LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (MENDTH00130025) on TOWN HIGHWAY 13, crossing MENDON BROOK, MENDON, VERMONT

Open-File Report 98-155

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (MENDTH00130025) on TOWN HIGHWAY 13, crossing MENDON BROOK, MENDON, VERMONT

By SUSAN A. WILLOUGHBY and MICHAEL IVANOFF

U.S. Geological Survey
Open-File Report 98-155

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

Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
Thomas J. Casadevall, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

Copies of this report may be purchased from:

U.S. Geological Survey
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

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		
cfs	cubic feet per second	LWW	left wingwall
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 25 (MENDTH00130025) ON TOWN HIGHWAY 13, CROSSING MENDON BROOK, MENDON, VERMONT

By Susan A. Willoughby and Michael Ivanoff

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MENDTH00130025 on Town Highway 13 crossing Mendon Brook, Mendon, 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 (Federal Highway Administration, 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 Taconic section of the New England physiographic province in south central Vermont. The 17.6 -mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover upstream of the bridge is pasture on the left and a house on the right; the immediate bank on the right side has dense woody vegetation. Downstream of the bridge is forested on the left, and a mix of pasture and forest on the right.

In the study area, Mendon Brook has an incised, straight channel with a slope of approximately 0.004 ft/ft, an average channel top width of 61 ft and an average bank height of 7 ft. The channel bed material ranges from cobbles to boulders with a median grain size (D_{50}) of 78.9 mm (0.259 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 27, 1995, indicated that the reach was stable.

The Town Highway 13 crossing of Mendon Brook is a 35-ft-long, one-lane bridge consisting of one 33-foot steel-beam span (Vermont Agency of Transportation, written communication, March 21, 1995). The opening length of the structure parallel to the bridge face is 30 ft. The bridge is supported by vertical, concrete faced “laid-up” stone abutments with wingwalls. The channel is skewed 0 degrees to the opening while the computed opening-skew-to-roadway is 5 degrees.

The footings of the upstream and downstream left wingwalls, and left and right abutments are exposed as observed during the Level I assessment. The scour protection measure at the site was type-3 stone fill (less than 48 inches diameter) at the upstream end of the upstream left wingwall, along the upstream end of the left abutment, on the downstream end of the downstream left wingwall, and on the downstream left bank. Type-2 stone fill (<36 inches diameter) is present along the left and right upstream banks. 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 0.6 to 2.6 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge. Abutment scour ranged from 11.2 to 16.1 ft. The worst-case abutment scour occurred at the 100-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.

Chittendon, VT. Quadrangle, 1:24,000, 1961
Photorevised 1988

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 MENDTH00130025 ***Stream*** Mendon Brook

County Rutland ***Road*** TH 13 ***District*** 3

Description of Bridge

Bridge length 35.0 ***ft*** ***Bridge width*** 14.3 ***ft*** ***Max span length*** 33.3 ***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*** 9/27/95

Description of stone fill Type-3, around the upstream end of the upstream left wingwall, upstream end of left abutment, and downstream end of downstream left wingwall.

Abutments and wingwalls are concrete faced "laid up" stone. The footings are exposed on both the left and right sides of the channel.

No -

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

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	9/27/95	0	0
Level II	9/27/95	0	0

Potential for debris Moderate. There is some debris caught on boulders along the left bank.

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

There are many large boulders in the channel and along the banks which could potentially catch debris or ice (9/27/95).

Description of the Geomorphic Setting

General topography The channel is located within a valley of moderate relief with little to no flood plain.

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

Date of inspection 9/27/95

DS left: Steep channel bank and mildly sloped overbank.

DS right: Steep channel bank and mildly sloped overbank.

US left: Steep channel bank to a mildly sloped overbank

US right: Steep channel bank to a moderately sloped overbank and small floodplain.

Description of the Channel

Average top width 61 ***ft*** ***Average depth*** 7 ***ft***

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

Straight and stable with non-alluvial channel boundaries and little to no flood plain.

9/27/95

Vegetative co Trees and brush

DS left: Pasture and forest

DS right: Pasture and a few trees along the bank

US left: Brush and small vegetation around a house; also trees along the bank.

US right: Yes

Do banks appear stable? The assessment of 9/27/95 noted some steepening of the upstream left bank and the downstream right bank, exposing large stones and boulders.

If not, describe location and type of instability and date of observation.

- (9/27/95)

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 17.6 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 3,400 ***ft***^{3}***/s*** ***Q500*** 5,100 ***ft***^{3}***/s***

The 100- and 500-year discharges are the median 100- and 500-year discharge values from several flood frequency curves derived from various empirical methods (Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887) and extrapolated 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. RM2 is a chiseled X on top of a subfooting at the US end of the right abutment,(elev. 492.71 ft, arbitrary survey datum). RM3 is a nail placed 6 ft up a NET&T telephone pole (no. 143069)(elev. 511.745 ft, arbitrary survey datum). BM1 VTAOT brass tablet on top of the DS end of the left abutment (elev. 498.72, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-33	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPR1	49	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 0.045 to 0.065, and overbank "n" values ranged from 0.028 to 0.038.

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

The surveyed 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 500.3 ***ft***
Average low steel elevation 498.9 ***ft***

100-year discharge 3,400 ***ft^3/s***
Water-surface elevation in bridge opening 495.3 ***ft***
Road overtopping? No ***Discharge over road*** - ***ft^3/s***
Area of flow in bridge opening 229 ***ft^2***
Average velocity in bridge opening 14.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 19.1 ***ft/s***

Water-surface elevation at Approach section with bridge 498.8
Water-surface elevation at Approach section without bridge 496.6
Amount of backwater caused by bridge 2.2 ***ft***

500-year discharge 5,100 ***ft^3/s***
Water-surface elevation in bridge opening 498.9 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,501 ***ft^3/s***
Area of flow in bridge opening 338 ***ft^2***
Average velocity in bridge opening 10.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.1 ***ft/s***

Water-surface elevation at Approach section with bridge 501.6
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 4.0 ***ft***

Incipient overtopping discharge 3,580 ***ft^3/s***
Water-surface elevation in bridge opening 495.3 ***ft***
Area of flow in bridge opening 230 ***ft^2***
Average velocity in bridge opening 15.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 20.0 ***ft/s***

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 496.8
Amount of backwater caused by bridge 2.5 ***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. Only the scour resulting from the 100-year discharge is represented on figure 8, because the 500-year discharge resulted in a lesser depth of scour.

