LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (SHERTH00380028) on TOWN HIGHWAY 38, crossing the OTTAUQUECHEE RIVER, SHERBURNE, VERMONT

Open-File Report 98-260

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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By RONDA L. BURNS and TIMOTHY SEVERANCE

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Pembroke, New Hampshire

1998

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

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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 28 (SHERTH00380028) ON TOWN HIGHWAY 38, CROSSING THE OTTAUQUECHEE RIVER, SHERBURNE, 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 SHERTH00380028 on Town Highway 38 crossing the Ottauquechee River, Sherburne, 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 central Vermont. The 23.2-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest downstream of the bridge and on the upstream left bank. On the upstream right bank, the surface cover is shrub and brushland.

In the study area, the Ottauquechee River has a straight channel with a slope of approximately 0.006 ft/ft, an average channel top width of 48 ft and an average bank height of 2 ft. The channel bed material ranges from sand to cobbles with a median grain size (D_{50}) of 65.1 mm (0.214 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 3, 1995, indicated that the reach was stable.

The Town Highway 38 crossing of the Ottauquechee River is a 39-ft-long, two-lane bridge consisting of one 37-foot concrete slab span (Vermont Agency of Transportation, written communication, March 14, 1995). The opening length of the structure parallel to the bridge face is 34.3 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 50 degrees to the opening while the computed opening-skew-to-roadway is 35 degrees.

Channel scour 4.5 ft deeper than the mean thalweg depth was observed under the bridge during the Level I assessment. The scour countermeasures at the site included type-1 stone fill (less than 12 inches diameter) along the upstream left and right banks. Type-2 stone fill (less than 36 inches diameter) was along the upstream left and right wingwalls, the left and right abutments, the downstream left wingwall, and the downstream left and right banks. Along the downstream right wingwall, there was type-3 stone fill (less than 48 inches diameter). 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. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. 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 0.1 to 1.9 ft. The worst-case contraction scour occurred at the incipient roadway-ovetopping discharge. Abutment scour ranged from 10.3 to 19.5 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.

Killington Peak, VT. quadrangle, 1:24,000, 1961, photoinspected 1983;
Pico Peak, VT. quadrangle, 1:24,000, 1961, photorevised 1980

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 SHERTH00380028 ***Stream*** Ottauquechee River

County Rutland ***Road*** TH 38 ***District*** 3

Description of Bridge

Bridge length 39 ***ft*** ***Bridge width*** 25.2 ***ft*** ***Max span length*** 37 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 10/3/95

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

Abutments and wingwalls are concrete. There is a 4.5 ft deep scour hole in the channel under the bridge.

Brief description of piers/abutments

Yes

Is bridge skewed to flood flow according to - survey? ***Angle*** 50 No

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

10/3/95

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	0	0	10/3/
Level II	95	0	0

Potential for debris Moderate. There is some debris caught upstream and at the bridge.

None as of 10/3/95.

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 high relief valley.

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

Date of inspection 10/3/95

DS left: Steep road embankment to TH 38

DS right: Moderately sloped overbank

US left: Steep valley wall

US right: Steep road embankment to TH 38

Description of the Channel

Average top width 48 *ft* ***Average depth*** 2 *ft*

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

Straight but wider at the bends and stable with non-alluvial channel boundaries.

10/3/95

Vegetative co Short grass and brush with trees on the overbank

DS left: Trees and brush

DS right: Trees and brush

US left: Short grass and brush with trees on the overbank

US right:

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

None as of 10/3/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 23.2 ***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? Yes

USGS gage description Ottauquechee River near West Bridgewater, VT

USGS gage number 01150900

Gage drainage area 23.4 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 5,500 ***ft³/s*** ***Q500*** 8,300 ***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) USGS survey

Datum tie between USGS survey and VTAOT plans The VTAOT, NGVD 1929, and USGS datums are the same.

Description of reference marks used to determine USGS datum. BM is a USGS survey disk on top of the concrete orifice platform on the upstream right bank (elev. 1,152.12 ft, arbitrary survey datum). RM1 is a metal disk on top of the upstream end of the left abutment (elev. 1,160.73 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 1,160.12 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	-38	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	18	1	Road Grade section
APPR1	63	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 0.035 to 0.050, and overbank "n" values ranged from 0.040 to 0.070.

Normal depth at the exit section (EXIT1) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0028 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1961).

The modelled approach section (APPR1) was surveyed 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.

Bridge Hydraulics Summary

Average bridge embankment elevation 1,160.3 *ft*
Average low steel elevation 1158.2 *ft*

100-year discharge 5,500 *ft^3/s*
Water-surface elevation in bridge opening 1,158.3 *ft*
Road overtopping? Yes *Discharge over road* 2,740 *ft^3/s*
Area of flow in bridge opening 263 *ft^2*
Average velocity in bridge opening 10.3 *ft/s*
Maximum WSPRO tube velocity at bridge 12.8 *ft/s*

Water-surface elevation at Approach section with bridge 1,161.3
Water-surface elevation at Approach section without bridge 1,158.6
Amount of backwater caused by bridge 2.7 *ft*

500-year discharge 8,300 *ft^3/s*
Water-surface elevation in bridge opening 1,158.3 *ft*
Road overtopping? Yes *Discharge over road* 5,940 *ft^3/s*
Area of flow in bridge opening 263 *ft^2*
Average velocity in bridge opening 9.0 *ft/s*
Maximum WSPRO tube velocity at bridge 11.1 *ft/s*

Water-surface elevation at Approach section with bridge 1,162.4
Water-surface elevation at Approach section without bridge 1,160.7
Amount of backwater caused by bridge 1.7 *ft*

Incipient overtopping discharge 2,440 *ft^3/s*
Water-surface elevation in bridge opening 1,155.2 *ft*
Area of flow in bridge opening 178 *ft^2*
Average velocity in bridge opening 13.7 *ft/s*
Maximum WSPRO tube velocity at bridge 17.7 *ft/s*

Water-surface elevation at Approach section with bridge 1,158.4
Water-surface elevation at Approach section without bridge 1,156.4
Amount of backwater caused by bridge 2.0 *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 incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100- and 500-year discharges resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results from these additional computations are presented in appendix F.

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.

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	1.8	0.1	1.9
Depth to armoring	3.8	1.4	N/A
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	17.5	19.5	10.3
Right abutment	14.6	15.1	14.7
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	2.5	1.9	2.6
Right abutment	2.5	1.9	2.6
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

