N/A
Fr, Froude number MC	1	0.67	1
Cf, Fr correction factor (<=1.0)	1.5	1	1.5
Elevation of Low Steel, ft	0	96.19	0
Elevation of Bed, ft	N/A	88.77772	N/A
Elevation of approach WS, ft	0	99.43	0
HF, bridge to approach, ft	0	0.11	0
Elevation of WS immediately US, ft	0	99.32	0
ya, depth immediately US, ft	N/A	10.54228	N/A
ya, depth immediately US, m	N/A	3.276035	N/A
Mean elev. of deck, ft	0	102.47	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	ERR	0.909625	ERR
Ys, depth of scour (chang), ft	N/A	2.760396	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)

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	1180	1730	0	1180	1730	0
a', abut.length blocking flow, ft	16.9	44.5	0	26.6	35.6	0
Ae, area of blocked flow ft2	42.95	149.99	0	88.22	201.65	0
Qe, discharge blocked abut.,cfs	108.17	274.95	0	281.59	562.25	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	2.51851	1.833122	ERR	3.191907	2.788247	ERR
ya, depth of f/p flow, ft	2.54	3.37	ERR	3.32	5.66	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	0	1	1	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	0	90	90	0
K2	1	1	0	1	1	0
Fr, froude number f/p flow	0.28	0.18	ERR	0.31	0.21	ERR
ys, scour depth, ft	8.51	11.41	N/A	12.32	16.49	N/A

HIRE equation (a'/ya > 25)

ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

Characteristic	Left 100 yr Q	Left 500 yr Q	Left Other Q	Right 100 yr Q	Right 500 yr Q	Right Other Q
a'(abut length blocked, ft)	16.9	44.5	0	26.6	35.6	0
y1 (depth f/p flow, ft)	2.54	3.37	ERR	3.32	5.66	ERR
a'/y1	6.65	13.20	ERR	8.02	6.28	ERR
Froude no. f/p flow	0.28	0.18	N/A	0.31	0.21	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	0.67		1	0.67	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	4.40708	7.412281		4.40708	7.412281	
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.06	0.00	ERR	2.06	0
Fr>0.8 (vertical abut.)	1.84	ERR	ERR	1.84	ERR	ERR