Contraction scour for the 100-year and incipient roadway-overtopping discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). 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 computed by use of the Laursen clear-water contraction scour equation and by use of the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). The results are presented in appendix F. Furthermore, for the 500-year discharge, which resulted in unsubmerged orifice flow, 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 for the left and right abutments 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	2.2	0.6	2.6
Depth to armoring	40.1	10.1	61.3
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	15.3	11.2	14.3
Right abutment	16.1	15.4	15.9
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	3.2	2.7	3.2
Right abutment	3.2	2.7	3.2
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

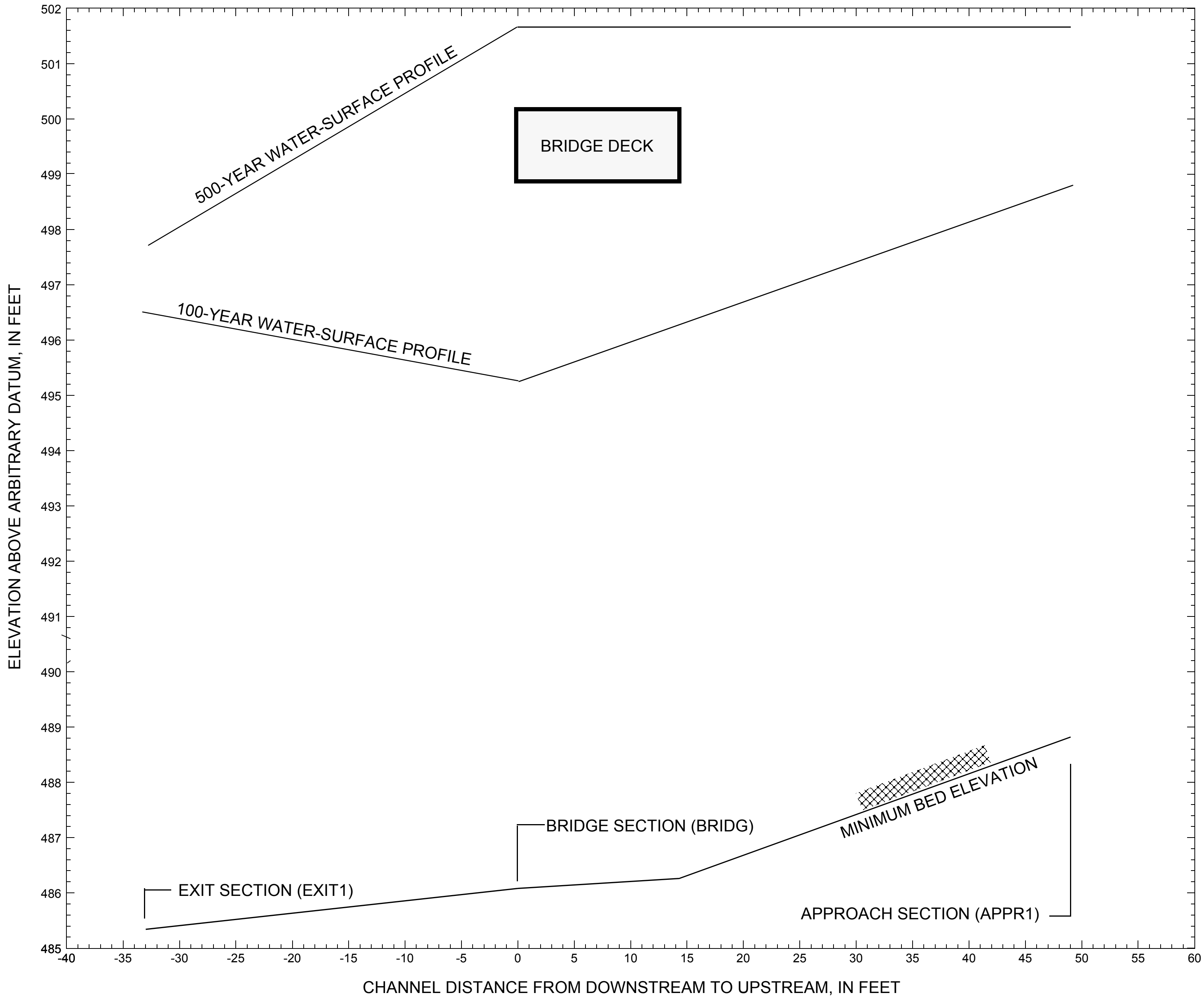


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure MENDTH00130025 on Town Highway 13, crossing Mendon Brook, Mendon, Vermont.