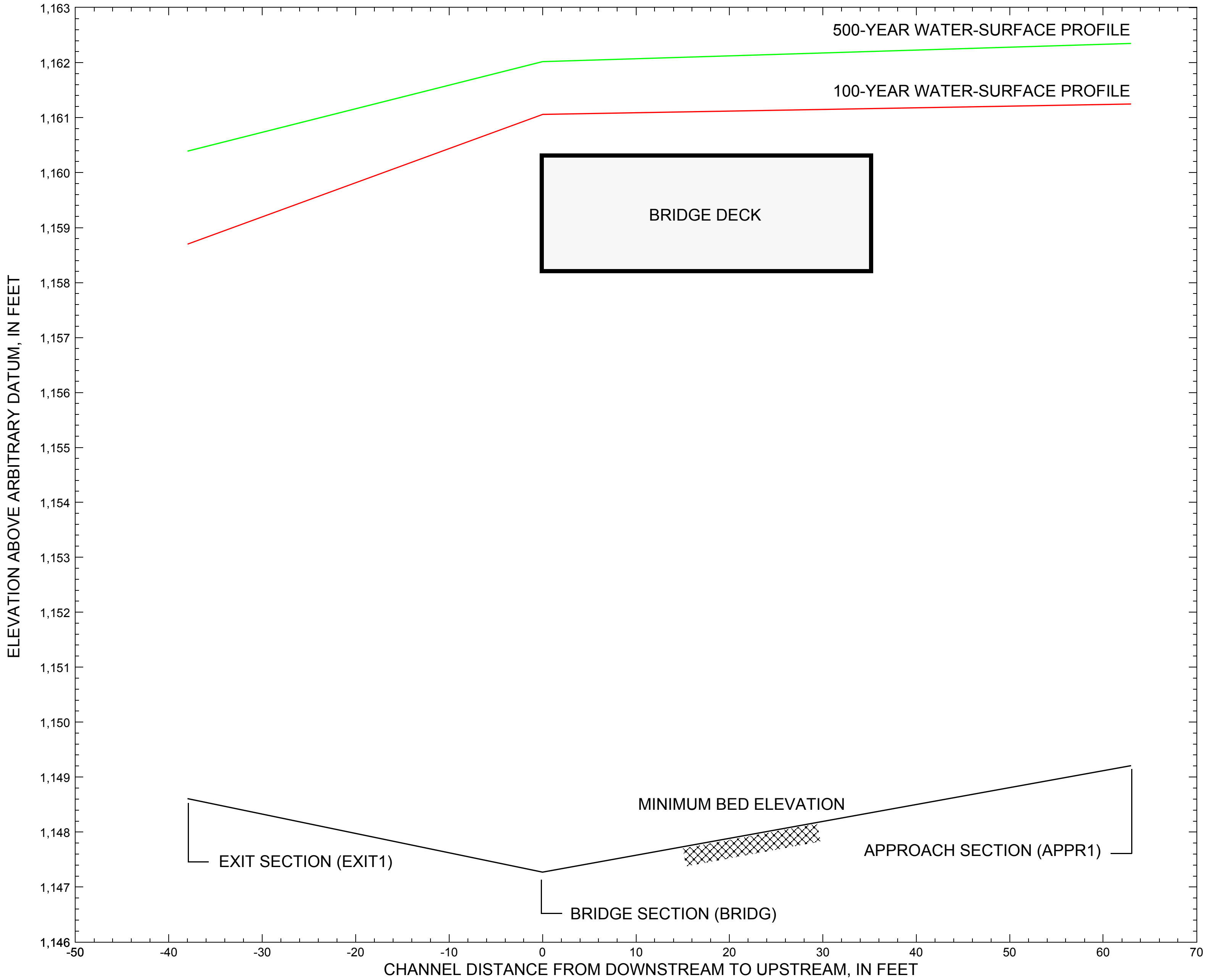

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure SHERTH00380028 on Town Highway 38, crossing the Ottauquechee River, Sherburne, Vermont.

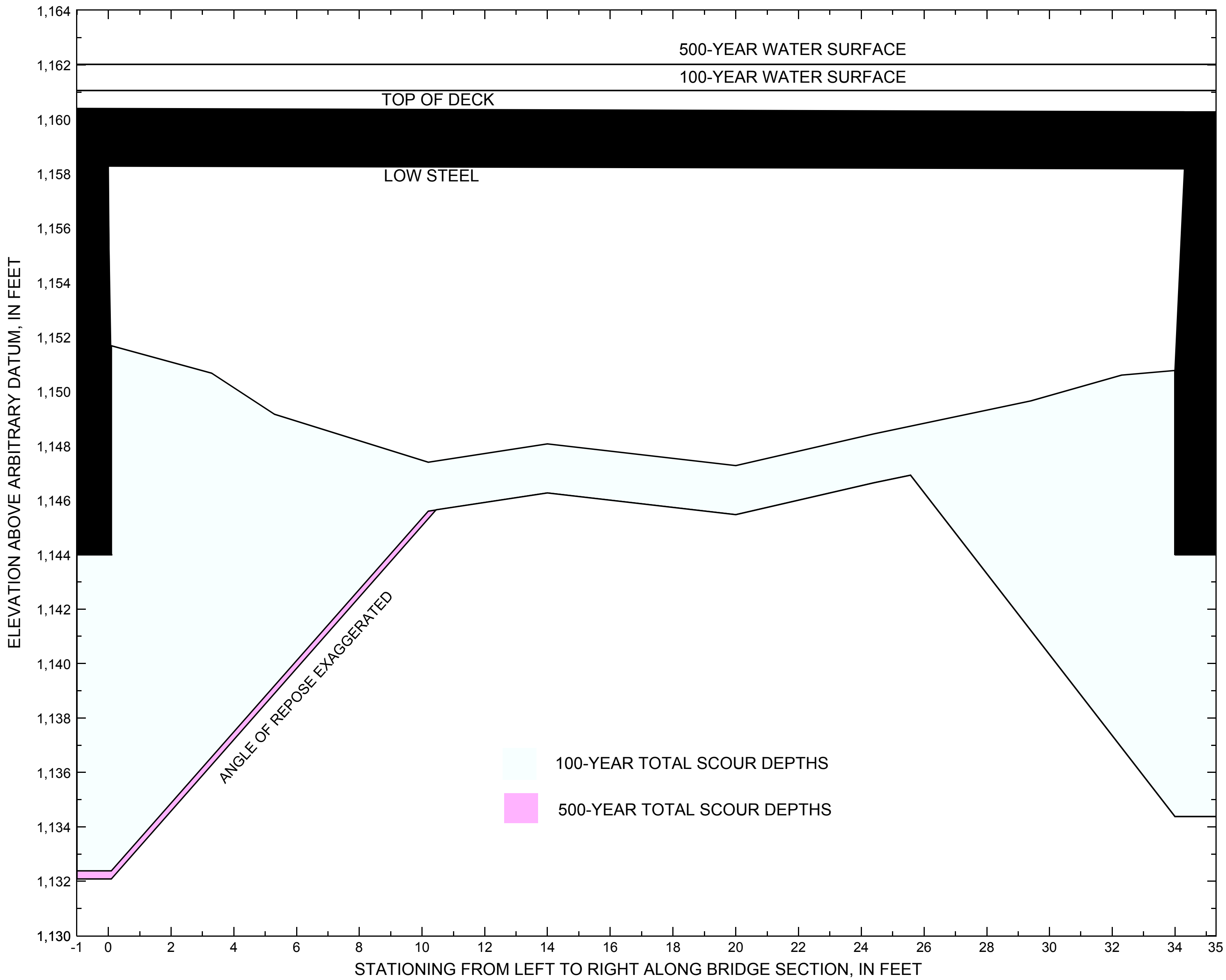

Figure 8. Scour elevations for the 100- and 500-year discharges at structure SHERTH00380028 on Town Highway 38, crossing the Ottauquechee River, Sherburne, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SHERTH00380028 on Town Highway 38, crossing the Ottauquechee River, Sherburne, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of 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 5,500 cubic-feet per second											
Left abutment	0.0	1,159.2	1,158.3	1,144.0	1,151.7	1.8	17.5	--	19.3	1,132.4	-11.6
Right abutment	34.3	1,158.9	1,158.2	1,144.0	1,150.8	1.8	14.6	--	16.4	1,134.4	-9.6

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure SHERTH00380028 on Town Highway 38, crossing the Ottauquechee River, Sherburne, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of 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 8,300 cubic-feet per second											
Left abutment	0.0	1,159.2	1,158.3	1,144.0	1,151.7	0.1	19.5	--	19.6	1,132.1	-11.9
Right abutment	34.3	1,158.9	1,158.2	1,144.0	1,150.8	0.1	15.1	--	15.2	1,135.6	-8.4

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, Pico Peak, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1980, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File sher028.wsp
T2        Hydraulic analysis for structure SHERTH00380028   Date: 26-FEB-98
T3        TH 38 CROSSING THE OTTAUQUECHEE RIVER IN SHERBURNE, VERMONT     RLB
*
J1         * * 0.01
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5500.0   8300.0   2420.0
SK          0.0028   0.0028   0.0028
*
XS   EXIT1    -38           0.
GR         -133.6,1178.23    -98.3,1163.33    -82.5,1162.14    -57.6,1160.89
GR          -39.1,1154.38      0.0,1152.71      8.5,1150.66     12.6,1149.92
GR           19.2,1150.02     32.7,1149.99     43.2,1148.61     49.0,1149.57
GR           51.8,1150.66     59.3,1153.78     71.4,1155.37     86.6,1156.33
GR           99.6,1156.60    117.9,1154.55    146.4,1155.07    186.9,1165.07
*
N           0.040       0.045        0.070
SA                  0.0       59.3
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0   1158.23      35.0
GR            0.0,1158.28      0.0,1151.68      3.3,1150.67      5.3,1149.16
GR           10.2,1147.40     14.0,1148.07     20.0,1147.27     24.4,1148.44
GR           29.4,1149.65     32.3,1150.60     34.0,1150.77     34.3,1158.18
GR            0.0,1158.28
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      41.2 * *     37.8     10.0
N           0.035
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     18      25.2     1
GR         -117.5,1172.95    -92.4,1162.01    -46.7,1161.40      0.0,1160.40
GR           34.1,1160.28     83.0,1159.97    139.1,1159.68    265.2,1158.90
GR          332.7,1159.72    361.0,1163.48    388.6,1167.08
*
AS   APPR1     63           0.
GR          -92.9,1174.60    -66.0,1160.94    -42.4,1156.75    -25.7,1156.67
GR          -19.2,1155.68      0.0,1153.52      5.5,1153.44     15.6,1150.67
GR           19.8,1150.20     24.1,1149.43     29.3,1149.21     34.1,1149.84
GR           36.3,1150.69     41.8,1152.38     47.1,1156.21     59.2,1159.57
GR           83.6,1159.98    139.1,1159.68    265.2,1158.90    332.7,1159.72
GR          361.0,1163.48    388.6,1167.08
*
N           0.050      0.040
SA                 59.2
*
HP 1 BRIDG  1158.28 1 1158.28
HP 2 BRIDG  1158.28 * * 2714
HP 2 RDWAY  1161.06 * * 2743
HP 1 APPR1  1161.25 1 1161.25
HP 2 APPR1  1161.25 * * 5500
*
HP 1 BRIDG  1158.28 1 1158.28
HP 2 BRIDG  1158.28 * * 2365
HP 2 RDWAY  1162.02 * * 5944
HP 1 APPR1  1162.35 1 1162.35
HP 2 APPR1  1162.35 * * 8300
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File sher028.wsp
      Hydraulic analysis for structure SHERTH00380028   Date: 26-FEB-98
      TH 38 CROSSING THE OTTAUQUECHEE RIVER IN SHERBURNE, VERMONT     RLB
         *** RUN DATE & TIME: 03-20-98  15:06

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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
           1     263.   26590.     0.    72.                     ********
 1158.28         263.   26590.     0.    72.  1.00     0.    34.********

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

     WSEL     LEW     REW    AREA        K        Q    VEL
   1158.28     0.0    34.3   262.9   26590.    2714.  10.32

X STA.         0.0        5.2        6.8        8.1        9.4       10.6
  A(I)            32.0       12.0       11.0       10.9       10.7
  V(I)            4.24      11.29      12.32      12.46      12.65

X STA.        10.6       11.9       13.1       14.4       15.7       17.0
  A(I)            10.9       10.7       11.0       10.9       11.1
  V(I)           12.44      12.74      12.36      12.41      12.21

X STA.        17.0       18.3       19.5       20.7       21.9       23.2
  A(I)            10.8       10.6       10.6       11.0       11.0
  V(I)           12.54      12.75      12.75      12.36      12.32

X STA.        23.2       24.6       26.0       27.6       29.2       34.3
  A(I)            11.0       11.3       11.5       11.6       32.1
  V(I)           12.30      12.02      11.84      11.66       4.22

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      18.

     WSEL     LEW     REW    AREA        K        Q    VEL
   1161.06   -30.8   342.8   497.8   14097.    2743.   5.51

X STA.       -30.8       28.3       57.3       91.4      118.1      139.7
  A(I)            30.3       24.2       35.3       32.1       28.7
  V(I)            4.53       5.67       3.88       4.27       4.78

X STA.       139.7      158.1      174.1      188.6      202.0      213.4
  A(I)            26.6       24.7       23.7       23.2       20.7
  V(I)            5.16       5.55       5.79       5.92       6.63

X STA.       213.4      224.7      235.9      246.8      257.0      266.8
  A(I)            21.0       21.8       22.0       21.2       21.0
  V(I)            6.53       6.29       6.22       6.46       6.55

X STA.       266.8      277.0      288.1      300.7      315.0      342.8
  A(I)            21.2       21.6       22.8       23.4       32.4
  V(I)            6.48       6.35       6.02       5.85       4.24

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      63.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
           1     797.   79934.   126.   129.                       11382.
           2     502.   27238.   285.   285.                        3777.
 1161.25        1299.  107172.   411.   414.  1.21   -67.   344.  11903.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      63.

     WSEL     LEW     REW    AREA        K        Q    VEL
   1161.25   -66.6   344.2  1298.7  107172.    5500.   4.24

X STA.       -66.6      -20.7      -11.1       -3.7        2.5        8.2
  A(I)           157.5       57.1       50.9       47.0       46.0
  V(I)            1.75       4.81       5.41       5.86       5.98

X STA.         8.2       12.8       16.6       20.2       23.5       26.7
  A(I)            42.4       39.0       38.5       38.3       37.4
  V(I)            6.49       7.05       7.15       7.17       7.35

X STA.        26.7       30.0       33.5       37.3       41.8       64.7
  A(I)            39.6       41.3       41.8       43.0       86.3
  V(I)            6.94       6.66       6.59       6.40       3.19

X STA.        64.7      142.6      199.2      243.2      281.0      344.2
  A(I)           111.3      100.0       91.4       85.7      104.2
  V(I)            2.47       2.75       3.01       3.21       2.64
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File sher028.wsp
        Hydraulic analysis for structure SHERTH00380028   Date: 26-FEB-98
        TH 38 CROSSING THE OTTAUQUECHEE RIVER IN SHERBURNE, VERMONT     RLB
           *** RUN DATE & TIME: 03-20-98  15:06

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     263.   26590.     0.    72.                     ********
  1158.28          263.   26590.     0.    72.  1.00     0.    34.********

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

         WSEL     LEW     REW    AREA        K        Q    VEL
      1158.28     0.0    34.3   262.9   26590.    2365.   9.00

X STA.         0.0        5.2        6.8        8.1        9.4       10.6
  A(I)            32.0       12.0       11.0       10.9       10.7
  V(I)            3.69       9.83      10.74      10.86      11.02

X STA.        10.6       11.9       13.1       14.4       15.7       17.0
  A(I)            10.9       10.7       11.0       10.9       11.1
  V(I)           10.84      11.10      10.77      10.82      10.64

X STA.        17.0       18.3       19.5       20.7       21.9       23.2
  A(I)            10.8       10.6       10.6       11.0       11.0
  V(I)           10.93      11.11      11.11      10.77      10.74

X STA.        23.2       24.6       26.0       27.6       29.2       34.3
  A(I)            11.0       11.3       11.5       11.6       32.1
  V(I)           10.72      10.47      10.32      10.16       3.68

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      18.

         WSEL     LEW     REW    AREA        K        Q    VEL
      1162.02   -92.4   350.0   886.9   34790.    5944.   6.70

X STA.       -92.4       -3.3       19.6       40.4       59.7       86.3
  A(I)            61.5       37.7       35.9       35.6       52.8
  V(I)            4.83       7.89       8.28       8.36       5.62

X STA.        86.3      110.4      131.6      151.5      169.5      185.8
  A(I)            51.3       47.7       46.9       44.4       42.2
  V(I)            5.79       6.24       6.34       6.69       7.05

X STA.       185.8      201.6      216.9      231.0      244.8      258.1
  A(I)            42.2       42.4       40.4       40.8       40.3
  V(I)            7.04       7.01       7.35       7.28       7.38

X STA.       258.1      270.7      284.1      299.2      315.4      350.0
  A(I)            39.0       39.9       42.1       42.2       61.6
  V(I)            7.63       7.44       7.05       7.03       4.83

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      63.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     937.  103311.   128.   132.                      14377.
             2     820.   60566.   293.   293.                       7777.
  1162.35         1756.  163876.   421.   425.  1.11   -69.   352.  19290.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      63.

         WSEL     LEW     REW    AREA        K        Q    VEL
      1162.35   -68.8   352.5  1756.3  163876.    8300.   4.73

X STA.       -68.8      -25.9      -13.0       -4.0        3.5       10.2
  A(I)           177.9       84.6       70.6       65.5       62.4
  V(I)            2.33       4.91       5.88       6.34       6.65

X STA.        10.2       15.5       20.1       24.4       28.6       32.9
  A(I)            58.3       55.3       54.2       53.7       56.8
  V(I)            7.12       7.51       7.66       7.73       7.31

X STA.        32.9       37.9       44.4       76.2      125.2      167.2
  A(I)            59.2       65.2      117.8      121.3      113.9
  V(I)            7.01       6.37       3.52       3.42       3.64

X STA.       167.2      203.0      235.5      265.5      296.3      352.5
  A(I)           106.0      102.7      100.7      100.6      129.7
  V(I)            3.91       4.04       4.12       4.13       3.20
```

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        U.S. Geological Survey WSPRO Input File sher028.wsp
        Hydraulic analysis for structure SHERTH00380028   Date: 26-FEB-98
        TH 38 CROSSING THE OTTAUQUECHEE RIVER IN SHERBURNE, VERMONT     RLB
           *** RUN DATE & TIME: 03-20-98  15:00

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     178.   21431.    28.    38.                        2557.
  1155.22          178.   21431.    28.    38.  1.00     0.    34.   2557.
1
  HP 2 BRIDG  1155.22 * * 2440

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

         WSEL     LEW     REW    AREA        K        Q    VEL
      1155.22     0.0    34.2   178.5   21431.    2440.  13.67

 X STA.        0.0        6.3        7.6        8.9       10.0       11.1
  A(I)            24.5        7.6        7.3        7.1        6.9
  V(I)            4.98      16.13      16.77      17.23      17.60

 X STA.       11.1       12.3       13.4       14.7       15.8       17.0
  A(I)             7.1        7.0        7.3        7.0        7.2
  V(I)           17.10      17.34      16.82      17.33      16.96

 X STA.       17.0       18.2       19.3       20.3       21.5       22.6
  A(I)             7.2        7.1        6.9        7.0        7.2
  V(I)           17.02      17.22      17.70      17.43      16.98

 X STA.       22.6       23.9       25.2       26.6       28.2       34.2
  A(I)             7.1        7.4        7.5        7.8       24.3
  V(I)           17.09      16.42      16.27      15.65       5.02

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      63.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     465.   36252.   107.   110.                        5499.
  1158.44          465.   36252.   107.   110.  1.00   -52.    55.   5499.

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      63.

         WSEL     LEW     REW    AREA        K        Q    VEL
      1158.44   -51.9    55.1   465.0   36252.    2440.   5.25

 X STA.      -51.9       -3.6        0.9        5.3        9.0       11.8
  A(I)           108.2       21.6       21.7       20.2       18.2
  V(I)            1.13       5.65       5.62       6.04       6.70

 X STA.       11.8       14.3       16.4       18.4       20.3       21.6
  A(I)            17.0       16.4       16.0       15.8       11.1
  V(I)            7.16       7.45       7.62       7.74      10.97

 X STA.       21.6       23.2       25.3       27.2       29.1       31.0
  A(I)            13.9       18.4       17.9       17.2       17.4
  V(I)            8.80       6.63       6.80       7.11       7.01

 X STA.       31.0       33.0       35.0       37.3       39.8       55.1
  A(I)            17.3       17.4       17.7       18.1       43.5
  V(I)            7.06       7.00       6.90       6.76       2.80
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File sher028.wsp
        Hydraulic analysis for structure SHERTH00380028   Date: 26-FEB-98
        TH 38 CROSSING THE OTTAUQUECHEE RIVER IN SHERBURNE, VERMONT     RLB
           *** RUN DATE & TIME: 03-20-98  15:06

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

 EXIT1:XS   ******   -51.    1042.  0.61 ***** 1159.32 1156.44   5500. 1158.70
       -38. ******   161.  103905.  1.42 ***** *******    0.50    5.28

 FULLV:FV      38.   -52.    1074.  0.58  0.10 1159.43 *******   5500. 1158.85
         0.    38.   162.  108185.  1.42  0.00    0.01    0.48    5.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.96    1158.57    1158.45

  ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =  1158.35    1174.60    0.50

  ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =  1158.35    1174.60    1158.45

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPR1"     KRATIO =  0.35

 APPR1:AS      63.   -53.     480.  2.04  0.46 1160.62 1158.45   5500. 1158.58
        63.    63.    56.   37967.  1.00  0.73    0.00    0.96   11.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =  1158.85    1158.23

            <<<<<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      38.     0.     263.  1.66 ***** 1159.94 1155.50   2714. 1158.28
         0. ******    34.   26590.  1.00 ***** *******    0.66   10.32

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   6.  0.800  0.000 1158.23 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      18.    38.  0.10  0.34 1161.49   -0.01   2743. 1161.06

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:    123.    48.   -31.    17.   0.7   0.5   4.3   5.6   0.9   3.1
    RT:   2619.   326.    17.   343.   2.2   1.5   6.4   5.5   1.9   3.1

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

 APPR1:AS      22.   -67.    1300.  0.34  0.15 1161.59 1158.45   5500. 1161.25
        63.    25.   344.  107316.  1.21  0.00   -0.01    0.46    4.23

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

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXIT1:XS     -38.   -51.   161.   5500.  103905.    1042.    5.28 1158.70
    FULLV:FV       0.   -52.   162.   5500.  108185.    1074.    5.12 1158.85
    BRIDG:BR       0.     0.    34.   2714.   26590.     263.   10.32 1158.28
    RDWAY:RG      18.*******   123.   2743.******************    1.00 1161.06
    APPR1:AS      63.   -67.   344.   5500.  107316.    1300.    4.23 1161.25

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

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    EXIT1:XS   1156.44    0.50 1148.61 1178.23************  0.61 1159.32 1158.70
    FULLV:FV   ********   0.48 1148.61 1178.23  0.10  0.00  0.58 1159.43 1158.85
    BRIDG:BR   1155.50    0.66 1147.27 1158.28************  1.66 1159.94 1158.28
    RDWAY:RG   *************** 1158.90 1172.95  0.10******  0.34 1161.49 1161.06
    APPR1:AS   1158.45    0.46 1149.21 1174.60  0.15  0.00  0.34 1161.59 1161.25
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File sher028.wsp
        Hydraulic analysis for structure SHERTH00380028   Date: 26-FEB-98
        TH 38 CROSSING THE OTTAUQUECHEE RIVER IN SHERBURNE, VERMONT     RLB
           *** RUN DATE & TIME: 03-20-98  15:06

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

EXIT1:XS   ******   -56.    1410.  0.75 ***** 1161.14 1157.81   8300. 1160.39
      -38. ******   168.  156701.  1.40 ***** *******    0.49    5.89

FULLV:FV      38.   -57.    1444.  0.72  0.10 1161.26 *******   8300. 1160.54
        0.    38.   169.  161977.  1.39  0.00    0.01    0.47    5.75
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.02    1160.56    1160.69

 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =  1160.04    1174.60    0.50

 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =  1160.04    1174.60    1160.69

 ===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 =  1160.69    1174.60    1160.69

APPR1:AS      63.   -65.    1069.  1.19 ***** 1161.88 1160.69   8300. 1160.69
       63.    63.   340.   83798.  1.27 ***** *******    0.95    7.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =  1160.54    1158.23

            <<<<<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      38.     0.     263.  1.26 ***** 1159.54 1154.91   2365. 1158.28
        0. ******    34.   26590.  1.00 ***** *******    0.57    8.99

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000 1158.23 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      18.    38.  0.10  0.39 1162.64    0.00   5944. 1162.02

           Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    629.   109.   -92.    17.   1.7   0.9   5.8   6.7   1.5   3.2
   RT:   5316.   333.    17.   350.   3.1   2.4   8.0   6.7   3.0   3.1

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

APPR1:AS      22.   -69.    1757.  0.39  0.24 1162.74 1160.69   8300. 1162.35
       63.    36.   353.  163954.  1.11  0.00    0.00    0.43    4.72

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -38.   -56.   168.   8300.  156701.    1410.    5.89 1160.39
   FULLV:FV       0.   -57.   169.   8300.  161977.    1444.    5.75 1160.54
   BRIDG:BR       0.     0.    34.   2365.   26590.     263.    8.99 1158.28
   RDWAY:RG      18.*******   629.   5944.*****************    1.00 1162.02
   APPR1:AS      63.   -69.   353.   8300.  163954.    1757.    4.72 1162.35

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXIT1:XS   1157.81    0.49 1148.61 1178.23************  0.75 1161.14 1160.39
   FULLV:FV  ********    0.47 1148.61 1178.23  0.10  0.00  0.72 1161.26 1160.54
   BRIDG:BR   1154.91    0.57 1147.27 1158.28************  1.26 1159.54 1158.28
   RDWAY:RG  *************** 1158.90 1172.95  0.10******  0.39 1162.64 1162.02
   APPR1:AS   1160.69    0.43 1149.21 1174.60  0.24  0.00  0.39 1162.74 1162.35
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File sher028.wsp
        Hydraulic analysis for structure SHERTH00380028   Date: 26-FEB-98
        TH 38 CROSSING THE OTTAUQUECHEE RIVER IN SHERBURNE, VERMONT     RLB
           *** RUN DATE & TIME: 03-20-98  15:00

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

EXIT1:XS   ******   -45.     492.  0.44 ***** 1156.73 1154.28   2440. 1156.28
      -38. ******    86.   46090.  1.16 ***** *******    0.49    4.96

 ===140 AT SECID "FULLV":  END OF CROSS SECTION EXTENDED VERTICALLY.
                         WSEL,YLT,YRT =  1156.42     1178.23    1156.33

FULLV:FV      38.   -45.     511.  0.41  0.10 1156.84 *******   2440. 1156.42
        0.    38.    87.   48417.  1.17  0.00    0.01    0.46    4.78
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     0.81     1156.41    1155.83

 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =  1155.92    1174.60    0.50

 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =  1155.92    1174.60    1155.83

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                         "APPR1"     KRATIO =  0.40

APPR1:AS      63.   -24.     272.  1.25  0.40 1157.67 1155.83   2440. 1156.41
       63.    63.    48.   19244.  1.00  0.42    0.01    0.81    8.98
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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      38.     0.     178.  2.91  0.23 1158.13 1155.02   2440. 1155.22
        0.    38.    34.   21411.  1.00  1.17    0.00    0.96   13.68

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ****** 1158.23 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      18.        <<<<<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      22.   -52.     465.  0.43  0.21 1158.87 1155.83   2440. 1158.44
       63.    27.    55.   36236.  1.00  0.53    0.01    0.44    5.25

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.524  0.132   31355.     8.    42.  1158.27

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -38.   -45.    86.   2440.   46090.     492.    4.96 1156.28
   FULLV:FV       0.   -45.    87.   2440.   48417.     511.    4.78 1156.42
   BRIDG:BR       0.     0.    34.   2440.   21411.     178.   13.68 1155.22
   RDWAY:RG      18.**************      0.******************    1.00********
   APPR1:AS      63.   -52.    55.   2440.   36236.     465.    5.25 1158.44

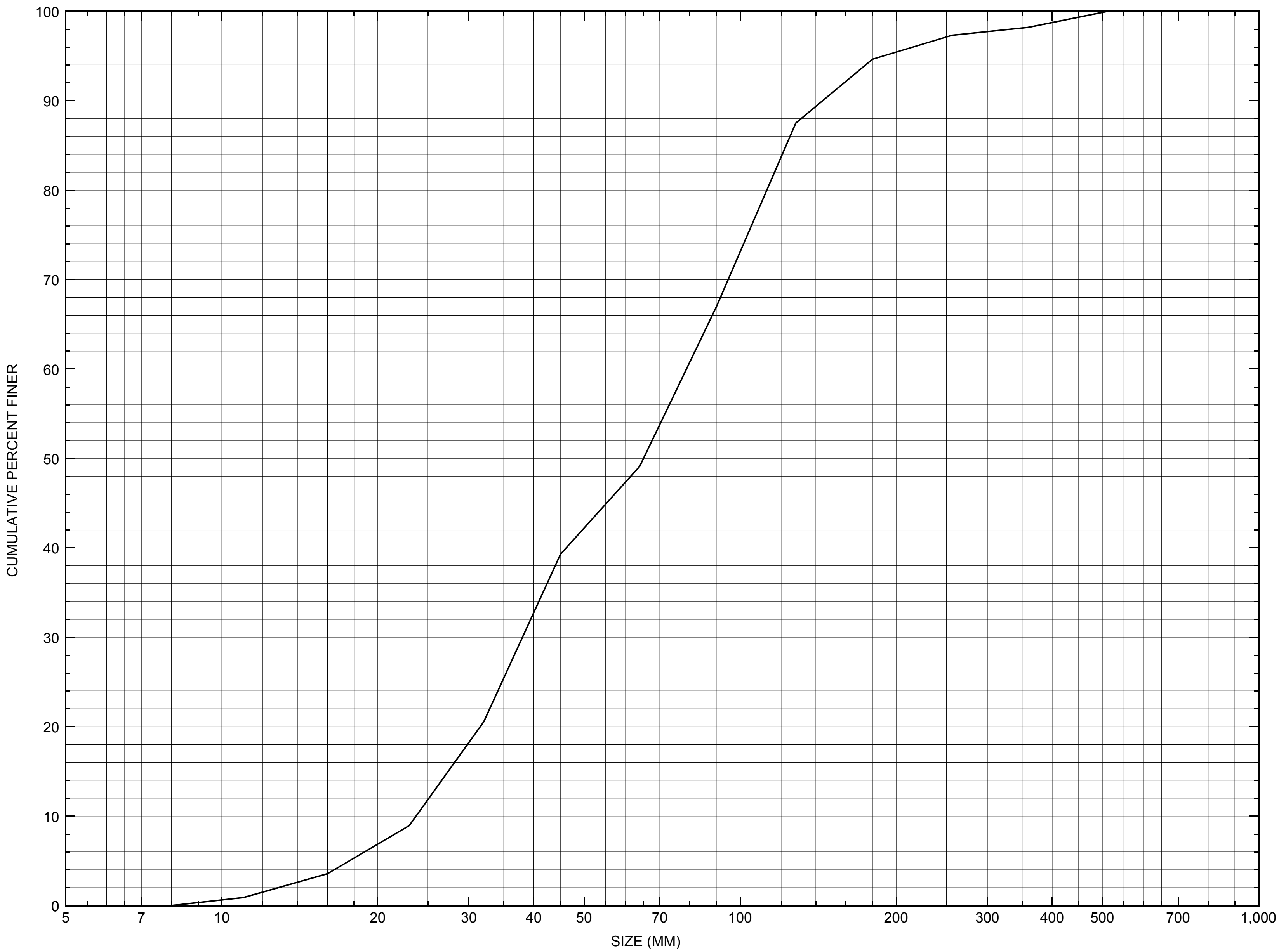
    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       8.    42.   31355.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS   1154.28    0.49 1148.61 1178.23************  0.44 1156.73 1156.28
   FULLV:FV   ********    0.46 1148.61 1178.23  0.10  0.00  0.41 1156.84 1156.42
   BRIDG:BR   1155.02    0.96 1147.27 1158.28  0.23  1.17  2.91 1158.13 1155.22
   RDWAY:RG   *************** 1159.97 1172.95**********************************
   APPR1:AS   1155.83    0.44 1149.21 1174.60  0.21  0.53  0.43 1158.87 1158.44
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure SHERTH00380028, in Sherburne, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SHERTH00380028

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 14 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 64825

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

Waterway *(I - 6)* OTTAUQUECHEE RIVER

Road Name *(I - 7):* -

Route Number TH038

Vicinity *(I - 9)* 0.07 MI TO JCT W US4

Topographic Map Killington Peak

Hydrologic Unit Code: 01080106

Latitude *(I - 16; nnnn.n)* 43374

Longitude *(i - 17; nnnnn.n)* 72456

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10112100281121

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

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

Year built *(I - 27; YYYY)* 1992

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000020

Deck Width *(I - 52; nn.n)* 252

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

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

Opening skew to Roadway *(I - 34; nn)* 30

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 030.3

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

Vertical clearance from streambed (*nnn.n ft*) 9.4

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

Waterway of full opening (*nnn.n ft*^{2}) 285.0

Comments:

The structural inspection report of 7/5/93 indicates the structure is a concrete slab type bridge. Both abutment walls have some minor fine cracks reported. Each abutment wall is protected by placed stone and boulder fill. The same stone fill is noted on the wingwalls and at least partially on the stream banks. This is a fairly new bridge and very few notes are on the structural report.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: **23.1**

Terrain character: **-**

Stream character & type: **-**

Streambed material: **-**

Discharge Data *(cfs)*: $Q_{2.33}$ **1300** Q_{10} **2500** Q_{25} **3500**

Q_{50} **4500** Q_{100} **5500** Q_{500} **-**

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

Estimated Discharge *(cfs)*: **-** Velocity at Q **25** *(ft/s)*: **10.1**

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*)	**1157.1**	**1159.8**	**1160.8**	**1161.5**	**1161.8**
Velocity (*ft / sec*)	-	-	**10.1**	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): **Y** Frequency: **Q5**

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

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

Upstream distance (*miles*): **-** Town: **Sherburne** Year Built: **1969**

Highway No. : **TH28** Structure No. : **24** Structure Type: **Pipe arch**

Clear span (*ft*): **17.0** Clear Height (*ft*): **10.1** Full Waterway (*ft^2*): **171.7**

Downstream distance (*miles*): - Town: Sherburne Year Built: 1956
Highway No. : US 4 Structure No. : 33 Structure Type: Rolled steel beam
Clear span (*ft*): 65.0 Clear Height (*ft*): 13.0 Full Waterway (ft^2): 845.0

Comments:

Flow over the road indicated on the plans is likely for discharges above 1950 cfs. The elevation at which the relief occurs is not provided. Based on the discharge of 1950 cfs, the discharge expected over the roadway may be on the order of 3550 cfs.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 23.17 mi^2

Lake/pond/swamp area 0.15 mi^2

Watershed storage *(ST)* 0.1 %

Bridge site elevation 1160 ft

Headwater elevation 2782 ft

Main channel length 8.067 mi

10% channel length elevation 1160 ft

85% channel length elevation 2320 ft

Main channel slope *(S)* 191.73 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)*: **09** / **1990**

Project Number **BRZ 1443(11)** Minimum channel bed elevation: **1146.0**

Low superstructure elevation: USLAB **1159.2** DSLAB **1159.2** USRAB **1158.9** DSRAB **1158.9**

Benchmark location description:

Spike in a root of an 18 inch diameter elm on the left bank upstream overbank area, about 15 feet bankward on the roadway from the left abutment and 70 feet from the roadway centerline upstream on the right side of a gravel driveway, elevation 1158.44.

Reference Point (*MSL, Arbitrary, Other*): **MSL** Datum (*NAD27, NAD83, Other*): **NGVD1929**

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **1144.0**

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

If 3: Footing bottom elevation: **-**

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

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

Briefly describe material at foundation bottom elevation or around piles:

The borings show both abutment footings set in a moist to wet sandy gravel.

Comments:

The plans show a USGS stream gage just upstream of the bridge on the right bank. The same hydrologic data is printed on the plans. Other points that may be used as reference marks are 1) The upstream right corner of the concrete deck, elevation 1160.69, or 2) The upstream left corner of the concrete deck, elevation 1161.25.

Cross-sectional Data

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

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

Comments: **There are several channel cross sections printed on and kept with the plans, which are listed under the last project number, BRZ1443(11). Orientation of the cross sections is inconsistent with any cross section data surveyed for this study and is not comparable. Data was not retreived.**

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

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: 2/16/96
Computerized by: CG Date: 2/16/96
Reviewd by: RB Date: 3/17/98

Structure Number SHERTH00380028

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. Severance Date *(MM/DD/YY)* 10 / 03 / 1995

2. Highway District Number 03 Mile marker -

County Rutland (021) Town Sherburne (64825)

Waterway *(I - 6)* Ottauquechee River Road Name -

Route Number TH 038 Hydrologic Unit Code: 01080106

3. Descriptive comments:

Located 0.07 miles to the junction with US 4.
There is a USGS gaging station on the upstream right bank.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 5 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 1 UB 1 DS 1 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 39 *(feet)* Span length 37 *(feet)* Bridge width 25.2 *(feet)*

Road approach to bridge:

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

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

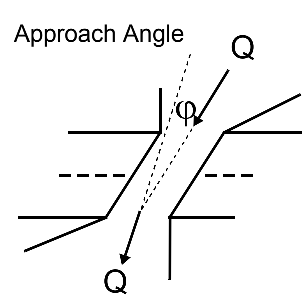
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

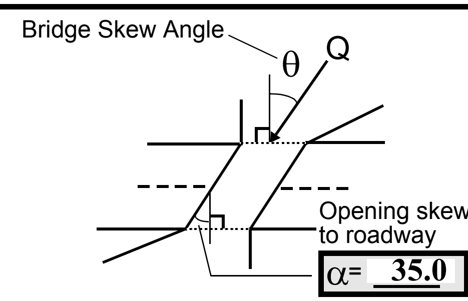
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	2	1
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: 20 16. Bridge skew: 50





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 20 feet US *(US, UB, DS)* to 0 feet DS

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

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

18. Bridge Type: **1a**

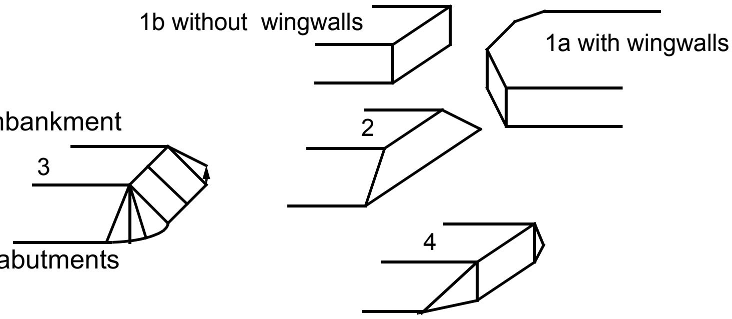
1a- Vertical abutments with wingwalls

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.)

7. Values are from the VTAOT database. Measured bridge length = 39.0 feet, measured span length = 36.6 feet, and measured bridge width = 25.3 feet.

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
42.0	**3.0**			**1.5**	**4**	**2**	**43**	**4**	**1**	**1**

23. Bank width **15.0** 24. Channel width **15.0** 25. Thalweg depth **36.5** 29. Bed Material **43**

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

Both banks have stone fill protection within one bridge length. Further upstream, cobbles and boulders, which were left behind after the fines washed out, line the channel.
There is a dry overflow channel that enters the main channel at 50 feet upstream on the left bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **96** 35. Mid-bar width: **12**

36. Point bar extent: **46** feet **US** (US, UB) to **137** feet **US** (US, UB, DS) positioned **65** %LB to **100** %RB

37. Material: **43**

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

-

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: **70** 42. Cut bank extent: **25** feet **US** (US, UB) to **145** 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.):

Much of the left bank is eroded. A small portion of the right bank has a cut-bank with a mid-bank distance of 84 feet. It extends from 76 feet upstream to 89 feet upstream.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **40**

47. Scour dimensions: Length **60** Width **8** Depth : **1** Position **15** %LB to **85** %RB

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

The scours starts at the bridge and extends 60 feet upstream. Scattered within this area, there are spots which approach 1 foot in depth. This scour area runs into the hole beneath 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
20.5		**1.5**		**2**	**-**	**-**	**-**

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.):

23

There is a large scour hole beneath the bridge. There is stone fill protection along the base of both abutments. A fine sand bar has formed along the base of the right abutment. The scour hole begins 5 feet upstream of the upstream bridge face and extends 14 feet downstream of the upstream bridge face. Two feet downstream of the upstream bridge face the scour depth is 4.5 feet. At the downstream bridge face the water depth is 3.0 feet and becomes shallower as you go downstream. At the center of the bridge the water depth is 4.5 feet.

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

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

There are a number of boulders across the channel at 137 feet upstream and debris has accumulated here. At high flow this will be washed downstream. At two bridge lengths upstream the channel constricts. The bar beneath the bridge is composed of twigs, sand, and leaves.

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		30	90	2	0	-	-	90.0
RABUT	1	0	90			2	0	28.0

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.):

-

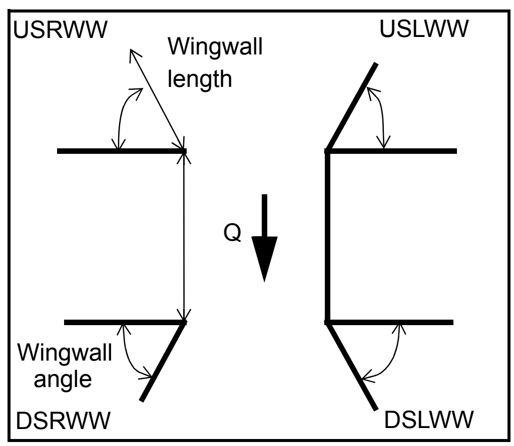
-

1

There is no scour as each abutment is protected by type-2 protection along the entire base.
A bar has formed along the right side of the under bridge channel at the base of the protection. The bar starts 5 feet under the bridge and is 16 feet long and extends 6 feet into the channel from the right abutment. Mid-bar width is 4 feet and the bar is composed of fine sand/silt and twigs/leaves.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						28.0	
