LEVEL II SCOUR ANALYSIS FOR BRIDGE 43 (HARDTH00CU0043) on CHURCH STREET, crossing the LAMOILLE RIVER, HARDWICK, VERMONT

U.S. Geological Survey
Open-File Report 96-745

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

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Pembroke, New Hampshire

1996

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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 43 (HARDTH00CU0043) ON CHURCH STREET, CROSSING THE LAMOILLE RIVER, 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 HARDTH00CU0043 on Church Street crossing the Lamoille River, 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 87.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is best characterized as suburban except for the downstream right surface cover which is pasture.

In the study area, the Lamoille River has an incised, straight channel with a slope of approximately 0.004 ft/ft, an average channel top width of 90 ft and an average channel depth of 8 ft. The predominant channel bed materials are cobble and gravel with a median grain size (D_{50}) of 99.5 mm (0.327 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 26, 1995, indicated that the reach was stable.

The Church Street crossing of the Lamoille River is a 100-ft-long, two-lane bridge consisting of one 97-foot steel-beam span (Vermont Agency of Transportation, written communication, March 17, 1995). The bridge is supported by a vertical, stone abutment with wingwalls on the left and a vertical concrete abutment with a stone spill-through slope on the right. The channel is skewed approximately 5 degrees to the opening while the opening-skew-to-roadway is 0 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 0.8 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge. Abutment scour ranged from 6.2 to 10.9 ft at the left abutment with worst-case occurring at the incipient-overtopping discharge. Abutment scour ranged from 8.5 to 12.3 ft at the right abutment with worst-case occurring 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
Caspian Lake, VT. Quadrangle, 1:24,000, 1986
Wolcott, VT. Quadrangle, 1:24,000, 1986
Woodbury, 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 HARDTH00CU0043 ***Stream*** Lamoille River

County Caledonia ***Road*** Church Street ***District*** 7

Description of Bridge

Bridge length 100 ***ft*** ***Bridge width*** 29.0 ***ft*** ***Max span length*** 97 ***ft***

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

Abutment type Stone, left; concrete, rt. ***Embankment type*** Sloping

Stone fill on abutment? Yes, right ***Date of inspection*** 7/26/95

Description of stone fill Stone blocks, approximately type-2 (less than 36 inches) in size, have been carefully placed around the right abutment providing a spill-through slope at the abutment face.

Left abutment is vertical and constructed of stone blocks. The right abutment is vertical, concrete and has a spill-through slope of stone blocks.

Y

Is bridge skewed to flood flow according to survey? N ***Angle*** 5

7/26/95

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	0	0	7/26/
Level II	95	0	0

Potential for debris Moderate. Ice jams have historically been a problem in this reach of the Lamoille River.

Describe any features near or at the bridge that may affect flow (include observation date) July 26, 1995.--A levee has been constructed along the left bank downstream of the bridge.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with 1,000- foot-wide, flat to slightly irregular flood plain with steep valley walls on both sides.

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

Date of inspection 7/26/95

DS left: Flood plain

DS right: Flood plain

US left: Flood plain

US right: Narrow flood plain to moderately sloped overbank.

Description of the Channel

Average top width 90 *ft* ***Average depth*** 8 *ft*

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

Straight, incised channel with alluvial boundaries.

7/26/95

Vegetative co Surface cover is primarily suburban with some grass and trees.

DS left: Pasture

DS right: Surface cover is primarily suburban with some grass and trees.

US left: Grass and trees.

US right: Y

Do banks appear stable? July 26, 1995. Banks appear stable, however protection has been placed on the right bank about 200 feet upstream. There is a levee on the immediate left channel bank downstream of the bridge. The streamward side of this levee has type-3 (less than 48 inches diameter) protection.

date of observation.

None as of July 26, 1995.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 87.6 ***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***: The drainage basin is rural, however, the bridge site is located in a residential setting.

Is there a USGS gage on the stream of interest? Yes

USGS gage description Lamoille at Johnson, Vermont

USGS gage number 04292000

Gage drainage area 310 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 10,100 ***ft³/s*** ***Q500*** 14,500 ***ft³/s***

The 100- and 500-year discharges were taken from the Flood Insurance Study for the Town of Hardwick (Federal Emergency Management Agency, 1987). The discharges were within a range defined by frequency curves developed from several empirical methods (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) VTAOT plans

Datum tie between USGS survey and VTAOT plans None. Elevations match VTAOT plans' datum to the nearest foot.

Description of reference marks used to determine USGS datum. RM1 is a VTAOT brass tablet in the top of the upstream end of the left abutment (elev. 812.56 ft, arbitrary survey datum). RM2 is a chiseled X on the downstream right corner of the bridge deck (elev. 814.88 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	-107	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	126	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 0.045 to 0.047, and overbank "n" values ranged from 0.035 to 0.050.

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 0.00375 ft/ft which taken from the 100-year water-surface data in the Flood Insurance Study for the Town of Hardwick (Federal Emergency Management Agency, 1987).

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

The 100-year and incipient road-overflow discharges did not overtop the levee along the downstream left bank, but the 500-year discharge did. Thus, two separate models were utilized to determine the hydraulics at the bridge. The 100-year and incipient road-overflow model had cross sections that ended at the top of bank/levee on the left side of the channel. The 500-year model included the left overbank, however the sections were ended near the buildings and homes on the left overbank. The area to the left of these structures is assumed to have ineffective flow.

Bridge Hydraulics Summary

Average bridge embankment elevation 813.6 ***ft***
Average low steel elevation 811.8 ***ft***

100-year discharge 10,100 ***ft^3/s***
Water-surface elevation in bridge opening 809.8 ***ft***
Road overtopping? N ***Discharge over road*** -- ***s***
Area of flow in bridge opening 811 ***ft^2***
Average velocity in bridge opening 12.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.2 ***ft/s***

Water-surface elevation at Approach section with bridge 811.1
Water-surface elevation at Approach section without bridge 811.2
Amount of backwater caused by bridge 0.0 ***t***

500-year discharge 14,500 ***ft^3/s***
Water-surface elevation in bridge opening 812.7 ***ft***
Road overtopping? Y ***Discharge over road*** 3,930
Area of flow in bridge opening 1,020 ***ft^2***
Average velocity in bridge opening 10.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.4 ***/s***

Water-surface elevation at Approach section with bridge 815.3
Water-surface elevation at Approach section without bridge 812.4
Amount of backwater caused by bridge 2.9

Incipient overtopping discharge 10,400 ***ft^3/s***
Water-surface elevation in bridge opening 809.9 ***ft***
Area of flow in bridge opening 822 ***ft^2***
Average velocity in bridge opening 12.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.5 ***ft/s***

Water-surface elevation at Approach section with bridge 811.3
Water-surface elevation at Approach section without bridge 811.3
Amount of backwater caused by bridge 0.0 ***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.

Contraction scour was computed by use of Laursen's live-bed contraction scour equation (Richardson and others, 1995, p. 30, equation 17) for the 100-year and incipient road overtopping discharge. 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 and Richardson and others, 1995, p. 145-146). The result of Laursen's live-bed contraction scour for the 500-year event was also computed and can be found in appendix F.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping. Abutment scour depths were applied for the entire spill-through embankment below the elevation at the toe of each embankment, as shown in figure 8.

