LEVEL II SCOUR ANALYSIS FOR BRIDGE 11 (VERSTH00380011) on TOWN HIGHWAY 38, crossing ALGERINE BROOK, VERSHIRE, VERMONT

Open-File Report 98-254

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 11 (VERSTH00380011) on TOWN HIGHWAY 38, crossing ALGERINE BROOK, VERSHIRE, VERMONT

By MICHAEL A. IVANOFF AND ERICK M. BOEHMLER

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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Box 25286
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 11 (VERSTH00380011) ON TOWN HIGHWAY 38, CROSSING ALGERINE BROOK, VERSHIRE, VERMONT

By **Michael A. Ivanoff and Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure VERSTH00380011 on Town Highway 38 crossing Algerine Brook, Vershire, 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 New England Upland section of the New England physiographic province in central Vermont. The 7.38-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest along the upstream left bank, shrubs and brush along the downstream left bank, and pasture along the right bank.

In the study area, Algerine Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 52 ft and an average bank height of 5 ft. The channel bed material ranges from silt to boulders with a median grain size (D_{50}) of 71.3 mm (0.234 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 6, 1995, indicated that the reach was stable.

The Town Highway 38 crossing of Algerine Brook is a 34-ft-long, two-lane bridge consisting of one 30-foot concrete T-beam span (Vermont Agency of Transportation, written communication, August 26, 1994). The opening length of the structure parallel to the bridge face is 29.7 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening while the computed opening-skew-to-roadway is zero degrees.

A scour hole 2.0 ft deeper than the mean thalweg depth was observed along the downstream end of the right abutment during the Level I assessment. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.8 to 1.0 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.7 to 9.8 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.

Vershire, VT. Quadrangle, 1:24,000, 1981
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 VERSTH00380011 ***Stream*** Algerine Brook

County Orange ***Road*** TH 38 ***District*** 4

Description of Bridge

Bridge length 34 ***ft*** ***Bridge width*** 23.1 ***ft*** ***Max span length*** 30 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 9/6/95

Description of stone fill None

Abutments and wingwalls are concrete. There is a two foot deep scour hole in front of the downstream end of the right abutment.

Yes 15

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

The bridge is located at a severe channel bend. The scour hole has developed in the location where the bend impacts the downstream end of the right abutment.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	9/6/95	0	0
Level II	9/6/95	0	0

Potential for debris Moderate. There is some debris caught on boulders and trees leaning over the upstream channel.

Describe any features near or at the bridge that may affect flow (include observation date) There was a large point bar along the upstream left bank extending through the bridge as of 9/6/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley.

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

Date of inspection 9/6/95

DS left: Moderately sloped overbank

DS right: Moderately sloped overbank

US left: Steep channel bank to the overbank

US right: Steep valley wall

Description of the Channel

Average top width 52 ***ft*** ***Average depth*** 5 ***ft***

Predominant bed material Cobbles /Boulders ***Bank material*** Cobbles/Silt/Clay

Sinuous but stable
with non-alluvial channel boundaries and irregular point and lateral bars.

9/6/95

Vegetative co Trees and brush

DS left: Short grass and brush with a few trees.

DS right: Trees

US left: Short grass and brush with a few trees.

US right: Yes

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

None noted 9/6/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 7.38 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,550 ***ft³/s*** ***Q500*** 2,200 ***ft³/s***

The 100- and 500-year discharges are based on the empirical equation developed and documented by FHWA (1983). The FHWA (1983) flood frequency curve is near the median of the range defined by several other 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 left abutment (elev. 501.59 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the upstream right wingwall (elev. 500.93 ft, arbitrary survey datum). RM3 is a spike 4 ft from the base of a utility pole (2263I) on the downstream left bank (elev. 513.94 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	-26	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPRO	58	1	Approach section

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.050 to 0.060, and overbank "n" values ranged from 0.040 to 0.050.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.022 ft/ft, which was computed from surveyed downstream thalweg points.

The approach section (APPRO) 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.

For the 100-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles for the 100-year discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 502.2 ***ft***
Average low steel elevation 498.5 ***ft***

100-year discharge 1,550 ***ft^3/s***
Water-surface elevation in bridge opening 495.2 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 130 ***ft^2***
Average velocity in bridge opening 11.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.1 ***ft/s***

Water-surface elevation at Approach section with bridge 498.4
Water-surface elevation at Approach section without bridge 496.4
Amount of backwater caused by bridge 2.0 ***ft***

500-year discharge 2,200 ***ft^3/s***
Water-surface elevation in bridge opening 498.8 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 228 ***ft^2***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.0 ***ft/s***

Water-surface elevation at Approach section with bridge 501.0
Water-surface elevation at Approach section without bridge 497.5
Amount of backwater caused by bridge 3.5 ***ft***

Incipient overtopping discharge -- ***ft^3/s***
Water-surface elevation in bridge opening -- ***ft***
Area of flow in bridge opening -- ***ft^2***
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-year 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 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 500-year discharge 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 500-year discharge 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 computations are presented in appendix F. Furthermore, for the 500-year discharge, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution also are provided 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	0.8	1.0	--
Depth to armoring	17.4	14.5	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour	6.7	7.0	--
Left abutment	7.4–	9.8-	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-year discharge	*500-year discharge* *(D50 in feet)*	*Incipient overtopping discharge*
Abutments:	1.8	2.4	--
Left abutment	1.8	2.4	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

