LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (SHRETH00060032) on TOWN HIGHWAY 6, crossing SARGENT BROOK, SHREWSBURY, VERMONT

Open-File Report 98-299

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (SHRETH00060032) on TOWN HIGHWAY 6, crossing SARGENT BROOK, SHREWSBURY, VERMONT

By RONDA L. BURNS and ERICK M. BOEHMLER

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Pembroke, New Hampshire

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

U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Velocity and Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2

OTHER ABBREVIATIONS

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

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 32 (SHRETH00060032) ON TOWN HIGHWAY 6, CROSSING SARGENT BROOK, SHREWSBURY, VERMONT

By **Ronda L. Burns and Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SHRETH00060032 on Town Highway 6 crossing Sargent Brook, also referred to as Branch of Cold River, Shrewsbury, 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 (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in south-central Vermont. The 6.34-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, Sargent Brook has an incised, sinuous channel with a slope of approximately 0.04 ft/ft, an average channel top width of 55 ft and an average bank height of 3 ft. The channel bed material ranges from sand to boulders with a median grain size (D_{50}) of 106.0 mm (0.348 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 28, 1995, indicated that the reach was stable.

The Town Highway 6 crossing of Sargent Brook is a 36-ft-long, one-lane bridge consisting of one 33-foot steel-stringer span (Vermont Agency of Transportation, written communication, March 15, 1995). The opening length of the structure parallel to the bridge face is 31.9 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is not skewed to the opening and the opening-skew-to-roadway is zero degrees.

During the Level I assessment, it was observed that the footings on the right abutment and downstream right wingwall were exposed up to 0.5 ft. Scour countermeasures at the site included type-2 stone fill (less than 36 inches diameter) along the left abutment, the downstream left wingwall, and at the downstream end of the downstream right wingwall. Type-3 stone fill (less than 48 inches diameter) was observed along the upstream right bank and the upstream left and right wingwalls. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. 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 0.3 to 1.0 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 6.1 to 7.8 ft and right abutment scour ranged from 13.2 to 17.5 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 Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number SHRETH00060032 ***Stream*** Sargent Brook

County Rutland ***Road*** TH 6 ***District*** 3

Description of Bridge

Bridge length 36 ***ft*** ***Bridge width*** 20.1 ***ft*** ***Max span length*** 33 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 9/28/95

Description of stone fill Type-2, along the left abutment, downstream left wingwall and at the downstream end of the downstream right wingwall. Type-3, along the upstream left and right wingwalls.

Brief description of piers/abutments Abutments and wingwalls are concrete. The footings on the right abutment and downstream right wingwall are exposed up to 0.5 ft.

Is bridge skewed to flood flow according to Yes ***survey?*** No ***Angle*** --

There is a moderate channel bend through the bridge.

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	9/28/95	0	0
Level II	9/28/95	0	0

Potential for debris Moderate. There is some debris scattered in the channel downstream.

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

A vegetated point bar, along the left bank and abutment, directed low flow towards the right abutment as of 9/28/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a narrow flood plain.

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

Date of inspection 9/28/95

DS left: Moderately sloped, irregular overbank

DS right: Steep valley wall

US left: Steep road embankment to a moderately sloped overbank

US right: Steep valley wall

Description of the Channel

Average top width 55 ***ft*** ***Average depth*** 3 ***ft***

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

Sinuous and locally braided with non-alluvial channel boundaries and narrow point bars.

Vegetative co 9/28/95

DS left: Trees

DS right: Trees

US left: Trees and brush

US right: Trees

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

Describe any obstructions in channel and date of observation. The assessment of 9/28/95 noted low flow conditions are influenced by a mid-channel bar in the downstream reach.

Hydrology

Drainage area 6.34 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/Green Mountain	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,800 ***ft³/s*** ***Q500*** 2,750 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database (written communication, May 1995). The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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 The USGS arbitrary survey datum was adjusted to the VTAOT plans' datum by subtracting 15.3 ft.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the left abutment (elev. 485.08 ft, arbitrary survey datum). RM2 is a steel stake with a yellow cap, 7 ft to the right and 14 ft upstream of the right abutment (elev. 483.08 ft, arbitrary survey datum). RM3 is a nail, 5 ft above the ground, in a telephone pole 20 ft from the upstream end of the right abutment (elev. 490.69 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	*Section Reference Distance (SRD) in feet*	*[2]Cross-section development*	*Comments*
EXIT1	-98	1	Exit section
EXITX	-35	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPR1	56	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 0.050 to 0.065, and the overbank "n" value was 0.080.

Critical depth at the exit section (EXIT1) was assumed for the 100- and 500-year discharges as the starting water surface. Normal depth was computed below critical depth approximately 0.4 ft, by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0380 ft/ft, which was estimated from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APPR1) was modelled one bridge length upstream of the upstream face, as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

For the 100- and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 485.5 *ft*
Average low steel elevation 482.7 *ft*

100-year discharge 1,800 *ft³/s*
Water-surface elevation in bridge opening 475.2 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 148 *ft²*
Average velocity in bridge opening 12.2 *ft/s*
Maximum WSPRO tube velocity at bridge 15.4 *ft/s*

Water-surface elevation at Approach section with bridge 478.3
Water-surface elevation at Approach section without bridge 476.7
Amount of backwater caused by bridge 1.6 *ft*

500-year discharge 2,750 *ft³/s*
Water-surface elevation in bridge opening 476.7 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 195 *ft²*
Average velocity in bridge opening 14.1 *ft/s*
Maximum WSPRO tube velocity at bridge 18.1 */s*

Water-surface elevation at Approach section with bridge 480.6
Water-surface elevation at Approach section without bridge 477.9
Amount of backwater caused by bridge 2.7 *ft*

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

Water-surface elevation at Approach section with bridge -
Water-surface elevation at Approach section without bridge -
Amount of backwater caused by bridge - *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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100- and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 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.