Elevation of total scour at the right abutment was above the base of the piles according to VTAOT plans for all modelled discharges.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	0.7	--	0.8
Clear-water scour	--	0.0	--
Depth to armoring	11.6	2.2	12.6
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	7.8	6.2	10.9
Right abutment	8.5	12.3	8.7
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	3.0	2.0	3.1
Right abutment	2.6	1.8	2.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

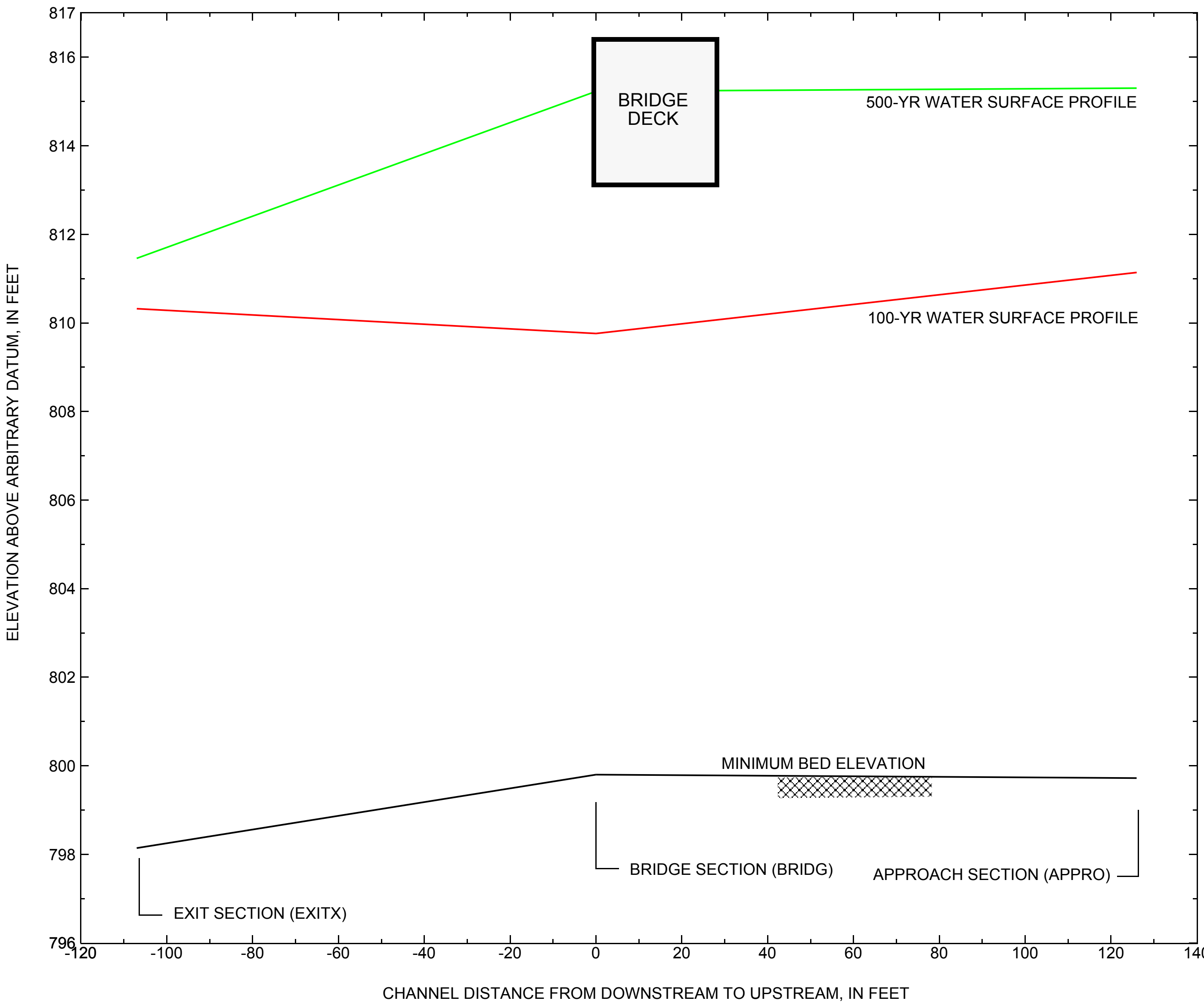

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure HARDTH00CU0043 on Church Street, crossing the Lamoille River, Hardwick, Vermont.