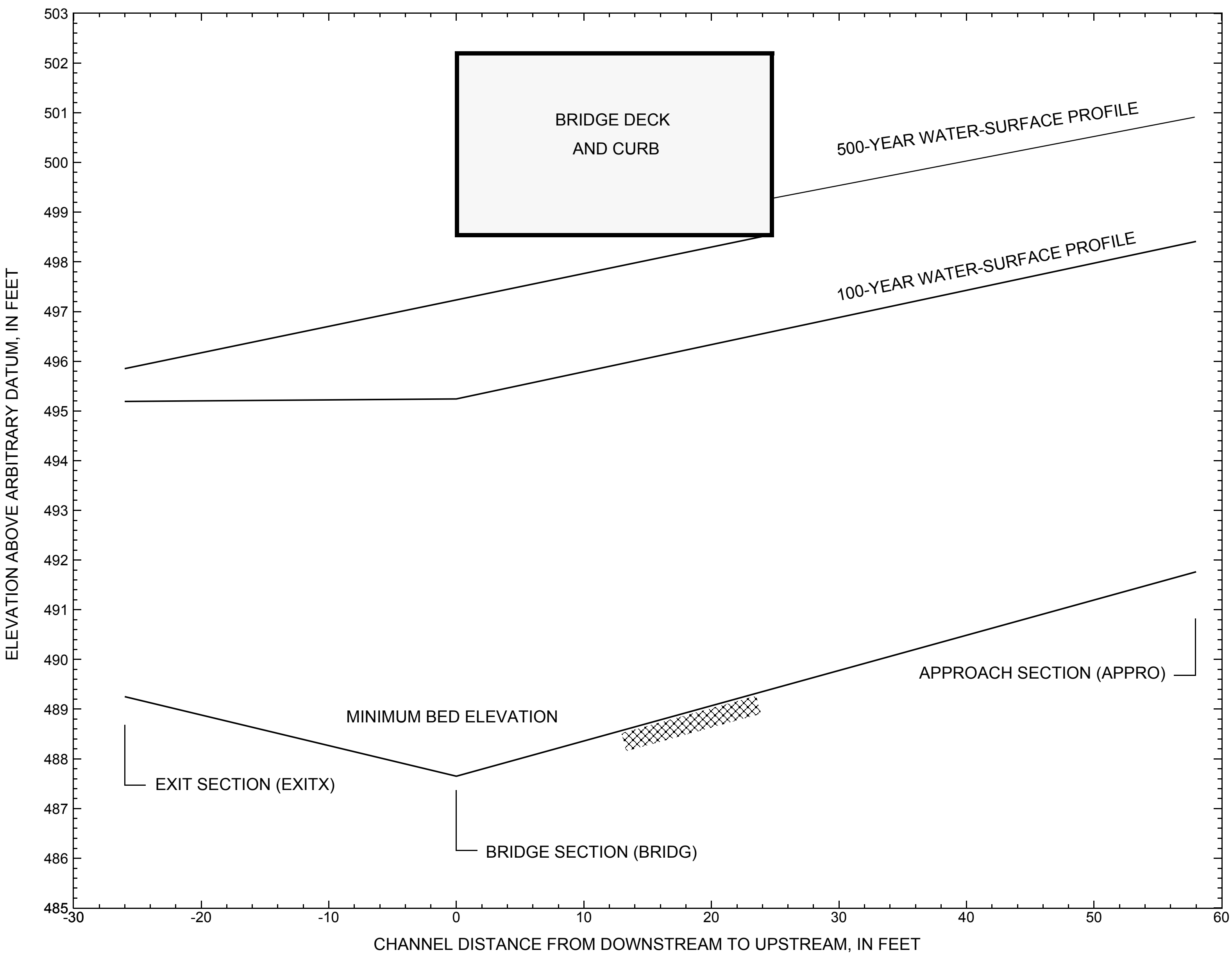

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure VERSTH00380011 on Town Highway 38, crossing Algerine Brook, Vershire, Vermont.