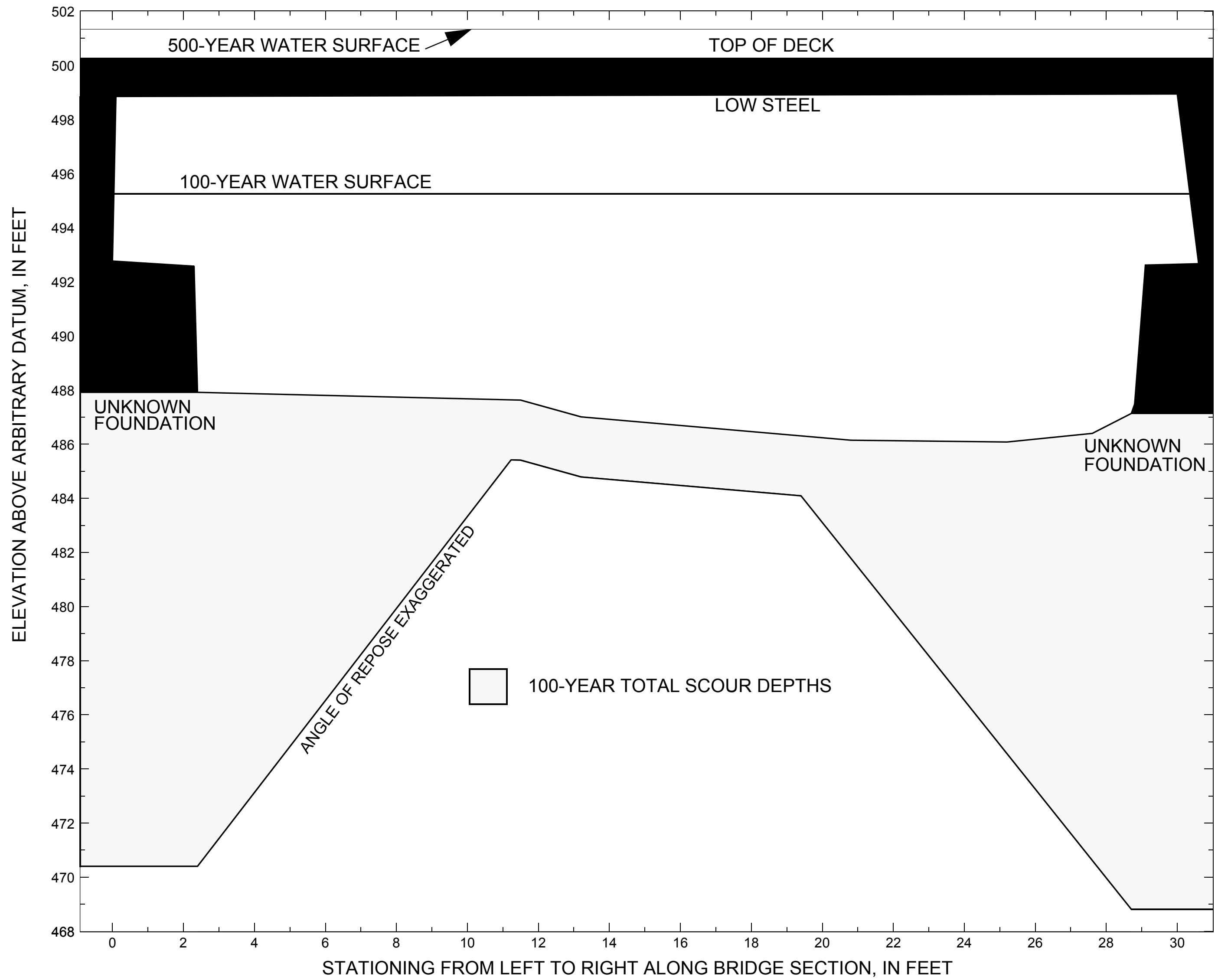


Figure 8. Scour elevations for the 100- and 500-year discharges at structure MENDTH00130025 on Town Highway 13, crossing Mendon Brook, Mendon, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MENDTH00130025 on Town Highway 13, crossing Mendon Brook, Mendon, 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 3,400 cubic-feet per second											
Left abutment	0.0	--	498.9	--	487.9	2.2	15.3	--	17.5	470.4	-
Right abutment	30.0	--	498.9	--	487.1	2.2	16.1	--	18.3	468.8	-

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 MENDTH00130025 on Town Highway 13, crossing Mendon Brook, Mendon, 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 5,100 cubic-feet per second											
Left abutment	0.0	--	498.9	--	487.9	0.6	11.2	--	11.8	476.1	-
Right abutment	30.0	--	498.9	--	487.1	0.6	15.4	--	16.0	471.1	-

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158.

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Geological Survey, 1961, Chittendon, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1988, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File mend025.wsp
T2        Hydraulic analysis for structure MENDTH00130025   Date: 03-DEC-97
T3        TH013 CROSSING MENDON BROOK IN MENDON, VERMONT        SAW
*
Q           3400.0   5100.0   3580.0
SK           0.004    0.004    0.004
*
XS   EXIT1    -33           0.
GR         -186.5, 502.35   -138.9, 501.51   -130.7, 500.98   -118.8, 499.25
GR         -102.7, 495.20    -84.2, 495.07    -58.6, 494.75    -54.1, 494.40
GR          -42.2, 493.92    -28.6, 493.90    -14.8, 493.85      0.0, 493.84
GR           16.0, 487.26     26.8, 486.54     28.7, 485.83     31.4, 485.34
GR           34.8, 485.56     39.3, 485.57     42.2, 485.95     43.7, 486.51
GR           47.5, 488.41     51.7, 497.12     76.0, 497.81    112.2, 498.18
GR          180.5, 499.47    231.7, 507.71    280.1, 510.51
*
N           0.038        0.060        0.030
SA                  0.0          51.7
*
XS   FULLV      0  * * *   0.0169
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    498.90       5.0
GR            0.0, 498.85      0.0, 492.77      2.3, 492.58      2.4, 487.92
GR           11.5, 487.63     13.2, 487.01     20.8, 486.15     25.2, 486.08
GR           27.6, 486.40     28.7, 487.14     28.8, 487.50     29.1, 492.62
GR           30.0, 492.67     30.0, 498.94      0.0, 498.85
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      22.3 * *      0.0      5.8
N           0.045
*
*            SRD    EMBWID   IPAVE
XR   RDWAY      9      14.3     1
GR         -183.4, 503.61   -130.2, 502.26    -97.5, 500.70    -66.6, 500.08
GR          -29.9, 500.24     -7.8, 499.90     -7.5, 500.34      0.0, 500.21
GR            2.2, 500.21     31.2, 500.25     34.9, 500.30     40.1, 500.35
GR           40.1, 500.42    144.2, 500.97    186.9, 503.97    249.4, 510.77
*
AS   APPR1     49           0.
GR         -233.4, 516.93   -215.1, 505.82   -164.6, 505.23   -111.7, 503.17
GR          -80.9, 500.85    -43.7, 499.70    -15.4, 499.00     -9.9, 492.84
GR           -2.9, 490.81      0.0, 490.45      1.7, 489.63      9.9, 488.82
GR           17.0, 489.36     22.4, 489.73     28.6, 489.63     34.1, 490.08
GR           39.9, 491.35     48.2, 497.88     54.5, 499.10     79.0, 499.91
GR          107.2, 499.98    163.1, 500.93    211.7, 502.19    212.1, 508.08
GR          224.6, 510.05
*
N           0.028        0.065        0.030
SA                -15.4         54.5
*
HP 1 BRIDG 495.26 1 495.26
HP 2 BRIDG 495.26 * * 3400
HP 1 APPR1 498.82 1 498.82
HP 2 APPR1 498.82 * * 3400
*
HP 1 BRIDG 498.94 1 498.94
HP 2 BRIDG 498.94 * * 3611
HP 1 BRIDG 497.82 1 497.82
HP 2 RDWAY 501.64 * * 1501
HP 1 APPR1 501.65 1 501.65
HP 2 APPR1 501.65 * * 5100
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File mend025.wsp
        Hydraulic analysis for structure MENDTH00130025   Date: 03-DEC-97
        TH013 CROSSING MENDON BROOK IN MENDON, VERMONT        SAW
           *** RUN DATE & TIME: 01-08-98  15:06

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     229.  22430.    30.    45.                         3599.
   495.26          229.  22430.    30.    45.  1.00     0.    30.   3599.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.26     0.0    30.0   229.1   22430.    3400.  14.84

X STA.         0.0        6.5        7.7        8.9       10.1       11.3
  A(I)            36.4        9.3        9.0        9.0        9.0
  V(I)            4.67      18.37      18.95      18.96      18.87

X STA.        11.3       12.5       13.6       14.6       15.7       16.7
  A(I)             9.2        8.9        8.8        9.0        8.8
  V(I)           18.48      19.11      19.32      18.98      19.31

X STA.        16.7       17.7       18.7       19.7       20.7       21.7
  A(I)             9.0        8.8        8.9        8.7        8.6
  V(I)           18.94      19.28      19.19      19.46      19.75

X STA.        21.7       22.6       23.5       24.4       25.4       30.0
  A(I)             8.3        8.5        8.5        8.3       34.2
  V(I)           20.38      20.08      19.89      20.40       4.98

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     492.  39809.    68.    74.                         7485.
   498.82          492.  39809.    68.    74.  1.00   -15.    53.   7485.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.82   -15.2    53.1   491.6   39809.    3400.   6.92