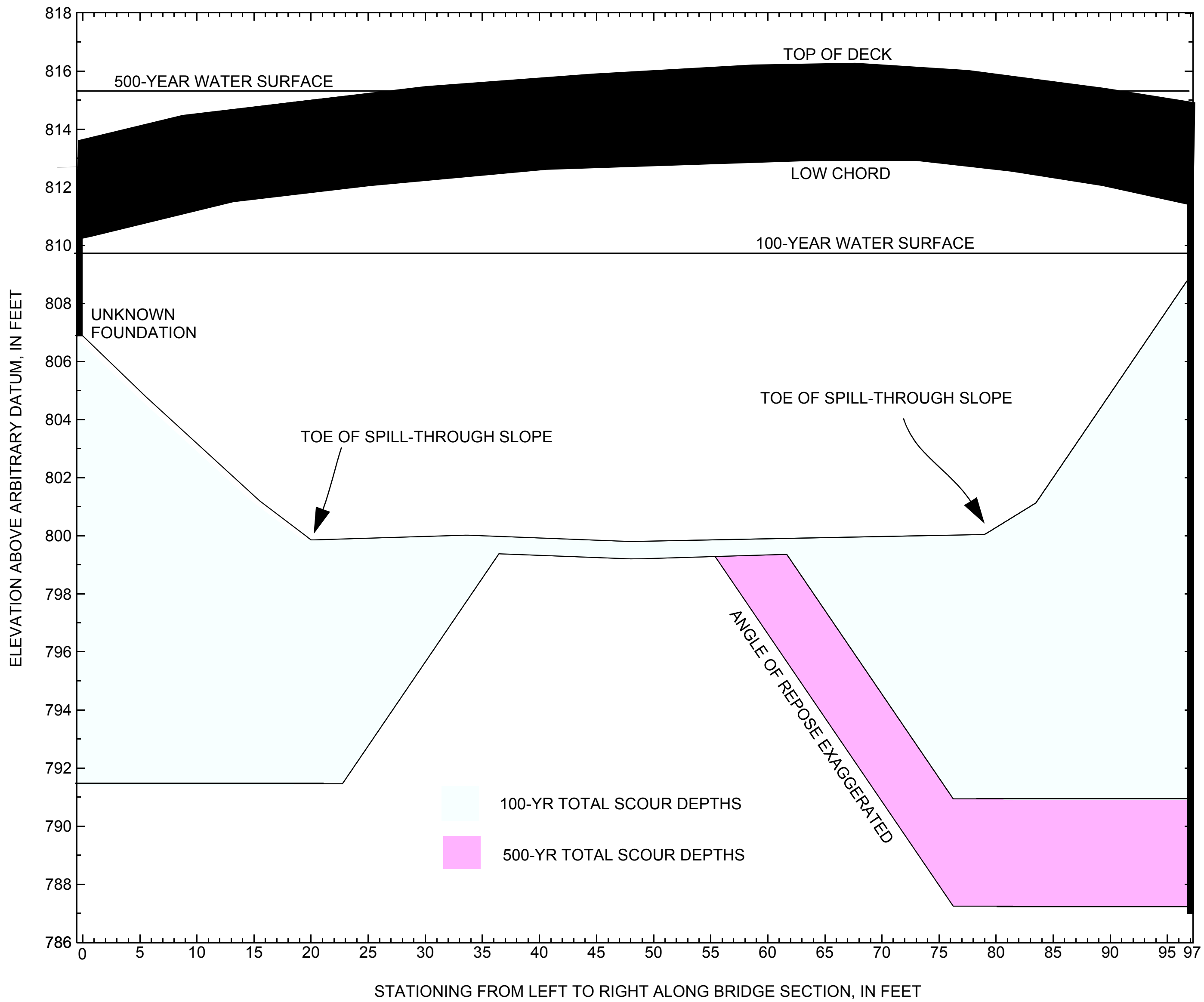

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure HARDTH00CU0043 on Church Street, crossing the Lamoille River, Hardwick, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure HARDTH00CU0043 on Church Street, crossing the Lamoille River, Hardwick, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of driven pile[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 10,100 cubic-feet per second											
Left abutment	0.0	810.20	810.17	--	--	--	--	--	--	--	--
Left Toe		--	--	--	799.9	0.7	7.8	--	8.5	791.4	--
Right Toe		--	--	--	800.0	0.7	8.5	--	9.2	790.8	--
Right abutment	96.7	811.29	811.32	787	--	--	--	--	--	--	4

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 HARDTH00CU0043 on Church Street, crossing the Lamoille River, Hardwick, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of driven pile[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 14,500 cubic-feet per second											
Left abutment	0.0	810.20	810.17	--	--	--	--	--	--	--	--
Left Toe		--	--	--	799.9	0.0	6.2	--	6.2	793.7	--
Right Toe		--	--	--	800.0	0.0	12.3	--	12.3	787.7	--
Right abutment	96.7	811.29	811.32	787	--	--	--	--	--	--	1