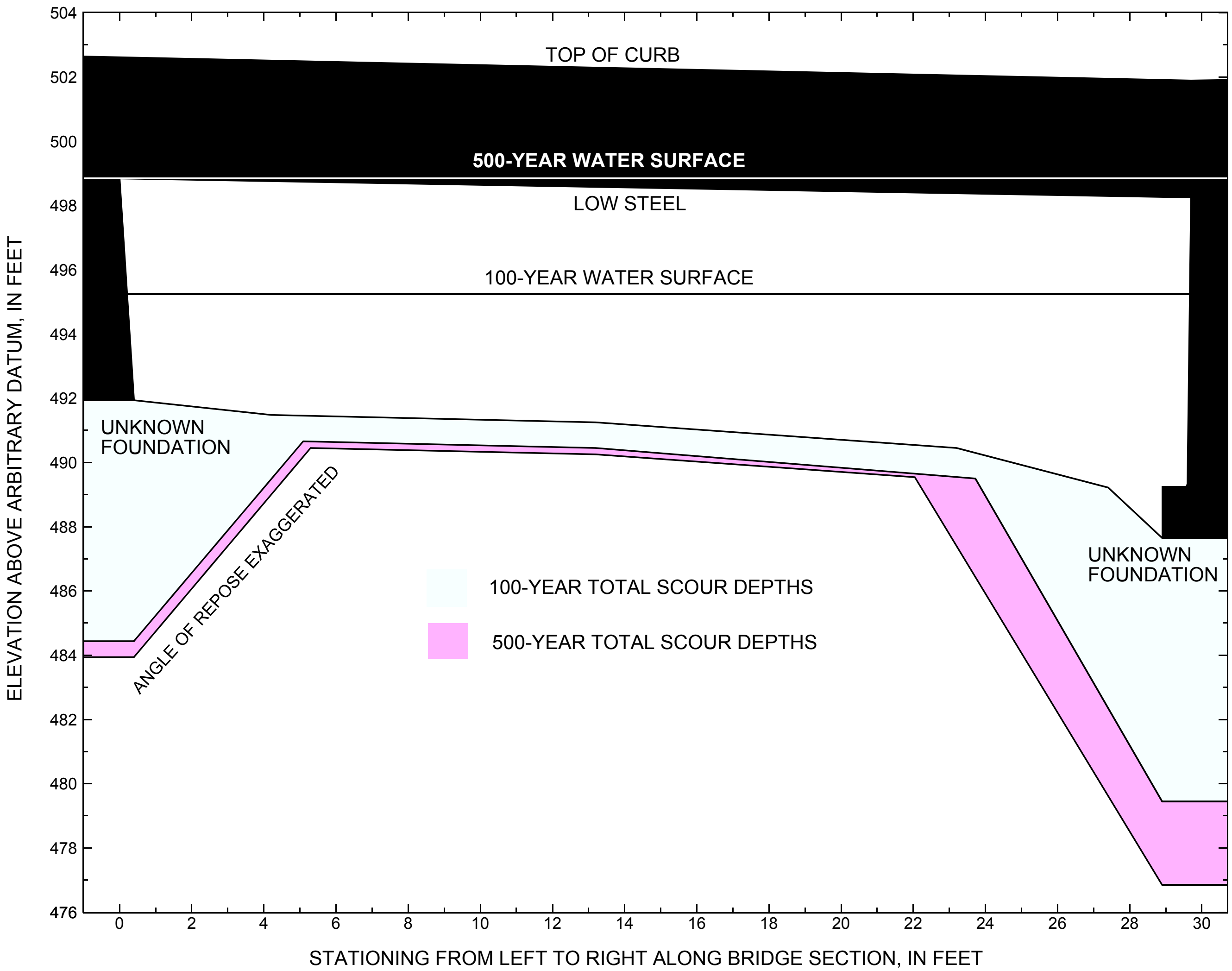

Figure 8. Scour elevations for the 100- and 500-year discharges at structure VERSTH00380011 on Town Highway 38, crossing Algerine Brook, Vershire, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure VERSTH00380011 on Town Highway 38, crossing Algerine Brook, Vershire, 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 1,550 cubic-feet per second											
Left abutment	0.0	--	498.8	--	491.9	0.8	6.7	--	7.5	484.4	--
Right abutment	29.7	--	498.2	--	487.6	0.8	7.4	--	8.2	479.4	--

1.Measured along the face of the most constricting side of the bridge.

2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure VERSTH00380011 on Town Highway 38, crossing Algerine Brook, Vershire, 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 2,200 cubic-feet per second											
Left abutment	0.0	--	498.8	--	491.9	1.0	7.0	--	8.0	483.9	--
Right abutment	29.7	--	498.2	--	487.6	1.0	9.8	--	10.8	476.8	--

1.Measured along the face of the most constricting side of the bridge.

2.Arbitrary datum for this study.

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U.S. Geological Survey, 1981, Vershire, 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 vers011.wsp
T2        Hydraulic analysis for structure VERSTH00380011   Date: 24-SEP-97
T3        Bridge 11 on Town Highway 38 over Algerine Brook Vershire, VT by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1550.0   2200.0
SK          0.022    0.022
*
XS   EXITX    -26
GR         -164.1, 514.34   -132.8, 501.32    -47.3, 499.45    -37.2, 495.29
GR            0.0, 492.53      8.8, 490.99     17.0, 490.49     19.5, 489.95
GR           23.0, 489.32     24.5, 489.25     26.3, 490.38     27.9, 492.14
GR           45.0, 495.57     84.8, 497.38    114.4, 497.28
N           0.050       0.055        0.040
SA                 0.0           45.0
*
XS   FULLV      0  * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.54       0.0
GR            0.0, 498.84      0.4, 491.94      4.2, 491.48     13.2, 491.25
GR           23.2, 490.45     27.4, 489.22     28.9, 487.65     29.6, 489.32
GR           29.6, 490.50     29.7, 498.25      0.0, 498.84
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      44.6 * *     67.9      5.3
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     12      15.0     1
GR         -255.6, 518.94   -184.6, 505.82   -127.1, 503.03   -114.0, 503.03
GR          -50.9, 502.67     -1.6, 501.55     -1.4, 502.61      0.0, 502.60
GR           31.7, 501.89     31.9, 500.95    155.4, 500.68    185.3, 511.26
*     69.3, 499.14     87.6, 498.26
*
AS   APPRO     58           0.
GR         -231.0, 517.82   -166.1, 505.69   -131.2, 503.44    -97.2, 502.91
GR          -24.0, 501.62     -5.4, 499.30      0.0, 494.38      3.6, 491.99
GR            8.1, 491.76     16.0, 492.02     21.2, 492.28     24.6, 491.90
GR           28.6, 492.24     34.8, 495.48     37.8, 498.54     52.3, 503.36
GR          108.4, 510.41
N           0.040       0.060
SA                -24.0
*
HP 1 BRIDG   495.24 1 495.24
HP 2 BRIDG   495.24 * * 1550
HP 1 APPRO   498.41 1 498.41
HP 2 APPRO   498.41 * * 1550
*
HP 1 BRIDG   498.84 1 498.84
HP 2 BRIDG   498.84 * * 2200
HP 1 BRIDG   496.83 1 496.83
HP 1 APPRO   500.95 1 500.95
HP 2 APPRO   500.95 * * 2200
*
EX
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File vers011.wsp
        Hydraulic analysis for structure VERSTH00380011   Date: 24-SEP-97
        Bridge 11 on Town Highway 38 over Algerine Brook Vershire, VT by MAI
           *** RUN DATE & TIME: 04-24-98  10:12
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     130.    8468.    29.    40.                       1555.
   495.24          130.    8468.    29.    40.  1.00     0.    30.   1555.