Because the influence of scour processes on the stone fill embankment material along the left abutment is uncertain, the scour depth at the left vertical concrete abutment wall is unknown. Therefore, the total scour depth computed at the toe of the embankment was applied for the entire stone fill embankment as shown in fig. 8.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.3	1.0	--
Depth to armoring	17.0	30.3	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	6.1	7.8	--
Right abutment	13.2	17.5	---
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	1.9	2.6	--
Right abutment	1.9	2.6	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--
	--	--	--

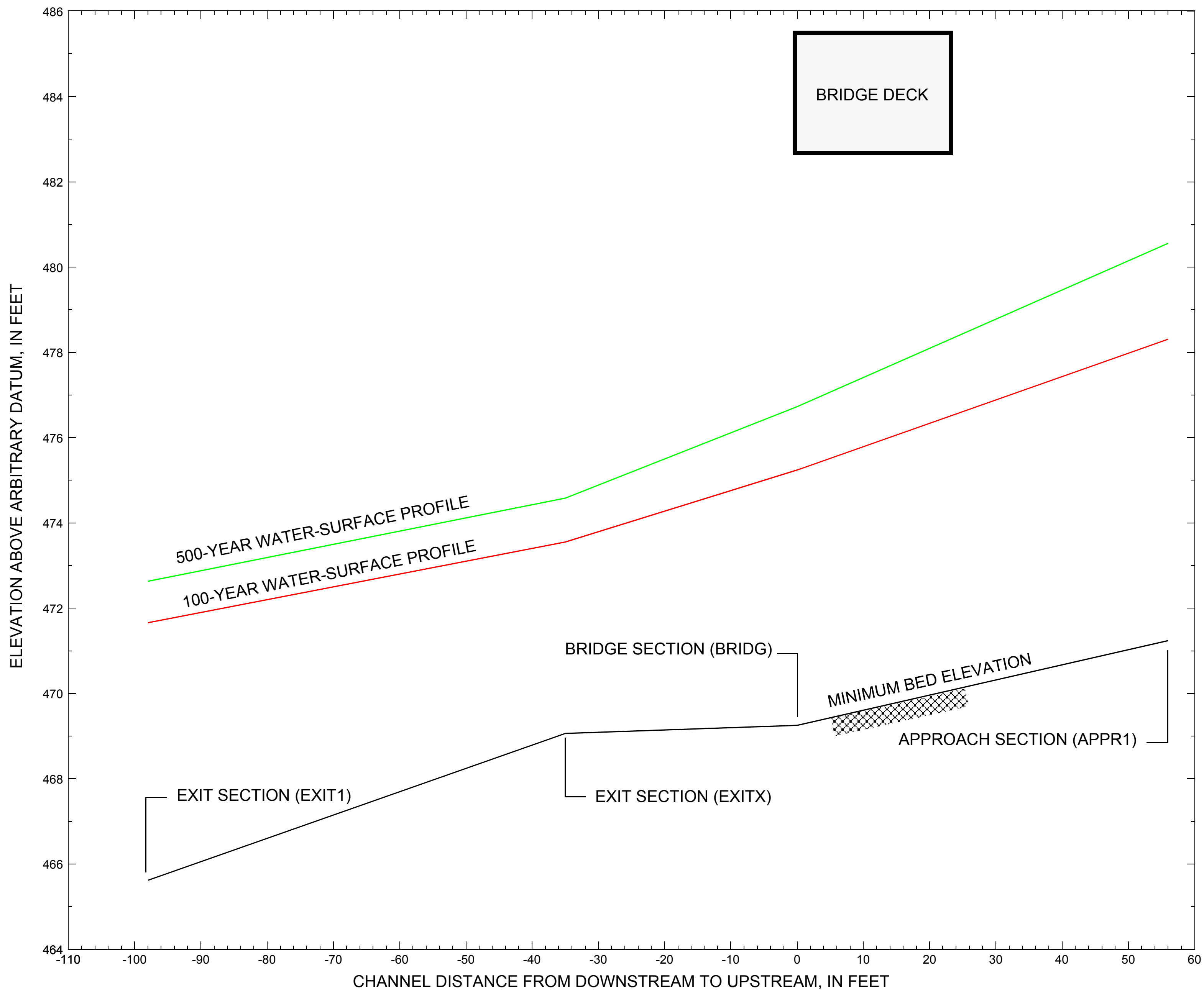

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure SHRETH00060032 on Town Highway 6, crossing Sargent Brook, Shrewsbury, Vermont.