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

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U.S. Geological Survey, 1986, Woodbury, 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

```
T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard043.wsp
T2        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00CU0043 USING FILE hard043.dca
T3        HYDRAULIC ANALYSIS OF HARD043
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           10100 14500 10400
SK          0.00375 0.00375 0.00375
*
XS   EXITX   -107
GR          -70.0, 815       -70.0, 808.84    -41.2, 808.95    -40.8, 808.49
GR           -7.8, 808.42      0.0, 810.38      5.3, 809.61     13.7, 802.73
GR           19.0, 800.02     21.2, 799.18     29.2, 798.82     44.5, 798.14
GR           56.6, 798.39     63.2, 799.22     69.7, 799.82     74.3, 800.54
GR           82.7, 803.46     93.1, 807.02    129.6, 806.50    187.1, 806.87
GR          257.7, 808.28    302.3, 813.01    387.5, 821.55    441.4, 827.76
N           0.035       0.047       0.035
SA               5.3         93.1
*            Since Normal depth is contained by the levee along the left
*            bank for the q100 and incipient road overflow discharge, but not
*            for the q500, two model runs are needed. In the Q100 and the
*            incipient overtopping run the left end of the exit section ends
*            at the levee (station 0.0).

XS   FULLV   0 * * * 0.012
*
BR   BRIDG   0 812.7
GR            0.0, 810.17      1.0, 806.88      5.5, 804.79     15.5, 801.20
GR           20.0, 799.86     33.5, 800.02     48.0, 799.80     64.6, 799.99
GR           79.0, 800.04     83.5, 801.13     96.3, 808.76     96.7, 811.32
GR           44.6, 813.08      0.0, 810.17
N            0.045
CD           1 36 * * 28 5
*
XR   RDWAY   15 29.0 1
GR          -80.0, 815       -80.0, 810.53    -53.3, 810.64    -17.7, 810.53
GR           -4.2, 812.57     -4.1, 813.49     40.5, 816.81    102.7, 816.05
GR          102.8, 814.66    114.3, 814.61    168.0, 814.01    221.2, 814.95
GR          312.1, 818.80    390.1, 824.64
*
AS   APPRO    126
GR          -90.0, 815       -90.0, 811.50    -59.2, 811.62    -57.5, 810.96
GR          -31.8, 811.53    -19.0, 811.45     -0.7, 811.20     13.6, 801.14
GR           17.8, 800.32     27.1, 800.40     45.1, 799.89     51.9, 799.72
GR           68.6, 800.17     73.4, 801.09     90.0, 808.22     96.5, 809.17
GR          133.8, 809.98    144.4, 811.51    162.4, 820.61
N            0.045         0.047         0.050
SA                  -0.7            90
*            Since Normal depth is contained by the levee along the left
*            bank for the q100, but not for the q500, two model runs are
*            needed. In this run (Q100) the left end of the exit section
*            ends at the levee.

HP 1 BRIDG    809.76 1 809.76
HP 2 BRIDG    809.76 * * 10100
HP 1 APPRO    811.14 1 811.14
HP 2 APPRO    811.14 * * 10100
HP 1 BRIDG    812.70 1 812.70
HP 2 BRIDG    812.70 * * 10563
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard043.wsp
CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00CU0043 USING FILE hard043.dca
HYDRAULIC ANALYSIS OF HARD043   Q100
   *** RUN DATE & TIME: 06-17-96  08:54

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      811.  106300.    96.   103.                      13343.
   809.76           811.  106300.    96.   103.  1.00     0.    96.  13343.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       809.76     0.1    96.5   810.6  106300.   10100.  12.46
X STA.         0.1       12.7       18.1       22.2       26.1       29.9
  A(I)             64.1       45.9       40.2       38.0       37.3
  V(I)             7.88      11.00      12.57      13.30      13.55

X STA.        29.9       33.6       37.4       41.0       44.6       48.2
  A(I)             36.3       36.8       35.8       35.5       35.7
  V(I)            13.91      13.74      14.12      14.21      14.13

X STA.        48.2       51.8       55.4       59.0       62.8       66.5
  A(I)             35.8       35.6       35.9       36.9       36.4
  V(I)            14.12      14.18      14.07      13.67      13.88

X STA.        66.5       70.3       74.3       78.3       83.1       96.5
  A(I)             37.1       38.8       38.9       44.3       65.4
  V(I)            13.61      13.03      12.98      11.39       7.72

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     126.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2      835.  112425.    91.    95.                      14386.
             3       79.    3107.    52.    52.                        553.
   811.14           914.  115531.   142.   147.  1.11    -1.   142.  12490.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     126.
         WSEL     LEW     REW    AREA        K        Q    VEL
       811.14    -0.6   141.8   914.0  115531.   10100.  11.05
X STA.        -0.6       13.8       18.3       22.4       26.2       29.9
  A(I)             72.7       47.8       43.8       40.6       40.7
  V(I)             6.95      10.56      11.53      12.42      12.42

X STA.        29.9       33.5       37.0       40.4       43.8       47.2
  A(I)             38.8       38.7       37.7       37.6       37.9
  V(I)            13.02      13.06      13.39      13.43      13.32

X STA.        47.2       50.4       53.7       57.0       60.4       63.8
  A(I)             37.0       37.2       37.4       38.3       37.6
  V(I)            13.66      13.59      13.51      13.18      13.43

X STA.        63.8       67.3       71.2       75.6       82.7      141.8
  A(I)             39.1       41.5       44.1       53.7      111.9
  V(I)            12.90      12.16      11.46       9.41       4.51
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard043.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00CU0043 USING FILE hard043.dca
        HYDRAULIC ANALYSIS OF HARD043     Q500
           *** RUN DATE & TIME: 06-17-96  08:08

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1017.  105122.    17.   185.                        44569.
   812.70         1017.  105122.    17.   185.  1.00     0.    97.  44569.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       812.70     0.0    96.7  1017.4  105122.   10563.  10.38
X STA.         0.0       13.7       19.6       24.2       28.6       32.8
  A(I)            83.9       61.4       53.5       53.0       50.1
  V(I)            6.30       8.61       9.87       9.97      10.55

X STA.        32.8       36.8       40.2       43.1       46.0       48.9
  A(I)            50.1       43.2       37.4       37.6       36.6
  V(I)           10.54      12.21      14.13      14.03      14.43

X STA.        48.9       51.8       54.6       58.0       61.9       65.7
  A(I)            37.2       37.1       42.8       48.7       48.4
  V(I)           14.20      14.24      12.33      10.85      10.91

X STA.        65.7       69.8       74.1       78.5       83.6       96.7
  A(I)            50.4       51.4       52.6       58.3       83.8
  V(I)           10.49      10.28      10.04       9.05       6.30

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      15.
         WSEL     LEW     REW    AREA        K        Q    VEL
       815.23   -80.0   227.8   456.7   40615.    3926.   8.60
X STA.       -80.0      -74.5      -70.5      -66.6      -62.8      -59.0
  A(I)            25.6       18.9       18.3       17.3       17.7
  V(I)            7.66      10.39      10.74      11.34      11.09

X STA.       -59.0      -55.1      -51.4      -47.6      -43.8      -40.0
  A(I)            17.8       17.4       17.5       17.4       17.4
  V(I)           11.06      11.30      11.20      11.30      11.27

X STA.       -40.0      -36.2      -32.5      -28.6      -24.8      -20.9
  A(I)            17.5       17.6       17.8       18.1       18.2
  V(I)           11.19      11.16      11.01      10.84      10.77

X STA.       -20.9      -16.8      -11.8       -2.0      154.6      227.8
  A(I)            19.1       20.8       28.3       57.8       56.2
  V(I)           10.26       9.46       6.93       3.40       3.49

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     126.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     348.   27691.    89.    93.                         3894.
             2    1212.  209121.    91.    96.                        25153.
             3     319.   28030.    62.    63.                         4109.
   815.30         1879.  264841.   242.   252.  1.26   -90.   152.  26506.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     126.
         WSEL     LEW     REW    AREA        K        Q    VEL
       815.30   -90.0   151.9  1879.1  264841.   14500.   7.72
X STA.       -90.0      -45.4       -3.9       12.1       17.8       22.8
  A(I)           173.1      161.5      123.1       81.7       74.3
  V(I)            4.19       4.49       5.89       8.87       9.75

X STA.        22.8       27.7       32.4       37.0       41.5       46.1
  A(I)            73.3       71.0       69.3       69.1       69.7
  V(I)            9.89      10.21      10.46      10.50      10.41

X STA.        46.1       50.5       54.9       59.3       63.9       68.5
  A(I)            68.0       68.3       68.6       70.4       70.7
  V(I)           10.66      10.62      10.57      10.30      10.25

X STA.        68.5       73.6       80.1       92.2      115.5      151.9
  A(I)            74.1       82.9      106.1      140.5      163.4
  V(I)            9.79       8.74       6.83       5.16       4.44
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         U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard043.wsp
         CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00CU0043 USING FILE hard043.dca
         HYDRAULIC ANALYSIS OF HARD043   Q100
            *** RUN DATE & TIME: 06-17-96  08:54

     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1      822.  108665.    96.   103.                       13625.
    809.88           822.  108665.    96.   103.  1.00     0.    96.  13625.

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        809.88     0.1    96.5   822.2  108665.   10400.  12.65
 X STA.         0.1       12.7       17.9       22.2       26.1       29.9
   A(I)             65.3       45.2       42.0       38.5       37.8
   V(I)             7.96      11.50      12.39      13.52      13.77

 X STA.        29.9       33.6       37.3       41.0       44.6       48.2
   A(I)             36.8       37.2       36.2       36.0       36.2
   V(I)            14.14      13.97      14.36      14.45      14.37

 X STA.        48.2       51.8       55.4       59.1       62.8       66.5
   A(I)             36.4       36.3       36.5       36.8       36.8
   V(I)            14.28      14.34      14.24      14.11      14.11

 X STA.        66.5       70.4       74.3       78.4       83.1       96.5
   A(I)             38.6       38.2       40.7       43.6       66.9
   V(I)            13.46      13.60      12.76      11.93       7.77

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     126.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1        1.       3.    10.    10.                           1.
              2      852.  116233.    91.    96.                       14826.
              3       89.    3725.    53.    53.                         652.
    811.33           942.  119961.   153.   158.  1.11   -10.   143.  12548.

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     126.
          WSEL     LEW     REW    AREA        K        Q    VEL
        811.33   -10.2   143.2   941.8  119961.   10400.  11.04
 X STA.       -10.2       13.6       18.3       22.3       26.2       29.9
   A(I)             74.4       50.5       43.5       42.8       40.6
   V(I)             6.99      10.31      11.95      12.15      12.79

 X STA.        29.9       33.5       37.1       40.5       44.0       47.3
   A(I)             39.8       39.7       38.7       39.2       38.3
   V(I)            13.06      13.11      13.43      13.27      13.58

 X STA.        47.3       50.6       53.9       57.2       60.6       64.1
   A(I)             37.9       38.1       38.3       39.3       39.4
   V(I)            13.71      13.65      13.58      13.24      13.18

 X STA.        64.1       67.7       71.5       76.1       83.6      143.2
   A(I)             40.3       41.4       46.0       56.1      117.5
   V(I)            12.90      12.56      11.30       9.26       4.43
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       U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard043.wsp
       CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00CU0043 USING FILE hard043.dca
       HYDRAULIC ANALYSIS OF HARD043   Q100

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

EXITX:XS   ******     0.    1394.  0.92 *****  811.24  808.91  10100.  810.32
     -107. ******   277.  164888.  1.12 ***** *******    0.60    7.25

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.84     810.57     810.19
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   809.82     829.04    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   809.82     829.04     810.19

FULLV:FV     107.     6.    1115.  1.50  0.54  812.07  810.19  10100.  810.57
        0.   107.   267.  121708.  1.18  0.29   -0.01    0.84    9.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.80     811.19     809.15
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   810.07     820.61    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   810.07     820.61     809.15

APPRO:AS     126.    -1.     921.  2.07  0.91  813.26  809.15  10100.  811.19
      126.   126.   142.  116592.  1.11  0.28    0.00    0.80   10.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   811.14       0.00     809.76     810.53
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

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

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

BRIDG:BR     107.     0.     811.  2.41  0.62  812.18  808.30  10100.  809.76
        0.   107.    96.  106323.  1.00  0.31   -0.01    0.76   12.46

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  812.70 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<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      90.    -1.     914.  2.10  0.75  813.24  809.15  10100.  811.14
      126.    91.   142.  115588.  1.11  0.32    0.00    0.81   11.05

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.324  0.022  113102.    -2.    94. ********

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -107.     0.   277.  10100.  164888.    1394.    7.25  810.32
   FULLV:FV       0.     6.   267.  10100.  121708.    1115.    9.06  810.57
   BRIDG:BR       0.     0.    96.  10100.  106323.     811.   12.46  809.76
   RDWAY:RG      15.**************      0.       0.       0.    1.00********
   APPRO:AS     126.    -1.   142.  10100.  115588.     914.   11.05  811.14

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    94.  113102.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    808.91    0.60  798.14  827.76************  0.92  811.24  810.32
   FULLV:FV    810.19    0.84  799.42  829.04  0.54  0.29  1.50  812.07  810.57
   BRIDG:BR    808.30    0.76  799.80  813.08  0.62  0.31  2.41  812.18  809.76
   RDWAY:RG  ****************  810.53  824.64  0.74******  2.09  812.51********
   APPRO:AS    809.15    0.81  799.72  820.61  0.75  0.32  2.10  813.24  811.14
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WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard043.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00CU0043 USING FILE hard043.dca
        HYDRAULIC ANALYSIS OF HARD043     Q500

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

EXITX:XS   ******   -70.    1904.  1.01 *****  812.47  810.09  14500.  811.46
     -107. ******   288.  236731.  1.12 ***** *******    0.62    7.62

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.86     811.68     811.37
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   810.96     829.04    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  810.96     829.04     811.37

FULLV:FV     107.   -70.    1528.  1.65  0.54  813.32  811.37  14500.  811.68
        0.   107.   278.  174668.  1.18  0.32   -0.01    0.87    9.49
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.23     811.90     812.40
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   811.18     820.61    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  811.18     820.61     812.40
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   812.40     820.61     812.40

APPRO:AS     126.   -90.    1185.  2.91 *****  815.30  812.40  14500.  812.40
      126.   126.   146.  150230.  1.25 ***** *******    1.08   12.24
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   814.54       0.00     810.23     810.53
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   819.34         0.     14500.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR     107.     0.    1017.  1.68 *****  814.38  808.53  10563.  812.70
        0. ******    97.  105122.  1.00 ***** *******    0.56   10.38

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.444  0.000  812.70 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.    97.  0.29  1.17  816.17    0.00    3926.  815.23

            Q    WLEN    LEW     REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   3090.    99.   -80.     19.   4.7   3.6  10.2   8.6   4.6   3.2
   RT:    836.   118.   103.    221.   1.2   0.8   6.0   8.7   1.8   3.0

===140 AT SECID "APPRO":  END OF CROSS SECTION EXTENDED VERTICALLY.
                             WSEL,YLT,YRT =   815.30      815.0      820.6

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

APPRO:AS      90.   -90.    1878.  1.17  0.52  816.46  812.40  14500.  815.30
      126.    92.   152.  264633.  1.26  0.00    0.00    0.55    7.72
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -107.   -70.   288.  14500.  236731.    1904.    7.62  811.46
   FULLV:FV       0.   -70.   278.  14500.  174668.    1528.    9.49  811.68
   BRIDG:BR       0.     0.    97.  10563.  105122.    1017.   10.38  812.70
   RDWAY:RG      15.*******  3090.   3926.******************    1.00  815.23
   APPRO:AS     126.   -90.   152.  14500.  264633.    1878.    7.72  815.30

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     810.09    0.62  798.14  827.76************  1.01  812.47  811.46
   FULLV:FV     811.37    0.87  799.42  829.04  0.54  0.32  1.65  813.32  811.68
   BRIDG:BR     808.53    0.56  799.80  813.08************  1.68  814.38  812.70
   RDWAY:RG  ****************  810.53  824.64  0.29******  1.17  816.17  815.23
   APPRO:AS     812.40    0.55  799.72  820.61  0.52  0.00  1.17  816.46  815.30
```