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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.24     0.2    29.7   130.3    8468.    1550.  11.90

X STA.         0.2        4.0        5.6        7.1        8.6       10.1
  A(I)            13.2        5.8        5.9        5.9        5.8
  V(I)            5.89      13.37      13.22      13.16      13.32

X STA.        10.1       11.6       13.0       14.5       15.8       17.1
  A(I)             5.8        5.7        5.7        5.7        5.6
  V(I)           13.34      13.70      13.62      13.67      13.75

X STA.        17.1       18.4       19.7       20.8       22.0       23.1
  A(I)             5.5        5.5        5.4        5.2        5.3
  V(I)           13.99      14.10      14.42      14.79      14.73

X STA.        23.1       24.1       25.1       26.0       26.9       29.7
  A(I)             5.2        5.2        5.0        4.8       18.2
  V(I)           14.82      14.90      15.64      16.14       4.26

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     220.   15460.    42.    46.                       2863.
   498.41          220.   15460.    42.    46.  1.00    -4.    38.   2863.



    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.41    -4.4    37.7   220.5   15460.    1550.   7.03

X STA.        -4.4        3.4        4.9        6.3        7.6        9.0
  A(I)            26.7        9.3        9.2        8.9        9.3
  V(I)            2.90       8.37       8.45       8.74       8.38

X STA.         9.0       10.4       11.8       13.2       14.7       16.1
  A(I)             9.2        9.1        9.2        9.4        9.3
  V(I)            8.47       8.55       8.38       8.25       8.31

X STA.        16.1       17.6       19.1       20.6       22.2       23.7
  A(I)             9.5        9.4        9.4        9.6        9.3
  V(I)            8.18       8.27       8.28       8.04       8.33

X STA.        23.7       25.1       26.5       28.0       29.6       37.7
  A(I)             9.0        9.4        9.3        9.8       26.3
  V(I)            8.59       8.28       8.31       7.89       2.95
```

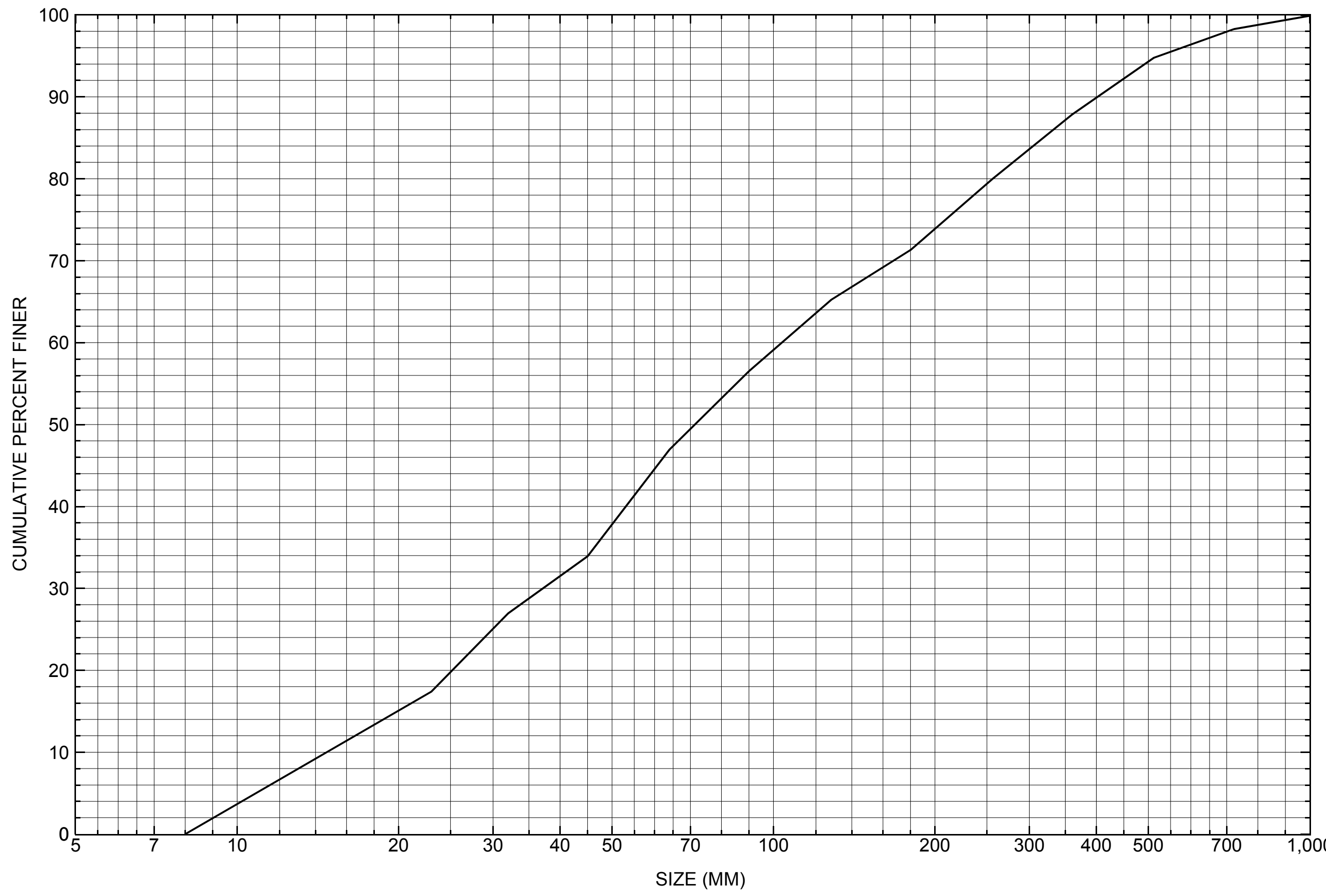
```
      U.S. Geological Survey WSPRO Input File vers011.wsp
      Hydraulic analysis for structure VERSTH00380011   Date: 24-SEP-97
      Bridge 11 on Town Highway 38 over Algerine Brook Vershire, VT by MAI
         *** RUN DATE & TIME: 04-24-98  10:12
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     228.   14039.     0.    77.                            0.
 498.84          228.   14039.     0.    77.  1.00     0.    30.      0.