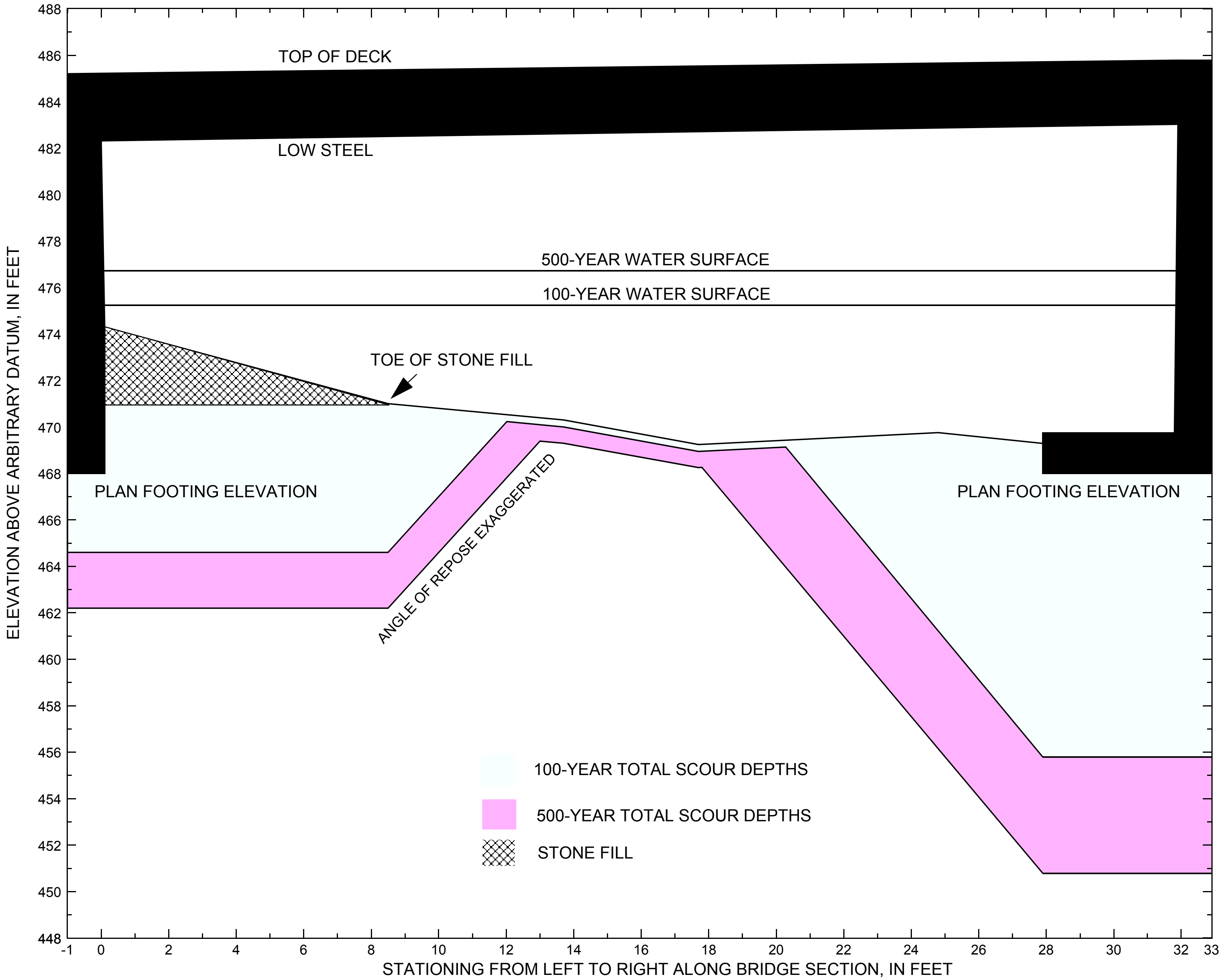

Figure 8. Scour elevations for the 100- and 500-year discharges at structure SHRETH00060032 on Town Highway 6, crossing Sargent Brook, Shrewsbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SHRETH00060032 on Town Highway 6, crossing Sargent Brook, Shrewsbury, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 1,800 cubic-feet per second											
Left abutment	0.0	482.3	482.3	468.0	471.0	0.3	6.1	--	6.4	464.6	-3.4
Right abutment	31.9	483.0	483.0	468.0	469.3	0.3	13.2	--	13.5	455.8	-12.2

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 SHRETH00060032 on Town Highway 6, crossing Sargent Brook, Shrewsbury, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 2,750 cubic-feet per second											
Left abutment	0.0	482.3	482.3	468.0	471.0	1.0	7.8	--	8.8	462.2	-5.8
Right abutment	31.9	483.0	483.0	468.0	469.3	1.0	17.5	--	18.5	450.8	-17.2

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, 1961, Killington Peak, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File shre032.wsp
T2        Hydraulic analysis for structure SHRETH00060032   Date: 10-MAR-98
T3        TH 6 CROSSING SARGENT BROOK IN SHREWSBURY, VT            RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1800.0   2750.0
SK          0.0380   0.0380
*
XS   EXIT1    -98           0.
GR         -472.4, 498.92   -380.8, 487.98   -242.4, 477.93   -101.7, 476.28
GR          -54.8, 471.31
GR            0.0, 470.48      8.4, 468.17     10.8, 466.03     17.9, 465.62
GR           23.1, 465.81     28.8, 466.33     35.0, 467.26     39.6, 469.95
GR           48.8, 472.58     61.6, 474.71     84.4, 491.26
*
N           0.080        0.065
SA                  0.0
*
XS   EXITX    -35           0.
GR         -472.4, 502.25   -380.8, 491.31   -242.4, 481.26   -101.7, 479.61
GR          -54.8, 474.64      0.0, 473.22     18.3, 469.90     28.8, 469.68
GR           35.0, 469.87     40.7, 469.52     47.0, 469.14     52.1, 469.06
GR           57.2, 470.24     62.4, 473.93     71.6, 475.91     84.4, 478.04
GR          107.2, 494.59
*
N           0.080        0.065
SA                  0.0
*
XS   FULLV      0  * * *   0.0019
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    482.68       0.0
GR            0.0, 482.32      0.1, 474.30      8.5, 471.00
GR           13.7, 470.30     17.7, 469.25     24.8, 469.76     27.9, 469.29
GR           28.0, 469.74     31.8, 469.74     31.9, 470.25     31.9, 483.03
GR            0.0, 482.32
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      31.5 * *     46.0      8.3
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     12      20.1     2
GR         -542.7, 507.95   -345.8, 489.51   -250.9, 484.57   -176.2, 482.90
GR         -118.4, 482.91    -42.2, 484.32      0.0, 485.21     33.0, 485.79
GR           89.7, 487.02    138.1, 489.89    361.0, 505.89
*
AS   APPR1     56           0.
GR         -473.1, 502.48   -405.3, 494.48   -306.9, 486.59   -230.2, 482.80
GR         -161.3, 481.57    -69.0, 481.89    -26.6, 482.36    -10.6, 478.15
GR            0.0, 475.54      4.5, 473.76     13.7, 473.53     17.9, 472.18
GR           22.4, 471.72     26.8, 471.24     31.7, 471.36     36.4, 472.03
GR           43.4, 474.56     47.4, 476.30     63.2, 477.42     74.1, 482.47
GR           83.1, 483.11    115.9, 503.42
*
N           0.080        0.060
SA                -26.6
*
HP 1 BRIDG  475.24 1 475.24
HP 2 BRIDG  475.24 * * 1800
HP 1 APPR1  478.31 1 478.31
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File shre032.wsp
        Hydraulic analysis for structure SHRETH00060032   Date: 10-MAR-98
        TH 6 CROSSING SARGENT BROOK IN SHREWSBURY, VT            RLB
           *** RUN DATE & TIME: 03-16-98  14:19

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     148.   10653.    32.    39.                         1810.
   475.24          148.   10653.    32.    39.  1.00     0.    32.   1810.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       475.24     0.1    31.9   147.9   10653.    1800.  12.17

X STA.         0.1        7.9        9.5       11.0       12.4       13.7
  A(I)            19.1        7.0        6.5        6.5        6.3
  V(I)            4.70      12.80      13.86      13.90      14.22

X STA.        13.7       14.9       16.0       17.1       18.1       19.0
  A(I)             6.2        6.1        5.9        5.9        5.9
  V(I)           14.51      14.65      15.23      15.30      15.31

X STA.        19.0       20.1       21.1       22.1       23.2       24.3
  A(I)             6.0        5.9        5.9        6.0        6.0
  V(I)           15.00      15.19      15.20      14.90      14.92

X STA.        24.3       25.4       26.4       27.4       28.6       31.9
  A(I)             6.0        5.9        5.9        6.6       18.2
  V(I)           15.00      15.38      15.28      13.70       4.94

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPR1;  SRD =      56.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     292.   17467.    76.    78.                         3247.
   478.31          292.   17467.    76.    78.  1.00   -11.    65.   3247.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPR1;  SRD =      56.

         WSEL     LEW     REW    AREA        K        Q    VEL
       478.31   -11.2    65.1   292.4   17467.    1800.   6.16

X STA.       -11.2        5.3        8.0       10.8       13.4       15.8
  A(I)            35.5       12.7       12.9       12.5       12.2
  V(I)            2.53       7.10       6.98       7.20       7.35

X STA.        15.8       17.9       19.7       21.5       23.2       24.8
  A(I)            11.8       11.4       11.3       11.3       11.2
  V(I)            7.61       7.93       7.94       7.97       8.00

X STA.        24.8       26.4       27.9       29.4       31.0       32.5
  A(I)            10.9       10.8       10.6       10.7       10.6
  V(I)            8.25       8.37       8.47       8.39       8.50

X STA.        32.5       34.1       35.8       37.6       39.7       65.1
  A(I)            10.7       10.8       11.0       11.8       51.6
  V(I)            8.41       8.33       8.17       7.65       1.74
```

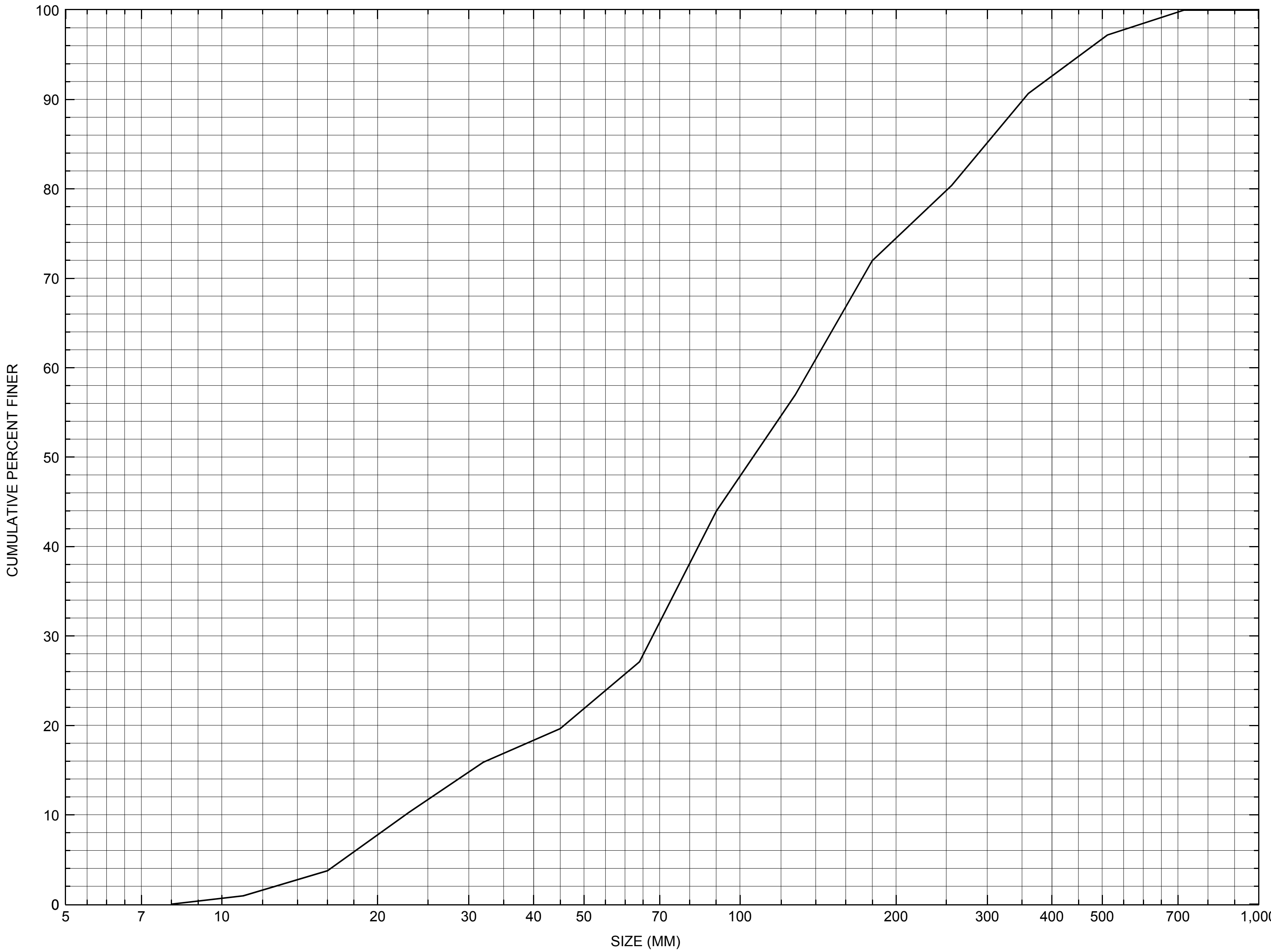
```
       U.S. Geological Survey WSPRO Input File shre032.wsp
       Hydraulic analysis for structure SHRETH00060032   Date: 10-MAR-98
       TH 6 CROSSING SARGENT BROOK IN SHREWSBURY, VT            RLB
          *** RUN DATE & TIME: 03-16-98  14:19

   CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     195.  16129.    32.    42.                         2746.
  476.73          195.  16129.    32.    42.  1.00     0.    32.   2746.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      476.73     0.1    31.9   195.3   16129.    2750.  14.08

X STA.         0.1        6.5        8.3        9.8       11.2       12.5
  A(I)            23.9        9.5        8.6        8.1        8.2
  V(I)            5.76      14.47      16.04      16.89      16.68

X STA.        12.5       13.8       15.0       16.2       17.3       18.3
  A(I)             8.0        8.2        8.0        7.9        7.7
  V(I)           17.11      16.84      17.21      17.36      17.92

X STA.        18.3       19.3       20.4       21.5       22.5       23.6
  A(I)             7.8        7.7        7.8        7.6        7.7
  V(I)           17.56      17.75      17.72      18.05      17.90

X STA.        23.6       24.7       25.8       26.9       28.1       31.9
  A(I)             7.8        7.7        7.7        8.7       26.7
  V(I)           17.71      17.95      17.75      15.83       5.14

   CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPR1;  SRD =      56.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            2     479.  35615.    90.    93.                         6284.
  480.56          479.  35615.    90.    93.  1.00   -20.    70.   6284.

   VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPR1;  SRD =      56.

        WSEL     LEW     REW    AREA        K        Q    VEL
      480.56   -19.8    70.0   479.2   35615.    2750.   5.74

X STA.       -19.8        2.7        5.8        8.8       11.6       14.5
  A(I)            65.5       20.6       20.1       20.0       19.9
  V(I)            2.10       6.67       6.84       6.87       6.91

X STA.        14.5       17.1       19.3       21.4       23.5       25.5
  A(I)            20.0       18.3       18.7       18.6       18.4
  V(I)            6.88       7.51       7.37       7.41       7.46

X STA.        25.5       27.5       29.5       31.5       33.5       35.5
  A(I)            18.5       18.0       18.4       18.0       18.2
  V(I)            7.42       7.65       7.48       7.66       7.57

X STA.        35.5       37.7       40.4       43.6       49.5       70.0
  A(I)            18.4       20.2       21.1       28.1       60.3
  V(I)            7.48       6.82       6.51       4.90       2.28
```

```
        U.S. Geological Survey WSPRO Input File shre032.wsp
        Hydraulic analysis for structure SHRETH00060032   Date: 10-MAR-98
        TH 6 CROSSING SARGENT BROOK IN SHREWSBURY, VT           RLB
           *** RUN DATE & TIME: 03-16-98  14:19

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXIT1":  USED WSI = CRWS.
                          WSI,CRWS =    471.29     471.66

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

EXIT1:XS   ******   -58.     227.  1.25 *****  472.91  471.66   1800.  471.66
      -98. ******    46.   11009.  1.27 ***** *******    1.07    7.95

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.98     473.55     473.32
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   471.16     502.25    0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   471.16     502.25     473.32

EXITX:XS      63.   -13.     200.  1.28  1.91  474.83  473.32   1800.  473.55
      -35.    63.    62.    9733.  1.02  0.01    0.00    0.98    8.98

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "FULLV"     KRATIO =  1.81

FULLV:FV      35.   -57.     336.  0.54  0.66  475.48 *******   1800.  474.95
        0.    35.    67.   17631.  1.20  0.00   -0.01    0.63    5.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    3.08     474.45     476.68
 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   474.45     503.42    0.50
 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   474.45     503.42     476.68
 ===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 "APPR1"
                  WSBEG,WSEND,CRWS =   476.68     503.42     476.68

APPR1:AS      56.    -5.     179.  1.56 *****  478.25  476.68   1800.  476.68
       56.    56.    53.    9355.  1.00 ***** *******    1.00   10.03
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1800.     475.24

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

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

BRIDG:BR      35.     0.     148.  2.31 *****  477.54  475.24   1800.  475.24
        0.    35.    32.   10641.  1.00 ***** *******    1.00   12.18

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  482.68 ****** ****** ******

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

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

APPR1:AS      25.   -11.     292.  0.59  0.45  478.90  476.68   1800.  478.31
       56.    26.    65.   17477.  1.00  0.90   -0.01    0.55    6.15

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.446  0.108   15675.     6.    38.   477.93

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K      AREA     VEL    WSEL
   EXIT1:XS     -98.   -58.    46.   1800.   11009.     227.    7.95  471.66
   EXITX:XS     -35.   -13.    62.   1800.    9733.     200.    8.98  473.55
   FULLV:FV       0.   -57.    67.   1800.   17631.     336.    5.36  474.95
   BRIDG:BR       0.     0.    32.   1800.   10641.     148.   12.18  475.24
   RDWAY:RG      12.**************      0.******************    2.00********
   APPR1:AS      56.   -11.    65.   1800.   17477.     292.    6.15  478.31

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       6.    38.   15675.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF    HO   VHD     EGL    WSEL
   EXIT1:XS    471.66    1.07  465.62  498.92************  1.25  472.91  471.66
   EXITX:XS    473.32    0.98  469.06  502.25  1.91  0.01  1.28  474.83  473.55
   FULLV:FV  ********    0.63  469.13  502.32  0.66  0.00  0.54  475.48  474.95
   BRIDG:BR    475.24    1.00  469.25  483.03************  2.31  477.54  475.24
   RDWAY:RG ***************  482.90  507.95********************************
   APPR1:AS    476.68    0.55  471.24  503.42  0.45  0.90  0.59  478.90  478.31
```

```
        U.S. Geological Survey WSPRO Input File shre032.wsp
        Hydraulic analysis for structure SHRETH00060032   Date: 10-MAR-98
        TH 6 CROSSING SARGENT BROOK IN SHREWSBURY, VT             RLB
           *** RUN DATE & TIME: 03-16-98  14:19

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXIT1":  USED WSI = CRWS.
                          WSI,CRWS =    472.21     472.63

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

EXIT1:XS   ******   -67.     334.  1.39 *****  474.03  472.63   2750.  472.63
      -98. ******    49.   16879.  1.32 ***** *******    0.99    8.25

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     1.16     474.42     474.58
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   472.13     502.25    0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   472.13     502.25     474.58
 ===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 "EXITX"
                   WSBEG,WSEND,CRWS =   474.58     502.25     474.58

EXITX:XS      63.   -52.     299.  1.54 *****  476.12  474.58   2750.  474.58
      -35.    63.    65.   15516.  1.17 ***** *******    1.10    9.20

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.79

FULLV:FV      35.   -68.     492.  0.60  0.61  476.73 *******   2750.  476.13
        0.    35.    73.   27756.  1.23  0.00    0.00    0.59    5.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   475.63     503.42    0.50
 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   475.63     503.42     477.86
 ===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 "APPR1"
                   WSBEG,WSEND,CRWS =   477.86     503.42     477.86

APPR1:AS      56.    -9.     258.  1.76 *****  479.62  477.86   2750.  477.86
       56.    56.    64.   14578.  1.00 ***** *******    1.00   10.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    2750.      476.73

            <<<<<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      35.     0.     195.  3.08 *****  479.81  476.73   2750.  476.73
        0.    35.    32.   16130.  1.00 ***** *******    1.00   14.08

    TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
      1. ****   1.  1.000 ******  482.68 ****** ****** ******

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

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

APPR1:AS      25.   -20.     479.  0.51  0.34  481.07  477.86   2750.  480.56
       56.    26.    70.   35611.  1.00  0.92   -0.02    0.44    5.74

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.567  0.256   26627.     6.    38.   480.35

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

   XSID:CODE     SRD    LEW     REW       Q        K      AREA     VEL    WSEL
  EXIT1:XS      -98.   -67.     49.   2750.   16879.      334.    8.25  472.63
  EXITX:XS      -35.   -52.     65.   2750.   15516.      299.    9.20  474.58
  FULLV:FV        0.   -68.     73.   2750.   27756.      492.    5.59  476.13
  BRIDG:BR        0.     0.     32.   2750.   16130.      195.   14.08  476.73
  RDWAY:RG       12.**************       0.******************    2.00********
  APPR1:AS       56.   -20.     70.   2750.   35611.      479.    5.74  480.56

   XSID:CODE   XLKQ   XRKQ       KQ
  APPR1:AS       6.    38.   26627.

 SECOND USER DEFINED TABLE.

   XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
  EXIT1:XS     472.63    0.99  465.62  498.92************  1.39  474.03  472.63
  EXITX:XS     474.58    1.10  469.06  502.25************  1.54  476.12  474.58
  FULLV:FV   ********    0.59  469.13  502.32  0.61  0.00  0.60  476.73  476.13
  BRIDG:BR     476.73    1.00  469.25  483.03************  3.08  479.81  476.73
  RDWAY:RG   ***************  482.90  507.95**********************************
  APPR1:AS     477.86    0.44  471.24  503.42  0.34  0.92  0.51  481.07  480.56
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure SHRETH00060032, in Shrewsbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SHRETH00060032

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 15 / 95

Highway District Number *(I - 2; nn)* 03

County *(FIPS county code; I - 3; nnn)* 021

Town *(FIPS place code; I - 4; nnnnn)* 65275

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

Waterway *(I - 6)* BRANCH OF COLD RIVER

Road Name *(I - 7):* -

Route Number TH006

Vicinity *(I - 9)* 0.3 MI TO JCT CL 3 TH 12

Topographic Map Killington Peak

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 43329

Longitude *(i - 17; nnnnn.n)* 72515

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10112200321122

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

Maximum span length *(I - 48; nnnn)* 0033

Year built *(I - 27; YYYY)* 1974

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000150

Deck Width *(I - 52; nn.n)* 201

Year of ADT *(I - 30; YY)* 92

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

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

Waterway adequacy *(I - 71; n)* 7

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 030.0

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

Vertical clearance from streambed (*nnn.n ft*) 010.0

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

Waterway of full opening (*nnn.n ft^2*) 200.0

Comments:

The structural inspection report of 6/7/94 indicates the structure is a steel stringer type bridge with a concrete deck. The abutments have randomly located cracks in the concrete. The wingwall concrete has random cracks and some spalling. The footing on the right abutment is exposed and the footing concrete has areas of heavy scaling and some minor local scour. The channel bed consists primarily of boulders and gravel. There is heavy stone riprap noted at both upstream wingwalls. There are a few small trees and other debris in the channel downstream of the bridge. No undermining or settling is reported. There is very little information readily available in the hydraulic section file.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area (mi^2): 6.4

Terrain character: -

Stream character & type: -

Streambed material: Gravel and boulders

Discharge Data (*cfs*): $Q_{2.33}$ - Q_{10} 850 Q_{25} 1150

Q_{50} 1450 Q_{100} - Q_{500} -

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

Estimated Discharge (*cfs*): - Velocity at Q 25 (*ft/s*): 13.0

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*)	-	-	5.4	6.4	-
Velocity (*ft / sec*)	-	-	13.0	-	-

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 6.34 mi^2

Lake/pond/swamp area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 1610 ft

Headwater elevation 3939 ft

Main channel length 4.52 mi

10% channel length elevation 1700 ft

85% channel length elevation 2900 ft

Main channel slope *(S)* 354.21 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)*: **11** / **1973**

Project Number **DSR 3C S5** Minimum channel bed elevation: **472.0**

Low superstructure elevation: USLAB **482.32** DSLAB **482.32** USRAB **483.0** DSRAB **483.0**

Benchmark location description:
BM#1 is a spike in the trunk or root of a 12 inch diameter spruce tree, located 223 feet right bankward on the roadway from the right abutment and 15 feet from the centerline of the roadway downstream, elevation 500.00.

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

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **468.0**

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: **1**

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

Briefly describe material at foundation bottom elevation or around piles:
The footings are shown as probably set in a very dense sandy silt and gravel.

Comments:
The same hydraulic information in the hydraulics section folder is found printed on the plans. The actual channel bed elevation prior to installing the bridge is shown on the plans at least 2 feet higher than the top of each abutment footing. The low superstructure elevation given is actually the minimum value. Some other points with elevations are: 1) The point on the top bankward edge of the upstream left wingwall where the concrete slope changes from horizontal to downward, elevation 485.04, and 2) the point at the same location as in (1) but on the upstream right wingwall, elevation 485.76.

Cross-sectional Data

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

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

Comments: **Upstream bridge face channel cross section from left to right banks.**

Station	0.7	5.0	10.0	11.0	20.0	30.5	30.5	30.5	-	-	-
Feature	LCL	-	-	LEW	-	TD	REW	LCR	-	-	-
Low chord elevation	482.3	-	-	-	-	-	-	483.0	-	-	-
Bed elevation	473.1	473.0	472.7	472.5	472.2	471.8	472.5	471.8	-	-	-
Low chord to bed	9.2	-	-	-	-	-	-	12.2	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: **Downstream bridge face channel cross section from left to right banks.**

Station	0.5	10.0	15.0	19.0	30.3	30.3	30.3	-	-	-	-
Feature	LCL	LEW	-	-	TD	REW	LCR	-	-	-	-
Low chord elevation	482.3	-	-	-	-	-	483.0	-	-	-	-
Bed elevation	473.5	473.2	473.0	472.8	472.3	473.3	472.3	-	-	-	-
Low chord to bed	8.8	-	-	-	-	-	10.7	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **JD** Date: **5/16/97**

Computerized by: **JD** Date: **5/16/97**

Reviewd by: **RB** Date: **3/18/98**

Structure Number **SHRETH00060032**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. Boehmler** Date *(MM/DD/YY)* **09** / **28** / 19**95**

2. Highway District Number **3** Mile marker **0**

County **Rutland (021)** Town **Shrewsbury (65275)**

Waterway *(I - 6)* **Branch of Cold River (Sargent Brook)** Road Name **-**

Route Number **TH6** Hydrologic Unit Code: **02010002**

3. Descriptive comments:

This structure is located 0.3 mile from town highway 12.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **6** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **2** UB **1** DS **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 **36.0** *(feet)* Span length **33.0** *(feet)* Bridge width **20.1** *(feet)*

Road approach to bridge:

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

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

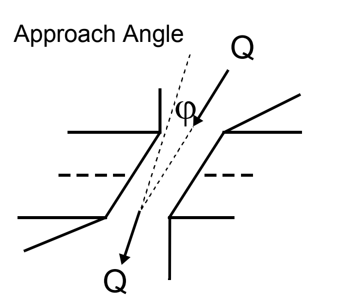
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

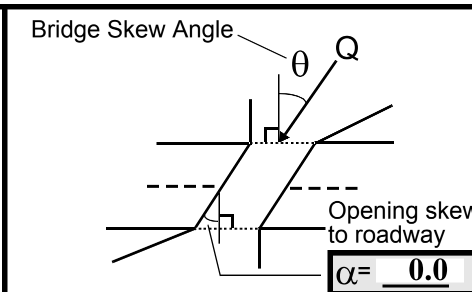
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	0	-	2	2
RBUS	0	-	2	1
RBDS	0	-	0	0
LBDS	0	-	2	1

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*
*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: **30** 16. Bridge skew: **0**





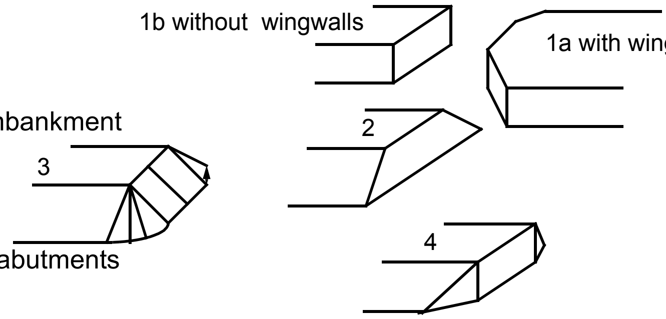
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **30** feet **US** *(US, UB, DS)* to **10** feet **UB**

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: **4**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

4. The surface cover is forest except for a pasture two bridge lengths bankward on the downstream right bank.
5. The upstream water surface is riffled and slopes consistently from 250 feet upstream to 50 feet upstream where the channel steepens until 2 feet under the bridge. The channel slope flattens out and the current water surface is pooled from 2 feet under the bridge to 30 feet downstream where the channel slope steepens again.
7. The measured bridge dimensions were the same as the historical values.

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
38.5	2.0			4.5	4	4	253	253	1	1

23. Bank width **20.0** 24. Channel width **20.0** 25. Thalweg depth **47.5** 29. Bed Material **432**

30 .Bank protection type: LB **0** RB **3** 31. Bank protection condition: LB **-** RB **1**

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

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

27. The banks are low, with predominantly sand and boulder material.
The channel is straight until 30 feet upstream of the bridge where it takes a bend to the left.
30. The right bank protection extends from 25 feet upstream to 0 feet upstream. It is also wingwall protection.

33. Point/Side bar present? Y ____ *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: 0US ____ 35. Mid-bar width: 15 ____

36. Point bar extent: 50 ____ feet US ____ *(US, UB)* to 40 ____ feet DS ____ *(US, UB, DS)* positioned 0 ____ %LB to 50 ____ %RB

37. Material: 324 ____

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

The upstream portion of this bar is vegetated with grass and shrubs, growing in silt, clay, and sand material.

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.):

There is a cut-bank on the left bank around 250 feet upstream, on the outside of a sharp bend.

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
32.0		1.0		2	7	7	-

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

*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*

*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*

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

432

-

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

70. Debris and Ice Comments:

2

Some debris is scattered in the channel downstream of the structure, but it has not accumulated in one particular place. The banks in the study area are heavily wooded. The bend and the point bar just upstream of the bridge could contribute to the capturing of ice and debris.

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**	**2**	**0**	**0**	**0**	**90.0**
RABUT	**1**	**10**	**90**			**2**	**2**	**32.0**

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

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

0

0.5

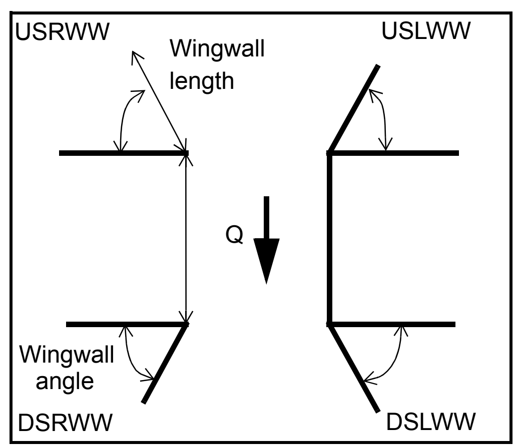
1

76. The right abutment footing is exposed to a depth between 0 and 0.5 ft along its entire length.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**32.0**	
USRWW:	**Y**		**1**		**0**	**1.0**	
DSLWW:	**0**		**0**		**Y**	**24.0**	
DSRWW:	**1**		**0**		**0**	**24.0**	

*Wingwall materials: **1**- Concrete; **2**- Stone masonry or drywall; **3**- steel or metal; **4**- wood*



82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**0**	**0**	**Y**	**0**	**1**	**1**	**1**	**-**
Condition	**Y**	**0**	**1**	**0.5**	**1**	**1**	**1**	**-**
Extent	**1**	**0**	**2**	**3**	**3**	**2**	**0**	**-**

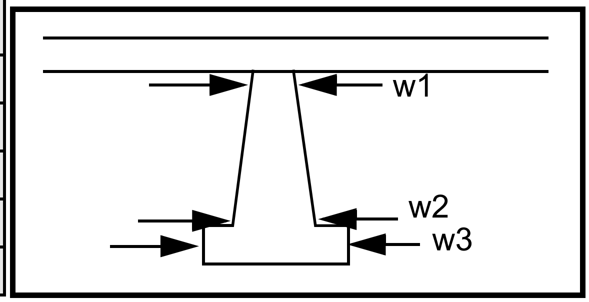
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
1
2
1
3

Piers:

84. Are there piers? **80.** *(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				25.0	14.0	70.0
Pier 2				10.0	45.0	12.0
Pier 3			-	50.0	17.0	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	The	een 0	abut-	stone	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	dow	and	ment	fill.	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	nstre	0.5	to 6	82.	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	am	ft,	feet	The	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	right	from	dow	left	*Y- yes; N- no*
91. Attack ∠ (BF)	wing	the	nstre	abut	
92. Pushed	wall	point	am	ment	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	foot-	wher	wher	is	
95. Cross-members	ing is	e it	e it is	pro-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	expo	meet	cov-	tecte	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	sed	s the	ered	d by	
98. Exposure depth	betw	right	with	stone	

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

fill and point bar material.

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 - Thalweg depth - Bed Material -

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB -

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: -

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

-
-
-
-

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

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

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

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

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

Scour dimensions: Length 4 Width 253 Depth: 253 Positioned 1 %LB to 1 %RB

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

435
0
0
-

Are there major confluences? - (Y or if N type ctrl-n mc) How many? 100.

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

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

Confluence comments (eg. confluence name):

are low banks and do not show signs of erosion.

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 COMPUTATIONS

Structure Number: SHRETH00060032 Town: SHREWSBURY
Road Number: TH 6 County: RUTLAND
Stream: BRANCH OF COLD RIVER (SARGENT BROOK)

Initials RLB Date: 3/16/98 Checked: ECW

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 Davis, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1800	2750	0
Main Channel Area, ft2	292	479	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	76	90	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.3477	0.3477	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	3.8	5.3	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	17467	35615	0
Conveyance, main channel	17467	35615	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1800.0	2750.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	6.2	5.7	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.9	10.4	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1800	2750	0
(Q) discharge thru bridge, cfs	1800	2750	0
Main channel conveyance	10653	16129	0
Total conveyance	10653	16129	0
Q2, bridge MC discharge,cfs	1800	2750	ERR
Main channel area, ft2	148	195	0
Main channel width (normal), ft	31.8	31.8	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	31.8	31.8	0
y_bridge (avg. depth at br.), ft	4.65	6.14	ERR
Dm, median (1.25*D50), ft	0.434625	0.434625	0
y2, depth in contraction,ft	4.99	7.18	ERR
ys, scour depth (y2-ybridge), ft	0.34	1.04	N/A

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1800	2750	N/A
Main channel area (DS), ft2	147.9	195.3	0
Main channel width (normal), ft	31.8	31.8	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	31.8	31.8	0.0
D90, ft	1.1558	1.1558	0.0000
D95, ft	1.4925	1.4925	0.0000
Dc, critical grain size, ft	0.9845	1.1483	ERR
Pc, Decimal percent coarser than Dc	0.148	0.102	0.000
Depth to armoring, ft	17.00	30.33	ERR

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 1995, p. 48, eq. 28)

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	1800	2750	0	1800	2750	0
a', abut.length blocking flow, ft	11.3	19.9	0	33.2	38.1	0
Ae, area of blocked flow ft2	24.31	57.93	0	100.14	180.7	0
Qe, discharge blocked abut.,cfs	61.64	121.61	0	486	935	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.54	2.10	ERR	4.85	5.17	ERR
ya, depth of f/p flow, ft	2.15	2.91	ERR	3.02	4.74	ERR
--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	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	0.305	0.217	ERR	0.492	0.419	ERR
ys, scour depth, ft	6.11	7.79	N/A	13.24	17.46	N/A

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

a'(abut length blocked, ft)	11.3	19.9	0	33.2	38.1	0
y1 (depth f/p flow, ft)	2.15	2.91	ERR	3.02	4.74	ERR
a'/y1	5.25	6.84	ERR	11.01	8.03	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.30	0.22	N/A	0.49	0.42	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	0	1	1	0
y, depth of flow in bridge, ft	4.65	6.14	0.00	4.65	6.14	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	1.94	2.57	ERR	1.94	2.57	ERR