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard043.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00CU0043 USING FILE hard043.dca
        HYDRAULIC ANALYSIS OF HARD043   Q100
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******     0.    1423.  0.93 *****  811.36  809.03  10400.  810.43
     -107. ******   278.  169789.  1.12 ***** *******    0.60    7.31

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.83     810.68     810.29
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   809.93     829.04    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   809.93     829.04     810.29

FULLV:FV     107.     6.    1143.  1.51  0.54  812.18  810.29  10400.  810.68
        0.   107.   268.  125768.  1.17  0.29    0.00    0.83    9.10
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.83     811.27     809.29
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   810.18     820.61    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   810.18     820.61     809.29

APPRO:AS     126.    -7.     936.  2.14  0.91  813.43  809.29  10400.  811.29
      126.   126.   143.  119048.  1.11  0.31    0.02    0.83   11.11
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   811.33       0.00     809.88     810.53
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

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

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

BRIDG:BR     107.     0.     822.  2.49  0.63  812.37  808.45  10400.  809.88
        0.   107.    96.  108621.  1.00  0.38   -0.01    0.76   12.65

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  812.70 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<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      90.   -11.     942.  2.11  0.75  813.44  809.29  10400.  811.33
      126.    91.   143.  120058.  1.11  0.33   -0.01    0.83   11.03

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.357  0.026  117150.    -2.    94. ********

