LEVEL II SCOUR ANALYSIS FOR BRIDGE 15 (SHRETH00300015) on TOWN HIGHWAY 30, crossing FREEMAN BROOK, SHREWSBURY, VERMONT

Open-File Report 98-192

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 15 (SHRETH00300015) on TOWN HIGHWAY 30, crossing FREEMAN BROOK, SHREWSBURY, VERMONT

By RONDA L. BURNS and TIMOTHY SEVERANCE

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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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Denver, CO 80225-0286

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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 15 (SHRETH00300015) ON TOWN HIGHWAY 30, CROSSING FREEMAN BROOK, SHREWSBURY, VERMONT

By **Ronda L. Burns and Timothy Severance**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SHRETH00300015 on Town Highway 30 crossing Freeman Brook, 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 1.09-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, Freeman Brook has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 36 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 88.2 mm (0.290 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 11, 1995, indicated that the reach was stable.

The Town Highway 30 crossing of Freeman Brook is a 30-ft-long, one-lane bridge consisting of one 27-foot steel-beam span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 25.7 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 18 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

No scour holes were observed at the site during the Level I assessment. Scour countermeasures observed were type-2 stone fill (less than 36 inches diameter) along the upstream left wingwall, type-3 stone fill (less than 48 inches diameter) along the upstream right wingwall, the left and right abutments, the downstream left and right wingwalls, and the downstream right bank, and type-4 stone fill (less than 60 inches diameter) along the downstream left bank. 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 was zero ft. Abutment scour ranged from 2.7 to 3.3 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.

Killington Peak, VT quadrangle, 1:24,000, 1961, 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 SHRETH00300015 ***Stream*** Freeman Brook

County Rutland ***Road*** TH 30 ***District*** 3

Description of Bridge

Bridge length 30 ***ft*** ***Bridge width*** 16 ***ft*** ***Max span length*** 27 ***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*** 10/11/95

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

Abutments and wingwalls are concrete.

Yes

18 No

Is bridge skewed to flood flow according to - ***survey?*** ***Angle***

10/11/95

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	10/11/
Level I	95	0	0
Level II			

Low.

Potential for debris

None as of 10/11/95.

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

Description of the Geomorphic Setting

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

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

Date of inspection 10/11/95

DS left: Steep channel bank to a moderately sloped overbank

DS right: Steep channel bank to a moderately sloped overbank

US left: Steep valley wall

US right: Steep channel bank to a moderately sloped overbank

Description of the Channel

Average top width 36 ft ***Average depth*** 5 ft

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

Sinuous but stable with non-alluvial channel boundaries and greater width at channel bends.

10/11/95

Vegetative co

DS left: Trees

DS right: Trees

US left: Trees

US right: Trees

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

None as of 10/11/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 1.09 ***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 450 ***ft³/s*** ***Q500*** 620 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database (written communication, May 1995) for this site. These values were within a range defined by flood frequency curves derived 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) USGS survey

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 499.74 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the upstream left wingwall (elev. 497.75 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	-22	1	Exit section
BRIDG	0	2	Downstream Bridge section (Templated from BRTEM)
BRTEM	16	1	Upstream Bridge section as surveyed (Used as a template)
USBRG	16	1	Modelled Upstream Bridge section (Templated from BRTEM)
APTEM	42	1	Approach section as surveyed (Used as a template)
APPRO	45	2	Modelled Approach section (Templated from APTEM)

[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.

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 0.0349 ft/ft, which was estimated from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.1129 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 location provides a consistent method for determining scour variables.

For the 100-year 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 can be 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.

For all modelled flows, the bridge was not a significant constriction in the channel. Therefore, the bridge sections at the upstream and downstream faces were modelled as open channel sections. This allowed the model to evaluate flow conditions through the bridge and at the approach section as unconstricted.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.9 ***ft***
Average low steel elevation 497.4 ***ft***

100-year discharge 450 ***ft³/s***
Water-surface elevation in bridge opening 494.4 ***ft***
Road overtopping? No ***Discharge over road*** - ***ft³/s***
Area of flow in bridge opening 53 ***ft²***
Average velocity in bridge opening 8.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.2 ***ft/s***

Water-surface elevation at Approach section with bridge -
Water-surface elevation at Approach section without bridge -
Amount of backwater caused by bridge N/A ***ft***

500-year discharge 620 ***ft³/s***
Water-surface elevation in bridge opening 495.0 ***ft***
Road overtopping? No ***Discharge over road*** - ***ft³/s***
Area of flow in bridge opening 66 ***ft²***
Average velocity in bridge opening 9.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.1 ***ft/s***

Water-surface elevation at Approach section with bridge -
Water-surface elevation at Approach section without bridge -
Amount of backwater caused by bridge N/A ***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 live-bed contraction scour equation (Richardson and Davis, 1995, p. 30, equation 17). At this site, the average channel velocity and the incipient-motion velocity of the bed material are nearly the same. For comparison, contraction scour was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20) and is presented in appendix F. 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 in front of the abutments is uncertain, the scour depth at the vertical abutment walls is unknown. Therefore, the total scour depth computed at the toe of the stone-fill was applied for the entire stone-fill embankment, as shown in figure 8.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	0.0	0.0	--
Clear-water scour	--	--	--
Depth to armoring	3.8	4.6	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	2.7	3.2	--
Right abutment	2.7	3.3	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge (D_{50} in feet)	Incipient overtopping discharge
Abutments:			
Left abutment	1.2	1.4	--
Right abutment	1.2	1.4	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

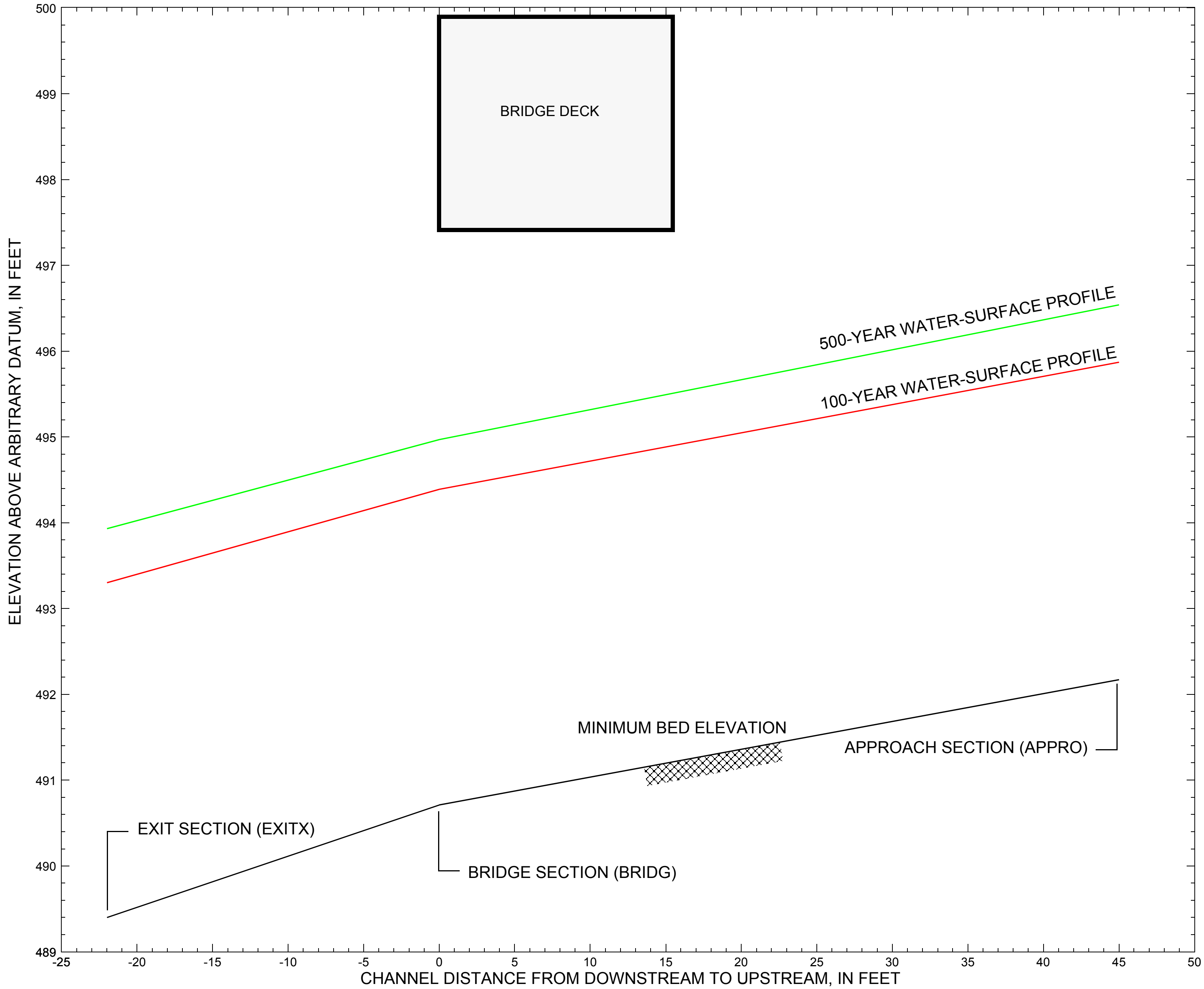

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure SHRETH00300015 on Town Highway 30, crossing Freeman Brook, Shrewsbury, Vermont.

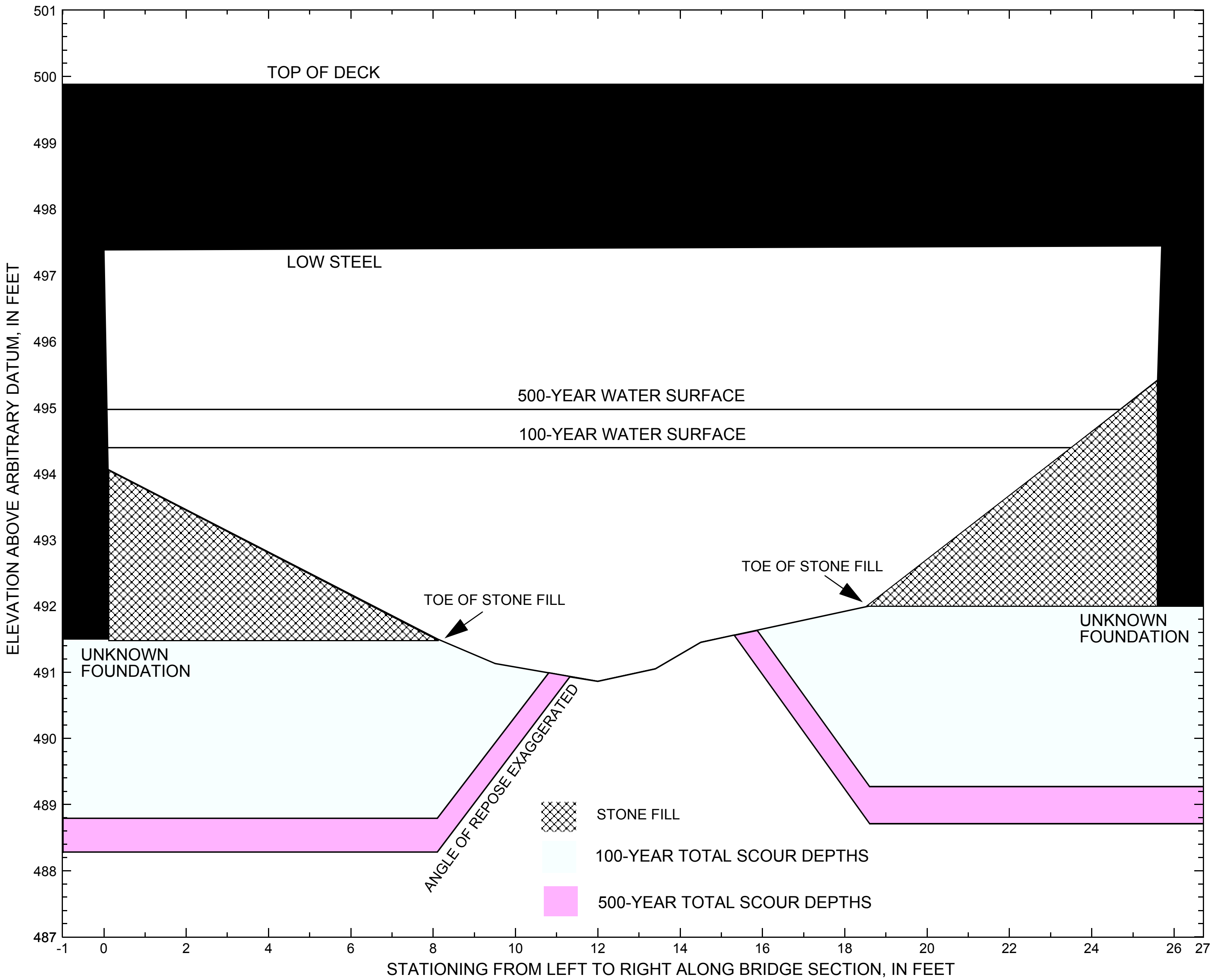

Figure 8. Scour elevations for the 100- and 500-year discharges at structure SHRETH00300015 on Town Highway 30, crossing Freeman Brook, Shrewsbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SHRETH00300015 on Town Highway 30, crossing Freeman Brook, Shrewsbury, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/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 450 cubic-feet per second											
Left abutment	0.0	--	497.4	--	491.5	0.0	2.7	--	2.7	488.8	--
Right abutment	25.7	--	497.4	--	492.0	0.0	2.7	--	2.7	489.3	--

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 SHRETH00300015 on Town Highway 30, crossing Freeman Brook, Shrewsbury, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/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 620 cubic-feet per second											
Left abutment	0.0	--	497.4	--	491.5	0.0	3.2	--	3.2	488.3	--
Right abutment	25.7	--	497.4	--	492.0	0.0	3.3	--	3.3	488.7	--

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 shre015.wsp
T2        Hydraulic analysis for structure SHRETH00300015   Date: 10-MAR-98
T3        TH 30 CROSSING FREEMAN 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            450.0    620.0
SK          0.0349   0.0349
*
XS   EXITX    -22           0.
GR          -74.7, 502.17    -28.3, 498.43     -7.0, 496.31      0.0, 493.59
GR            4.4, 489.75      5.8, 489.45      7.8, 489.40      9.9, 489.40
GR           10.4, 489.80     12.3, 489.99     24.4, 493.06     40.3, 495.98
GR          124.0, 497.64    166.8, 499.26    191.8, 502.49    246.5, 513.18
*
N           0.080         0.060         0.080
SA                  -7.0         40.3
*
XT   BRTEM     16
GR            0.0, 497.38      0.0, 494.06      8.1, 491.50
GR            9.5, 491.13     12.0, 490.86     13.4, 491.05     14.5, 491.45
GR           18.6, 492.00     25.6, 495.41     25.7, 497.44
*
XS   BRIDG     0  15.0  * *  0.0092
GT
N           0.050
*
XS   USBRG    16  15.0  * *  0.0092
GT
N           0.050
*
XT   APTEM     42           0.
GR          -89.5, 514.35    -40.4, 503.95    -12.1, 502.09     -4.8, 498.67
GR            0.0, 496.76      3.9, 493.57      7.0, 492.52      9.6, 491.92
GR           12.0, 491.83     15.7, 492.35     16.6, 492.71     17.6, 492.92
GR           21.4, 496.27     24.4, 496.96     44.1, 497.27     94.4, 501.50
GR          118.2, 506.97    166.9, 510.86
*
XS   APPRO     45  * * *  0.1129
GT
N           0.065         0.080
SA                  24.4
*
HP 1 BRIDG  494.39 1 494.39
HP 2 BRIDG  494.39 * * 450
HP 1 APPRO  495.87 1 495.87
HP 2 APPRO  495.87 * * 450
*
HP 1 BRIDG  494.97 1 494.97
HP 2 BRIDG  494.97 * * 620
HP 1 APPRO  496.54 1 496.54
HP 2 APPRO  496.54 * * 620
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File shre015.wsp
       Hydraulic analysis for structure SHRETH00300015   Date: 10-MAR-98
       TH 30 CROSSING FREEMAN BROOK IN SHREWSBURY, VT             RLB
          *** RUN DATE & TIME: 03-24-98  14:20

   CROSS-SECTION PROPERTIES:  ISEQ =  2;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
           1       53.    2589.    23.    25.                          450.
  494.39           53.    2589.    23.    25.  1.00     0.    24.    450.

   VELOCITY DISTRIBUTION:  ISEQ =  2;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      494.39     0.0    23.8    52.5    2589.     450.   8.57

X STA.         0.0         5.4         6.5         7.4         8.2         8.9
  A(I)             6.9         2.6         2.3         2.2         2.1
  V(I)            3.24        8.81        9.83       10.22       10.55

X STA.         8.9         9.5        10.1        10.7        11.3        11.9
  A(I)             2.1         2.0         2.0         2.0         2.1
  V(I)           10.73       11.01       11.17       11.10       10.91

X STA.        11.9        12.5        13.1        13.7        14.4        15.1
  A(I)             2.1         2.1         2.1         2.1         2.1
  V(I)           10.96       10.86       10.83       10.57       10.49

X STA.        15.1        15.9        16.7        17.5        18.5        23.8
  A(I)             2.2         2.2         2.3         2.3         6.7
  V(I)           10.38       10.21        9.93        9.66        3.35

   CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = APPRO;  SRD =      45.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
           1       49.    2000.    19.    21.                          452.
  495.87           49.    2000.    19.    21.  1.00     2.    21.    452.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = APPRO;  SRD =      45.

        WSEL     LEW     REW    AREA        K        Q    VEL
      495.87     1.5    20.6    49.5    2000.     450.   9.10

X STA.         1.5         5.7         6.5         7.3         7.9         8.5
  A(I)             6.4         2.3         2.2         2.1         2.0
  V(I)            3.53        9.68       10.14       10.80       11.27

X STA.         8.5         9.1         9.7        10.2        10.8        11.3
  A(I)             2.0         2.0         1.9         2.0         2.0
  V(I)           11.03       11.28       11.75       11.41       11.35

X STA.        11.3        11.9        12.4        12.9        13.5        14.1
  A(I)             2.0         2.0         2.0         2.0         2.0
  V(I)           11.33       11.34       11.44       11.31       11.16

X STA.        14.1        14.7        15.3        15.9        16.7        20.6
  A(I)             2.0         2.0         2.1         2.3         6.2
  V(I)           11.31       11.01       10.85        9.81        3.62
```

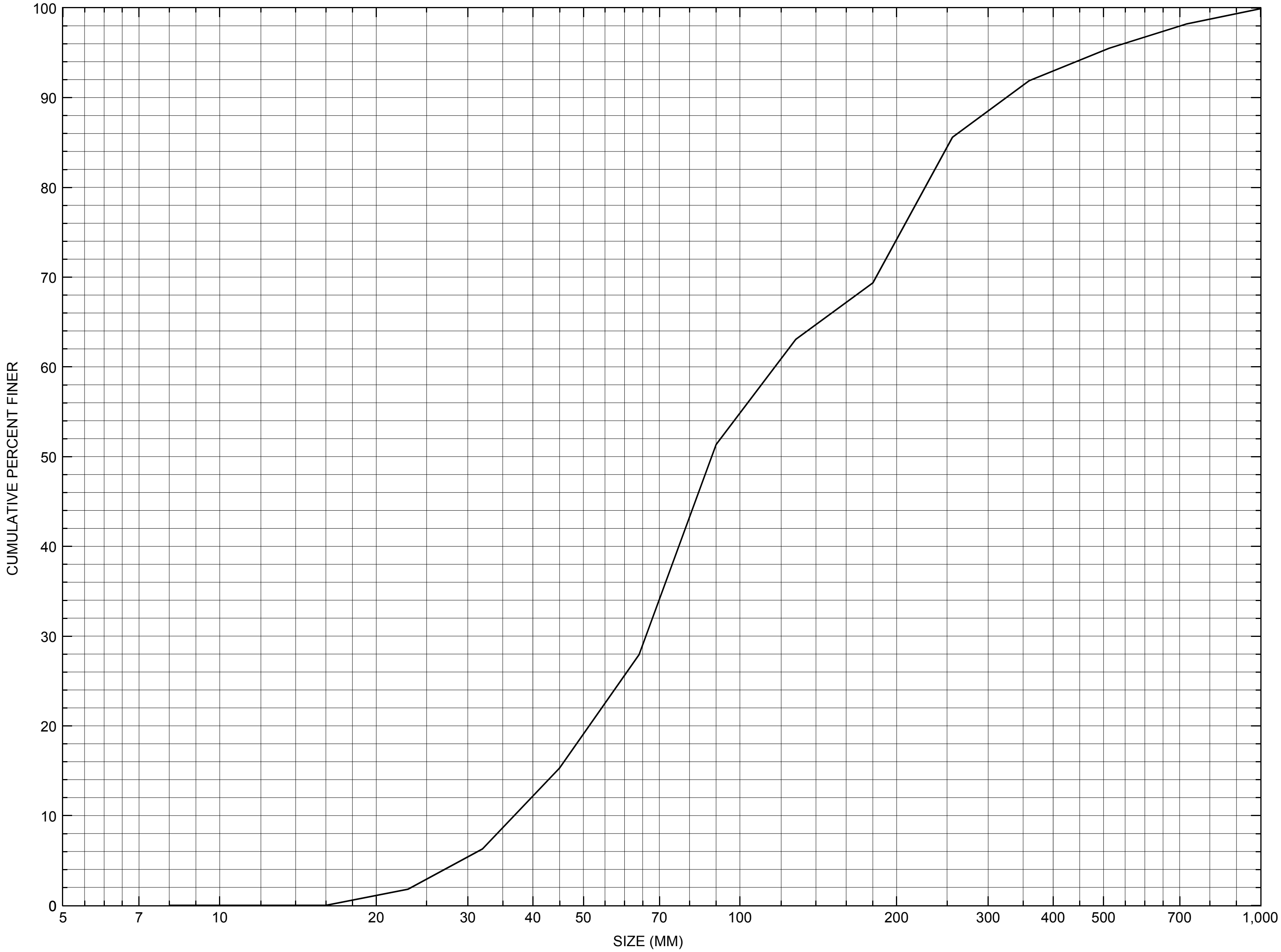
```
        U.S. Geological Survey WSPRO Input File shre015.wsp
        Hydraulic analysis for structure SHRETH00300015   Date: 10-MAR-98
        TH 30 CROSSING FREEMAN BROOK IN SHREWSBURY, VT             RLB
           *** RUN DATE & TIME: 03-24-98  14:20

    CROSS-SECTION PROPERTIES:  ISEQ =  2;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      66.    3627.    24.    27.                          622.
   494.97           66.    3627.    24.    27.  1.00     0.    25.    622.

    VELOCITY DISTRIBUTION:  ISEQ =  2;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.97     0.0    25.0    66.2    3627.     620.   9.37

X STA.         0.0         4.6         5.9         6.9         7.7         8.5
  A(I)             8.0         3.3         2.9         2.9         2.7
  V(I)            3.87        9.50       10.64       10.84       11.46

X STA.         8.5         9.2         9.9        10.6        11.2        11.9
  A(I)             2.7         2.6         2.6         2.6         2.6
  V(I)           11.66       11.86       12.03       11.96       11.76

X STA.        11.9        12.5        13.1        13.8        14.5        15.3
  A(I)             2.6         2.6         2.6         2.7         2.7
  V(I)           12.09       11.95       11.92       11.59       11.35

X STA.        15.3        16.1        17.0        17.8        18.8        25.0
  A(I)             2.7         2.7         2.8         2.9         9.1
  V(I)           11.48       11.32       11.03       10.77        3.42

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = APPRO;  SRD =      45.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      63.    2794.    21.    23.                          621.
   496.54           63.    2794.    21.    23.  1.00     1.    21.    621.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = APPRO;  SRD =      45.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.54     0.7    21.3    62.8    2794.     620.   9.88

X STA.         0.7         5.4         6.2         7.0         7.7         8.3
  A(I)             8.4         2.8         2.7         2.6         2.5
  V(I)            3.68       11.10       11.36       11.73       12.31

X STA.         8.3         8.9         9.5        10.1        10.7        11.3
  A(I)             2.5         2.5         2.5         2.5         2.5
  V(I)           12.32       12.35       12.50       12.58       12.52

X STA.        11.3        11.8        12.4        13.0        13.6        14.2
  A(I)             2.5         2.5         2.5         2.5         2.5
  V(I)           12.38       12.39       12.47       12.55       12.17

X STA.        14.2        14.8        15.5        16.2        16.9        21.3
  A(I)             2.5         2.6         2.6         2.7         8.3
  V(I)           12.63       11.99       11.86       11.33        3.73
```

```
        U.S. Geological Survey WSPRO Input File shre015.wsp
        Hydraulic analysis for structure SHRETH00300015   Date: 10-MAR-98
        TH 30 CROSSING FREEMAN BROOK IN SHREWSBURY, VT             RLB
           *** RUN DATE & TIME: 03-24-98  14:20

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

EXITX:XS   ******     0.      58.  0.92 *****  494.23  493.10    450.  493.30
      -22. ******    26.    2407.  1.00 ***** *******    0.90    7.70

 ===125 FR# EXCEEDS FNTEST AT SECID "BRIDG":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    3.26     492.87     494.39

 ===110 WSEL NOT FOUND AT SECID "BRIDG":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   492.80     497.29    0.50

 ===115 WSEL NOT FOUND AT SECID "BRIDG":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   492.80     497.29     494.39

 ===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 "BRIDG"
                   WSBEG,WSEND,CRWS =   494.39     497.29     494.39

BRIDG:XS      22.     0.      53.  1.14 *****  495.53  494.39    450.  494.39
        0.    22.    24.    2596.  1.00 ***** *******    1.00    8.55

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "USBRG"     KRATIO =  1.44

USBRG:XS      16.     0.      67.  0.69  0.33  495.86 *******    450.  495.17
       16.    16.    25.    3731.  1.00  0.00    0.00    0.70    6.67

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.13     495.63     495.87

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   494.67     514.69    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   494.67     514.69     495.87

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   495.87     514.69     495.87

APPRO:XS      29.     2.      49.  1.29 *****  497.16  495.87    450.  495.87
       45.    29.    21.    2000.  1.00 ***** *******    1.00    9.10

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -22.     0.    26.    450.    2407.      58.    7.70  493.30
   BRIDG:XS       0.     0.    24.    450.    2596.      53.    8.55  494.39
   USBRG:XS      16.     0.    25.    450.    3731.      67.    6.67  495.17
   APPRO:XS      45.     2.    21.    450.    2000.      49.    9.10  495.87

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.10    0.90  489.40  513.18************  0.92  494.23  493.30
   BRIDG:XS    494.39    1.00  490.71  497.29************  1.14  495.53  494.39
   USBRG:XS  ********    0.70  490.86  497.44  0.33  0.00  0.69  495.86  495.17
   APPRO:XS    495.87    1.00  492.17  514.69************  1.29  497.16  495.87
```

```
        U.S. Geological Survey WSPRO Input File shre015.wsp
        Hydraulic analysis for structure SHRETH00300015   Date: 10-MAR-98
        TH 30 CROSSING FREEMAN BROOK IN SHREWSBURY, VT             RLB
           *** RUN DATE & TIME: 03-24-98  14:20

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

EXITX:XS   ******    -1.       76.  1.05 *****  494.97  493.72    620.  493.93
      -22. ******    29.    3318.  1.00 ***** *******    0.91    8.21

 ===125 FR# EXCEEDS FNTEST AT SECID "BRIDG":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.45     494.30     494.97

 ===110 WSEL NOT FOUND AT SECID "BRIDG":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.43     497.29    0.50

 ===115 WSEL NOT FOUND AT SECID "BRIDG":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.43     497.29     494.97

 ===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 "BRIDG"
                  WSBEG,WSEND,CRWS =   494.97     497.29     494.97

BRIDG:XS      22.     0.       66.  1.37 *****  496.33  494.97    620.  494.97
        0.    22.    25.    3624.  1.00 ***** *******    1.00    9.37

USBRG:XS      16.     0.       83.  0.87  0.34  496.67 *******    620.  495.80
       16.    16.    26.    5061.  1.00  0.00    0.00    0.72    7.48

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.17     496.20     496.54

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.30     514.69    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.30     514.69     496.54

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   496.54     514.69     496.54

APPRO:XS      29.     1.       63.  1.52 *****  498.06  496.54    620.  496.54
       45.    29.    21.    2794.  1.00 ***** *******    1.00    9.88

  FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
  EXITX:XS     -22.    -1.    29.    620.    3318.      76.    8.21  493.93
  BRIDG:XS       0.     0.    25.    620.    3624.      66.    9.37  494.97
  USBRG:XS      16.     0.    26.    620.    5061.      83.    7.48  495.80
  APPRO:XS      45.     1.    21.    620.    2794.      63.    9.88  496.54

 SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX     HF    HO  VHD      EGL    WSEL
  EXITX:XS    493.72    0.91  489.40  513.18************  1.05  494.97  493.93
  BRIDG:XS    494.97    1.00  490.71  497.29************  1.37  496.33  494.97
  USBRG:XS  ********    0.72  490.86  497.44  0.34  0.00  0.87  496.67  495.80
  APPRO:XS    496.54    1.00  492.17  514.69************  1.52  498.06  496.54
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure SHRETH00300015, in Shrewsbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SHRETH00300015

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 22 / 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)* FREEMAN BROOK

Road Name *(I - 7):* -

Route Number TH030

Vicinity *(I - 9)* 0.4 MI JCT CL 2 TH 3

Topographic Map Killington Peak

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 43303

Longitude *(i - 17; nnnnn.n)* 72486

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10112200151122

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

Maximum span length *(I - 48; nnnn)* 0027

Year built *(I - 27; YYYY)* 1976

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 160

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

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

Opening skew to Roadway *(I - 34; nn)* 15

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span *(nnn.n ft)* 027.8

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

Vertical clearance from streambed *(nnn.n ft)* 005.5

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

Waterway of full opening *(nnn.n ft^2)* 153.0

Comments:

The structural inspection report of 6/8/94 indicates the structure is a steel stringer type bridge with a concrete deck. The abutment walls and wingwalls are concrete. The right abutment wall is reported in good condition. There are two diagonal cracks at each corner of the abutment and wingwalls. The left abutment wall and its wingwalls are reported in relatively good condition. There is large stone fill protection in front of each abutment and all wingwalls. The streambed is noted as consisting of boulders and gravel mainly. The channel proceeds straight through the crossing. The footings are noted in the report as not visible and settling is not apparent. There is some minor debris build-up noted downstream. The report also noted there are no gravel bars under the bridge.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **1.3**

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} **250** Q_{25} **320**

Q_{50} **380** Q_{100} **450** Q_{500} -

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

Estimated Discharge *(cfs)*: - Velocity at Q **25** *(ft/s)*: **8.0**

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: **Channel is noted as much narrower upstream than the bridge opening and the bridge is not expected to create backwater.**

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*)	-	**4.1**	**4.7**	**5.1**	**5.6**
Velocity (*ft / sec*)	-	-	**8.0**	-	-

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} (*ft³/ sec*): -

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

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

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

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft²*): -

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

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **1.09** mi^2 Lake/pond/swamp area **0** mi^2
Watershed storage *(ST)* **0** %
Bridge site elevation **1725** ft Headwater elevation **3286** ft
Main channel length **1.44** mi
10% channel length elevation **1780** ft 85% channel length elevation **2340** ft
Main channel slope *(S)* **519.96** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY):* - / -

Project Number - Minimum channel bed elevation: -

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS

Cross-sectional Data

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

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

Comments: **The low chord elevation coordinate in this cross section was taken from the 10/11/95 survey done for this report. The station and low chord to bed lengths come from a sketch attached to a 5/21/92 bridge inspection report. This section is of the US bridge face.**

Station	0	6.5	11.33	15.83	25.83	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	497.44	497.44	497.44	497.44	497.44	-	-	-	-	-	-
Bed elevation	494.94	491.77	491.11	491.69	494.77	-	-	-	-	-	-
Low chord to bed	2.50	5.67	6.33	5.75	2.67	-	-	-	-	-	-

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

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

Comments: -

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

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: CG Date: 02/20/96
Computerized by: CG Date: 02/20/96
Reviewd by: RB Date: 03/27/98

Structure Number SHRETH00300015

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. Severance Date *(MM/DD/YY)* 10 / 11 / 1995

2. Highway District Number 3 Mile marker 0

County Rutland (021) Town Shrewsbury (65275)

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

Route Number TH 30 Hydrologic Unit Code: 02010002

3. Descriptive comments:

Located 0.4 miles from Town Highway 3.

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 2 DS 2 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 30.0 *(feet)* Span length 27.0 *(feet)* Bridge width 16.0 *(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)*

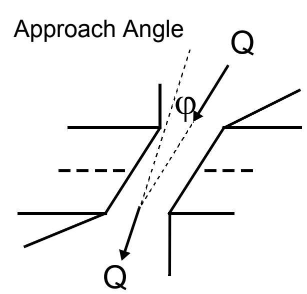
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

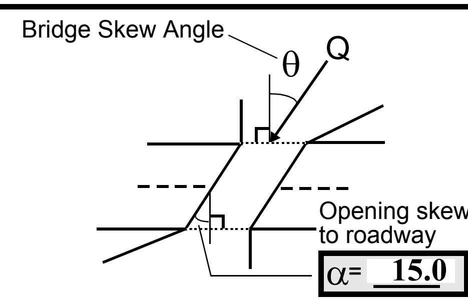
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 2 16. Bridge skew: 18





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 49 feet US *(US, UB, DS)* to 63 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 70 feet DS *(US, UB, DS)* to 154 feet DS

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

18. Bridge Type: 1a

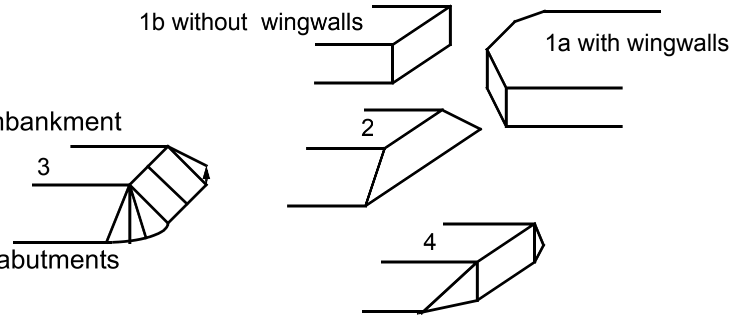
1a- Vertical abutments with wingwalls

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.)

Measured bridge length = 30 feet, measured span length = 28 feet, and measured bridge width = 16.2 feet.
This bridge has a concrete deck with concrete curbing and a steel railing.
The left bank is slightly higher/steeper than the right bank upstream.
The channel is straight through the bridge section.

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
26.5	3.0			4.0	4	4	54	54	1	1

23. Bank width 40.0 24. Channel width 30.0 25. Thalweg depth 24.5 29. Bed Material 543

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

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

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

There is protection around the bridge itself, but none on the upstream banks. Boulders and cobbles line the channel banks. The fines have washed away.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **40** 35. Mid-bar width: **6**

36. Point bar extent: **32** feet **US** (US, UB) to **44** feet **US** (US, UB, DS) positioned **55** %LB to **100** %RB

37. Material: **43**

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

There is an additional point bar extending from 63 feet upstream to 86 feet upstream. It has a mid-bar distance of 79 feet, a mid-bar width of 7 feet, and is positioned 45% LB to 100% RB. The material is boulders, cobbles, gravel, and sand.

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: **52** 42. Cut bank extent: **49** feet **US** (US, UB) to **63** feet **US** (US, UB, DS)

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

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

-

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

There is some localized scour, but none is due to the bridge.

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
13.5		**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.):

43

There is a bar along the base of the right abutment protection. It extends from 2 feet upstream to ten feet under the bridge. The mid-bar distance is 5 feet. The mid-bar width is 3 feet. It is positioned 60% LB to 70% RB.

At the streamward edge of the bar, there is a very small scour hole from 4 feet under the bridge to 7 feet under the bridge. It is 2 feet wide and 0.25 feet deep.

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 1____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

1

Although the vertical clearance is about 6 feet, the channel beneath the bridge and between the abutments is wide.

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	-	-	90.0
RABUT	1	0	90			2	0	25.0

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.):

-

-

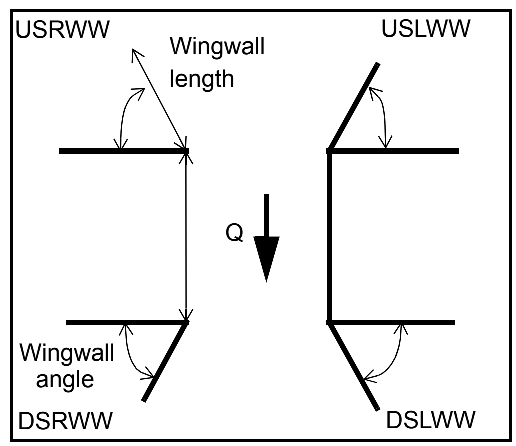
1

Both abutments have stone/ boulder protection. The flow is not near the abutments. (25% LABUT to 75% RABUT).

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						25.0	
USRWW:	Y		1		0	0.5	
DSLWW:	-		-		Y	20.0	
DSRWW:	1		0		-	20.0	

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	Y	-	1	1	1	1
Condition	Y	-	1	-	1	1	1	1
Extent	1	-	0	2	3	3	3	-

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

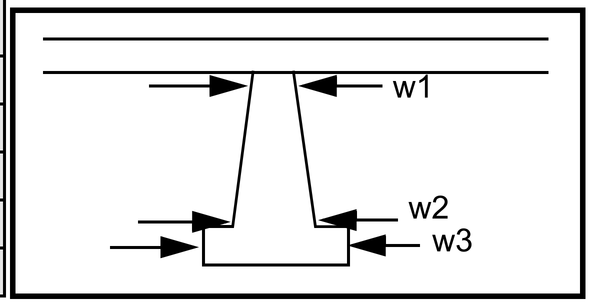
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**6.5**	**7.0**	**60.0**	**30.0**	**25.0**
Pier 2	**8.0**	**6.5**	-	**60.0**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**ere is**	**ream**	**other**	**left**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**pro-**	**left**	**three**	**wing**	*1- Solid pier, 2- column, 3- bent*
88. Material	**tec-**	**wing**	**wing**	**wall**	*1- Wood; 2- concrete; 3- metal; 4- stone*
89. Shape	**tion**	**wall,**	**walls**	**pro-**	*1- Round; 2- Square; 3- Pointed*
90. Inclined?	**alon**	**but**	**. The**	**tec-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**g the**	**it is**	**spac**	**tion**	
92. Pushed	**entir**	**not**	**es**	**have**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**e**	**piled**	**betw**	**been**	
95. Cross-members	**base**	**as**	**een**	**filled**	*0- none; 1- laterals; 2- diagonals; 3- both*
96. Scour Condition	**of**	**high**	**the**	**in**	*0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed*
97. Scour depth	**the**	**as at**	**upst**	**and**	
98. Exposure depth	**upst**	**the**	**ream**	**some**	

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

vegetation exists in the spaces.

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 4_____ Depth: 4_____ Positioned 0___ %LB to 1___ %RB

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

435
4
3
1

Are there major confluences? 1____ *(Y or if N type ctrl-n mc)* How many? Pro-

Confluence 1: Distance tec-_ Enters on tion__ *(LB or RB)* Type exte__ *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

the downstream left wingwall to 57 feet downstream on the left bank.
There is protection piled from 44 feet to 58 feet downstream on the right bank.

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: SHRETH00300015 Town: SHREWSBURY
Road Number: TH 30 County: RUTLAND
Stream: FREEMAN BROOK

Initials RLB Date: 3/24/98 Checked: MAI

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	450	620	0
Main Channel Area, ft2	49.5	62.8	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	19.1	20.6	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.2895	0.2895	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	2.6	3.0	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	2000	2794	0
Conveyance, main channel	2000	2794	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	450.0	620.0	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	9.1	9.9	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	8.7	8.9	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	1	1	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Live-Bed Contraction Scour

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

Characteristic	Approach 100 yr	500 yr	Other Q	Bridge 100 yr	500 yr	Other Q
Q1, discharge, cfs	450	620	0	450	620	0
Total conveyance	2000	2794	0	2589	3627	0
Main channel conveyance	2000	2794	0	2589	3627	0
Main channel discharge	450	620	ERR	450	620	ERR
Area - main channel, ft2	49.5	62.8	0	52.5	66.2	0
(W1) channel width, ft	19.1	20.6	0	16.6	17.2	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	19.1	20.6	0	16.6	17.2	0
D50, ft	0.2895	0.2895	0.2895			
w, fall velocity, ft/s (p. 32)	4.4024	4.4024	0			
y, ave. depth flow, ft	2.59	3.05	N/A	3.16	3.85	ERR
S1, slope EGL	0.0362	0.0384	0			
P, wetted perimeter, MC, ft	21	23	0			
R, hydraulic Radius, ft	2.357	2.730	ERR			
V*, shear velocity, ft/s	1.658	1.837	N/A			
V*/w	0.377	0.417	ERR			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.59	0.59	0			
y2,depth in contraction, ft	2.82	3.39	ERR			
ys, scour depth, ft (y2-y_bridge)	-0.35	-0.46	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	450	620	0
(Q) discharge thru bridge, cfs	450	620	0
Main channel conveyance	2589	3627	0
Total conveyance	2589	3627	0
Q2, bridge MC discharge,cfs	450	620	ERR
Main channel area, ft2	53	66	0
Main channel width (normal), ft	16.6	17.2	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	16.6	17.2	0

y_bridge (avg. depth at br.), ft	3.16	3.85	ERR
Dm, median (1.25*D50), ft	0.361875	0.361875	0
y2, depth in contraction,ft	2.80	3.57	ERR
ys, scour depth (y2-ybridge), ft	-0.36	-0.27	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	450	620	N/A
Main channel area (DS), ft2	52.5	66.2	0
Main channel width (normal), ft	16.6	17.2	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	16.6	17.2	0.0
D90, ft	1.0663	1.0663	0.0000
D95, ft	1.6004	1.6004	0.0000
Dc, critical grain size, ft	0.5748	0.6169	ERR
Pc, Decimal percent coarser than Dc	0.311	0.286	0.000
Depth to armoring, ft	3.82	4.62	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)

	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	450	620	0	450	620	0
a', abut.length blocking flow, ft	1.3	1.7	0	1.2	1.7	0
Ae, area of blocked flow ft2	1.98	3.04	0	1.91	3.21	0
Qe, discharge blocked abut.,cfs	6.96	11.21	0	6.92	11.98	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.52	3.69	ERR	3.62	3.73	ERR
ya, depth of f/p flow, ft	1.52	1.79	ERR	1.59	1.89	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0	0.55	0.55	0

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

theta	105	105	0	75	75	0
K2	1.02	1.02	0.00	0.98	0.98	0.00
Fr, froude number f/p flow	0.502	0.486	ERR	0.506	0.479	ERR
ys, scour depth, ft	2.71	3.22	N/A	2.73	3.29	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)	1.3	1.7	0	1.2	1.7	0
y1 (depth f/p flow, ft)	1.52	1.79	ERR	1.59	1.89	ERR
a'/y1	0.85	0.95	ERR	0.75	0.90	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.50	0.49	N/A	0.51	0.48	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	3.16	3.85	0.00	3.16	3.85	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.)	1.32	1.61	ERR	1.32	1.61	ERR
Fr<=0.8 (spillthrough abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (spillthrough abut.)	1.17	1.42	ERR	1.17	1.42	ERR