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

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.84     0.0    29.7   228.0   14039.    2200.   9.65

X STA.         0.0        3.5        4.9        6.3        7.7        9.1
  A(I)            23.5       10.2       10.0        9.8       10.3
  V(I)            4.68      10.82      11.03      11.19      10.64

X STA.         9.1       10.4       11.8       13.2       14.5       15.9
  A(I)             9.9       10.0       10.1       10.0       10.1
  V(I)           11.07      11.01      10.91      10.98      10.85

X STA.        15.9       17.2       18.5       19.8       21.1       22.3
  A(I)             9.9       10.0        9.9        9.7        9.6
  V(I)           11.13      11.01      11.16      11.35      11.50

X STA.        22.3       23.5       24.7       25.8       26.8       29.7
  A(I)             9.9        9.6        9.2        9.4       27.0
  V(I)           11.10      11.51      12.00      11.72       4.07

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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     177.   13443.    30.    44.                         2462.
 496.83          177.   13443.    30.    44.  1.00     0.    30.   2462.

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           2     349.   25602.    64.    69.                         4644.
 500.95          349.   25602.    64.    69.  1.00   -19.    45.   4644.



  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

       WSEL     LEW     REW    AREA        K        Q    VEL
     500.95   -18.6    45.1   349.4   25602.    2200.   6.30

X STA.       -18.6        4.4        5.8        7.2        8.6        9.9
  A(I)            68.5       12.5       12.4       12.7       12.4
  V(I)            1.61       8.83       8.88       8.64       8.85

X STA.         9.9       11.3       12.7       14.1       15.6       17.0
  A(I)            12.7       13.0       12.7       12.9       12.9
  V(I)            8.68       8.47       8.65       8.49       8.55

X STA.        17.0       18.6       20.1       21.7       23.2       24.7
  A(I)            13.5       13.8       13.7       13.2       13.5
  V(I)            8.14       7.96       8.05       8.35       8.18

X STA.        24.7       26.2       27.7       29.2       31.0       45.1
  A(I)            13.1       13.2       13.2       14.7       44.8
  V(I)            8.37       8.31       8.35       7.47       2.46
```

```
        U.S. Geological Survey WSPRO Input File vers011.wsp
        Hydraulic analysis for structure VERSTH00380011   Date: 24-SEP-97
        Bridge 11 on Town Highway 38 over Algerine Brook Vershire, VT by MAI
           *** RUN DATE & TIME: 04-24-98  10:12

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

EXITX:XS   ******   -36.     194.  1.09 *****  496.28  495.08   1550.  495.19
      -26. ******    43.   10448.  1.10 ***** *******    0.94    7.99

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.60

FULLV:FV      26.   -39.     271.  0.55  0.36  496.63 *******   1550.  496.09
        0.    26.    56.   16746.  1.08  0.00    0.00    0.62    5.71
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.00     496.45     496.45

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   495.59     517.82    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   495.59     517.82     496.45

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.48

APPRO:AS      58.    -2.     142.  1.86  1.03  498.30  496.45   1550.  496.45
       58.    58.    36.    8086.  1.00  0.66   -0.01    1.00   10.93
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1550.     495.24

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

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

BRIDG:BR      26.     0.     130.  2.20 *****  497.44  495.24   1550.  495.24
        0.    26.    30.    8465.  1.00 ***** *******    1.00   11.90

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.54 ****** ****** ******

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

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

APPRO:AS      13.    -4.     221.  0.77  0.25  499.18  496.45   1550.  498.41
       58.    14.    38.   15478.  1.00  1.50    0.02    0.54    7.03

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.224  0.029   14948.    -1.    29.   497.98

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -26.   -36.    43.   1550.   10448.     194.    7.99  495.19
   FULLV:FV       0.   -39.    56.   1550.   16746.     271.    5.71  496.09
   BRIDG:BR       0.     0.    30.   1550.    8465.     130.   11.90  495.24
   RDWAY:RG      12.**************       0.******************    1.00********
   APPRO:AS      58.    -4.    38.   1550.   15478.     221.    7.03  498.41

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    29.   14948.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO  VHD      EGL    WSEL
   EXITX:XS     495.08    0.94  489.25  514.34************  1.09  496.28  495.19
   FULLV:FV   ********    0.62  489.25  514.34  0.36  0.00  0.55  496.63  496.09
   BRIDG:BR     495.24    1.00  487.65  498.84************  2.20  497.44  495.24
   RDWAY:RG  ***************  500.68  518.94**********************************
   APPRO:AS     496.45    0.54  491.76  517.82  0.25  1.50  0.77  499.18  498.41
```

```
        U.S. Geological Survey WSPRO Input File vers011.wsp
        Hydraulic analysis for structure VERSTH00380011   Date: 24-SEP-97
        Bridge 11 on Town Highway 38 over Algerine Brook Vershire, VT by MAI
           *** RUN DATE & TIME: 04-24-98  10:12

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

EXITX:XS   ******   -39.     249.  1.30 *****  497.15  495.77   2200.  495.85
      -26. ******    51.   14819.  1.07 ***** *******    0.97    8.83

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.60

FULLV:FV      26.   -41.     349.  0.67  0.36  497.51 *******   2200.  496.83
        0.    26.    73.   23688.  1.09  0.00    0.00    0.66    6.30
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.19     496.93     497.48

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   496.33     517.82    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   496.33     517.82     497.48

 ===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 =   497.48     517.82     497.48

APPRO:AS      58.    -3.     182.  2.26 *****  499.75  497.48   2200.  497.48
       58.    58.    37.   11718.  1.00 ***** *******    1.00   12.07
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.40     499.82     500.07     498.54

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      26.     0.     228.  1.49 *****  500.33  496.45   2234.  498.84
        0. ******    30.   14039.  1.00 ***** *******    0.62    9.80

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.473 ******  498.54 ****** ****** ******

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

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

APPRO:AS      13.   -19.     349.  0.62  0.18  501.57  497.48   2200.  500.95
       58.    14.    45.   25602.  1.00  1.49    0.02    0.47    6.30

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -26.   -39.    51.   2200.   14819.     249.    8.83  495.85
   FULLV:FV       0.   -41.    73.   2200.   23688.     349.    6.30  496.83
   BRIDG:BR       0.     0.    30.   2234.   14039.     228.    9.80  498.84
   RDWAY:RG      12.**************      0.       0.       0.    1.00********
   APPRO:AS      58.   -19.    45.   2200.   25602.     349.    6.30  500.95

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     495.77    0.97  489.25  514.34************  1.30  497.15  495.85
   FULLV:FV  ********     0.66  489.25  514.34  0.36  0.00  0.67  497.51  496.83
   BRIDG:BR     496.45    0.62  487.65  498.84************  1.49  500.33  498.84
   RDWAY:RG  ****************  500.68  518.94************  0.62  501.25********
   APPRO:AS     497.48    0.47  491.76  517.82  0.18  1.49  0.62  501.57  500.95

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure VERSTH00380011, in Vershire, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number VERSTH00380011

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. Ivanoff

Date *(MM/DD/YY)* 08 / 26 / 94

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 74950

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

Waterway *(I - 6)* Algerine Brook

Road Name *(I - 7)*: Algerine Road

Route Number TH 38

Vicinity *(I - 9)* 0.05 miles to jct with TH 2

Topographic Map Vershire

Hydrologic Unit Code: 01080103

Latitude *(I - 16; nnnn.n)* 43549

Longitude *(i - 17; nnnnn.n)* 72169

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10091400110914

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

Maximum span length *(I - 48; nnnn)* 0030

Year built *(I - 27; YYYY)* 1928

Structure length *(I - 49; nnnnnn)* 000034

Average daily traffic, ADT *(I - 29; nnnnnn)* 000250

Deck Width *(I - 52; nn.n)* 231

Year of ADT *(I - 30; YY)* 94

Channel & Protection *(I - 61; n)* 6

Opening skew to Roadway *(I - 34; nn)* 10

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

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

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

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 007.5

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

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

Comments:

The structural inspection report of 8/31/93 indicated a concrete T-beam bridge with asphalt road approaches. There are concrete abutments with minor staining. The right abutment has a couple of diagonal cracks and moderate leakage. The left abutment footing is not in view. The downstream end of the right abutment footing is exposed with concentrated channel scour at the wall. Undermining and settlement are not apparent. There is minor embankment erosion. The channel makes a sharp turn into the bridge. There is natural stone and boulder fill in the upstream channel.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: **Stone and gravel with some boulders**
-

Streambed material: -

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -
-

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

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

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

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

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

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

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

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

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

Comments:

-

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 7.38 mi^2 Lake/pond/swamp area 0.02 mi^2

Watershed storage *(ST)* 0.3 %

Bridge site elevation 920 ft Headwater elevation 2080 ft

Main channel length 3.49 mi

10% channel length elevation 970 ft 85% channel length elevation 1590 ft

Main channel slope *(S)* 236.87 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? N *If no, type ctrl-n xs*

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

Comments: **NO CROSS SECTION INFORMATION**

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: **NO CROSS SECTION INFORMATION**

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: 02/22/96

Computerized by: CG Date: 02/22/96

Reviewd by: MAI Date: 05/04/98

Structure Number VERSTH00380011

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. Boehmler Date *(MM/DD/YY)* 09 / 06 / 1995

2. Highway District Number 07 Mile marker 0

County Orange (017) Town Vershire (74950)

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

Route Number TH 38 Hydrologic Unit Code: 01080103

3. Descriptive comments:

The site is located 0.05 miles from the junction of Town Highway 2

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 4 LBDS 5 RBDS 4 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 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 34 *(feet)* Span length 30 *(feet)* Bridge width 23.1 *(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 11.Type	Protection 12.Cond.	13.Erosion	14.Severity
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	2	1
LBDS	0	-	2	2

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

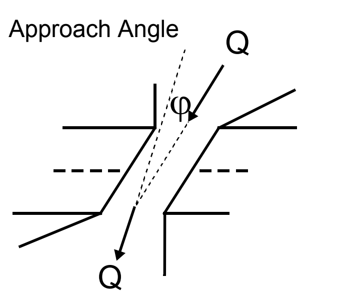
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

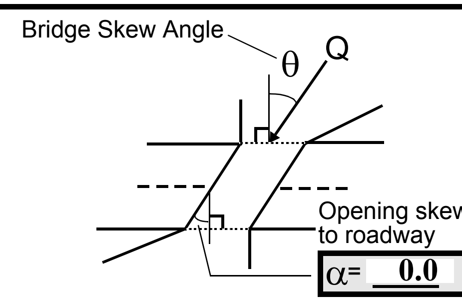
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