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

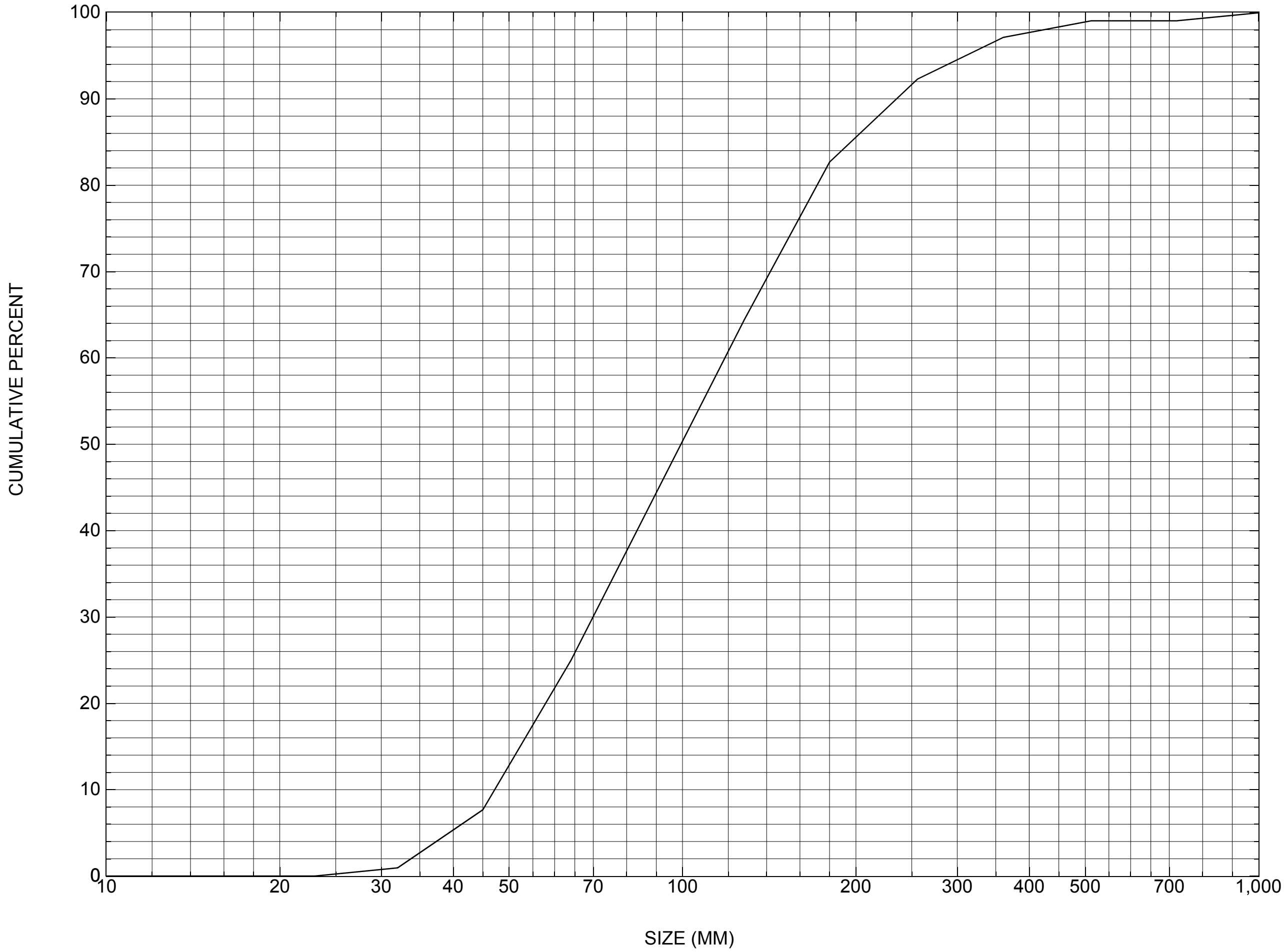
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -107.     0.   278.  10400.  169789.    1423.    7.31  810.43
   FULLV:FV      0.      6.   268.  10400.  125768.    1143.    9.10  810.68
   BRIDG:BR      0.      0.    96.  10400.  108621.     822.   12.65  809.88
   RDWAY:RG     15.**************       0.       0.       0.    1.00********
   APPRO:AS     126.   -11.   143.  10400.  120058.     942.   11.03  811.33