X STA.       -15.2       -4.5       -1.7        0.9        3.1        5.3
  A(I)            52.3       22.4       21.5       20.5       20.2
  V(I)            3.25       7.60       7.92       8.28       8.40

X STA.         5.3        7.4        9.4       11.4       13.5       15.6
  A(I)            20.2       20.3       19.7       20.6       20.2
  V(I)            8.40       8.39       8.64       8.26       8.40

X STA.        15.6       17.7       19.8       22.1       24.3       26.5
  A(I)            19.8       20.1       20.4       20.4       20.3
  V(I)            8.58       8.45       8.33       8.32       8.38

X STA.        26.5       28.7       30.9       33.2       35.6       53.1
  A(I)            20.2       20.2       20.2       21.0       71.0
  V(I)            8.40       8.43       8.40       8.10       2.39
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File mend025.wsp
        Hydraulic analysis for structure MENDTH00130025   Date: 03-DEC-97
        TH013 CROSSING MENDON BROOK IN MENDON, VERMONT        SAW
           *** RUN DATE & TIME: 01-08-98  15:06

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

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     338.  28683.     0.    82.                           0.
   498.94          338.  28683.     0.    82.  1.00     0.    30.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.94     0.0    30.0   337.7   28683.    3611.  10.69

X STA.         0.0        5.3        6.6        7.9        9.1       10.4
  A(I)            47.3       14.1       13.8       13.9       14.1
  V(I)            3.82      12.77      13.10      13.01      12.85

X STA.        10.4       11.6       12.9       14.0       15.2       16.3
  A(I)            14.0       14.2       13.6       13.6       13.8
  V(I)           12.94      12.69      13.24      13.24      13.09

X STA.        16.3       17.4       18.5       19.6       20.7       21.7
  A(I)            13.7       13.9       13.7       13.5       13.2
  V(I)           13.16      13.02      13.20      13.42      13.64

X STA.        21.7       22.8       23.8       24.9       25.9       30.0
  A(I)            13.2       13.5       13.3       12.9       44.5
  V(I)           13.67      13.36      13.61      13.99       4.06

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

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     306.  33747.    30.    50.                        5545.
   497.82          306.  33747.    30.    50.  1.00     0.    30.   5545.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.64  -117.2   153.7   305.1   12793.    1501.   4.92

X STA.      -117.2      -80.8      -71.1      -63.1      -55.1      -46.7
  A(I)            27.7       13.4       12.2       12.1       12.6
  V(I)            2.71       5.60       6.13       6.19       5.98

X STA.       -46.7      -37.9      -28.8      -20.2      -12.9       -5.0
  A(I)            12.8       12.9       12.7       11.8       12.4
  V(I)            5.87       5.81       5.92       6.34       6.07

X STA.        -5.0        6.6       21.0       36.1       53.4       64.0
  A(I)            16.3       20.4       20.9       21.1       11.8
  V(I)            4.59       3.68       3.59       3.56       6.37

X STA.        64.0       75.6       88.8      103.2      120.9      153.7
  A(I)            12.4       13.2       13.3       14.9       20.3
  V(I)            6.06       5.70       5.65       5.05       3.70

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     120.   8704.    76.    76.                         860.
             2     689.  68849.    70.    76.                       12281.
             3     177.  10501.   136.   136.                        1148.
   501.65          987.  88054.   282.   288.  1.10   -92.   191.   9995.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.65   -91.5   190.9   987.1   88054.    5100.   5.17

X STA.       -91.5      -33.9       -9.9       -5.2       -1.4        2.0
  A(I)            75.6       76.3       44.7       40.5       39.3
  V(I)            3.37       3.34       5.70       6.29       6.49

X STA.         2.0        5.0        8.0       10.9       13.9       16.9
  A(I)            36.8       37.0       37.2       37.7       37.0
  V(I)            6.92       6.89       6.86       6.76       6.89

X STA.        16.9       19.9       23.0       26.2       29.3       32.4
  A(I)            36.4       38.1       37.2       37.1       37.3
  V(I)            7.01       6.70       6.85       6.88       6.84

X STA.        32.4       35.7       39.4       62.1       93.0      190.9
  A(I)            38.1       39.9      101.9       58.3      100.7
  V(I)            6.69       6.39       2.50       4.37       2.53
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File mend025.wsp
        Hydraulic analysis for structure MENDTH00130025   Date: 03-DEC-97
        TH013 CROSSING MENDON BROOK IN MENDON, VERMONT        SAW
           *** RUN DATE & TIME: 01-08-98  15:06

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

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     230.   22556.   30.    45.                        3620.
   495.29          230.   22556.   30.    45.  1.00     0.    30.   3620.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.29     0.0    30.0   230.0   22556.    3580.  15.57

X STA.         0.0        6.5        7.7        8.9       10.1       11.3
  A(I)             36.5        9.0        9.3        9.0        9.0
  V(I)             4.90      19.91      19.23      19.89      19.80

X STA.        11.3       12.5       13.6       14.6       15.7       16.7
  A(I)              9.2        8.9        8.8        9.0        8.8
  V(I)            19.40      20.06      20.28      19.92      20.27

X STA.        16.7       17.7       18.7       19.7       20.7       21.7
  A(I)              9.0        8.9        8.9        8.8        8.6
  V(I)            19.86      20.23      20.13      20.41      20.72

X STA.        21.7       22.6       23.5       24.4       25.3       30.0
  A(I)              8.4        8.5        8.6        8.4       34.3
  V(I)            21.38      21.06      20.86      21.40       5.21

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1       1.      19.   11.    11.                           3.
             2     522.   43348.   70.    76.                        8098.
             3       0.       4.    5.     5.                           1.
   499.26          524.   43371.   85.    91.  1.01   -26.    59.   7351.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.26   -25.9    59.3   523.9   43371.    3580.   6.83

X STA.       -25.9       -4.9       -2.1        0.5        2.9        5.1
  A(I)             55.1       23.8       22.8       22.3       21.4
  V(I)             3.25       7.53       7.84       8.03       8.36

X STA.         5.1        7.2        9.3       11.3       13.4       15.5
  A(I)             21.4       21.4       21.3       21.6       21.2
  V(I)             8.36       8.35       8.39       8.31       8.44

X STA.        15.5       17.6       19.8       22.0       24.3       26.5
  A(I)             20.9       21.2       21.5       21.6       21.4
  V(I)             8.57       8.44       8.31       8.29       8.36

X STA.        26.5       28.8       31.0       33.3       35.7       59.3
  A(I)             21.4       21.3       21.4       22.2       78.7
  V(I)             8.38       8.41       8.38       8.07       2.27
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File mend025.wsp
        Hydraulic analysis for structure MENDTH00130025   Date: 03-DEC-97
        TH013 CROSSING MENDON BROOK IN MENDON, VERMONT        SAW
           *** RUN DATE & TIME: 01-08-98  15:06