Channel approach to bridge (BF):

15. Angle of approach: 25 16. Bridge skew: 15





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

Where? RB *(LB, RB)* Severity 3

Range? 20 feet US *(US, UB, DS)* to 19 feet UB

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

Where? RB *(LB, RB)* Severity 2

Range? 50 feet DS *(US, UB, DS)* to 115 feet DS

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

18. Bridge Type: **1a**

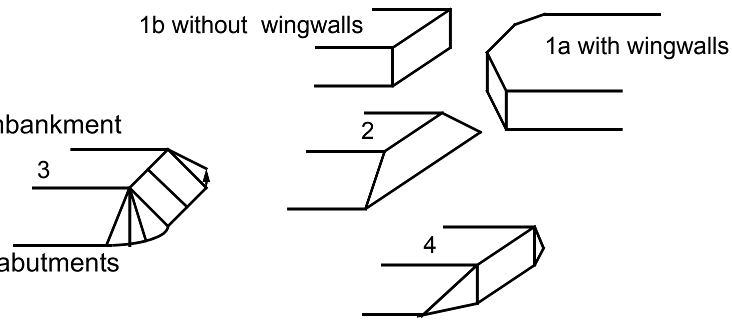
1a- Vertical abutments with wingwalls

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.)

The bridge dimensions measured are: bridge length = 33.0; span length = 30.5; bridge width = 23.0. The surface cover on the upstream left bank consists of a narrow strip of trees between the roadway and the channel. The upstream right bank is pasture and a home garden within two bridge lengths and is forest further upstream. The downstream right bank is grass surrounding a house. The left bank upstream is mainly brush with some small trees and shrubs.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF)		22. Bank angle (BF)		26. % Veg. cover (BF)		27. Bank material (BF)		28. Bank erosion (BF)	
	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
31.0	**9.5**			**3.0**	**4**	**4**	**415**	**415**	**0**	**3**

23. Bank width **10.0** 24. Channel width **25.0** 25. Thalweg depth **58.5** 29. Bed Material **451**

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 a higher mud fraction here than gravel but there is some fine gravel and sand in the mud (clayey) material. The upstream channel is asymmetrical with the thalweg along the right bank and a bar has developed on the left bank. The right bank is heavily eroded and scalloped.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **45** 35. Mid-bar width: **22**

36. Point bar extent: **150** feet **US** *(US, UB)* to **35** feet **DS** *(US, UB, DS)* positioned **0** %LB to **45** %RB

37. Material: **435**

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

The bar is unvegetated.

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

41. Mid-bank distance: **55.0** 42. Cut bank extent: **150** feet **US** *(US, UB)* to **25** feet **US** *(US, UB, DS)*

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

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

The type of failure varies from slip in the area of 100 ft upstream to 25 ft upstream to block type in the area of 160 ft upstream to 100 ft upstream. Some evidence of a land slide remains from previous flooding around 90 ft upstream on the right bank. The roots are greatly exposed and trees are leaning inward or have fallen into the channel in this area.

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
7.5		0.5		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.):

451

There is some fine gravel and sand intermixed with the silt and clay material.

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

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

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

70. Debris and Ice Comments:

2

Debris (whole trees and branches) are scattered about in the channel, but there is no one specific area of accumulation. The channel bends upstream and has a lot of trees on the banks with bank cutting on the right bank. Some possible ice scarring on trees is present on the right bank about 50 ft upstream.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**-**	**90**	**2**	**0**	**0**	**0**	**90.0**
RABUT	**1**	**15**	**90**			**2**	**2**	**29.5**

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

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

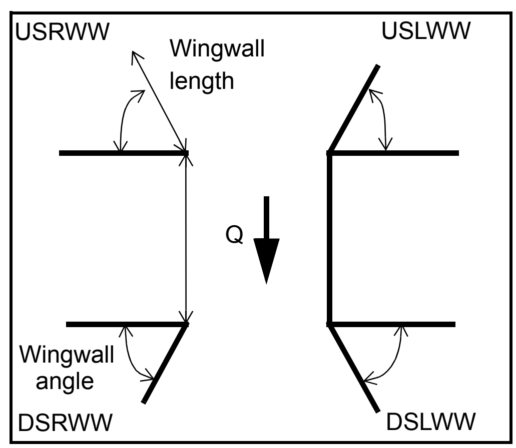
2.0
0
1

The right abutment footing is exposed, but the top is flush with the streambed, then the streambed rises steeply from the footing edge toward the left abutment. A scour hole has developed along the right abutment where the footing is exposed. The scour hole is 38 ft long, 7 ft wide, and is positioned 85% left bank to 100% right bank. The deepest point is at the downstream face of the bridge.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**29.5**	
USRWW:	**Y**		**1**		**0**	**1.0**	
DSLWW:	**0**		**0**		**Y**	**25.0**	
DSRWW:	**1**		**0**		**0**	**24.5**	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**0**	**0**	**Y**	**1.5**	**-**	**-**	**-**	**-**
Condition	**Y**	**0**	**1**	**0**	**-**	**-**	**-**	**-**
Extent	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**-**

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

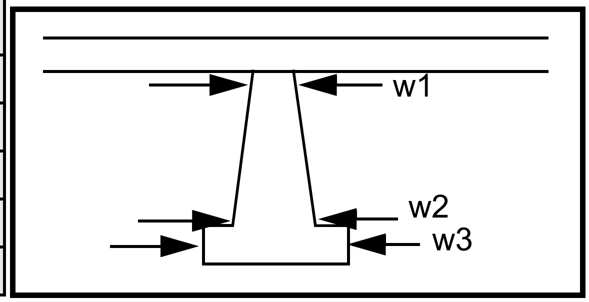
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**45.0**	**16.0**	**90.0**
Pier 2				**28.5**	**45.0**	**16.5**
Pier 3			**-**	**45.0**	**14.5**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

Bank width (BF) -_____ Channel width -_____ 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.):
-
-
-
-
-
-
-
NO PIERS

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

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

105. Drop structure comments (eg. downstream scour depth):
2
1
413
413
1
2

106. Point/Side bar present? 45 (Y or N. if N type ctrl-n pb) Mid-bar distance: 1 Mid-bar width: 0

Point bar extent: 0 feet - (US, UB, DS) to - feet Th (US, UB, DS) positioned e %LB to do %RB

Material: wn

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

stream channel continues to bend left, but the point bar ends near 35 ft downstream. Stone fill is located in spots on the right bank downstream in the area of 70 ft downstream to 125 ft downstream.

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

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

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

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

N

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

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

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

RE

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

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

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

Confluence comments (eg. confluence name):

-

-

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)*:

-

NO POINT BARS

Y

RB

90

50

DS

145

DS

1

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: VERSTH00380011 Town: Vershire
Road Number: TH 38 County: Orange
Stream: Algerine Brook

Initials MAI Date: 10/16/97 Checked: RF

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

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1550	2200	0
Main Channel Area, ft2	220	349	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	42	64	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.234	0.234	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.2	5.5	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	15460	25602	0
Conveyance, main channel	15460	25602	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1550.0	2200.0	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	7.0	6.3	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.1	9.2	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1550	2200	0
(Q) discharge thru bridge, cfs	1550	2200	0
Main channel conveyance	8468	14039	0
Total conveyance	8468	14039	0
Q2, bridge MC discharge,cfs	1550	2200	ERR
Main channel area, ft2	130	228	0
Main channel width (normal), ft	29.5	29.7	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.5	29.7	0
y_bridge (avg. depth at br.), ft	4.42	7.68	ERR
Dm, median (1.25*D50), ft	0.2925	0.2925	0
y2, depth in contraction,ft	5.25	7.04	ERR
ys, scour depth (y2-ybridge), ft	**0.83**	-0.63	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 other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1550	2200	0
Q, thru bridge MC, cfs	1550	2200	N/A
Vc, critical velocity, ft/s	9.10	9.16	N/A
Va, velocity MC approach, ft/s	7.05	6.30	N/A
Main channel width (normal), ft	29.5	29.7	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.5	29.7	0.0
qbr, unit discharge, ft2/s	52.5	74.1	ERR
Area of full opening, ft2	130.3	228.0	0.0
Hb, depth of full opening, ft	4.42	7.68	ERR
Fr, Froude number, bridge MC	0	0.62	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	177	N/A
**Hb, depth at downstream face, ft	N/A	5.96	ERR
**Fr, Froude number at DS face	ERR	0.90	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A

Elevation of Low Steel, ft	0	498.54	0
Elevation of Bed, ft	-4.42	490.86	N/A
Elevation of Approach, ft	0	500.95	0
Friction loss, approach, ft	0	0.18	0
Elevation of WS immediately US, ft	0.00	500.77	0.00
ya, depth immediately US, ft	4.42	9.91	N/A
Mean elevation of deck, ft	0	502.25	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.94	ERR
**Cc, for downstream face (<=1.0)	ERR	0.854473	ERR
Ys, scour w/Chang equation, ft	N/A	**0.95**	N/A
Ys, scour w/Umbrell equation, ft	N/A	1.04	N/A

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

**Ys, scour w/Chang equation, ft	N/A	3.50	N/A
**Ys, scour w/Umbrell equation, ft	ERR	2.75	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	5.25	7.04	0.00
WSEL at downstream face, ft	--	496.83	--
Depth at downstream face, ft	N/A	5.96	N/A
Ys, depth of scour (Laursen), ft	N/A	1.08	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	1550	2200	N/A
Main channel area (DS), ft2	130.3	177	0
Main channel width (normal), ft	29.5	29.7	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	29.5	29.7	0.0
D90, ft	1.3185	1.3185	0.0000
D95, ft	1.7160	1.7160	0.0000
Dc, critical grain size, ft	1.0357	0.9683	ERR
Pc, Decimal percent coarser than Dc	0.152	0.167	0.000
Depth to armoring, ft	**17.35**	**14.49**	N/A

Abutment Scour

Froehlich's Abutment Scour

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

(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1550	2200	0	1550	2200	0
a', abut.length blocking flow, ft	4.6	18.6	0	8	15.4	0
Ae, area of blocked flow ft2	15.75	55.4	0	25.98	55.42	0
Qe, discharge blocked abut.,cfs	45.71	88.96	0	76.54	189.44	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.90	1.61	ERR	2.95	3.42	ERR

ya, depth of f/p flow, ft	3.42	2.98	ERR	3.25	3.60	ERR

--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)

K1	0.82	0.82	0.82	0.82	0.82	0.82

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

theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.276	0.164	ERR	0.288	0.318	ERR
ys, scour depth, ft	**6.73**	**7.02**	N/A	**7.42**	**9.82**	N/A

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

a'(abut length blocked, ft)	4.6	18.6	0	8	15.4	0
y1 (depth f/p flow, ft)	3.42	2.98	ERR	3.25	3.60	ERR
a'/y1	1.34	6.24	ERR	2.46	4.28	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.28	0.16	N/A	0.29	0.32	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 others, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	0.9	0	1	0.9	0
y, depth of flow in bridge, ft	4.42	5.96	0.00	4.42	5.96	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.)	**1.85**	**2.42**	ERR	**1.85**	**2.42**	ERR