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    94.  117150.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    809.03    0.60  798.14  827.76************  0.93  811.36  810.43
   FULLV:FV    810.29    0.83  799.42  829.04  0.54  0.29  1.51  812.18  810.68
   BRIDG:BR    808.45    0.76  799.80  813.08  0.63  0.38  2.49  812.37  809.88
   RDWAY:RG ****************  810.53  824.64  0.73******  2.12  812.70********
   APPRO:AS    809.29    0.83  799.72  820.61  0.75  0.33  2.11  813.44  811.33
```

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 HARDTH00CU0043, in Hardwick, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number HARDTH00CU0043

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 17 / 95

Highway District Number *(I - 2; nn)* 07

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

Town *(FIPS place code; I - 4; nnnnn)* 31750

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

Waterway *(I - 6)* LAMOILLE RIVER

Road Name *(I - 7)*: CHURCH STREET

Route Number -

Vicinity *(I - 9)* @ JCT W CL1 TH1

Topographic Map Caspian.Lake

Hydrologic Unit Code: 02010005

Latitude *(I - 16; nnnn.n)* 44305

Longitude *(i - 17; nnnnn.n)* 72222

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030500430305

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

Maximum span length *(I - 48; nnnn)* 0097

Year built *(I - 27; YYYY)* 1964

Structure length *(I - 49; nnnnnn)* 000100

Average daily traffic, ADT *(I - 29; nnnnnn)* 000750

Deck Width *(I - 52; nn.n)* 290

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

Channel & Protection *(I - 61; n)* 7

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*) 011.3

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 single span, steel stringer type bridge. The right abutment is concrete while the left abutment and its wingwalls are grouted, "laid-up" stone blocks with a concrete cap. The stone abutment is remaining from the previous structure. The report indicates only minor cracks and small spalls on the right abutment wall overall. The concrete cap of the left abutment has a few minor fine cracks reported overall and a small vertical crack. Cracks also are noted extending down through the stone blocks of the abutment wall. Carefully laid in place, the report notes large stone blocks covering most of the embankment in front **(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: Sand and boulders

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -
Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ 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 (*ft²*): -

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

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

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

Comments:

the right abutment and around its ends. There is stone and boulder stone fill also noted in front of the left abutment wall and some evident on the banks up- and downstream of the bridge.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **87.61** mi^2

Lake and pond area **2.29** mi^2

Watershed storage *(ST)* **2.61** %

Bridge site elevation **807** ft

Headwater elevation **1798** ft

Main channel length **17.376** mi

10% channel length elevation **974** ft

85% channel length elevation **1339** ft

Main channel slope *(S)* **28.0** 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? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY):* 07 / 1964

Project Number TF-18/1964 Minimum channel bed elevation: 800.0

Low superstructure elevation: USLAB 810.20 DSLAB 810.20 USRAB 811.29 DSRAB 811.29

Benchmark location description:

BM#1, spike in root of a 10 inch elm tree located at the top of the right bank downstream about 60 feet along a line approximately parallel with the right abutment wall, elevation 808.45.

Reference Point (*MSL, Arbitrary, Other*): Arbitrary Datum (*NAD27, NAD83, Other*): Arbitrary

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

If 1: Footing Thickness ______ Footing bottom elevation: ______

If 2: Pile Type: 2 (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: 16.0

If 3: Footing bottom elevation: ______

Is boring information available? Y *If no, type ctrl-n bi* Number of borings taken: 5

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

Briefly describe material at foundation bottom elevation or around piles:

The piles were likely driven into mainly stone fill material and perhaps into native silt and sand material below.

Comments:

Other points are shown on the plans with elevations: 1) the point on top of the concrete section of the left abutment extension upstream at the streamward edge where the concrete meets the stone upstream left wingwall, elevation 812.85. The old left abutment remained for the current bridge. The right abutment is new with a bottom elevation at 802.50 and steel H type piles driven at least 16 feet where the highest boring refusal elevation was noted at 786.63 feet. Another point with an elevation noted is at the top of the concrete on the upstream corner of the right abutment at the streamward edge, elevation 816.63.

Cross-sectional Data

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

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

Comments: **Upstream channel cross section at stationing 5 + 10, 10 feet from the centerline of the roadway on the bridge deck. The channel baseline is skewed 83 degrees from the roadway section running along the right bank.**

Station	-95.0	-94.0	-81.0	-71.3	-44.3	-18.0	-13.5	-11	-2.2	+1.8	
Feature	LCL	footing	LEW	BLB			BRB	REW	footing	LCR	
Low cord elevation	811.0	base							edge	811.2	
Bed elevation	811.0	803.5	802.0	800.0	800.3	799.8	800.0	802.0	t805	810.0	
Low cord to bed length									b802.5		

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

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

Comments: **Downstream channel cross section at stationing 4 + 90, 10 feet from the centerline of the roadway on the bridge deck.**

Station	-98.0	-88.0	-74.0	-62.0	-50.0	-38.0	-24.0	-13.0	-4.0	-1.0	
Feature	LCL		LEW					REW	footing	LCR	
Low cord elevation	811.0								edge	811.4	
Bed elevation	807.0	804.0	802.0	800.0	799.7	799.8	799.9	802.0	t805	810.0	
Low cord to bed length									b802.5		

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: **RB** Date: **4/12/96**

Computerized by: **RB** Date: **4/12/96**

Reviewd by: **SAO** Date: **10/18/96**

Structure Number **HARDTH00CU0043**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R**. **HAMMOND** Date *(MM/DD/YY)* **7** / **26** / 19**95**

2. Highway District Number **7** Mile marker **000**

County **CALEDONIA 005** Town **HARDWICK 31750**

Waterway *(I - 6)* **LAMOILLE RIVER** Road Name **CHURCH STREET**

Route Number **-** Hydrologic Unit Code: **02010005**

3. Descriptive comments:

Located near the junction of Church Street and State Highway 15.

B. Bridge Deck Observations

4. Surface cover... LBUS **2** RBUS **2** LBDS **2** RBDS **4** Overall **2**

*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

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

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

7. Bridge length **100** *(feet)* Span length **97** *(feet)* Bridge width **29** *(feet)*

Road approach to bridge:

8. LB **1** RB **0** *(**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 ________ US right ________

	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	5	1	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	3	1	0	-

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

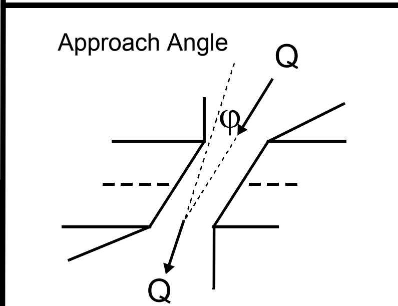
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

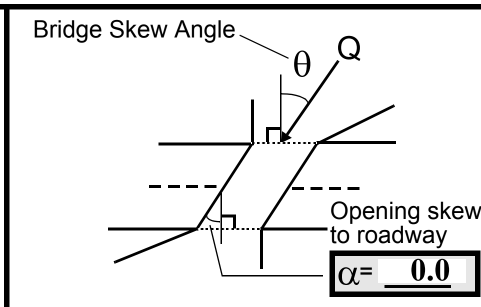
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **5**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*

Where? **LB** *(LB, RB)* Severity **1**

Range? **100** feet **DS** *(US, UB, DS)* to **200** feet **DS**

Channel impact zone 2: Exist? **N** *(Y or N)*

Where? **-** *(LB, RB)* Severity **-**

Range? **-** feet **-** *(US, UB, DS)* to **-** feet **-**

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

18. Bridge Type: **1a/3**

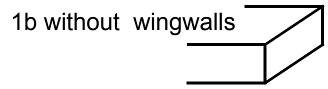
1a- Vertical abutments with wingwalls

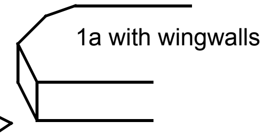
1b- Vertical abutments without wingwalls

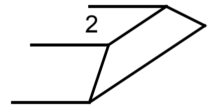
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face

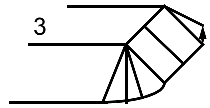
3- Spill through abutments

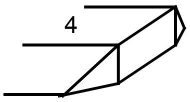
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.











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

7. Values are from the VT AOT files. Measured values match the historical form.

18. The right abutment has a spill-through slope at its face constructed with laid up stone. The left abutment is vertical with wingwalls.

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