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

EXIT1:XS   ******  -108.     645.  0.47 *****  496.95  493.07   3400.  496.48
      -33. ******    51.   53730.  1.09 ***** *******    0.48    5.27

FULLV:FV      33.  -106.     566.  0.64  0.16  497.18 *******   3400.  496.54
        0.    33.    51.   45084.  1.14  0.08   -0.02    0.59    6.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPR1"     KRATIO =  0.56

APPR1:AS      49.   -13.     353.  1.44  0.50  498.07 *******   3400.  496.63
       49.    49.    47.   25265.  1.00  0.40   -0.01    0.70    9.62
         <<<<<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      33.     0.     229.  3.43  0.32  498.69  494.99   3400.  495.26
        0.    33.    30.   22418.  1.00  1.41    0.00    0.95   14.85

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.90 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL      ERR       Q    WSEL
   RDWAY:RG       9.         <<<<<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      27.   -15.     492.  0.74  0.37  499.56  495.26   3400.  498.82
       49.    28.    53.   39799.  1.00  0.51    0.01    0.45    6.92

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.499  0.282   28562.     0.    30.   498.56

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -33.  -108.    51.   3400.   53730.     645.    5.27  496.48
   FULLV:FV       0.  -106.    51.   3400.   45084.     566.    6.01  496.54
   BRIDG:BR       0.     0.    30.   3400.   22418.     229.   14.85  495.26
   RDWAY:RG       9.**************      0.******************    1.00********
   APPR1:AS      49.   -15.    53.   3400.   39799.     492.    6.92  498.82

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       0.    30.   28562.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS      FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    493.07    0.48  485.34  510.51************  0.47  496.95  496.48
   FULLV:FV  ********    0.59  485.90  511.07  0.16  0.08  0.64  497.18  496.54
   BRIDG:BR    494.99    0.95  486.08  498.94  0.32  1.41  3.43  498.69  495.26
   RDWAY:RG  ****************  499.90  510.77**********************************
   APPR1:AS    495.26    0.45  488.82  516.93  0.37  0.51  0.74  499.56  498.82
```

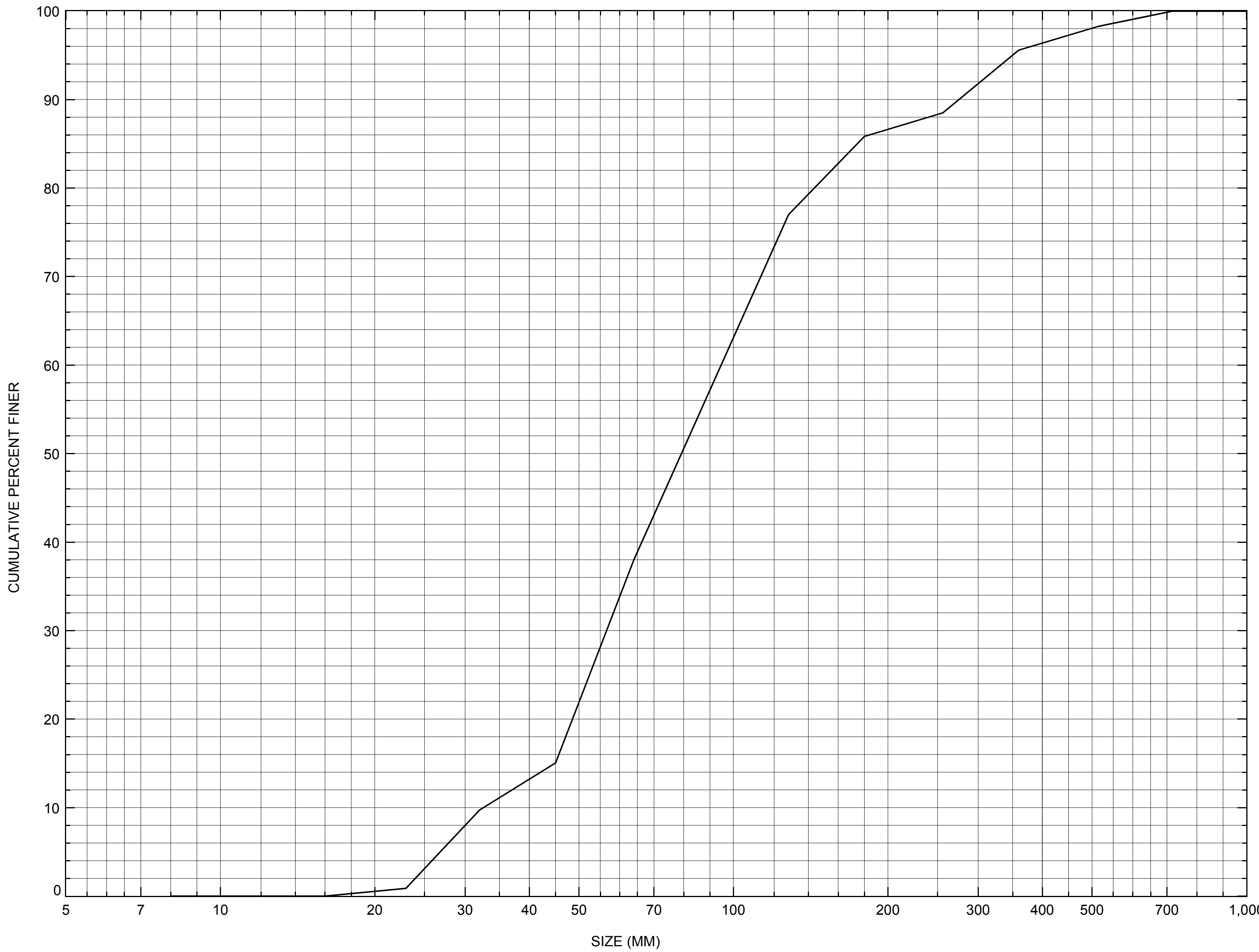
WSPRO OUTPUT FILE (continued)

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File mend025.wsp
        Hydraulic analysis for structure MENDTH00130025   Date: 03-DEC-97
        TH013 CROSSING MENDON BROOK IN MENDON, VERMONT        SAW
           *** RUN DATE & TIME: 01-08-98  15:06

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

EXIT1:XS   ******  -113.     857.  0.57 *****  498.32  495.87   5100.  497.75
      -33. ******    74.   80620.  1.04 ***** *******    0.50    5.95

FULLV:FV      33.  -111.     771.  0.71  0.15  498.53 *******   5100.  497.82
        0.    33.    57.   69299.  1.05  0.07   -0.01    0.56    6.62
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.85     497.55      496.81
 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   497.32     516.93     0.50
 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   497.32     516.93     496.81
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPR1"     KRATIO =  0.45

APPR1:AS      49.   -14.     410.  2.41  0.59  499.96  496.81   5100.  497.55
       49.    49.    48.   31432.  1.00  0.85    0.00    0.85   12.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   503.19       0.00     497.26     499.90
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.79     500.53     500.86     498.90
 ===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      33.     0.     338.  1.78 *****  500.72  495.28   3611.  498.94
        0. ******    30.   28683.  1.00 ***** *******    0.56   10.69

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.454 ******  498.90 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG        9.    35.  0.12  0.46  501.99    0.00   1501.  501.64

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    857.   133.  -117.    16.   1.7   1.3   5.9   5.0   1.6   3.1
   RT:    644.   137.    16.   154.   1.4   1.0   5.3   4.8   1.3   3.1

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

APPR1:AS      27.    -91.     986.  0.46  0.21  502.10  496.81   5100.  501.65
       49.    28.   191.   87952.  1.10  0.51    0.00    0.51    5.17

       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     -33.  -113.    74.   5100.   80620.     857.    5.95  497.75
   FULLV:FV       0.  -111.    57.   5100.   69299.     771.    6.62  497.82
   BRIDG:BR       0.     0.    30.   3611.   28683.     338.   10.69  498.94
   RDWAY:RG       9.*******   857.   1501.*********       0.    1.00  501.64
   APPR1:AS      49.   -91.   191.   5100.   87952.     986.    5.17  501.65

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    495.87    0.50  485.34  510.51************  0.57  498.32  497.75
   FULLV:FV  ********    0.56  485.90  511.07  0.15  0.07  0.71  498.53  497.82
   BRIDG:BR    495.28    0.56  486.08  498.94************  1.78  500.72  498.94
   RDWAY:RG  ****************  499.90  510.77  0.12******  0.46  501.99  501.64
   APPR1:AS    496.81    0.51  488.82  516.93  0.21  0.51  0.46  502.10  501.65
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File mend025.wsp
        Hydraulic analysis for structure MENDTH00130025   Date: 03-DEC-97
        TH013 CROSSING MENDON BROOK IN MENDON, VERMONT        SAW
           *** RUN DATE & TIME: 01-08-98  15:06

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

EXIT1:XS   ******  -108.     670.  0.48 *****  497.12  493.25   3580.  496.64
      -33. ******    51.   56583.  1.08 ***** *******    0.48    5.35

FULLV:FV      33.  -106.     590.  0.64  0.16  497.34 *******   3580.  496.69
        0.    33.    51.   47645.  1.12  0.08   -0.02    0.59    6.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPR1"     KRATIO =  0.55

APPR1:AS      49.   -13.     360.  1.53  0.51  498.28 *******   3580.  496.75
       49.    49.    47.   26025.  1.00  0.45   -0.01    0.72    9.93
         <<<<<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      33.     0.     230.  3.77  0.33  499.06  495.24   3580.  495.29
        0.    33.    30.   22570.  1.00  1.61    0.00    0.99   15.56

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.90 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<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      27.   -26.     524.  0.73  0.37  499.99  495.42   3580.  499.26
       49.    28.    59.   43343.  1.01  0.56    0.01    0.49    6.84

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.501  0.288   30820.     0.    30.   499.02

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -33.  -108.    51.   3580.   56583.     670.    5.35  496.64
   FULLV:FV       0.  -106.    51.   3580.   47645.     590.    6.06  496.69
   BRIDG:BR       0.     0.    30.   3580.   22570.     230.   15.56  495.29
   RDWAY:RG       9.**************      0.******************    1.00********
   APPR1:AS      49.   -26.    59.   3580.   43343.     524.    6.84  499.26

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       0.    30.   30820.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    493.25    0.48  485.34  510.51************  0.48  497.12  496.64
   FULLV:FV  ********    0.59  485.90  511.07  0.16  0.08  0.64  497.34  496.69
   BRIDG:BR    495.24    0.99  486.08  498.94  0.33  1.61  3.77  499.06  495.29
   RDWAY:RG  ****************  499.90  510.77**********************************
   APPR1:AS    495.42    0.49  488.82  516.93  0.37  0.56  0.73  499.99  499.26
  ER

 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 MENDTH00130025, in Mendon, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MENDTH00130025

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 21 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 04125

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

Waterway *(I - 6)* Mendon Brook

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

Route Number TH013

Vicinity *(I - 9)* 0.03 MI TO JCT W US4

Topographic Map Chittenden

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 43391

Longitude *(i - 17; nnnnn.n)* 72553

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10111000251110

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

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

Year built *(I - 27; YYYY)* 1973

Structure length *(I - 49; nnnnnn)* 000035

Average daily traffic, ADT *(I - 29; nnnnnn)* 000025

Deck Width *(I - 52; nn.n)* 143

Year of ADT *(I - 30; YY)* 91

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

Opening skew to Roadway *(I - 34; nn)* 05

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 011.0

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

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

Comments:

The structural inspection report of 9/10/93 indicates the structure is a steel stringer type bridge. The right abutment wall is noted as concrete faced "laid-up" stone with a concrete footing and large boulders "laid-up" at both ends of the wall forming short wingwalls. The abutment concrete has a few fine cracks and minor spalls reported overall. A new section of concrete footing has been poured at the end to correct for an undermining problem the report indicates. The left abutment and its wingwalls are concrete. This abutment also has a "knee-wall" (subfooter). The report indicates the concrete has a few minor cracks and spalls. There are numerous large boulders present in the channel US and DS. **(Continued, page 32)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

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} (*ft^3/ sec*): -

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

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

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

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

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

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

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

Comments:

Some of the boulders are lining the banks, reportedly, with some signs of bank erosion from previous flooding.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **17.57** mi^2 Lake/pond/swamp area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **1030** ft Headwater elevation **4235** ft

Main channel length **7.68** mi

10% channel length elevation **1200** ft 85% channel length elevation **2460** ft

Main channel slope *(S)* **218.75** 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:

The VTAOT survey, B94007 (1994) disk is on top of the downstream end of the left abutment.

-

Reference Point (*MSL, Arbitrary, Other*): **MSL** Datum (*NAD27, NAD83, Other*): **NAVD 1988**

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

If 1: Footing Thickness ________ Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

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

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

Comments: **The low chord to bed distances, and lengths between stations were taken from a sketch dated 9/7/93 that was attached to a bridge inspection report. The elevations have been made to line up with the low chord reports used in this report.**

Station	0	13	21	26	33	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	498.9	498.9	498.9	498.9	498.9	-	-	-	-	-	-
Bed elevation	492.4	487.1	486	486.2	487.9	-	-	-	-	-	-
Low chord to bed	6.5	11.8	12.9	12.7	11	-	-	-	-	-	-

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: 01/30/95
Computerized by: CG Date: 2/2/96
Reviewd by: SAW Date: 1/26/98

Structure Number MENDTH00130025

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. Ivanoff Date *(MM/DD/YY)* 09 / 27 / 1995

2. Highway District Number 03 Mile marker 0

County Rutland (021) Town Mendon (04125)

Waterway *(I - 6)* Mendon Brook Road Name Medway Road

Route Number TH 13 Hydrologic Unit Code: 02010002

3. Descriptive comments:

This site is located 0.03 miles from US 4.

B. Bridge Deck Observations

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

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

7. Bridge length 35.0 *(feet)* Span length 33.0 *(feet)* Bridge width 14.3 *(feet)*

Road approach to bridge:

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

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

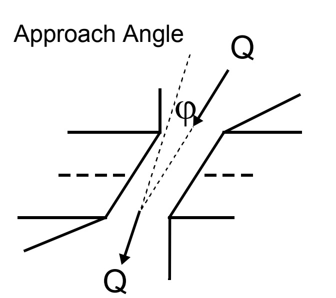
10. Embankment slope (*run / rise in feet / foot*):
US left 0.0:1 US right 0.0:1

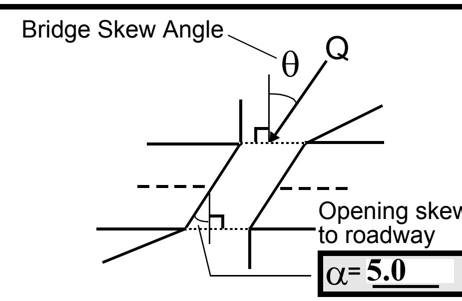
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	3	1	0	0
RBUS	2	1	0	0
RBDS	2	1	0	0
LBDS	2	1	0	0

*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: 0 16. Bridge skew: 0





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 0
Range? 8 feet US *(US, UB, DS)* to 5 feet DS

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 0
Range? 76 feet US *(US, UB, DS)* to 30 feet US

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

18. Bridge Type: **1a**

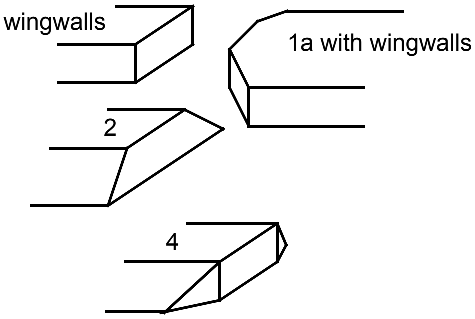
1a- Vertical abutments with wingwalls

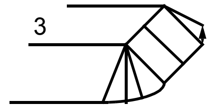
1b- Vertical abutments without wingwalls

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. The bridge dimension values are from the VTAOT database. Measured bridge length equals 34.5 ft, span equals 31.5 ft, width equals 12.0 ft.

4. Trees line the banks with few trees on the upstream left bank.

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
33.5	**6.0**			**7.7**	**2**	**4**	**543**	**543**	**1**	**0**

23. Bank width **50.0** 24. Channel width **40.0** 25. Thalweg depth **69.9** 29. Bed Material **453**

30 .Bank protection type: LB **2** RB **2** 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.):

27. Bank material is composed of boulder, cobble and gravel.

29. Bed material is composed of cobble, boulder and gravel.

30. The large stones that line both banks appear to be native.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **76** 35. Mid-bar width: **22**

36. Point bar extent: **127** feet **US** (US, UB) to **42** feet **US** (US, UB, DS) positioned **50** %LB to **100** %RB

37. Material: **54**

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

Side bar consists of boulder, cobble and gravel.

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

41. Mid-bank distance: **52** 42. Cut bank extent: **015** feet **US** (US, UB) to **30** 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.):

A steepened bank along the outside of a bend has a 6-ft diameter boulder along the base.

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
50.0		1.0		2	7	7	-

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

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

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

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

453

63. Bed material consists of cobble, boulder and gravel.

Larger stones line the left abutment; the flow is along the right abutment.

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

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

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

70. Debris and Ice Comments:

2

There are many large boulders where debris could get caught. Along the left bank there are large boulders and debris.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	2	0	4.5	90.0
RABUT	1	5	90			2	2	30.0

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

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

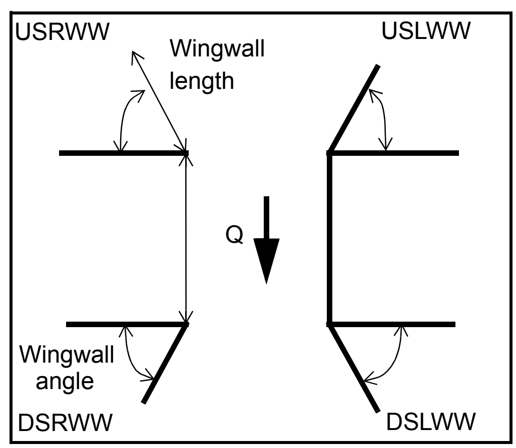
0
6
1

Channel flow is along the right abutment which has a 3 foot high footing and 6 ft of exposed footings. The lower step footing is along the upstream 5 ft of right abutment as noted during the Level I asessment (September 27, 1995) and as noted on the historical form (March 21, 1995). The lower step footing was possible added since the structural inspection of 9/10/93.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						30.0	
USRWW:	Y		1		2	1.5	
DSLWW:	0		4.5		N	18.0	
DSRWW:	-		-		-	16.0	

*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	-	2	N	-	1	-	3	-
Condition	Y	0	-	-	2	-	2	-
Extent	1	4.0	-	3	-	3	0	-

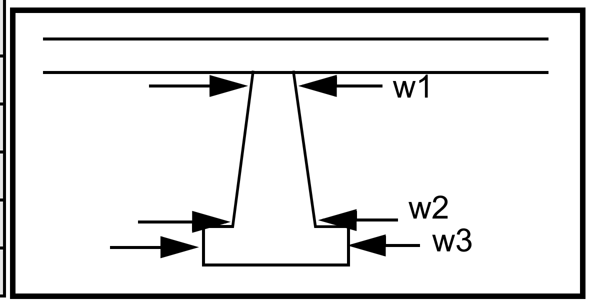
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? **Sto** *(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	**60.0**	-		**12.0**	-	**45.0**
Pier 2	**8.0**	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**ne and**	**and**	**scat-**		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**boul-**	**right**	**tered**		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**ders**	**abut**	**at**		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**have**	**ment**	**the**		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**been**	**wing**	**base**		*Y- yes; N- no*
91. Attack ∠ (BF)	**place**	**walls**	**of**		
92. Pushed	**d at**	**.**	**the**		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**the**	**Som**	**left**		
95. Cross-members	**ends**	**e**	**abut**	**N**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**of**	**boul-**	**ment**	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**the**	**ders**	**.**	-	
98. Exposure depth	**left**	**are**		-	

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.):
-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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: __NO__ Mid-bar width: __PIE__

Point bar extent: __RS__ 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.):

4

Is a cut-bank present? __3__ *(Y or if N type ctrl-n cb)* Where? __543__ *(LB or RB)* Mid-bank distance: __453__

Cut bank extent: __0__ feet __1__ *(US, UB, DS)* to __453__ feet __3__ *(US, UB, DS)*

Bank damage: __0__ *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

1

-

Left bank material is composed of boulder, cobbble and gravel. Right bank material is composed of cobble, boulder and gravel.

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

Scour dimensions: Length __mate__ Width __rial__ Depth: __is__ Positioned __co__ %LB to __mp__ %RB

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

osed of cobble, boulder and gravel.

Native stone is in place and extends along left bank.

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

Confluence 1: Distance _____ 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):

N

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 DROP STRUCTURE

Y
130
20
115
DS
188
DS

109. G. Plan View Sketch

\- 0

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: MENDTH00130025 Town: MENDON
Road Number: TH13 County: RUTLAND
Stream: MENDON BROOK

Initials SAW Date: 12/16/97 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 others, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3400	5100	3580
Main Channel Area, ft2	492	689	522
Left overbank area, ft2	0	120	1
Right overbank area, ft2	0	177	0
Top width main channel, ft	68	70	70
Top width L overbank, ft	0	76	11
Top width R overbank, ft	0	136	5
D50 of channel, ft	0.2588	0.2588	0.2588
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.2	9.8	7.5
y1, average depth, LOB, ft	ERR	1.6	0.1
y1, average depth, ROB, ft	ERR	1.3	0.0
Total conveyance, approach	39809	88054	43371
Conveyance, main channel	39809	68849	43348
Conveyance, LOB	0	8704	19
Conveyance, ROB	0	10501	4
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	3400.0	3987.7	3578.1
Ql, discharge, LOB, cfs	0.0	504.1	1.6
Qr, discharge, ROB, cfs	0.0	608.2	0.3
Vm, mean velocity MC, ft/s	6.9	5.8	6.9
Vl, mean velocity, LOB, ft/s	ERR	4.2	1.6
Vr, mean velocity, ROB, ft/s	ERR	3.4	ERR
Vc-m, crit. velocity, MC, ft/s	9.9	10.5	10.0
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

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	3400	3611	3580
Main channel area (DS), ft2	229	306	230
Main channel width (normal), ft	30.0	30.0	30.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	30.0	30.0	30.0
D90, ft	0.9030	0.9030	0.9030
D95, ft	1.1488	1.1488	1.1488
Dc, critical grain size, ft	1.0341	0.5787	1.1344
Pc, Decimal percent coarser than Dc	0.072	0.147	0.053
Depth to armoring, ft	40.07	10.09	61.30

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	3400	5100	3580
(Q) discharge thru bridge, cfs	3400	3611	3580
Main channel conveyance	22430	28683	22556
Total conveyance	22430	28683	22556
Q2, bridge MC discharge,cfs	3400	3611	3580
Main channel area, ft2	229	338	230
Main channel width (normal), ft	30.0	30.0	30.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30	30	30
y_bridge (avg. depth at br.), ft	7.63	11.27	7.67
Dm, median (1.25*D50), ft	0.3235	0.3235	0.3235
y2, depth in contraction,ft	9.85	10.37	10.30
ys, scour depth (y2-ybridge), ft	**2.22**	-0.89	**2.63**

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	3400	5100	3580
Q, thru bridge MC, cfs	3400	3611	3580
Vc, critical velocity, ft/s	9.94	10.46	9.99
Va, velocity MC approach, ft/s	6.91	5.79	6.85
Main channel width (normal), ft	30.0	30.0	30.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.0	30.0	30.0
qbr, unit discharge, ft2/s	113.3	120.4	119.3
Area of full opening, ft2	229.0	338.0	230.0
Hb, depth of full opening, ft	7.63	11.27	7.67
Fr, Froude number, bridge MC	0	0.56	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	306	N/A
**Hb, depth at downstream face, ft	N/A	10.20	N/A
**Fr, Froude number at DS face	ERR	0.65	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	498.9	0
Elevation of Bed, ft	0.00	487.63	0.00
Elevation of Approach, ft	0	501.65	0
Friction loss, approach, ft	0	0.21	0
Elevation of WS immediately US, ft	0.00	501.44	0.00
ya, depth immediately US, ft	0.00	13.81	0.00
Mean elevation of deck, ft	0	500.27	0
w, depth of overflow, ft (>=0)	0.00	1.17	0.00
Cc, vert contrac correction (<=1.0)	ERR	0.97	ERR
**Cc, for downstream face (<=1.0)	ERR	0.79	ERR
Ys, scour w/Chang equation, ft	N/A	**0.57**	N/A
Ys, scour w/Umbrell equation, ft	N/A	-1.17	N/A

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

**Ys, scour w/Chang equation, ft	N/A	4.37	N/A
**Ys, scour w/Umbrell equation, ft	ERR	-0.10	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	9.85	10.37	10.30
WSEL at downstream face, ft	--	497.82	--
Depth at downstream face, ft	N/A	10.20	N/A
Ys, depth of scour (Laursen), ft	N/A	0.17	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)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	3400	5100	3580	3400	5100	3580
a', abut.length blocking flow, ft	15.3	91.6	26	23.1	160.9	29.3
Ae, area of blocked flow ft2	89.9	124	97.9	120.7	252.5	131.8
Qe, discharge blocked abut.,cfs	498.3	---	543.9	648.5	--	696.1
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	5.54	4.56	5.56	5.37	4.12	5.28
ya, depth of f/p flow, ft	5.88	1.35	3.77	5.23	1.57	4.50
--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	85	85	85	95	95	95
K2	0.99	0.99	0.99	1.01	1.01	1.01
Fr, froude number f/p flow	0.403	0.482	0.505	0.414	0.481	0.439
ys, scour depth, ft	**15.29**	**11.17**	**14.29**	**16.07**	**15.35**	**15.9**2

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)	15.3	91.6	26	23.1	160.9	29.3
y1 (depth f/p flow, ft)	5.88	1.35	3.77	5.23	1.57	4.50
a'/y1	2.60	67.67	6.91	4.42	102.53	6.51
Skew correction (p. 49, fig. 16)	0.98	0.98	0.98	1.01	1.01	1.01
Froude no. f/p flow	0.40	0.48	0.50	0.41	0.48	0.44
Ys w/ corr. factor K1/0.55:						
vertical	ERR	7.61	ERR	ERR	9.06	ERR
vertical w/ ww's	ERR	6.24	ERR	ERR	7.43	ERR
spill-through	ERR	4.18	ERR	ERR	4.98	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	0.95	0.65	0.99	0.95	0.65	0.99
y, depth of flow in bridge, ft	7.63	10.20	7.67	7.63	10.20	7.67
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.66	ERR	ERR	2.66	ERR
Fr>0.8 (vertical abut.)	3.15	ERR	3.20	3.15	ERR	3.20