USRWW:	Y		1		0	3.5	
DSLWW:	-		-		Y	35.0	
DSRWW:	1		0		-	35.0	



*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	2	2	2	-

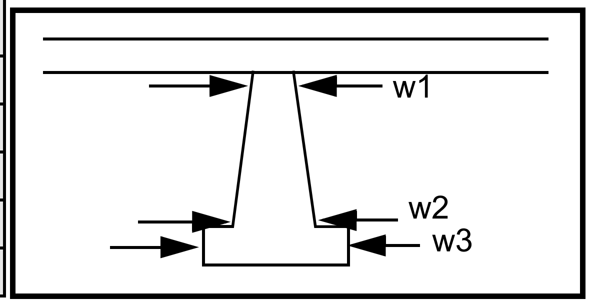
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
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				**70.0**	**11.0**	**10.0**
Pier 2		**5.0**		**16.0**	**18.0**	**75.0**
Pier 3		**-**	**-**	**10.0**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e pro-**	**There**	**the**	**nstrea**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**tec-**	**is a**	**brid**	**m**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**tion**	**lot of**	**ge.**	**brid**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**for**	**stone**	**At**	**ge**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**the**	**fill**	**32**	**face,**	*Y- yes; N- no*
91. Attack ∠ (BF)	**wing**	**on**	**feet**	**the**	
92. Pushed	**walls**	**the**	**dow**	**stone**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**is in**	**dow**	**nstre**	**fill is**	
95. Cross-members	**good**	**nstre**	**am**	**visi-**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**con-**	**am**	**of**	**ble**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**ditio**	**side**	**the**	**acro**	
98. Exposure depth	**n.**	**of**	**dow**	**ss**	

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

channel.

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
-	-			-	N	-	-	-	-	-

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? - (Y or if N type ctrl-n cb) Where? NO (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: 3

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

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

43
2
2
1

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

Confluence 1: Distance 65 Enters on feet (LB or RB) Type dow (**1**- perennial; **2**- ephemeral)

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

Confluence comments (eg. confluence name):

the right bank, there is a dry channel entering from the direction of US 4. There is a bar at its mouth where course sand and fine gravel have washed into the channel. There are several small boulders in the down-

F. Geomorphic Channel Assessment

107. Stage of reach evolution str

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)*:

eam channel. There are two scour holes downstream.
The channel is braided 145 feet downstream of the downstream bridge face.

109. G. Plan View Sketch

- N

point bar (pb)	debris	flow (Q)	stone wall
cut-bank (cb)	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: SHERTH00380028 Town: SHERBURNE
Road Number: TH 38 County: RUTLAND
Stream: OTTAUQUECHEE RIVER

Initials RLB Date: 3/6/98 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	5500	8300	2440
Main Channel Area, ft2	797	937	465
Left overbank area, ft2	0	0	0
Right overbank area, ft2	502	820	0
Top width main channel, ft	126	128	107
Top width L overbank, ft	0	0	0
Top width R overbank, ft	285	293	0
D50 of channel, ft	0.2136	0.2136	0.2136
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.3	7.3	4.3
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	1.8	2.8	ERR
Total conveyance, approach	107172	163876	36252
Conveyance, main channel	79934	103311	36252
Conveyance, LOB	0	0	0
Conveyance, ROB	27238	60566	0
Percent discrepancy, conveyance	0.0000	-0.0006	0.0000
Qm, discharge, MC, cfs	4102.2	5232.5	2440.0
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	1397.8	3067.5	0.0
Vm, mean velocity MC, ft/s	5.1	5.6	5.2
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.8	3.7	ERR
Vc-m, crit. velocity, MC, ft/s	9.1	9.3	8.6
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	0
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	5500	8300	2440
(Q) discharge thru bridge, cfs	2714	2365	2440
Main channel conveyance	26590	26590	21431
Total conveyance	26590	26590	21431
Q2, bridge MC discharge,cfs	2714	2365	2440
Main channel area, ft2	263	263	179
Main channel width (normal), ft	28.1	28.1	28.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	28.1	28.1	28
y_bridge (avg. depth at br.), ft	9.36	9.36	6.38
Dm, median (1.25*D50), ft	0.267	0.267	0.267
y2, depth in contraction,ft	9.07	8.06	8.31
ys, scour depth (y2-ybridge), ft	-0.28	-1.29	**1.93**

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	2714	2365	2440
Main channel area (DS), ft2	262.9	262.9	178.5
Main channel width (normal), ft	28.1	28.1	28.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	28.1	28.1	28.0
D90, ft	0.4732	0.4732	0.4732
D95, ft	0.6189	0.6189	0.6189
Dc, critical grain size, ft	0.3572	0.2712	0.7239
Pc, Decimal percent coarser than Dc	0.219	0.375	0.038
Depth to armoring, ft	**3.82**	**1.36**	**N/A**

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and Davis, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	5500	8300	2440
Q, thru bridge MC, cfs	2714	2365	2440
Vc, critical velocity, ft/s	9.11	9.34	8.56
Va, velocity MC approach, ft/s	5.15	5.58	5.25
Main channel width (normal), ft	28.1	28.1	28.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	28.1	28.1	28.0
qbr, unit discharge, ft2/s	96.6	84.2	87.1
Area of full opening, ft2	262.9	262.9	178.5
Hb, depth of full opening, ft	9.36	9.36	6.38
Fr, Froude number, bridge MC	0.66	0.57	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	1158.23	1158.23	1158.23
Elevation of Bed, ft	1148.87	1148.87	1151.86
Elevation of Approach, ft	1161.25	1162.35	0
Friction loss, approach, ft	0.15	0.24	0
Elevation of WS immediately US, ft	1161.10	1162.11	0.00
ya, depth immediately US, ft	12.23	13.24	-1151.86
Mean elevation of deck, ft	1160.3	1160.3	1160.3
w, depth of overflow, ft (>=0)	0.80	1.81	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.95	ERR
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	**1.79**	**0.12**	N/A
Ys, scour w/Umbrell equation, ft	-0.19	0.43	N/A

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

**Ys, scour w/Chang equation, ft	ERR	N/A	N/A

**Ys, scour w/Umbrell equation, ft	ERR	N/A	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	9.07	8.06	8.31
WSEL at downstream face, ft	--	--	--
Depth at downstream face, ft	N/A	N/A	N/A
Ys, depth of scour (Laursen), ft	N/A	N/A	N/A

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	5500	8300	2440	5500	8300	2440
a', abut.length blocking flow, ft	69.7	71.9	55	52.4	52.4	24
Ae, area of blocked flow ft2	301.55	344.47	140.65	178.82	189.41	113.13
Qe, discharge blocked abut.,cfs	--	--	305	--	--	603.9
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.56	4.15	2.17	3.45	4.15	5.34
ya, depth of f/p flow, ft	4.33	4.79	2.56	3.41	3.61	4.71
--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	125	125	125	55	55	55
K2	1.04	1.04	1.04	0.94	0.94	0.94
Fr, froude number f/p flow	0.294	0.312	0.239	0.409	0.407	0.433
ys, scour depth, ft	**17.49**	**19.45**	**10.32**	**14.59**	**15.13**	**14.66**

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)	69.7	71.9	55	52.4	52.4	24
y1 (depth f/p flow, ft)	4.33	4.79	2.56	3.41	3.61	4.71
a'/y1	16.11	15.01	21.51	15.35	14.50	5.09
Skew correction (p. 49, fig. 16)	1.08	1.08	1.08	0.87	0.87	0.87
Froude no. f/p flow	0.29	0.31	0.24	0.41	0.41	0.43
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	0.66	0.57	0.96	0.66	0.57	0.96
y, depth of flow in bridge, ft	9.36	9.36	6.38	9.36	9.36	6.38
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**2.52**	**1.88**	ERR	**2.52**	**1.88**	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	**2.64**	ERR	ERR	**2.64**