70.0	**10.0**			**7.0**	**1**	**1**	**7**	**2**	**0**	**0**

23. Bank width **35.0** 24. Channel width **25.0** 25. Thalweg depth **91.0** 29. Bed Material **43**

30 .Bank protection type: LB **5** RB **0** 31. Bank protection condition: LB **1** 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.):

30. There is a laid up stone wall along the left bank.

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

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

37. Material: -

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

NO POINT BARS

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

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
60.0		1.0		2	7	7	0

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 90.0 63. Bed Material 0

*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.):

43

-

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

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

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

70. Debris and Ice Comments:

2

Two residents say the ice will build up and flood over onto the highway and into the buildings on the other side of the highway. One claims that before the dam upstream was removed there was not much of an ice problem.

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	0	-	-	90.0
RABUT	2	0	50			0	0	96.5

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.):

-

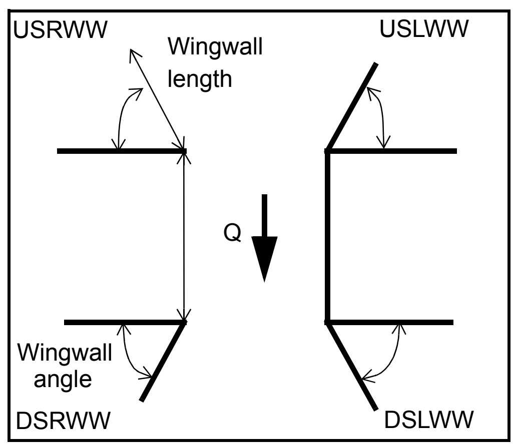
-

2

The left abutment is laid up stone with a concrete cap. There is sloping gravel and cobble in front of it. The right abutment is concrete with stones laid up in front so that it acts like a spill through type abutment. Only 2 feet of the vertical concrete abutment is visible.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						96.5	
USRWW:	Y		1		0	1.5	
DSLWW:	-		-		N	30.0	
DSRWW:	-		-		-	28.5	



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

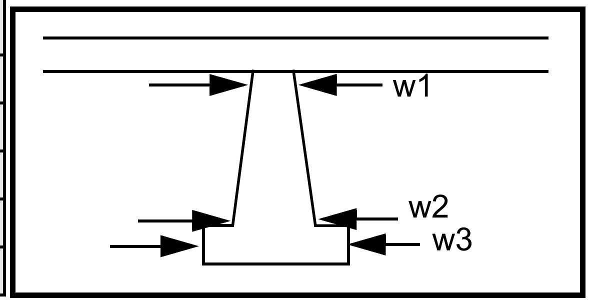
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1			-	**55.0**	**16.5**	-
Pier 2		**5.0**	-	**95.0**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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
-	-			-	-	-	-	-	-	-

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.):
-
-
-
-
-
-
-
NO PIERS

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):
1
1
2
2
0
0

106. Point/Side bar present? 43 (Y or N. if N type ctrl-n pb) Mid-bar distance: 3 Mid-bar width: 0

Point bar extent: 1 feet - (US, UB, DS) to The feet ban (US, UB, DS) positioned k %LB to pro %RB

Material: tec

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

tion on the left bank is for protecting the highway embankment parallel to the river.

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

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

N

Is channel scour present? - (Y or if N type ctrl-n cs) Mid-scour distance: NO

Scour dimensions: Length DRO Width P Depth: STR Positioned UC %LB to TU %RB

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

RE

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

Confluence 1: Distance Y Enters on 150 (LB or RB) Type 15 (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance 100 Enters on DS (LB or RB) Type 200 (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

DS

70

F. Geomorphic Channel Assessment

107. Stage of reach evolution 100

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)*:

43

There is not much difference in height above the normal bottom of the channel, however, the channel bends slightly in this area.

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:	HARDTH00CU0043	Town:	Hardwick
Road Number:	Church Street	County:	Caledonia
Stream:	Lamoille River		

Initials SAO Date: 6/17/96 Checked: MAI

I. 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	10100	14500	10400
Main Channel Area, ft2	835	1212	852
Left overbank area, ft2	0	348	1
Right overbank area, ft2	79	319	89
Top width main channel, ft	91	91	91
Top width L overbank, ft	0	89	10
Top width R overbank, ft	52	63	53
D50 of channel, ft	0.327	0.327	0.327
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.2	13.3	9.4
y1, average depth, LOB, ft	ERR	3.9	0.1
y1, average depth, ROB, ft	1.5	5.1	1.7
Total conveyance, approach	115531	264841	119961
Conveyance, main channel	112425	209121	116233
Conveyance, LOB	0	27691	3
Conveyance, ROB	3107	28030	3725
Percent discrepancy, conveyance	-0.0009	-0.0004	0.0000
Qm, discharge, MC, cfs	9828.5	11449.3	10076.8
Ql, discharge, LOB, cfs	0.0	1516.1	0.3
Qr, discharge, ROB, cfs	271.6	1534.6	322.9
Vm, mean velocity MC, ft/s	11.8	9.4	11.8
Vl, mean velocity, LOB, ft/s	ERR	4.4	0.3
Vr, mean velocity, ROB, ft/s	3.4	4.8	3.6
Vc-m, crit. velocity, MC, ft/s	11.2	11.9	11.2
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	1	0	1
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and others, 1995, p. 30, eq. 17 and 18)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	10100	14500	10400	10100	10536	10400
Total conveyance	115531	264841	119961	106300	105122	108665
Main channel conveyance	112425	209121	116233	106300	105122	108665
Main channel discharge	9828	11449	10077	10100	10536	10400
Area - main channel, ft2	835	1212	852	811	1017	822
(W1) channel width, ft	91	91	91	96.4	96.7	96.4
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	91	91	91	96.4	96.7	96.4
D50, ft	0.327	0.327	0.327			
w, fall velocity, ft/s (p. 32)	4.7	4.7	4.7			
y, ave. depth flow, ft	9.18	13.32	9.36	8.41	10.52	8.53
S1, slope EGL	0.0094	0.016	0.0099			
P, wetted perimeter, MC, ft	95	96	96			
R, hydraulic Radius, ft	8.789	12.625	8.875			
V*, shear velocity, ft/s	1.631	2.550	1.682			
V*/w	0.347	0.543	0.358			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.59	0.64	0.59			
y2,depth in contraction, ft	9.08	11.93	9.30			
ys, scour depth, ft (y2-y_bridge)	0.67	1.41	0.77			
ys, scour depth, ft (y2-yfullv)	N/A	0.47	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	835	1212	852
Main channel width, ft	91	91	91
y1, main channel depth, ft	9.18	13.32	9.36
Bridge Section			
(Q) total discharge, cfs	10100	14500	10400

(Q) discharge thru bridge, cfs	10100	10536	10400
Main channel conveyance	106300	105122	108665
Total conveyance	106300	105122	108665
Q2, bridge MC discharge,cfs	10100	10536	10400
Main channel area, ft2	811	1017	822
Main channel width (skewed), ft	96.4	96.7	96.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	96.4	96.7	96.4
y_bridge (avg. depth at br.), ft	8.41	10.52	8.53
Dm, median (1.25*D50), ft	0.40875	0.40875	0.40875
y2, depth in contraction,ft	8.61	8.91	8.83
ys, scour depth (y2-ybridge), ft	0.20	-1.61	0.31
ys, scour depth (y2-yfullv), ft	N/A	-2.55	N/A

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	10563	0
Vc, critical velocity, ft/s	0	11.9	0
Vc, critical velocity, m/s	0	3.626943	0
Main channel width (skewed), ft	0	96.7	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	0	96.7	0
qbr, unit discharge, ft^2/s	ERR	109.2347	ERR
qbr, unit discharge, m^2/s	N/A	10.14725	N/A
Area of full opening, ft^2	0	1017.4	0
Hb, depth of full opening, ft	ERR	10.5212	ERR
Hb, depth of full opening, m	N/A	3.206705	N/A
Fr, Froude number MC	1	0.56	1
Cf, Fr correction factor (<=1.0)	1.5	1	1.5
Elevation of Low Steel, ft	0	810.74	0
Elevation of Bed, ft	N/A	800.2188	N/A
Elevation of approach WS, ft	0	815.3	0
HF, bridge to approach, ft	0	0.52	0
Elevation of WS immediately US, ft	0	814.78	0
ya, depth immediately US, ft	N/A	14.5612	N/A
ya, depth immediately US, m	N/A	4.524922	N/A
Mean elev. of deck, ft	0	815.45	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	ERR	0.917495	ERR
Ys, depth of scour (chang), ft	N/A	-0.51636	N/A

ARMORING

D90	0.772	0.772	0.772
D95	1.02	1.02	1.02
Critical grain size,Dc, ft	0.6540	0.4140	0.6713
Decimal-percent coarser than Dc	0.145	0.367	0.138
Depth to armoring,ft	11.57	2.14	12.58

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	10100	14500	10400	10100	14500	10400
a', abut.length blocking flow, ft	0.7	19	10.3	45.3	55.2	46.7
Ae, area of blocked flow ft2	3.53	27.7	32.2	85.8	217.9	92.1
Qe, discharge blocked abut.,cfs	24.6	--	225	387.1	--	407.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	6.97	4.96	6.99	4.51	4.73	4.42
ya, depth of f/p flow, ft	5.04	1.46	3.13	1.89	3.95	1.97
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.547	0.404	0.696	0.578	0.373	0.555
ys, scour depth, ft	7.82	6.17	10.92	8.52	12.34	8.68

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)	0.7	19	10.3	45.3	55.2	46.7
y1 (depth f/p flow, ft)	5.04	1.46	3.13	1.89	3.95	1.97
a'/y1	0.14	13.03	3.29	23.92	13.98	23.68
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.55	0.40	0.70	0.58	0.37	0.56
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	0.76	0.56	0.76	0.76	0.56	0.76
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	8.41	10.52	8.53	8.41	10.52	8.53
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	3.00	2.04	3.05	3.00	2.04	3.05
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	2.62	1.78	2.66	2.62	1.78	2.66
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR