LEVEL II SCOUR ANALYSIS FOR BRIDGE 42 (HARDELMSTR0042) on ELM STREET, crossing COOPER BROOK, HARDWICK, VERMONT

U.S. Geological Survey
Open-File Report 96-565

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

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By SCOTT A. OLSON

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Pembroke, New Hampshire
1996

U.S. DEPARTMENT OF THE INTERIOR
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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 42 (HARDELMSTR0042) ON ELM STREET, CROSSING COOPER BROOK, HARDWICK, VERMONT

By **Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure HARDELMSTR0042 on Elm Street crossing Cooper Brook, Hardwick, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in north-central Vermont. The 16.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the overbanks are primarily grass covered with some brush along the immediate channel banks except the upstream right bank and overbank which is forested and the downstream left overbank which has a lumberyard.

In the study area, Cooper Brook has a sinuous channel with a slope of approximately 0.005 ft/ft, an average channel top width of 50 ft and an average channel depth of 6 ft. The predominant channel bed materials are sand and gravel with a median grain size (D_{50}) of 1.25 mm (0.00409 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 24, 1995, indicated that the reach was stable.

The Elm Street crossing of Cooper Brook is a 39-ft-long, two-lane bridge consisting of one 37-foot concrete span (Vermont Agency of Transportation, written communication, March 17, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening while the opening-skew-to-roadway is 45 degrees.

On August 17, 1995 the site was revisited to investigate the effect of the August 4-5, 1995 flood on the structure. Channel features such as scour holes and point bars were shifted by the high flow event. Details of these changes can be found in the Level I data form in Appendix E. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and G.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). 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 3.4 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge which was less than the 100-year discharge. Abutment scour ranged from 7.1 to 10.4 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1993, p. 48). 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 maps.

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

LEVEL II SUMMARY

Structure Number HARDELMSTR0042 ***Stream*** Cooper Brook

County Caledonia ***Road*** ELM ST. ***District*** 7

Description of Bridge

Bridge length 39 ***ft*** ***Bridge width*** 25.4 ***ft*** ***Max span length*** 37 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 7/24/95 and 8/17/95

Description of stone fill Sparse type-2 (less than 36 inches diameter), along both abutments, upstream wingwalls and the downstream right wingwall.

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

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 40

There is a mild channel bend through reach. The bend results in flow impacting the right abutment.

7/24/95 and 8/17/95

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*
	0	0	7/24/
Level I	95	0	0
Level II	Moderate.		

Potential for debris

Describe any features near or at the bridge that may affect flow (include observation date)

July 24, 1995 and August 17, 1995. Lumber yard on downstream left bank may be a potential source of debris.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief, upland valley with a flat to slightly irregular, flood plain.

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

Date of inspection 7/24/95 and 8/17/95

DS left: Flood plain.

DS right: Narrow flood plain.

US left: Flood plain.

US right: Steeply sloped overbank.

Description of the Channel

Average top width 50 ***ft*** ***Average depth*** 6 ***ft***

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

Slightly sinuous with alluvial channel boundaries.

7/24/95 and 8/17/95

Vegetative co Primarily grass with brush on immediate banks. At lumber yard, no cover.

DS left: Primarily grass with brush on immediate banks.

DS right: Primarily grass with brush on immediate banks. At lumber yard, no cover.

US left: Forested

US right: Y

Do banks appear stable? Some bank cutting, but reach has only a slight bend and banks are considered stable. ***If not, describe location and type of instability and date of observation.***

July 24, 1995, None; August 17, 1995, None.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 16.6 ***mi***^{2}

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 -- ***mi***^{2}

Is there a lake/p No
There is a pond upstream at Mackville, but it is considered to have minimal storage effect.

Calculated Discharges

Q100 2,300 ***ft***^{3}***/s*** ***Q500*** 3,200 ***ft***^{3}***/s***

The 100-year discharge is from the VTAOT database. The 500-year discharge was determined from a graphical extrapolation of the 10-, 25-, 50-, and 100-year discharges available in the database for bridge 42.

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 Add 2.13 feet to USGS survey to obtain VTAOT plans datum and mean sea level.

Description of reference marks used to determine USGS datum. RM1 is the center of a brass tablet in the downstream end of the right abutment (elev. 809.44 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 809.16 ft, arbitrary survey datum). RM3 is a chiseled X in the upstream end of the right abutment (elev. 809.79 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	-49	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	20	1	Road Grade section
APPRO	62	2	Modelled Approach section (Templated from SURVA)
SURVA	81	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.032 to 0.040, and overbank "n" values ranged from 0.040 to 0.060.

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 0.0049 ft/ft which was determined from surveyed thalweg points.

The surveyed approach section (SURVA) was moved along the approach channel slope (0.011 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 809.4 *ft*
Average low steel elevation 807.6 *ft*

100-year discharge 2,300 *ft³/s*
Water-surface elevation in bridge opening 807.7 *ft*
Road overtopping? Y *Discharge over road* 1,150 *ft³/s*
Area of flow in bridge opening 158 *ft²*
Average velocity in bridge opening 7.3 *ft/s*
Maximum WSPRO tube velocity at bridge 8.5 *ft/s*

Water-surface elevation at Approach section with bridge 810.8
Water-surface elevation at Approach section without bridge 810.2
Amount of backwater caused by bridge 0.6 *ft*

500-year discharge 3,200 *ft³/s*
Water-surface elevation in bridge opening 807.7 *ft*
Road overtopping? Y *Discharge over road* 2,200
Area of flow in bridge opening 158 *ft²*
Average velocity in bridge opening 6.4 *ft/s*
Maximum WSPRO tube velocity at bridge 7.4 *ft/s*

Water-surface elevation at Approach section with bridge 811.4
Water-surface elevation at Approach section without bridge 811.0
Amount of backwater caused by bridge 0.4

Incipient overtopping discharge 1,320 *ft³/s*
Water-surface elevation in bridge opening 807.7 *ft*
Area of flow in bridge opening 158 *ft²*
Average velocity in bridge opening 8.4 *ft/s*
Maximum WSPRO tube velocity at bridge 9.8 *ft/s*

Water-surface elevation at Approach section with bridge 809.4
Water-surface elevation at Approach section without bridge 808.3
Amount of backwater caused by bridge 1.1 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of the live-bed contraction scour equation (Richardson and others, 1993, p. 33, equation 16). For contraction scour computations, 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. All three discharges resulted in submerged orifice flow. The results of Chang's contraction scour (Richardson and others, 1995, p. 145-146) for these events were also computed and can be found in appendix F. Because the Chang equation for pressure flow scour was derived solely with data for clear-water scour, it is not currently understood how well it would predict in live-bed conditions. Therefore, although pressure flow conditions exist for all three of the modelled flows, the reported scour depths were computed using Laursen's live-bed contraction scour equation. In this case, the incipient road-overflow model resulted in the worst-case contraction scour with a scour depth of 3.4 ft. The incipient road-overflow also resulted in the worst-case total scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). 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	1.0	0.0	3.4
Clear-water scour	--	--	--
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	9.5	10.4	8.2
Right abutment	7.1	7.3	9.2
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	1.4	1.1	1.9
Right abutment	1.4	1.1	1.9
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

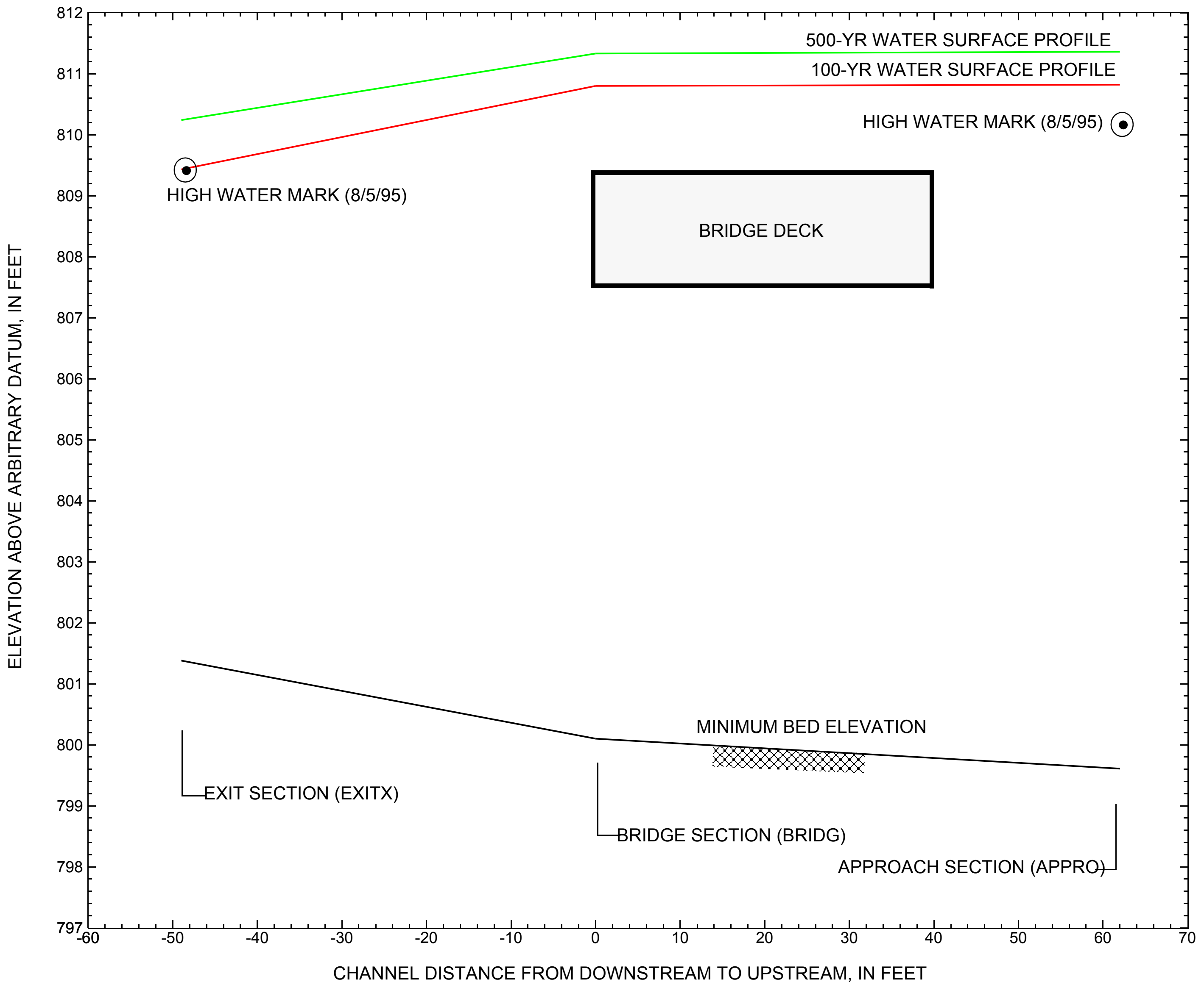

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure HARDELMSTR0042 on Elm Street, crossing Cooper Brook, Hardwick, Vermont.

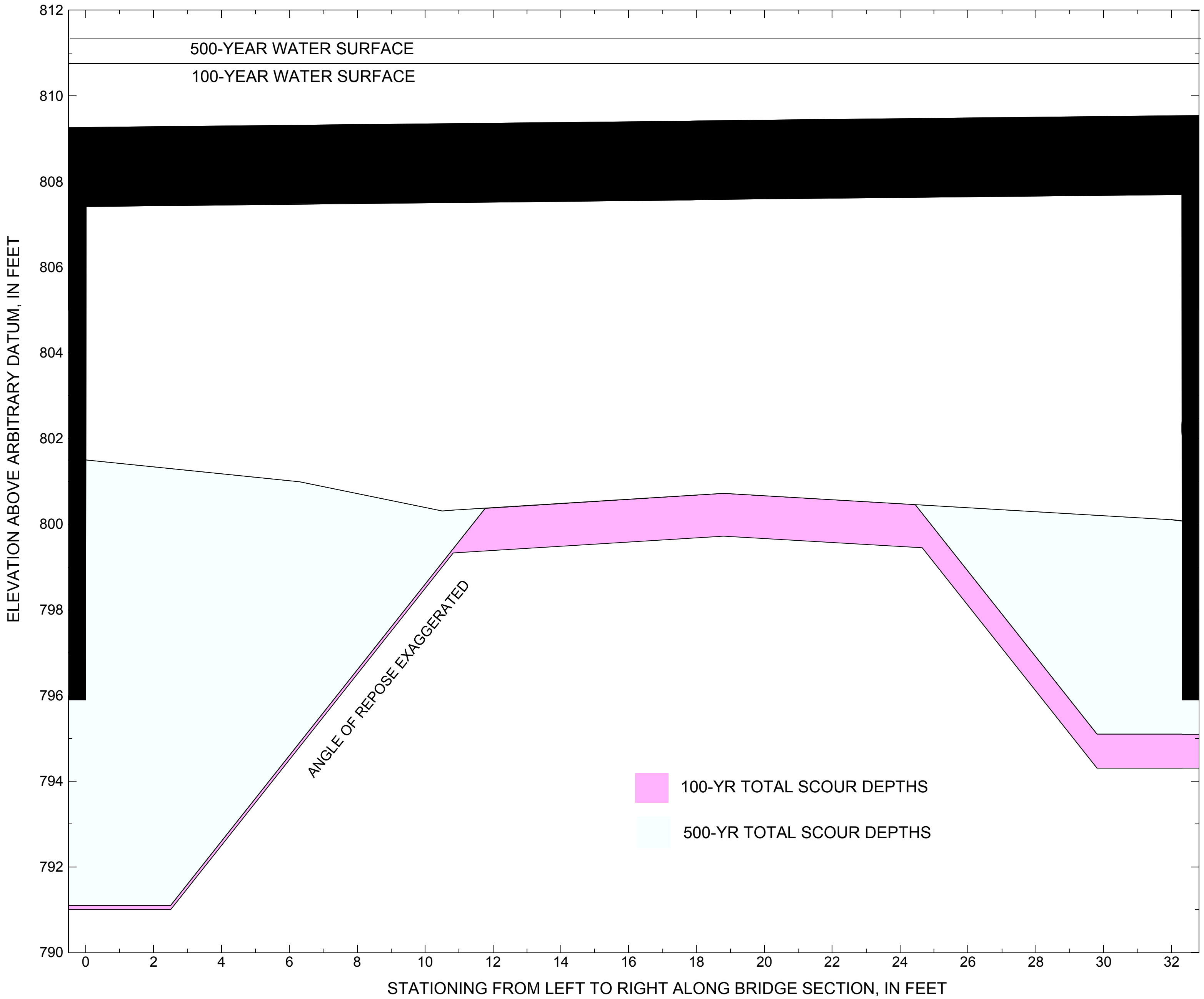

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure HARDELMSTR0042 on Elm Street, crossing Cooper Brook, Hardwick, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure HARDELMSTR0042 on Elm Street, crossing Cooper Brook, Hardwick, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum bridge seat 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 2,300 cubic-feet per second											
Left abutment	0.0	809.04	807.42	795.9	801.5	1.0	9.5	--	10.5	791.0	-4.9
Right abutment	32.3	809.26	807.70	795.9	802.4	1.0	7.1	--	8.1	794.3	-1.6

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 HARDELMSTR0042 on Elm Street, crossing Cooper Brook, Hardwick, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum bridge seat 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 3,200 cubic-feet per second											
Left abutment	0.0	809.04	807.42	795.9	801.5	0.0	10.4	--	10.4	791.1	-4.8
Right abutment	32.3	809.26	807.70	795.9	802.4	0.0	7.3	--	7.3	795.1	-0.8

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 hard042.wsp
T2        CREATED ON 14-AUG-95 FOR BRIDGE HARDELMST0042  USING FILE hard042.dca
T3        HYDRAULIC ANALYSIS OF HARD042     SAO
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2300 3200 1324
SK          0.0049 0.0049 0.0049
*
*           The following commented data is the pre-flood exit section data...
*
*           -70.5, 809.68    -21.0, 809.20    -12.0, 807.02     -5.2, 804.49
*             0.0, 802.30      2.3, 801.22      7.3, 800.09     11.6, 800.64
*            17.3, 801.27     23.0, 802.30     26.7, 804.01     29.2, 804.91
*            37.0, 808.45     62.7, 809.26     92.2, 809.39    105.3, 808.00
*           117.3, 812.62    174.6, 817.39
*
XS   EXITX   -49
GR         -300.0, 811.94
GR          -70.5, 809.68    -21.0, 809.20    -12.0, 807.60     -5.2, 804.76
GR            0.0, 801.89      2.3, 801.38      7.3, 801.43     11.6, 801.63
GR           17.3, 801.66     23.0, 802.30     26.7, 804.01     29.2, 804.91
GR           37.0, 808.45     62.7, 809.26     92.2, 809.39    105.3, 808.00
GR          117.3, 812.62    174.6, 817.39
N              0.060     0.040     0.040
SA                  -21        37
*
XS   FULLV   0
*
*            The following commented data is the pre-flood x-section
*            data for the bridge...
*
*             0.0, 807.37      0.0, 804.26      6.3, 802.32     10.5, 801.37
*            18.8, 800.67     26.9, 800.41     32.1, 800.67     32.3, 802.36
*            32.3, 807.62      0.0, 807.37
*
BR   BRIDG   0 807.5 45
GR            0.0, 807.42      0.0, 801.48      6.3, 800.99     10.5, 800.31
GR           18.8, 800.72     26.9, 800.34     32.1, 800.10     32.3, 802.36
GR           32.3, 807.70      0.0, 807.42
N            0.032
CD           1 50.5 * * 42.5 10.4
*
XR   RDWAY   20 25.4 2
GR         -300.0, 812.20
GR         -151.8, 810.46   -110.0, 809.97      0.0, 809.28     31.9, 809.51
GR           63.8, 809.87     89.8, 810.09     91.0, 813.14    108.0, 822.29
BP           0
*
*            The following commented data is the pre-flood x-section
*            data for the approach...
*
*          -232.6, 810.73   -207.4, 810.37    -93.3, 809.45    -35.5, 809.51
*           -19.7, 809.09    -15.7, 808.03     -6.0, 804.33     -3.1, 803.93
*             0.0, 802.37      2.9, 800.81      6.9, 800.52     10.2, 800.23
*            17.8, 800.71     21.4, 802.25     23.2, 803.08     24.7, 804.32
```

```
*           27.4, 804.62     34.3, 809.87     46.4, 810.78     58.3, 820.41
*
XT   SURVA     81
GR         -300.0, 811.69
GR         -232.6, 810.73   -207.4, 810.37    -93.3, 809.45    -35.5, 809.51
GR          -19.7, 809.09    -15.7, 808.03     -6.0, 804.33     -3.1, 804.10
GR            0.0, 801.92      2.9, 801.65      6.9, 801.14     10.2, 800.62
GR           17.8, 799.82     21.4, 800.29     23.2, 801.21     24.7, 804.28
GR           27.4, 804.62     34.3, 809.87     46.4, 810.78     58.3, 820.41
*
*            The following GT value is based upon the slope between the
*            bridge and approach thalwegs
*
AS   APPRO     62
GT            -0.21
N            0.051      0.040     0.055
SA                -19.7       34.3
BP           0
*
HP 1 BRIDG    807.70 1 807.70
HP 2 BRIDG    807.70 * * 1146
HP 2 RDWAY    810.80 * * 1154
HP 1 APPRO    810.82 1 810.82
HP 2 APPRO    810.82 * * 2300
*
HP 1 BRIDG    807.70 1 807.70
HP 2 BRIDG    807.70 * * 1008
HP 2 RDWAY    811.33 * * 2198
HP 1 APPRO    811.36 1 811.36
HP 2 APPRO    811.36 * * 3200
*
HP 1 BRIDG    807.70 1 807.70
HP 2 BRIDG    807.70 * * 1324
HP 1 APPRO    809.37 1 809.37
HP 2 APPRO    809.37 * * 1324
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard042.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDELMST0042  USING FILE hard042.dca
        HYDRAULIC ANALYSIS OF HARD042      SAO
           *** RUN DATE & TIME: 08-23-95  10:04
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     158.  14181.     0.    59.                    8175169.
   807.70          158.  14181.     0.    59.  1.00     0.   32.8175169.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       807.70     0.0    32.3   158.2   14181.    1146.   7.24
 X STA.        0.0         3.1         5.1         6.8         8.4         9.9
   A(I)            13.2         8.8         7.9         7.6         7.2
   V(I)            4.34        6.52        7.23        7.58        7.91

 X STA.        9.9        11.3        12.6        14.0        15.4        16.7
   A(I)             7.1         6.9         6.8         6.9         6.8
   V(I)            8.07        8.26        8.46        8.32        8.39

 X STA.       16.7        18.1        19.6        21.0        22.4        23.8
   A(I)             6.8         7.0         6.8         7.0         7.0
   V(I)            8.40        8.19        8.43        8.21        8.16

 X STA.       23.8        25.1        26.6        28.1        29.7        32.3
   A(I)             7.0         7.3         7.8         8.5        13.8
   V(I)            8.19        7.87        7.35        6.75        4.16

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      20.
         WSEL     LEW     REW    AREA        K        Q    VEL
       810.80  -180.8    90.1   260.3    8379.    1154.   4.43
 X STA.     -180.8      -108.1       -85.4       -66.7       -51.7       -38.8
   A(I)            30.9        20.8        19.4        17.3        15.9
   V(I)            1.86        2.78        2.97        3.33        3.63

 X STA.      -38.8       -27.1       -18.1       -11.9        -5.9        -0.2
   A(I)            15.4        12.4         8.7         8.8         8.5
   V(I)            3.74        4.65        6.61        6.54        6.79

 X STA.       -0.2         5.6        11.5        17.9        24.5        31.7
   A(I)             8.7         8.7         9.0         9.0         9.5
   V(I)            6.63        6.62        6.39        6.42        6.05

 X STA.       31.7        39.5        48.7        59.4        72.4        90.1
   A(I)             9.7        10.6        11.1        11.9        13.7
   V(I)            5.96        5.46        5.18        4.83        4.21

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     260.   8148.   234.   234.                        1555.
             2     397.  52323.    54.    60.                        6105.
             3       9.    180.    12.    13.                          40.
   810.82          665.  60651.   300.   306.  1.82  -254.    47.   4165.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
         WSEL     LEW     REW    AREA        K        Q    VEL
       810.82  -253.7    46.7   665.4   60651.    2300.   3.46
 X STA.     -253.7      -108.4       -53.8       -13.9        -7.3        -3.5
   A(I)           120.0        84.6        71.3        32.3        25.8
   V(I)            0.96        1.36        1.61        3.56        4.45

 X STA.       -3.5        -0.3         2.0         4.2         6.2         8.1
   A(I)            25.2        21.1        20.2        19.7        19.0
   V(I)            4.57        5.46        5.70        5.83        6.04

 X STA.        8.1        10.0        11.8        13.5        15.2        16.9
   A(I)            18.8        18.7        18.2        18.5        18.8
   V(I)            6.11        6.15        6.31        6.22        6.11

 X STA.       16.9        18.6        20.4        22.5        26.1        46.7
   A(I)            19.2        20.0        22.0        28.6        43.3
   V(I)            6.00        5.74        5.22        4.02        2.65
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard042.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDELMST0042  USING FILE hard042.dca
        HYDRAULIC ANALYSIS OF HARD042     SAO
           *** RUN DATE & TIME: 08-23-95  10:04
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     158.   14181.     0.    59.                      8175169.
   807.70          158.   14181.     0.    59.  1.00     0.   32.8175169.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       807.70     0.0    32.3   158.2  14181.    1008.   6.37
 X STA.         0.0         3.1         5.1         6.8         8.4         9.9
  A(I)             13.2         8.8         7.9         7.6         7.2
  V(I)             3.82        5.73        6.36        6.66        6.96

 X STA.         9.9        11.3        12.6        14.0        15.4        16.7
  A(I)              7.1         6.9         6.8         6.9         6.8
  V(I)             7.10        7.26        7.44        7.32        7.38

 X STA.        16.7        18.1        19.6        21.0        22.4        23.8
  A(I)              6.8         7.0         6.8         7.0         7.0
  V(I)             7.39        7.20        7.42        7.22        7.18

 X STA.        23.8        25.1        26.6        28.1        29.7        32.3
  A(I)              7.0         7.3         7.8         8.5        13.8
  V(I)             7.21        6.92        6.46        5.94        3.66

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      20.
         WSEL     LEW     REW    AREA        K        Q    VEL
       811.33  -225.9    90.3   415.8  16208.    2198.   5.29
 X STA.      -225.9      -133.3      -105.7       -84.7       -67.0       -51.4
  A(I)             50.3        34.4        30.5        27.9        26.3
  V(I)             2.19        3.19        3.60        3.95        4.18

 X STA.       -51.4       -37.6       -24.9       -16.1        -9.0        -2.3
  A(I)             24.4        23.5        16.9        14.0        13.4
  V(I)             4.50        4.68        6.49        7.86        8.19

 X STA.        -2.3         4.4        11.3        18.4        26.0        33.9
  A(I)             13.7        13.8        13.9        14.2        14.5
  V(I)             8.04        7.96        7.92        7.73        7.56

 X STA.        33.9        42.5        52.3        63.0        75.1        90.3
  A(I)             15.0        16.1        16.4        17.1        19.5
  V(I)             7.33        6.81        6.70        6.42        5.65

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     397.   14900.   272.   272.                         2718.
             2     426.   58885.    54.    60.                         6790.
             3      15.     460.    13.    13.                           95.
   811.36          838.   74246.   339.   345.  1.97  -292.    47.   5331.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
         WSEL     LEW     REW    AREA        K        Q    VEL
       811.36  -291.6    47.4   838.0  74246.    3200.   3.82
 X STA.      -291.6      -149.6       -98.4       -57.5       -20.6        -9.0
  A(I)            133.3        95.8        86.0        79.2        46.4
  V(I)             1.20        1.67        1.86        2.02        3.45

 X STA.        -9.0        -4.6        -0.9         1.7         4.1         6.3
  A(I)             30.5        29.0        25.5        23.5        22.7
  V(I)             5.25        5.52        6.26        6.81        7.05

 X STA.         6.3         8.5        10.5        12.4        14.4        16.2
  A(I)             22.5        21.8        21.7        22.0        21.3
  V(I)             7.12        7.35        7.39        7.27        7.49

 X STA.        16.2        18.2        20.2        22.5        26.4        47.4
  A(I)             22.7        23.2        25.4        33.1        52.5
  V(I)             7.04        6.90        6.30        4.84        3.05
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard042.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDELMST0042  USING FILE hard042.dca
        HYDRAULIC ANALYSIS OF HARD042     SAO
           *** RUN DATE & TIME: 08-23-95  10:04
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      158.   14181.     0.    59.                    8175169.
   807.70           158.   14181.     0.    59.  1.00     0.   32.8175169.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA         K        Q    VEL
       807.70     0.0    32.3   158.2   14181.    1324.   8.37
X STA.        0.0        3.1        5.1        6.8        8.4        9.9
  A(I)           13.2        8.8        7.9        7.6        7.2
  V(I)           5.01       7.53       8.35       8.75       9.14

X STA.        9.9       11.3       12.6       14.0       15.4       16.7
  A(I)            7.1        6.9        6.8        6.9        6.8
  V(I)           9.33       9.54       9.77       9.62       9.70

X STA.       16.7       18.1       19.6       21.0       22.4       23.8
  A(I)            6.8        7.0        6.8        7.0        7.0
  V(I)           9.71       9.46       9.74       9.49       9.43

X STA.       23.8       25.1       26.6       28.1       29.7       32.3
  A(I)            7.0        7.3        7.8        8.5       13.8
  V(I)           9.47       9.09       8.49       7.80       4.81

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       11.      82.    90.    90.                         23.
             2      319.   36482.    54.    59.                       4408.
   809.37           330.   36565.   143.   149.  1.06  -109.    34.   2752.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
         WSEL     LEW     REW    AREA         K        Q    VEL
       809.37  -109.4    33.9   329.9   36565.    1324.   4.01
X STA.     -109.4       -7.7       -3.8       -0.7        1.4        3.3
  A(I)           39.8       20.5       18.9       16.2       14.6
  V(I)           1.66       3.23       3.50       4.10       4.54

X STA.        3.3        5.0        6.7        8.2        9.7       11.1
  A(I)           14.1       13.8       13.2       12.9       12.4
  V(I)           4.70       4.80       5.00       5.12       5.32

X STA.       11.1       12.5       13.8       15.2       16.5       17.8
  A(I)           12.6       12.5       12.5       12.7       12.7
  V(I)           5.23       5.32       5.28       5.23       5.22

X STA.       17.8       19.2       20.7       22.4       25.4       33.9
  A(I)           13.4       14.2       15.3       21.0       26.5
  V(I)           4.93       4.66       4.32       3.15       2.49
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard042.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDELMST0042  USING FILE hard042.dca
        HYDRAULIC ANALYSIS OF HARD042     SAO
           *** RUN DATE & TIME: 08-23-95  10:04

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

EXITX:XS   ******   -45.     332.  0.87 *****  810.30  807.54   2300.  809.43
      -49. ******   109.   32856.  1.16 ***** *******    0.90    6.93

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.80     809.84     807.54

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   808.93     817.39    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   808.93     817.39     807.54

FULLV:FV      49.   -85.     401.  0.67  0.20  810.50  807.54   2300.  809.82
        0.    49.   110.   38520.  1.31  0.00   -0.01    0.81    5.74
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      62.  -207.     482.  0.53  0.18  810.69 *******   2300.  810.15
       62.    62.    41.   47287.  1.51  0.00    0.01    0.74    4.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   809.82     807.50

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =    1154.       947.    1.22

            <<<<<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      49.     0.     158.  0.82 *****  808.52  804.91   1146.  807.70
        0. ******    32.   14181.  1.00 ***** *******    0.58    7.25

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  807.50 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.    37.  0.05  0.34  811.10    0.00   1154.  810.80

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    815.   197.  -181.    17.   1.5   0.9   5.0   4.5   1.2   3.0
   RT:    338.    73.    17.    90.   1.4   1.1   5.1   4.4   1.4   2.9

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

APPRO:AS      12.  -253.     664.  0.34  0.06  811.16  806.80   2300.  810.82
       62.    17.    47.   60577.  1.82  0.00    0.00    0.55    3.46

 FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -49.   -45.   109.   2300.   32856.     332.    6.93  809.43
   FULLV:FV       0.   -85.   110.   2300.   38520.     401.    5.74  809.82
   BRIDG:BR       0.     0.    32.   1146.   14181.     158.    7.25  807.70
   RDWAY:RG      20.*******   815.   1154.******************    2.00  810.80
   APPRO:AS      62.  -253.    47.   2300.   60577.     664.    3.46  810.82

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    807.54    0.90  801.38  817.39************  0.87  810.30  809.43
   FULLV:FV    807.54    0.81  801.38  817.39  0.20  0.00  0.67  810.50  809.82
   BRIDG:BR    804.91    0.58  800.10  807.70************  0.82  808.52  807.70
   RDWAY:RG  ****************  809.28  822.29  0.05******  0.34  811.10  810.80
   APPRO:AS    806.80    0.55  799.61  820.20  0.06  0.00  0.34  811.16  810.82
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard042.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDELMST0042  USING FILE hard042.dca
        HYDRAULIC ANALYSIS OF HARD042     SAO
           *** RUN DATE & TIME: 08-23-95  10:04

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

EXITX:XS   ******  -127.     490.  0.98 *****  811.21  809.02   3200.  810.24
      -49. ******   111.   45672.  1.48 ***** *******    0.97    6.53

FULLV:FV      49.  -178.     622.  0.68  0.20  811.42 *******   3200.  810.74
        0.    49.   112.   56086.  1.66  0.00    0.01    0.80    5.14
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      62.  -269.     733.  0.56  0.17  811.60 *******   3200.  811.04
       62.    62.    47.   65838.  1.89  0.00    0.01    0.70    4.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   810.74     807.50

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =     2198.      1662.    1.32

            <<<<<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      49.     0.     158.  0.63 *****  808.33  804.56   1008.  807.70
        0. ******    32.   14181.  1.00 ***** *******    0.51    6.37

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  807.50 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.    37.  0.07  0.45  811.74    0.00   2198.  811.33

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1583.   242.  -226.    17.   2.0   1.2   6.0   5.3   1.6   3.1
   RT:    615.    74.    17.    90.   1.9   1.6   6.3   5.3   2.0   3.0

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

APPRO:AS      12.  -291.     837.  0.45  0.08  811.80  808.03   3200.  811.36
       62.    20.    47.   74155.  1.97  0.00    0.00    0.60    3.82

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -49.  -127.   111.   3200.   45672.     490.    6.53  810.24
   FULLV:FV       0.  -178.   112.   3200.   56086.     622.    5.14  810.74
   BRIDG:BR       0.     0.    32.   1008.   14181.     158.    6.37  807.70
   RDWAY:RG      20.*******  1583.   2198.******************    2.00  811.33
   APPRO:AS      62.  -291.    47.   3200.   74155.     837.    3.82  811.36

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    809.02    0.97  801.38  817.39************  0.98  811.21  810.24
   FULLV:FV  ********    0.80  801.38  817.39  0.20  0.00  0.68  811.42  810.74
   BRIDG:BR    804.56    0.51  800.10  807.70************  0.63  808.33  807.70
   RDWAY:RG  ****************  809.28  822.29  0.07******  0.45  811.74  811.33
   APPRO:AS    808.03    0.60  799.61  820.20  0.08  0.00  0.45  811.80  811.36
```
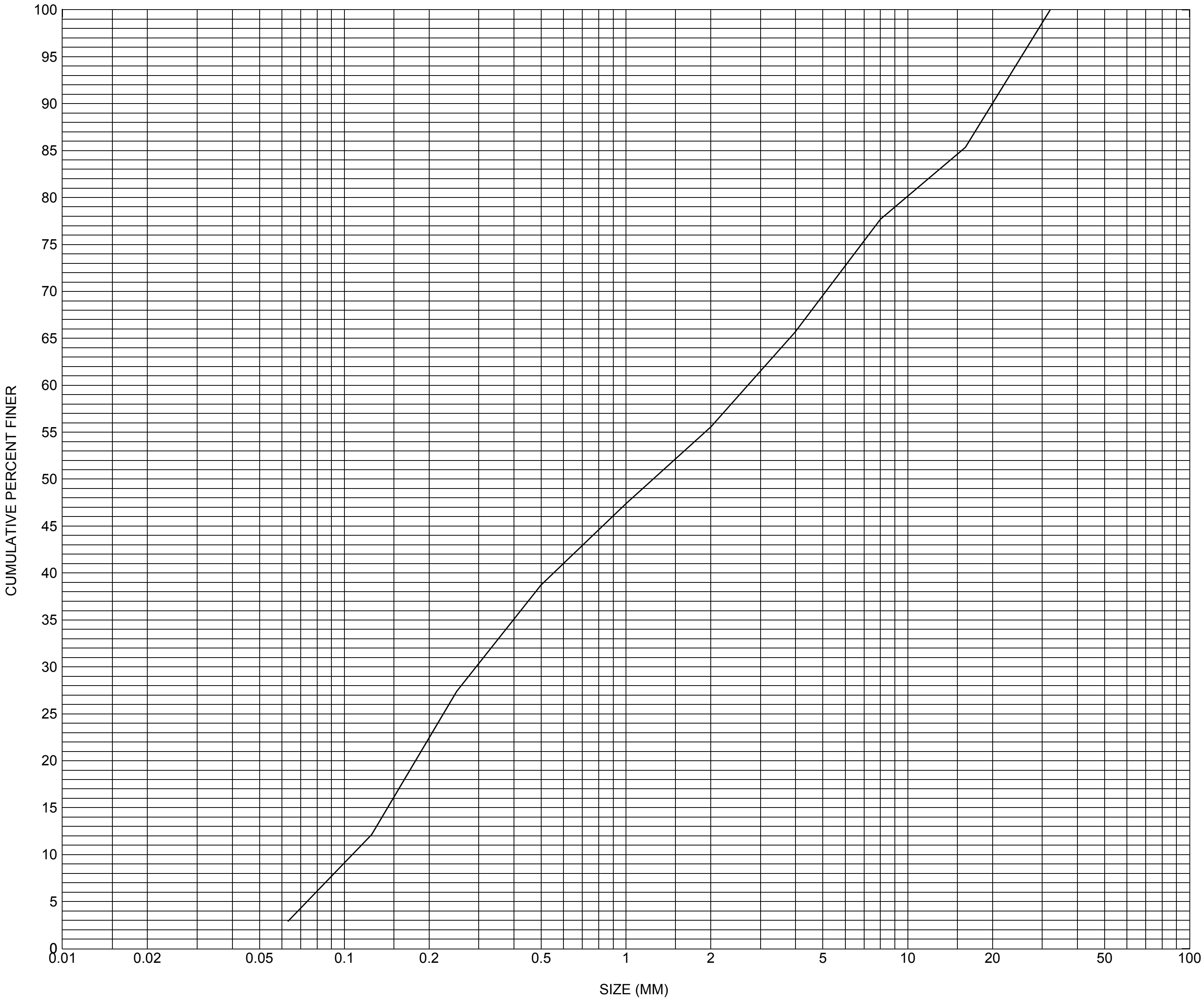

WSPRO OUTPUT FILE (continued)

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard042.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDELMST0042  USING FILE hard042.dca
        HYDRAULIC ANALYSIS OF HARD042     SAO
           *** RUN DATE & TIME: 08-23-95  10:04

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

EXITX:XS   ******   -12.     200.  0.68 *****  808.26  805.96   1324.  807.58
      -49. ******    35.   18900.  1.00 ***** *******    0.57    6.62

FULLV:FV      49.   -14.     216.  0.59  0.22  808.49 *******   1324.  807.90
        0.    49.    36.   20694.  1.00  0.00    0.01    0.52    6.14
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      62.   -17.     262.  0.40  0.19  808.68 *******   1324.  808.28
       62.    62.    32.   27564.  1.00  0.00    0.00    0.39    5.06
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   807.90     807.50

            <<<<<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      49.     0.     158.  1.09 *****  808.79  805.34   1323.  807.70
        0. ******    32.   14181.  1.00 ***** *******    0.67    8.36

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   3.  0.800  0.000  807.50 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.        <<<<<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      12.  -110.     331.  0.27  0.04  809.64  805.15   1324.  809.37
       62.    12.    34.   36611.  1.07  0.00    0.00    0.48    4.01

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   809.33

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -49.   -12.    35.   1324.   18900.     200.    6.62  807.58
   FULLV:FV       0.   -14.    36.   1324.   20694.     216.    6.14  807.90
   BRIDG:BR       0.     0.    32.   1323.   14181.     158.    8.36  807.70
   RDWAY:RG      20.**************      0.       0.       0.    2.00********
   APPRO:AS      62.  -110.    34.   1324.   36611.     331.    4.01  809.37

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    805.96    0.57  801.38  817.39************  0.68  808.26  807.58
   FULLV:FV  ********    0.52  801.38  817.39  0.22  0.00  0.59  808.49  807.90
   BRIDG:BR    805.34    0.67  800.10  807.70************  1.09  808.79  807.70
   RDWAY:RG  ****************  809.28  822.29************  0.27  809.59********
   APPRO:AS    805.15    0.48  799.61  820.20  0.04  0.00  0.27  809.64  809.37
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for bed sample taken from the channel approach of structure HARDELMSTR0042, in Hardwick, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number HARDELMSTR0042

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)* COOPER BROOK

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

Route Number -

Vicinity *(I - 9)* ON ELM ST 0.2 MI W VT 15

Topographic Map Caspian.Lake

Hydrologic Unit Code: 02010005

Latitude *(I - 16; nnnn.n)* 44302

Longitude *(i - 17; nnnnn.n)* 72226

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030500420305

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

Maximum span length *(I - 48; nnnn)* 0037

Year built *(I - 27; YYYY)* 1985

Structure length *(I - 49; nnnnnn)* 000039

Average daily traffic, ADT *(I - 29; nnnnnn)* 000075

Deck Width *(I - 52; nn.n)* 254

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

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

Opening skew to Roadway *(I - 34; nn)* 48

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

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

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

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 025.0

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

Vertical clearance from streambed (*nnn.n ft*) 006.7

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

Waterway of full opening (*nnn.n* ft^2) 175.0

Comments:

The structural inspection report of 5/21/93 indicates the structure is a concrete slab type bridge. The deck is curved. The abutment walls and wingwalls are concrete. The right abutment reportedly has two fine vertical cracks and small leaks. Similarly the left abutment has three fine vertical cracks noted. The report also indicates that there is stone fill protection placed around the ends of the wingwalls and at least partially along the banks. Much of the visible stone fill, originally placed in front of the left abutment, was used to build a small “homemade” dam across the channel just downstream of the bridge.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **16.4**

Terrain character: **Hilly**

Stream character & type: **Straight and a tributary to the Lamoille River.**

Streambed material: **Sandy to sandy gravel**

Discharge Data *(cfs)*: $Q_{2.33}$ **725** Q_{10} **1200** Q_{25} **1500**

Q_{50} **1900** Q_{100} **2300** Q_{500} **-**

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

Estimated Discharge *(cfs)*: **-** Velocity at Q **25** *(ft/s)*: **5.5**

Ice conditions *(Heavy, Moderate, Light)* : **Moderate** Debris *(Heavy, Moderate, Light)*: **Mod. to Heavy**

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

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

Describe any significant site conditions upstream or downstream that may influence the stream's stage: **The stage of the river at this site is influenced during high frequency floods and ice jamming due to the Lamoille river about 0.5 miles downstream.**

Watershed storage area (*in percent*): **5** %

The watershed storage area is: **1** (*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*)	806.6	808.5	809.6	811.2	811.9
Velocity (*ft / sec*)	5.7	6.7	8.6	10.9	13.1

Long term stream bed changes: **Estimated scour depths are expected to be between 1 and 3 feet.**

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): **Y** Frequency: **Q45**

Relief Elevation (*ft*): **811.0** Discharge over roadway at Q_{100} (*ft³/ sec*): **475.0**

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

Upstream distance (*miles*): **0.5** Town: **Hardwick** Year Built: **-**

Highway No. : **VT14** Structure No. : **92&93** Structure Type: **-**

Clear span (*ft*): **7.0** Clear Height (*ft*): **7.0** Full Waterway (*ft²*): **49.0**

Downstream distance (*miles*): **0.5** Town: **Hardwick** Year Built: **-**

Highway No. : **VT15** Structure No. : **67** Structure Type: **-**

Clear span (*ft*): **59.0** Clear Height (*ft*): **6.0** Full Waterway (ft^2): **354.0**

Comments:

The stone fill class recommended for bank protection at this site is type II.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **16.56** mi^2 Lake and pond area **.791** mi^2

Watershed storage *(ST)* **4.78** %

Bridge site elevation **820** ft Headwater elevation **1929** ft

Main channel length **7.495** mi

10% channel length elevation **824** ft 85% channel length elevation **1421** ft

Main channel slope *(S)* **106.2** 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):* **04** / **1984**

Project Number **BRZ1447(3)** Minimum channel bed elevation: **803.0**

Low superstructure elevation: USLAB **809.04** DSLAB **808.62** USRAB **809.26** DSRAB **808.87**

Benchmark location description:

Bronze disk [center of engraved triangle] on top of the concrete near the corner of the downstream right wingwall where it meets the right abutment, elevation 811.57.

Reference Point (*MSL, Arbitrary, Other*): **MSL** Datum (*NAD27, NAD83, Other*): **NAD1929**

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **798.0**

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? **Y** *If no, type ctrl-n bi* Number of borings taken: **2**

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

Briefly describe material at foundation bottom elevation or around piles:

The footings are set in a wet, brown, sandy gravel.

Comments:

Other points displayed on the plans with elevations are: 1) The point on the top streamward edge of the concrete upstream left wingwall where the concrete meets the left abutment, elevation 811.70, and 2) the point at the top streamward edge of the concrete upstream right wingwall where the concrete slope changes from horizontal to downward, elevation 812.00.

Cross-sectional Data

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

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

Comments: **Orientation of the cross sections is inconsistent with any cross section data surveyed for this study and is not comparable. Data was not retrieved.**

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: MAI Date: 09/13/95
Computerized by: MAI Date: 09/12/95
Reviewd by: SAO Date: 8/23/96

Structure Number HARDELMST0042

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. Hammond   Date *(MM/DD/YY)* 07 / 24 / 1995
2. Highway District Number 7   Mile marker 0
County Caledonia (005)   Town Hardwick (31750)
Waterway *(I - 6)* Cooper Brook   Road Name Elm Street
Route Number -   Hydrologic Unit Code: 02010005
3. Descriptive comments:
On Elm Street 0.2 miles west of VT 15.
Site revisited on 08/17/95 by J. Ayotte after high water flows. Comments made during the revisit are in *italics*.

B. Bridge Deck Observations

4. Surface cover... LBUS 2   RBUS 6   LBDS 2   RBDS 2   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 1   UB 1   DS 1   *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 39.0 *(feet)*   Span length 37.0 *(feet)*   Bridge width 25.4 *(feet)*

Road approach to bridge:

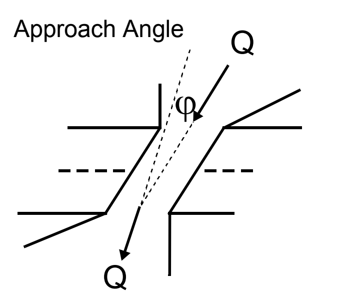
8. LB 2   RB 2   *(**0** even, **1-** lower, **2-** higher)*
9. LB 2   RB 2   *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left --:1   US right 2.5:1

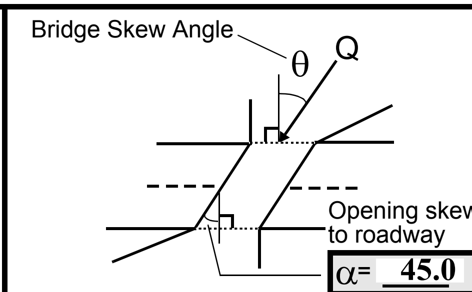
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	2	2
RBDS	0	-	0	-
LBDS	0	-	2	2

*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: 20   16. Bridge skew: 40





17. Channel impact zone 1:   Exist? Y *(Y or N)*
Where? RB *(LB, RB)*   Severity 2
Range? 15 feet US *(US, UB, DS)* to 0 feet US
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 & 4**

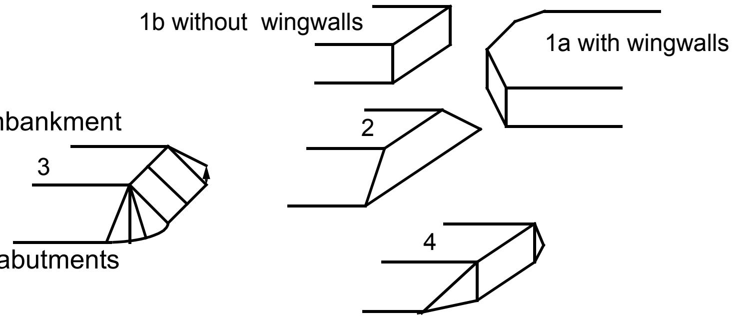
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. Left bank upstream is used to store lumber and is relatively flat. There are logs and cut lumber.

7. Measured length upstream 36.7 and downstream 39.7, span upstream 32.3 and downstream 34.6, and width 25.4 feet.

8. Road is slightly higher than the bridge deck.

18. Upstream bridge face right wingwall is type 4 and left is type 1a. The downstream bridge face right wingwall is type 1a and left is type 4.

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
41.0	**5.5**			**7.0**	**1**	**2**	**2**	**2**	**1**	**1**

23. Bank width **20.0** 24. Channel width **30.0** 25. Thalweg depth **50.0** 29. Bed Material **32**

30 .Bank protection type: LB **2** RB **1** 31. Bank protection condition: LB **2** RB **3**

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

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

27. Bank material consist of sand.

28. Bed material consist of gravel and sand.

30. Left bank protection extent is 57 to 64 feet upstream.
Right bank protection extent is along the base of the wingwall to 23 feet upstream. The protection is sparse.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **0** 35. Mid-bar width: **6**
36. Point bar extent: **50** feet **US** (US, UB) to **55** feet **DS** (US, UB, DS) positioned **0** %LB to **20** %RB
37. Material: **23**
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
On 8/17/95, the point bar dimensions had changed to 10 ft US to 56 ft US. The mid-bar distance was 45 ft US and the mid-bar width was 7 ft.

39. Is a cut-bank present? **Y** (Y or if N type ctrl-n cb) 40. Where? **LB** (LB or RB)
41. Mid-bank distance: **80** 42. Cut bank extent: **90** feet **US** (US, UB) to **55** feet **US** (US, UB, DS)
43. Bank damage: **3** (1- eroded and/or creep; 2- slip failure; 3- block failure)
44. Cut bank comments (eg. additional cut banks, protection condition, etc.):
Roots are undercut and exposed. The cut is unusual in that it is on the inside of the bend.
On 8/17/95: Block failure with small trees fallen into the channel.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **10 US**
47. Scour dimensions: Length **10** Width **3** Depth : **1** Position **60** %LB to **75** %RB
48. Scour comments (eg. additional scour areas, local scouring process, etc.):
Small scour hole with a firm base.
On 08/17/95 the scour hole positioned 50% LB to 95% RB, from 0 to 58 feet upstream with a mid-scour distance at 20 feet US. Scour depth is 1.5 feet.

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
23.0		2.0		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.):
321
63. Bed material consist of gravel, sand, and some silt/clay.
On 8/17/95: A scour hole exists under the middle of the bridge from the upstream to the downstream face, positioned 15% LB to 100% RB, with a scour depth of 2 feet.
On 8/17/95: The under bridge portion of the left bank point bar has been removed from flows.

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

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

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

70. Debris and Ice Comments:

1

69. Hydraulic report indicated moderate ice conditions.

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		-	90	2	0	-	0	90.0
RABUT	1	20	90			2	1	23.0

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

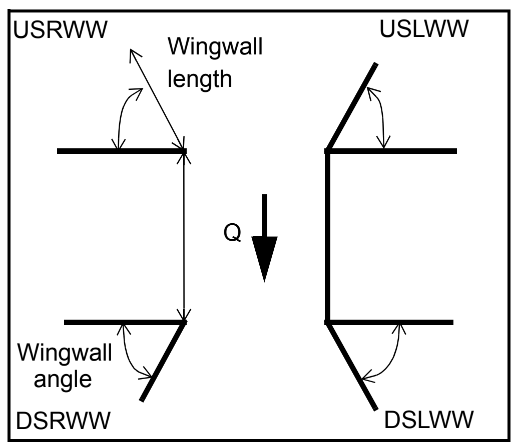
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

.5
0
1

75. The deepest part of channel under the bridge is along the right abutment. Footings not exposed.
On 8/17/95: the deepest point is at the center of the channel under the bridge.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						23.0	
USRWW:	Y		1		0	1.5	
DSLWW:	-		-		Y	38.0	
DSRWW:	1		0		-	41.5	



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

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

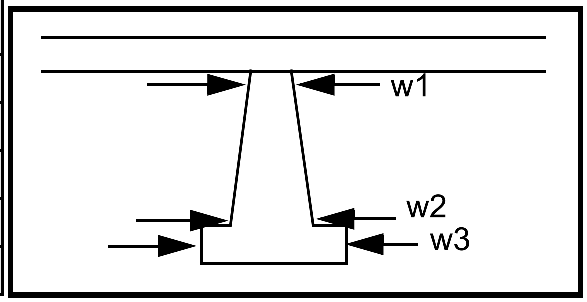
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
2
1
1

Piers:

84. Are there piers? **Pr** *(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				**10.0**	**19.0**	**105.0**
Pier 2	**11.5**	**9.0**		**95.0**	**20.0**	**20.5**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**otec-**	***alon***	***fine***	***the***	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**tion**	***g left***	***silt.***	***pro-***	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**is**	***abut-***	***Duri***	***tec-***	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**spar**	***ment***	***ng***	***tion***	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**se.**	***exist***	***pre-***	***had***	*Y- yes; N- no*
91. Attack ∠ (BF)	**82.**	***s and***	***vious***	***been***	
92. Pushed	***On***	***is***	***level***	***com-***	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	***8/17/***	***cov-***	***I***	***pletel***	
95. Cross-members	***95:***	***ered***	***data***	***y***	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	***pro-***	***by a***	***col-***	***cov-***	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	***tec-***	***layer***	***lec-***	***ered***	
98. Exposure depth	***tion***	***of***	***tion,***	***by a***	

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

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: 1______

Scour dimensions: Length 1_____ Width 2_____ Depth: 2____ Positioned 1____ %LB to 1____ %RB

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

231
0
0
-

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

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

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

Confluence comments (eg. confluence name):

sand.
Bed material consists of sand, gravel, and some silt/clay.

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

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 ANALYSIS

Structure Number: HARDELMST0042 Town: HARDWICK
Road Number: ELM STREET County: CALEDONIA
Stream: COOPER BROOK

Initials SAO Date: 08/23/95 Checked: EMB

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

Neills Equation
Vc=11.52*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1993, p. 31, eq. 14)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2300	3200	1324
Main Channel Area, ft2	397	426	319
Left overbank area, ft2	260	397	11
Right overbank area, ft2	9	15	0
Top width main channel, ft	54	54	54
Top width L overbank, ft	234	272	90
Top width R overbank, ft	12	13	0
D50 of channel, ft	0.00409	0.00409	0.00409
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	7.4	7.9	5.9
y1, average depth, LOB, ft	1.1	1.5	0.1
y1, average depth, ROB, ft	0.8	1.2	0.0
Total conveyance, approach	60651	74246	36565
Conveyance, main channel	52323	58885	36482
Conveyance, LOB	8148	14900	82
Conveyance, ROB	180	460	0
Percent discrepancy, conveyance	0	0.001347	0.002735
Qm, discharge, MC, cfs	1984.187	2537.941	1320.995
Ql, discharge, LOB, cfs	308.9875	642.1895	2.969178
Qr, discharge, ROB, cfs	6.825939	19.82598	0
Vm, mean velocity MC, ft/s	5.0	6.0	4.1
Vl, mean velocity, LOB, ft/s	1.2	1.6	0.3
Vr, mean velocity, ROB, ft/s	0.8	1.3	0.0
Vc-m, crit. velocity, MC, ft/s	2.6	2.6	2.5
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	0.0
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	0.0

Results

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

Main Channel	1	1	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 or ys=y2-y1
(Richardson and others, 1993, p. 33, eq. 16)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	2300	3200	1324	1146	1008	1324
Total conveyance	60651	74246	36565	14181	14181	14181
Main channel conveyance	52323	58885	36482	14181	14181	14181
Main channel discharge	1984	2538	1321	1146	1008	1324
Area - main channel, ft2	397	426	319	158	158	158
(W1) channel width, ft	54	54	54	22.8	22.8	22.8
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	54	54	54	22.8	22.8	22.8
D50, ft	0.00409	0.00409	0.00409			
w, fall velocity, ft/s (p. 34)	0.503	0.503	0.503			
y1, ave. depth flow, ft	7.351852	7.888889	5.907407	6.929825	6.929825	6.929825
S1, slope EGL	0.0031	0.0031	0.0031			
P, wetted perimeter, MC, ft	60	60	59			
R, hydraulic Radius, ft	6.616667	7.1	5.40678			
V*, shear velocity, ft/s	0.812697	0.841856	0.734646			
V*/w	1.615699	1.673671	1.460529			
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	0.64	0.64	0.64			
y2,depth in contraction, ft	7.97	6.21	10.28			
ys, scour depth, ft (y2-y_bridge)	1.04	-0.72	3.35			
ys, scour depth, ft (y2-y1)	0.62	-1.68	4.37			

ARMORING

D90	0.0655	0.0655	0.0655
D95	0.0829	0.0829	0.0829
Critical grain size,Dc, ft	23.49	18.17335	31.35377
Percent coarser than Dc	N/A	N/A	N/A
depth to armoring, ft	N/A	N/A	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	1146	1008	1324
Vc, critical velocity, ft/s	2.60	2.60	2.50
Vc, critical velocity, m/s	0.792441	0.792441	0.761963
Main channel width (skewed), ft	22.8	22.8	22.8

Cum. width of piers, ft	0	0	0
W, adjusted width, ft	22.8	22.8	22.8
qbr, unit discharge, ft^2/s	50.26316	44.21053	58.07018
qbr, unit discharge, m^2/s	4.669144	4.106891	5.394369
Area of full opening, ft^2	158.2	158.2	158.2
Hb, depth of full opening, ft	6.938596	6.938596	6.938596
Hb, depth of full opening, m	2.114781	2.114781	2.114781
Fr, Froude number MC	0.58	0.51	0.67
Cf, Fr correction factor (<=1.0)	1	1	1
Elevation of Low Steel, ft	807.56	807.56	807.56
Elevation of Bed, ft	800.6214	800.6214	800.6214
Elevation of approach WS, ft	810.82	811.36	809.37
HF, bridge to approach, ft	0.06	0.08	0.04
Elevation of WS immediately US, ft	810.76	811.28	809.33
ya, depth immediately US, ft	10.1386	10.6586	8.708596
ya, depth immediately US, m	3.150589	3.31218	2.706214
Mean elev. of deck, ft	809.4	809.4	809.4
w, depth of overflow, ft (>=0)	1.36	0	0
Cc, vert contrac correction (<=1.0)	0.941789	0.885387	0.943868
Ys, depth of scour (chang), ft	13.58828	12.26663	17.67086

Abutment Scour

Froehlich's Abutment Scour

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

(Richardson and others, 1993, p. 49, eq. 24)

	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	2300	3200	1324	2300	3200	1324
a', abut.length blocking flow, ft	19.7	19.7	109.4	23.9	24.6	11.1
Ae, area of blocked flow ft2	67.9	72.1	84.6	42.1	41.8	44.7
Qe, discharge blocked abut.,cfs	--	--	220.7	--	--	123.6
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	3.91	4.71	2.61	3.17	3.70	2.77
ya, depth of f/p flow, ft	3.45	3.66	0.77	1.76	1.70	4.03
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	45	45	45	135	135	135
K2	0.913831	0.913831	0.913831	1.054124	1.054124	1.054124
Fr, froude number f/p flow	0.312	0.349	0.523	0.328	0.355	0.243
ys, scour depth, ft	9.54	10.41	8.22	7.14	7.29	9.18

HIRE equation (a'/ya > 25)

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

(Richardson and others, 1993, p. 50, eq. 25)

a'(abut length blocked, ft)	19.7	19.7	109.4	23.9	24.6	11.1
y1 (depth fp flow, ft)	3.45	3.66	0.77	1.76	1.70	4.03
a'/y1	5.72	5.38	141.47	13.57	14.48	2.76
Froude no. f/p flow	0.31	0.35	0.52	0.33	0.36	0.24
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	4.54	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	3.72	ERR	ERR	ERR
spill-through	ERR	ERR	2.50	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)

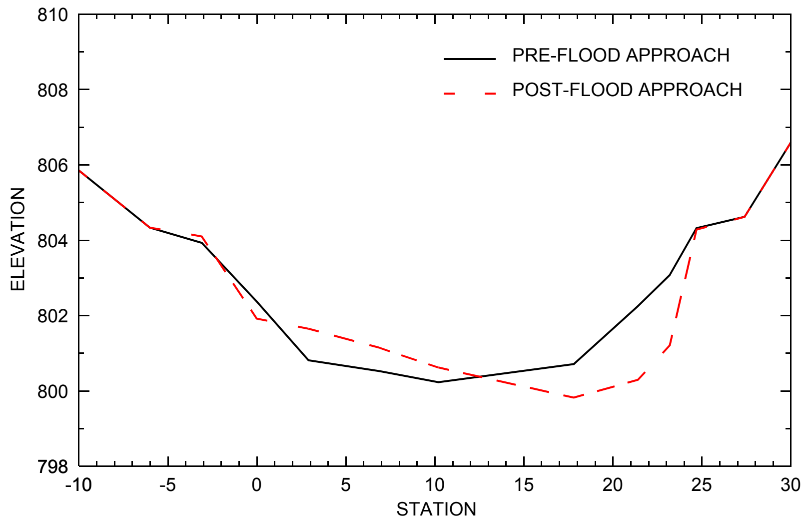
(Richardson and others, 1993, p118-119, eq. 93,94)

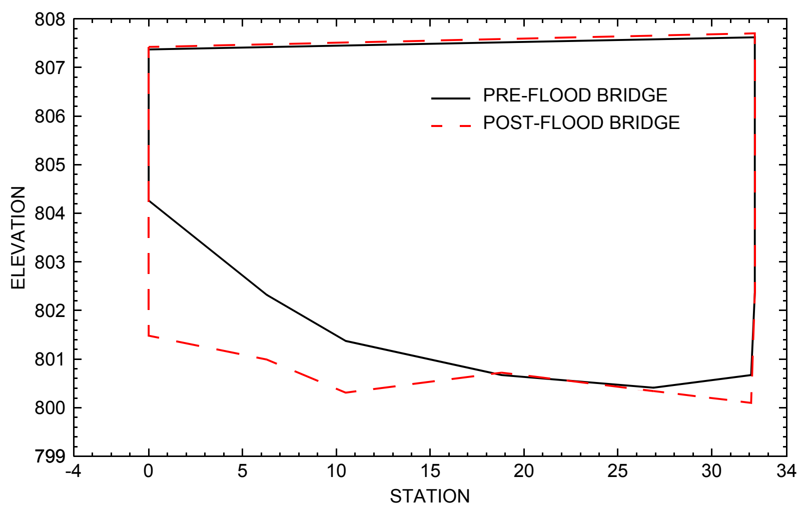
Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.58	0.51	0.67			
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	6.92	6.92	6.92			
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.44	1.11	1.92	0.00	0.00	0
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.26	0.97	1.68	0.00	0.00	0
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR

APPENDIX G:

POST AUGUST 5-6, 1995 FLOOD DATA FOR STRUCTURE HARDELMSTR0042

This appendix shows plots of pre- and post- flood channel surveys in the vicinity of Bridge 42 on Elm Street crossing Cooper Brook, in Hardwick, Vermont. Also included are photos from August 17, 1995 (after the flood event).





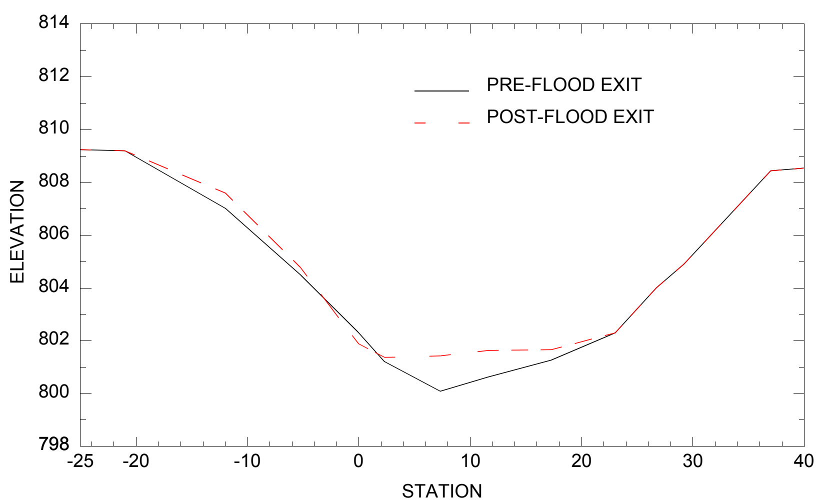


Figure G-1. Pre- (July 24, 1995) and post-flood (August 8, 1995) surveys of three cross sections in the vicinity of Hardwick bridge 42 on Elm Street, Hardwick, Vermont.

Figure G-2. Structure HARDELMSTR0042 viewed from upstream (August 17, 1995).

Figure G-3. Downstream channel viewed from structure HARDELMSTR0042 (August 17, 1995).

Figure G-4. Structure HARDELMSTR0042 viewed from downstream (August 17, 1995).

Figure G-5. Upstream channel viewed from structure HARDELMSTR0042 (August 17, 1995).