LEVEL II SCOUR ANALYSIS FOR BRIDGE 21 (MIDBTH00230021) on TOWN HIGHWAY 23, crossing the MIDDLEBURY RIVER, MIDDLEBURY, VERMONT

Open-File Report 97-754

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

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

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By ERICK M. BOEHMLER and JAMES R. DEGNAN

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Pembroke, New Hampshire

1997

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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 21 (MIDBTH00230021) ON TOWN HIGHWAY 23, CROSSING THE MIDDLEBURY RIVER, MIDDLEBURY, VERMONT

***By* Erick M. Boehmler and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MIDBTH00230021 on Town Highway 23 crossing the Middlebury River, Middlebury, 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 (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in west-central Vermont. The 44.8-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is suburban consisting of single houses, each with a lawn, trees, and shrubs on all of the overbank areas bordering the river.

In the study area, the Middlebury River has a straight channel with a slope of approximately 0.02 ft/ft, an average channel top width of 87 ft and an average channel depth of 11 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 152 mm (0.498 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 18, 1996, indicated that the reach was stable.

The Town Highway 23 crossing of the Middlebury River is a 52-ft-long, two-lane bridge consisting of one 49-foot steel-beam span (Vermont Agency of Transportation, written communication, December 14, 1995). The opening length of the structure parallel to the bridge face is 42.3 feet. The bridge is supported by vertical, concrete abutments with wingwalls at each end of the left abutment only. The channel is skewed approximately 10 degrees to the opening. The opening-skew-to-roadway from the VTAOT records is zero degrees while 5 degrees was computed from surveyed points.

A scour hole 1.0 foot deeper than the mean thalweg depth was observed in the channel at the upstream bridge face during the Level I assessment. The scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) on the upstream and downstream banks and the upstream and downstream left wingwalls. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is 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 1.2 to 1.8 feet. The worst-case contraction scour occurred at the incipient overtopping discharge, which is less than the 500-year discharge. Abutment scour ranged from 17.7 to 23.7 feet. 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 others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number MIDBTH00230021 ***Stream*** Middlebury River

County Addison ***Road*** TH 23 ***District*** 5

Description of Bridge

Bridge length 52 ***ft*** ***Bridge width*** 25.3 ***ft*** ***Max span length*** 49 ***ft***

Alignment of bridge to road (on curve or straight) Right is straight; left is curved

Abutment type Vertical, concrete ***Embankment type*** None

Stone fill on abutment? No ***Date of inspection*** 6/18/96

Description of stone fill Type-2 is noted on the upstream and downstream banks and the upstream and downstream left wingwalls.

Brief description of piers/abutments Abutments and wingwalls are concrete. Only the left abutment has wingwalls.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 10

Is there a channel bend? If so, describe (mild, moderate, severe) There is a mild channel bend at the bridge.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	6/18/96	0	0
Level II	6/18/96	0	0

Potential for debris Moderate. There is some debris accumulation along the banks.

Describe any features near or at the bridge that may affect flow (include observation date) None evident on 6/18/96.

Description of the Geomorphic Setting

General topography The channel is located in a high relief valley setting, with no flood plains and moderately sloping valley walls on both sides.

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

Date of inspection 6/18/96

DS left: Steep channel bank to a narrow overbank.

DS right: Steep channel bank to a narrow overbank.

US left: Steep channel bank to a narrow overbank.

US right: Steep channel bank to a narrow overbank.

Description of the Channel

Average top width 87 ***ft*** ***Average depth*** 11 ***ft***

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

Perennial but flashy, straight and stable with non-alluvial boundaries and narrow point bars.

6/18/96

Vegetative co Trees and brush.

DS left: Small trees, shrubs and brush.

DS right: Trees.

US left: Trees.

US right:

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

None evident on 6/18/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 44.8 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: Although the watershed area is rural, there are houses on the overbank areas bordering the river near this site.

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 6,000 ***ft³/s*** ***Q500*** 8,500 ***ft³/s***

The 100- and 500-year discharges are based on discharge-frequency curves computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957 a&b; and Talbot, 1887) and the values provided in the VTAOT database for bridge 20 in Middlebury about 0.25 mile downstream. Each discharge-frequency curve was extrapolated to the 500-year event. The discharges selected for the hydraulic analysis of this site were those from the VTAOT discharge-frequency curve due to the central tendency of the curve with those derived from the empirical equations.

Description of the Water-Surface Profile Model (WSPRO) Analysis

Datum for WSPRO analysis (USGS survey, sea level, VTAOT plans) VTAOT plans

Datum tie between USGS survey and VTAOT plans --

Description of reference marks used to determine USGS datum. RM1 is the center point of a chisled "X" at the right end on top of the downstream concrete curb. RM2 is the center of an engraved triangle on a metallic tablet set in the top of the upstream concrete curb at the left end (elev. 104.09 feet, arbitrary survey datum). RM3 is the center point of a chiseled "X" on top of the concrete downstream left wingwall at the downstream end (elev. 100.01feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-57	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APPRO	73	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 0.060 to 0.075, and the overbank "n" value was 0.055.

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 0.0188 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1944).

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

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

At this site, the elevation of the right overbank area, including the road approach, is lower than the bridge and the right bank upstream. For the 500-year discharge, WSPRO provides a solution in which the channel is less than bank-full and a disproportionate quantity of the flow is modeled as weir flow over the roadway from the right overbank area. Therefore, modifications to the approach and roadway cross-sections were made to achieve a reasonable division of flow between the channel (through the bridge) and the right overbank (over the roadway). These modifications yielded an approach water surface elevation just above the bank full elevation.

Bridge Hydraulics Summary

Average bridge embankment elevation 102.8 *ft*
Average low steel elevation 99.3 *ft*

100-year discharge 6,000 *ft³/s*
Water-surface elevation in bridge opening 93.1 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 359 *ft²*
Average velocity in bridge opening 16.7 *ft/s*
Maximum WSPRO tube velocity at bridge 20.9 *ft/s*

Water-surface elevation at Approach section with bridge 98.7
Water-surface elevation at Approach section without bridge 95.6
Amount of backwater caused by bridge 3.1 *ft*

500-year discharge 8,500 *ft³/s*
Water-surface elevation in bridge opening 95.2 *ft*
Road overtopping? Yes *Discharge over road* 1,090 *ft³/s*
Area of flow in bridge opening 449 *ft²*
Average velocity in bridge opening 16.5 *ft/s*
Maximum WSPRO tube velocity at bridge 20.8 *ft/s*

Water-surface elevation at Approach section with bridge 100.0
Water-surface elevation at Approach section without bridge 97.5
Amount of backwater caused by bridge 2.5

Incipient overtopping discharge 6,820 *ft³/s*
Water-surface elevation in bridge opening 93.9 *ft*
Area of flow in bridge opening 392 *ft²*
Average velocity in bridge opening 17.4 *ft/s*
Maximum WSPRO tube velocity at bridge 21.8 *ft/s*

Water-surface elevation at Approach section with bridge 99.8
Water-surface elevation at Approach section without bridge 96.3
Amount of backwater caused by bridge 3.5 *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 others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. Bedrock was exposed across the channel upstream of this site and may be a feature limiting the depth of scour at the bridge. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

The bottom of the footing elevation, available from plans of the site, was above the streambed elevation adjacent to both of the abutments. A structural inspection report of the site indicates both abutment footings rest on large boulders with some void sections evident between boulders. However, the voids were filled with stone and concrete on the right abutment at the time of the site visit. The area of contact between the footing and underlying material is displayed with cross-hatched shading in figure 8. The scour depths computed and shown in figure 8, and tables 1 and 2, were subtracted from the streambed elevation surveyed immediately adjacent to the footing of each abutment.

Contraction scour for each discharge modeled was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 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-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.4	1.2	1.8
Depth to armoring	53.4	27.1	70.0
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	17.7	21.5	19.6
Right abutment	19.9	23.7	21.5
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	3.6	4.3	4.0
Right abutment	3.6	4.3	4.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--
	--	--	--

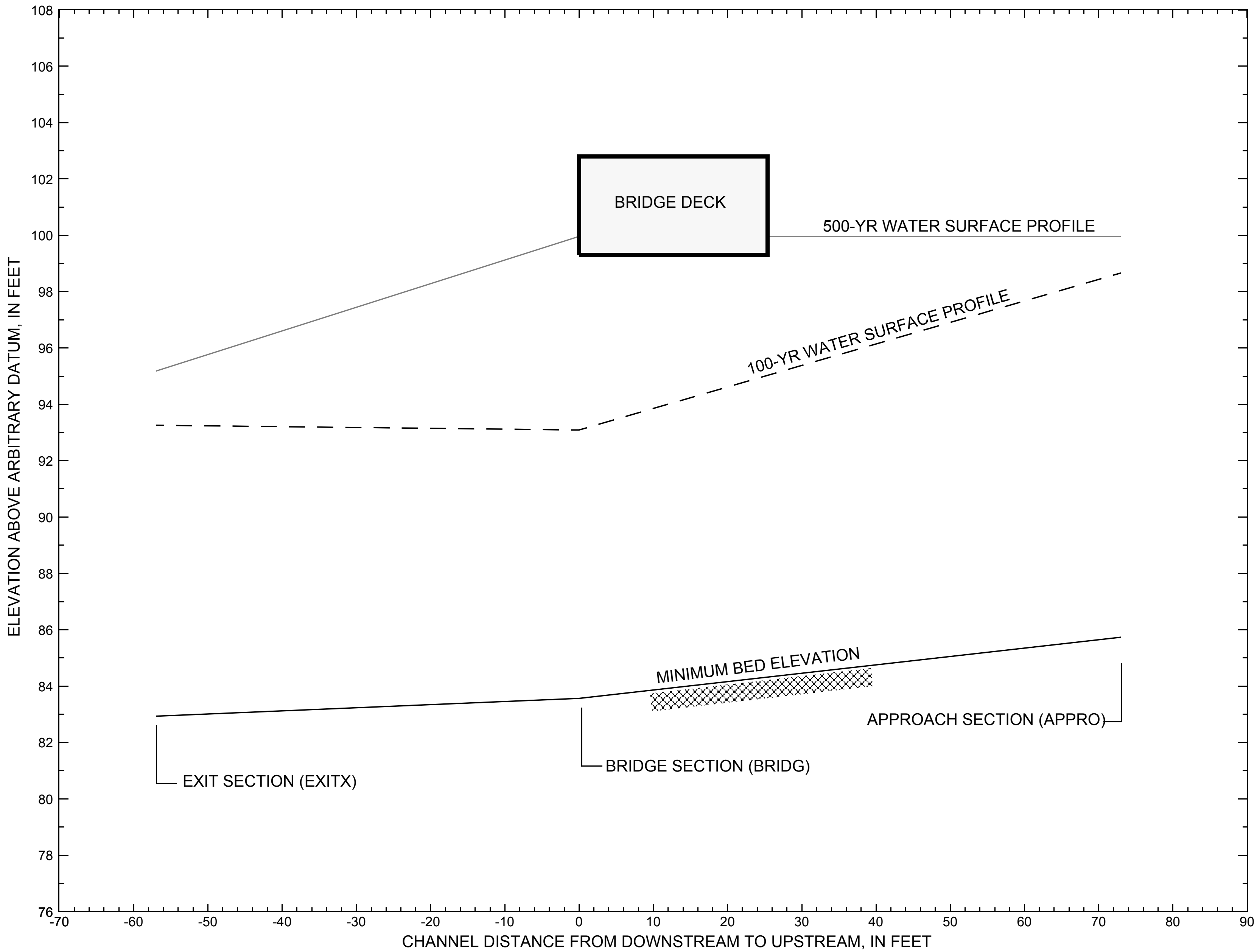

Figure 7. Water-surface profiles for the 100-year and incipient overtopping discharges at structure MIDBTH00230021 on Town Highway 23, crossing the Middlebury River, Middlebury, Vermont.

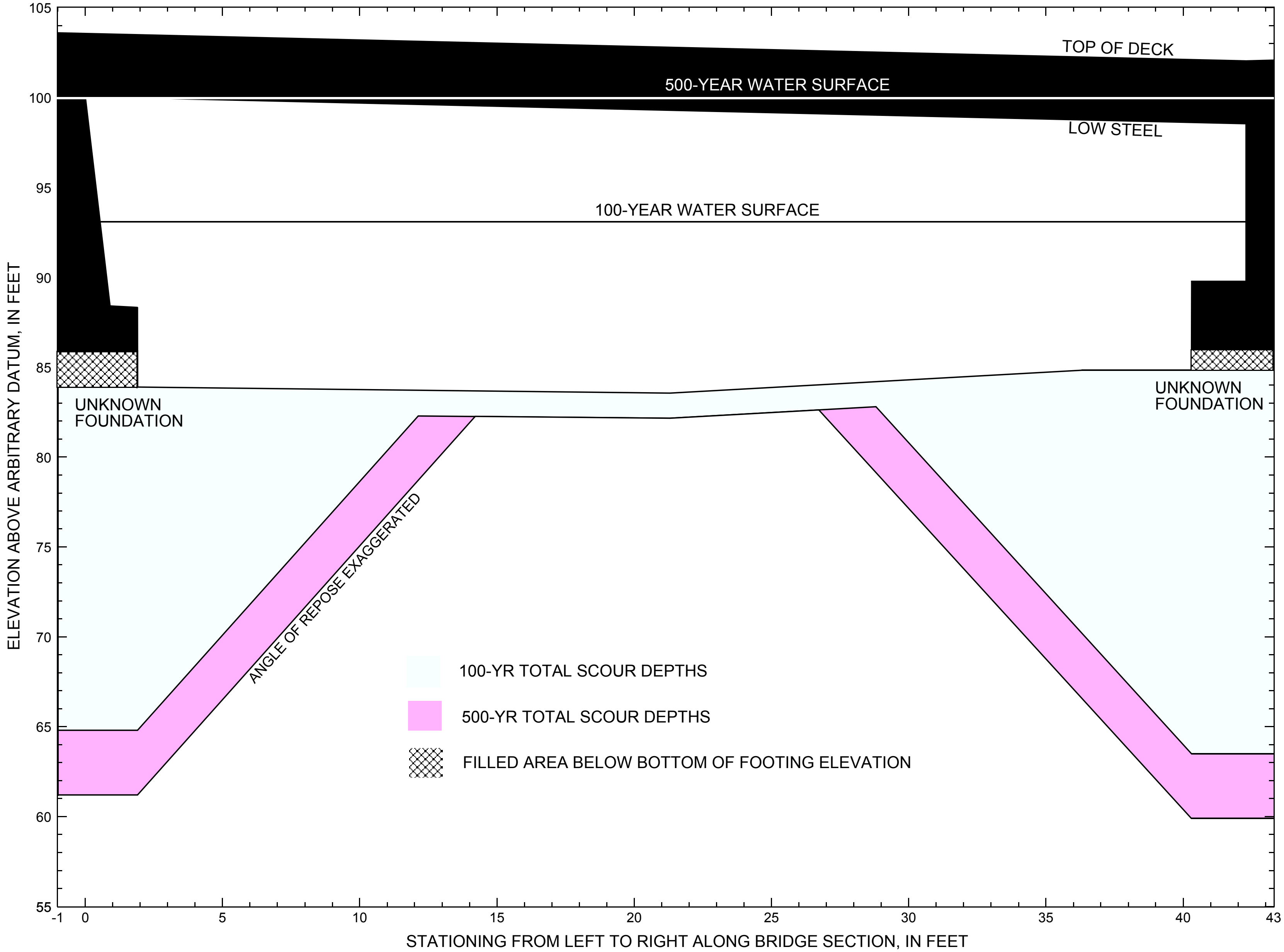

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure MIDBTH00230021 on Town Highway 23, crossing the Middlebury River, Middlebury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MIDBTH00230021 on Town Highway 23, crossing the Middlebury River, Middlebury, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT Bridge seat elevation (feet)	Surveyed Low cord 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 6,000 cubic-feet per second											
Left abutment	0.0	100.0	100.1	85.9	83.9	1.4	17.7	--	19.1	64.8	-21.1
Right abutment	42.3	98.5	98.6	85.9	84.8	1.4	19.9	--	21.3	63.5	-22.4

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 MIDBTH00230021 on Town Highway 23, crossing the Middlebury River, Middlebury, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT Bridge seat elevation (feet)	Surveyed Low cord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 8,500 cubic-feet per second											
Left abutment	0.0	100.0	100.1	85.9	83.9	1.2	21.5	--	22.7	61.2	-24.7
Right abutment	42.3	98.5	98.6	85.9	84.8	1.2	23.7	--	24.9	59.9	-26.0

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, 1944, East Middlebury, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Photorevised, 1972; Photoinspected 1983; Contour interval, 20 feet; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File midb021.io.wsp
T2        Hydraulic analysis for structure MIDBTH00230021   Date: 16-JUN-97
T3        Town Highway 23 crossing the Middlebury River, Middlebury, VT      EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          6000.0   6820.0
SK         0.0188   0.0188
*
XS   EXITX    -57
GR         -118.7, 102.78    -56.9, 100.15    -24.1,  97.39    -11.1,  88.52
GR            0.0,  85.64      1.4,  84.84      7.1,  84.34     11.7,  83.16
GR           22.0,  82.93     28.4,  83.33     39.0,  84.68     40.4,  85.50
GR           54.4,  88.54     58.6,  94.96    117.7,  95.69    291.6,  95.69
GR          351.0,  96.70    378.9,  99.68
*
*          The coordinates at stations 291.6, 351.0, and 378.9 were taken from
*          the surveyed roadway section points.
N          0.070          0.055
SA                 58.6
*
XS   FULLV      0  * * *  0.0078
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0     99.30      5.0
GR            0.0, 100.05      0.9,  88.41      1.9,  88.32      1.9,  83.89
GR            4.9,  83.79     21.3,  83.56     36.3,  84.83     40.3,  84.83
GR           40.3,  89.78     42.3,  89.78     42.3,  98.55      0.0, 100.05
*
*        BRTYPE  BRWDTH
CD          1      35.7
*
N          0.060
*
*            SRD    EMBWID   IPAVE
XR   RDWAY    14      25.3     1
GR         -670.3, 111.21   -580.6, 106.63   -553.8, 106.30   -416.7, 105.26
GR         -238.3, 103.02   -214.6, 102.91    -75.3, 102.96    -36.5, 103.49
GR            0.0, 103.56     49.2, 102.04     49.2, 105.00
*          The following were removed from the section to prevent road
*          overflow before overtopping the approach top of right bank at
*          station 65.0 for the Q100 and to determine the incipient
*          discharge.
*          67.0, 100.90    123.2,  96.39
*          197.4,  94.67    291.6,  95.33    351.0,  96.70    378.9,  99.68
*
AS   APPRO     73
GR          -35.4, 105.88    -23.8, 106.28    -22.1,  97.73    -10.6,  92.29
GR            0.0,  87.70      2.8,  86.82     12.4,  86.42     23.1,  86.33
GR           31.0,  85.73     36.4,  86.63     41.7,  87.90     53.4,  91.79
GR           65.0,  99.77
*
N          0.075
*
HP 1 BRIDG 93.09 1 93.09
HP 2 BRIDG 93.09 * * 6000
HP 1 APPRO 98.66 1 98.66
HP 2 APPRO 98.66 * * 6000
*
HP 1 BRIDG 93.87 1 93.87
HP 2 BRIDG 93.87 * * 6820
HP 1 APPRO 99.77 1 99.77
HP 2 APPRO 99.77 * * 6820
*
EX
ER
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T1        U.S. Geological Survey WSPRO Input File midb021.wsp
T2        Hydraulic analysis for structure MIDBTH00230021   Date: 16-JUN-97
T3        Town Highway 23 crossing the Middlebury River, Middlebury, VT      EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           8500.0
SK          0.0188
*           The results from this model are questionable. At this discharge,
*           water is expected to be spilling over the top of the right bank.
*           The TH 23 roadway on the right side of the bridge is
*           significantly lower than the approach top of bank point and the
*           bridge deck. Therefore, a type 4 or 5 bridge flow solution is
*           expected with an approach water surface elevation just above the
*           elevation of the top of bank point. This was forced by inserting
*           a vertical wall at the approach top of right bank point and on
*           the roadway section. The vertical wall on the roadway section was
*           systematically moved closer to the bridge until a solution was
*           attained and the solution provided an approach water surface
*           just above the top of right bank point elevation.
*
XS   EXITX    -57
GR         -118.7, 102.78    -56.9, 100.15    -24.1,  97.39    -11.1,  88.52
GR            0.0,  85.64      1.4,  84.84      7.1,  84.34     11.7,  83.16
GR           22.0,  82.93     28.4,  83.33     39.0,  84.68     40.4,  85.50
GR           54.4,  88.54     58.6,  94.96    117.7,  95.69    291.6,  95.33
GR          351.0,  96.70    378.9,  99.68
*
*           Coordinates at stations 291.6, 351.0, and 378.9 were taken from
*           the surveyed roadway section points.
*
N           0.070         0.055
SA                 58.6
*
XS   FULLV      0  * * *   0.0078
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0     99.30      5.0
GR            0.0, 100.05      0.9,  88.41      1.9,  88.32      1.9,  83.89
GR            4.9,  83.79     21.3,  83.56     36.3,  84.83     40.3,  84.83
GR           40.3,  89.78     42.3,  89.78     42.3,  98.55      0.0, 100.05
*
*         BRTYPE  BRWDTH
CD           1      35.7
*
N           0.060
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     14      25.3     1
GR         -670.3, 111.21   -580.6, 106.63   -553.8, 106.30   -416.7, 105.26
GR         -238.3, 103.02   -214.6, 102.91    -75.3, 102.96    -36.5, 103.49
GR            0.0, 103.56     49.2, 102.04     67.0, 100.90    123.2,  96.39
GR          140.0, 96.00     140.0, 105.00
*           197.4,  94.67    291.6,  95.33    351.0,  96.70    378.9,  99.68
*
AS   APPRO     73
GR          -35.4, 105.88    -23.8, 106.28    -22.1,  97.73    -10.6,  92.29
GR            0.0,  87.70      2.8,  86.82     12.4,  86.42     23.1,  86.33
GR           31.0,  85.73     36.4,  86.63     41.7,  87.90     53.4,  91.79
GR           65.0,  99.77     65.0, 101.00
*
N           0.075
*
HP 1 BRIDG 95.24 1 95.24
HP 2 BRIDG 95.24 * * 7413
HP 2 RDWAY 99.96 * * 1087
HP 1 APPRO 99.96 1 99.96
HP 2 APPRO 99.96 * * 8500
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File midb021.io.wsp
     Hydraulic analysis for structure MIDBTH00230021   Date: 16-JUN-97
     Town Highway 23 crossing the Middlebury River, Middlebury, VT      EMB
        *** RUN DATE & TIME: 07-29-97  15:05

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      359     29880     42     59                          5995
 93.09           359     29880     42     59  1.00      1     42     5995

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

      WSEL     LEW     REW    AREA        K        Q    VEL
     93.09     0.5    42.3   359.4   29880.    6000.  16.69

X STA.         0.5        5.0        7.2        9.0       10.8       12.5
  A(I)            34.3       20.0       17.2       16.5       15.7
  V(I)            8.75      15.02      17.43      18.21      19.13

X STA.        12.5       14.1       15.7       17.2       18.8       20.3
  A(I)            15.3       14.9       14.7       14.6       14.6
  V(I)           19.66      20.17      20.38      20.57      20.53

X STA.        20.3       21.8       23.4       25.0       26.7       28.4
  A(I)            14.3       14.7       14.9       15.4       15.7
  V(I)           20.91      20.48      20.14      19.43      19.17

X STA.        28.4       30.3       32.2       34.4       36.9       42.3
  A(I)            16.1       16.9       18.7       20.4       34.7
  V(I)           18.62      17.74      16.05      14.71       8.66

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      778     64247     86     92                         13300
 98.66           778     64247     86     92  1.00    -21     63    13300

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

      WSEL     LEW     REW    AREA        K        Q    VEL
     98.66   -22.3    63.4   777.9   64247.    6000.   7.71

X STA.       -22.3       -6.9       -1.8        2.0        5.0        7.9
  A(I)            68.3       46.1       41.6       35.9       35.3
  V(I)            4.39       6.51       7.20       8.35       8.50

X STA.         7.9       10.8       13.5       16.1       18.8       21.4
  A(I)            34.3       32.9       32.6       32.3       32.3
  V(I)            8.74       9.12       9.21       9.30       9.28

X STA.        21.4       24.0       26.6       29.1       31.7       34.3
  A(I)            32.5       31.9       32.1       33.1       33.1
  V(I)            9.23       9.40       9.33       9.06       9.08

X STA.        34.3       37.1       40.4       44.1       49.1       63.4
  A(I)            34.3       37.5       39.4       45.5       66.8
  V(I)            8.74       8.01       7.62       6.60       4.49
```

```
     U.S. Geological Survey WSPRO Input File midb021.wsp
     Hydraulic analysis for structure MIDBTH00230021   Date: 16-JUN-97
     Town Highway 23 crossing the Middlebury River, Middlebury, VT      EMB
        *** RUN DATE & TIME: 07-29-97  15:03

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      449     41306     42     63                         8355
 95.24           449     41306     42     63  1.00      0     42     8355

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

      WSEL     LEW     REW    AREA        K        Q    VEL
     95.24     0.4    42.3   449.1   41306.    7413.  16.51

X STA.         0.4        5.0        7.3        9.2       10.9       12.7
  A(I)            44.0       25.6       22.0       20.3       19.8
  V(I)            8.42      14.48      16.88      18.22      18.73

X STA.        12.7       14.3       15.9       17.4       19.0       20.5
  A(I)            18.7       18.5       18.0       17.8       17.8
  V(I)           19.78      19.99      20.63      20.84      20.80

X STA.        20.5       22.1       23.6       25.3       26.9       28.6
  A(I)            18.1       17.9       18.5       18.5       19.4
  V(I)           20.52      20.72      20.01      20.05      19.13

X STA.        28.6       30.5       32.4       34.6       37.0       42.3
  A(I)            20.0       21.1       22.7       25.5       44.8
  V(I)           18.53      17.59      16.32      14.51       8.26

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      14.

      WSEL     LEW     REW    AREA        K        Q    VEL
     99.96    78.7   140.0   142.7    6501.    1087.   7.62

X STA.        78.7       98.3      104.2      108.4      111.6      114.4
  A(I)            15.4       10.6        9.4        8.1        7.6
  V(I)            3.54       5.11       5.80       6.72       7.15

X STA.       114.4      116.8      118.9      120.9      122.6      124.3
  A(I)             7.1        6.8        6.3        6.1        5.9
  V(I)            7.68       8.00       8.61       8.96       9.23

X STA.       124.3      125.8      127.4      128.9      130.3      131.8
  A(I)             5.7        5.6        5.4        5.5        5.4
  V(I)            9.48       9.68      10.01       9.94      10.08

X STA.       131.8      133.2      134.6      136.1      137.6      140.0
  A(I)             5.4        5.4        5.7        5.9        9.4
  V(I)           10.03      10.06       9.54       9.25       5.76

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      891     78535     88     95                        16119
 99.96           891     78535     88     95  1.00    -22     65    16119

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

      WSEL     LEW     REW    AREA        K        Q    VEL
     99.96   -22.5    65.0   890.6   78535.    8500.   9.54

X STA.       -22.5       -8.2       -2.9        1.1        4.3        7.3
  A(I)            77.2       52.1       46.9       42.0       40.4
  V(I)            5.50       8.16       9.06      10.12      10.53

X STA.         7.3       10.2       13.1       15.8       18.5       21.2
  A(I)            38.5       38.4       37.2       36.9       36.9
  V(I)           11.04      11.08      11.41      11.53      11.51

X STA.        21.2       23.9       26.6       29.2       31.9       34.6
  A(I)            36.5       36.9       36.6       37.6       38.4
  V(I)           11.65      11.51      11.62      11.30      11.06

X STA.        34.6       37.6       41.0       44.9       50.1       65.0
  A(I)            40.2       43.0       45.2       52.6       77.0
  V(I)           10.56       9.88       9.40       8.09       5.52
```

```
        U.S. Geological Survey WSPRO Input File midb021.io.wsp
        Hydraulic analysis for structure MIDBTH00230021   Date: 16-JUN-97
        Town Highway 23 crossing the Middlebury River, Middlebury, VT      EMB
           *** RUN DATE & TIME: 07-29-97  15:05

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      392     33914     42     60                          6821
    93.87           392     33914     42     60  1.00      0     42     6821

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

         WSEL     LEW     REW    AREA        K        Q    VEL
        93.87     0.5    42.3   391.9   33914.    6820.  17.40

X STA.         0.5        5.0        7.2        9.1       10.8       12.5
  A(I)            37.5       21.8       19.3       17.9       17.0
  V(I)            9.08      15.64      17.66      19.04      20.01

X STA.        12.5       14.2       15.8       17.3       18.9       20.4
  A(I)            16.6       16.4       15.9       15.7       15.8
  V(I)           20.57      20.79      21.45      21.65      21.61

X STA.        20.4       21.9       23.5       25.1       26.8       28.5
  A(I)            15.8       15.6       16.2       16.8       16.6
  V(I)           21.60      21.82      21.11      20.34      20.51

X STA.        28.5       30.4       32.3       34.5       37.0       42.3
  A(I)            17.9       18.4       19.8       22.9       37.9
  V(I)           19.04      18.50      17.21      14.89       9.00

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      874     76312     88     95                         15673
    99.77           874     76312     88     95  1.00    -22     65    15673

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

         WSEL     LEW     REW    AREA        K        Q    VEL
        99.77   -22.5    65.0   874.0   76312.    6820.   7.80

X STA.       -22.5       -8.2       -2.7        1.2        4.4        7.4
  A(I)            74.7       53.6       44.8       41.2       39.6
  V(I)            4.57       6.37       7.61       8.28       8.62

X STA.         7.4       10.3       13.1       15.8       18.5       21.2
  A(I)            37.7       37.6       36.5       36.1       36.2
  V(I)            9.04       9.07       9.35       9.44       9.42

X STA.        21.2       23.9       26.6       29.2       31.8       34.6
  A(I)            36.2       36.6       36.3       35.8       38.6
  V(I)            9.43       9.32       9.40       9.54       8.83

X STA.        34.6       37.5       40.9       44.8       49.9       65.0
  A(I)            38.7       42.2       44.4       51.6       75.8
  V(I)            8.82       8.08       7.68       6.61       4.50
```

```
        U.S. Geological Survey WSPRO Input File midb021.io.wsp
        Hydraulic analysis for structure MIDBTH00230021   Date: 16-JUN-97
        Town Highway 23 crossing the Middlebury River, Middlebury, VT      EMB
           *** RUN DATE & TIME: 07-29-97  15:05

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

EXITX:XS   ******    -17      563  1.76 *****   95.02   91.46    6000   93.26
       -56 ******     57    43719  1.00 ***** *******    0.69   10.65

FULLV:FV       57    -18      624  1.44  0.92   95.93 *******    6000   94.50
         0     57     58    50888  1.00  0.00   -0.01    0.60    9.61
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       73    -17      529  2.00  1.40   97.62 *******    6000   95.61
        73     73     59    36857  1.00  0.28    0.00    0.76   11.35
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                    SECID "BRIDG"     Q,CRWS =    6000.       93.09

            <<<<<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       57      1      359  4.33 *****   97.42   93.09    6000   93.09
         0     57     42    29882  1.00 ***** *******    1.00   16.69

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******   99.30 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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       37    -21      778  0.93  0.72   99.58   94.31    6000   98.66
        73     38     63    64222  1.00  1.44    0.01    0.45    7.72

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.453  0.180   52553.     2.    44.    98.24

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -57.   -18.    57.   6000.   43719.     563.   10.65   93.26
   FULLV:FV       0.   -19.    58.   6000.   50888.     624.    9.61   94.50
   BRIDG:BR       0.     1.    42.   6000.   29882.     359.   16.69   93.09
   RDWAY:RG      14.**************       0.******************     1.00********
   APPRO:AS      73.   -22.    63.   6000.   64222.     778.    7.72   98.66

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    44.   52553.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS      91.46    0.69   82.93  102.78************  1.76   95.02   93.26
   FULLV:FV   ********    0.60   83.37  103.22  0.92  0.00  1.44   95.93   94.50
   BRIDG:BR      93.09    1.00   83.56  100.05************  4.33   97.42   93.09
   RDWAY:RG   ****************  102.04  111.21**********************************
   APPRO:AS      94.31    0.45   85.73  106.28  0.72  1.44  0.93   99.58   98.66
```

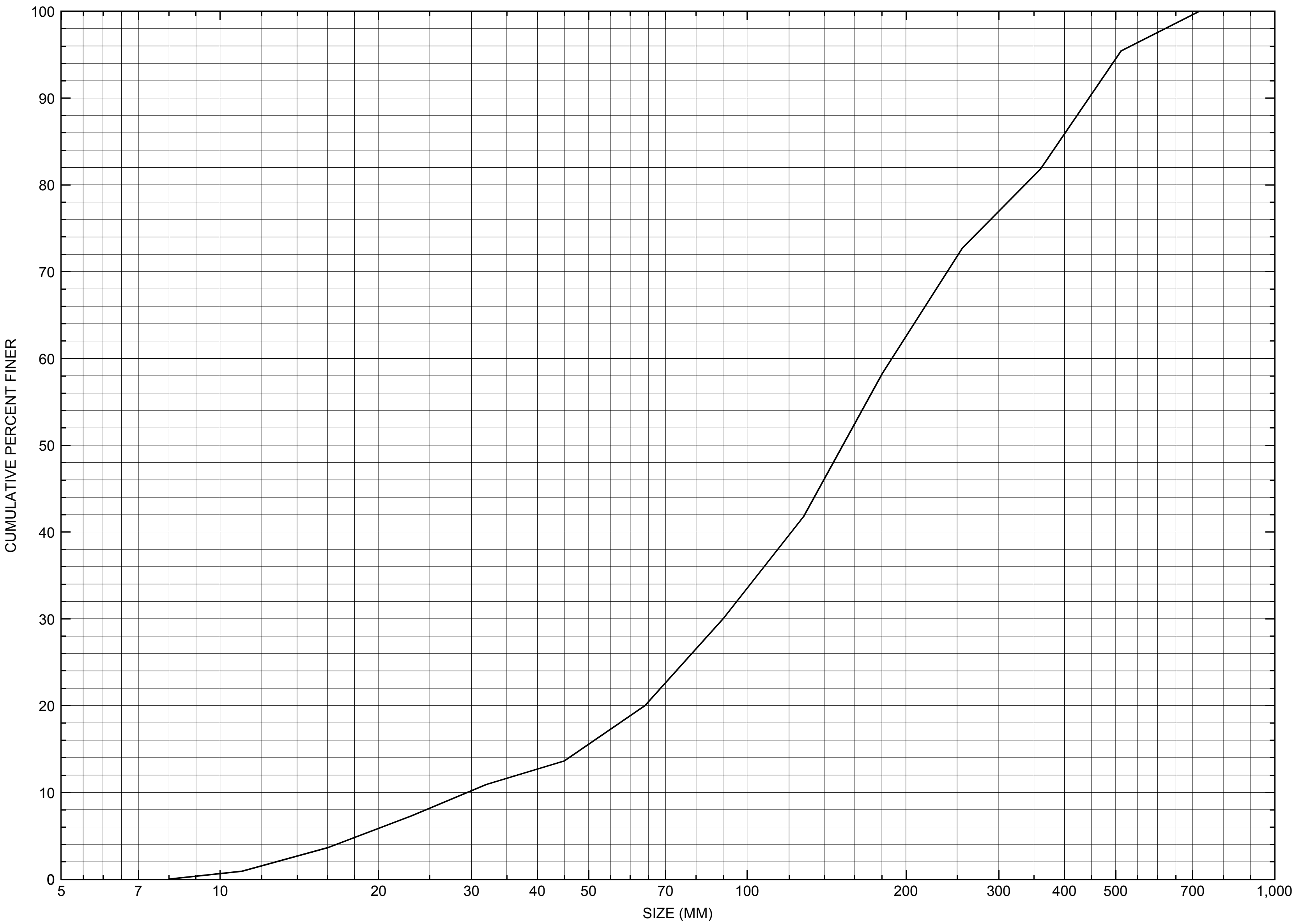
```
        U.S. Geological Survey WSPRO Input File midb021.wsp
        Hydraulic analysis for structure MIDBTH00230021   Date: 16-JUN-97
        Town Highway 23 crossing the Middlebury River, Middlebury, VT      EMB
           *** RUN DATE & TIME: 07-29-97  15:03

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

EXITX:XS   ******    -20      715  2.21 *****   97.39   93.11    8500   95.18
       -56 ******     76    61947  1.00 ***** *******    0.78   11.89

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.98      96.81      93.56

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =    94.68     103.22    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =    94.68     103.22      93.56

FULLV:FV       57    -22     1045  1.38  0.82   98.21   93.56    8500   96.82
         0     57    337    80990  1.35  0.00   -0.01    0.98    8.13
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.65

APPRO:AS       73    -21      682  2.41  1.23   99.95 *******    8500   97.53
        73     73     62    52958  1.00  0.51    0.00    0.77   12.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   101.92       0.00      95.37      96.00

 ===260 ATTEMPTING FLOW CLASS 4 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       57      0      449  4.24  1.41   99.48   94.41    7413   95.24
         0     57     42    41296  1.00  0.67    0.00    0.89   16.51

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******   99.30 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.    48.  0.56  1.42  100.81    0.00   1087.   99.96

           Q    WLEN    LEW    REW   DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0. ****** ****** ****** ***** ***** ***** ***** ***** *****
   RT:   1087.    61.    79.   140.   4.0   2.3   8.4   7.6   3.2   3.1

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

APPRO:AS       37    -22      891  1.42  0.76  101.38   96.00    8500   99.96
        73     39     65    78560  1.00  1.15    0.02    0.53    9.54

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.496  0.202   62564.     1.    43. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -57.   -21.    76.   8500.   61947.     715.   11.89   95.18
   FULLV:FV       0.   -23.   337.   8500.   80990.    1045.    8.13   96.82
   BRIDG:BR       0.     0.    42.   7413.   41296.     449.   16.51   95.24
   RDWAY:RG      14.*******     0.   1087.       0.*********    1.00   99.96
   APPRO:AS      73.   -23.    65.   8500.   78560.     891.    9.54   99.96

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    43.   62564.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS      93.11    0.78   82.93  102.78************  2.21   97.39   95.18
   FULLV:FV      93.56    0.98   83.37  103.22  0.82  0.00  1.38   98.21   96.82
   BRIDG:BR      94.41    0.89   83.56  100.05  1.41  0.67  4.24   99.48   95.24
   RDWAY:RG ***************      96.00  111.21  0.56******  1.42  100.81   99.96
   APPRO:AS      96.00    0.53   85.73  106.28  0.76  1.15  1.42  101.38   99.96
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File midb021.io.wsp
        Hydraulic analysis for structure MIDBTH00230021   Date: 16-JUN-97
        Town Highway 23 crossing the Middlebury River, Middlebury, VT      EMB
           *** RUN DATE & TIME: 07-29-97  15:05

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

EXITX:XS   ******    -18      614  1.92 *****   95.84   92.03    6820   93.93
       -56 ******     58    49703  1.00 ***** *******    0.69   11.10

FULLV:FV       57    -19      678  1.57  0.93   96.76 *******    6820   95.19
         0     57     58    57474  1.00  0.00   -0.01    0.60   10.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       73    -18      582  2.13  1.40   98.43 *******    6820   96.30
        73     73     60    42305  1.00  0.28    0.00    0.76   11.71
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =     6820.      93.87

            <<<<<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       57      0      392  4.71 *****   98.58   93.87    6820   93.87
         0     57     42    33926  1.00 ***** *******    1.00   17.40

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******   99.30 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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       37    -22      874  0.95  0.69  100.71   94.90    6820   99.77
        73     39     65    76263  1.00  1.44    0.02    0.44    7.81

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.470  0.200   60854.     2.    43.    99.38

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -57.    -19.    58.   6820.   49703.     614.   11.10   93.93
   FULLV:FV       0.    -20.    58.   6820.   57474.     678.   10.06   95.19
   BRIDG:BR       0.      0.    42.   6820.   33926.     392.   17.40   93.87
   RDWAY:RG      14.**************       0.*****************     1.00********
   APPRO:AS      73.    -23.    65.   6820.   76263.     874.    7.81   99.77

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    43.   60854.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     92.03    0.69   82.93  102.78************  1.92   95.84   93.93
   FULLV:FV  ********    0.60   83.37  103.22  0.93  0.00  1.57   96.76   95.19
   BRIDG:BR     93.87    1.00   83.56  100.05************  4.71   98.58   93.87
   RDWAY:RG  ****************  102.04  111.21**********************************
   APPRO:AS     94.90    0.44   85.73  106.28  0.69  1.44  0.95  100.71   99.77
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count transect at the channel approach of structure MIDBTH00230021, in Middlebury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MIDBTH00230021

General Location Descriptive

Data collected by *(First Initial, Full last name)* L. Medalie

Date *(MM/DD/YY)* 12 / 14 / 95

Highway District Number *(I - 2; nn)* 05

County *(FIPS county code; I - 3; nnn)* 001

Town *(FIPS place code; I - 4; nnnnn)* 44350

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

Waterway *(I - 6)* MIDDLEBURY RIVER

Road Name *(I - 7):* -

Route Number TH 23

Vicinity *(I - 9)* 0.05 MI TO JCT W VT125

Topographic Map East.Middlebury

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 43583

Longitude *(i - 17; nnnnn.n)* 73055

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011100210111

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

Maximum span length *(I - 48; nnnn)* 0049

Year built *(I - 27; YYYY)* 1927

Structure length *(I - 49; nnnnnn)* 000052

Average daily traffic, ADT *(I - 29; nnnnnn)* 000600

Deck Width *(I - 52; nn.n)* 253

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 1973

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

Clear span (*nnn.n ft*) 42.5

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

Vertical clearance from streambed (*nnn.n ft*) 14.5

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

Waterway of full opening (*nnn.n* ft^2) 550

Comments:

According to the structural inspection report dated 12/8/94, the right abutment appears to be concrete faced laid-up stone with a concrete footing and back-wall. The concrete facing has cracks overall, with some leaks, mostly on the ends. The footing is spalled along its bottom with voided sections. The left abutment, its wingwalls, back-wall and footing are concrete. The footing is badly spalled, with deep areas of section loss, especially at the left end. The left abutment face is fairly new, with a few cracks and small leaks on its ends. The upstream left wingwall has a couple of deep horizontal spalls near the end of the abutment, with a few cracks and small leaks. The downstream left wingwall **(continued, page 34)**

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: 45.5

Terrain character: Mountainous

Stream character & type: -

Streambed material: Large boulders, gravel

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} 3000 Q_{25} 4200

Q_{50} 5000 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)* : Moderate Debris *(Heavy, Moderate, Light)*: Moderate

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

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

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

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

The watershed storage area is: 2 (*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*): Y *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): 0.25 Town: Middlebury Year Built: -

Highway No. : VT 125 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:

is much shorter with some deep surface spalls, cracks, and leaks overall. Large boulders have been placed around the ends of each abutment. About 1-1.5' of scour at each abutment is noted. According to hydraulics analysis, for the new structure, estimated scour depth is 2-3'; velocity of stream at design state is 14.5 fps (in constriction); ordinary high water elevation is 92.4 feet; Design high water elevation is 98.2 feet.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **44.771** mi^2 Lake and pond area **0.164** mi^2
Watershed storage *(ST)* **0.37** %
Bridge site elevation **460** ft Headwater elevation **3234** ft
Main channel length **10.69** mi
10% channel length elevation **710** ft 85% channel length elevation **1740** ft
Main channel slope *(S)* **128.47** ft / mi

Watershed Precipitation Data

Average site precipitation -- in Average headwater precipitation -- in

Maximum 2yr-24hr precipitation event *(I24,2)* -- in

Average seasonal snowfall *(Sn)* -- ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: - / 1973

Project Number TF 7135 Minimum channel bed elevation: --

Low superstructure elevation: USLAB 100.01 DSLAB 100.01 USRAB 98.48 DSRAB 98.48

Benchmark location description:

BM #1 downstream end of downstream left wingwall, elev. 100'.
BM #2-A, S1 pole #25/1, in channel 5' from upstream bridge face, towards left bank, elev. 99.91'.
BM #1-N, spot on concrete wall, near upstream end of left road approach, about 40' from Labut face.

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

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

If 1: Footing Thickness 2.5 Footing bottom elevation: 85.9

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

Briefly describe material at foundation bottom elevation or around piles:

NO DRILL BORING INFORMATION AVAILABLE.

Comments:

The footing thickness shown above is for the left abutment. The right abutment footing thickness is shown to be 3.9 feet. Both abutment footings are shown with the same bottom elevation. The low superstructure elevations are bridge seat elevations taken from the plans.

Cross-sectional Data

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

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

Comments: **This is a cross-section of the downstream face. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 12/8/94. The sketch was done on 11/5/92. Low chord elevations are based on those from the plans.**

Station	0	4.0	10.3	40.1	42.5	-	-	-	-	-	-
Feature	RAB	-	-	-	LAB	-	-	-	-	-	-
Low cord elevation	98.5	98.6	98.9	99.9	100.0	-	-	-	-	-	-
Bed elevation	89.6	84.6	83.3	85.5	88.4	-	-	-	-	-	-
Low cord to bed length	8.9	14.0	15.6	14.4	11.6	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

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

Comments:

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 8/14/96
Computerized by: EW Date: 8/15/96
Reviewd by: EB Date: 6/16/97

Structure Number MIDBTH00230021

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 06 / 18 / 1996

2. Highway District Number 05 Mile marker 000000

County ADDISON (001) Town MIDDLEBURY (44350)

Waterway *(I - 6)* MIDDLEBURY RIVER Road Name -

Route Number TH 23 Hydrologic Unit Code: 02010002

3. Descriptive comments:

This bridge is located 0.05 mile from the junction of Town Highway 23 and VT 125. The right abutment is concrete faced laid-up stone. The left abutment is concrete. There are large boulders at the ends of each abutment.

B. Bridge Deck Observations

4. Surface cover... LBUS 2 RBUS 2 LBDS 2 RBDS 2 Overall 2
*(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 52 *(feet)* Span length 49 *(feet)* Bridge width 25.3 *(feet)*

Road approach to bridge:

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

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

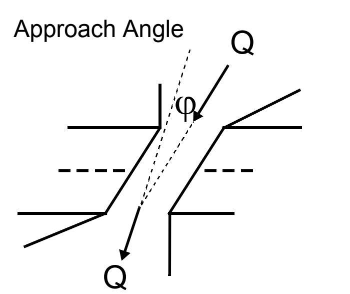
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

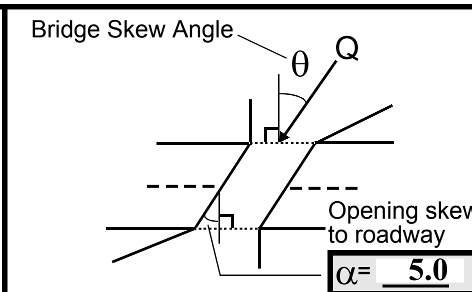
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	2

*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: 5 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 145 feet US *(US, UB, DS)* to 30 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 30 feet US *(US, UB, DS)* to 0 feet DS

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

18. Bridge Type: **1a**

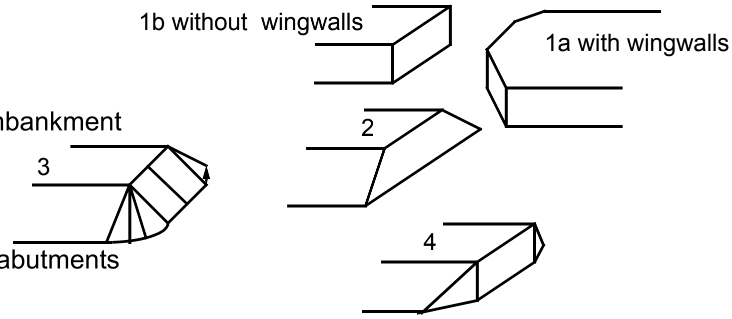
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular 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 on the previous page were those taken from the VTAOT files. During the site visit, the bridge length measured 52.1 feet and the bridge width measured 26.2 feet. The bridge width measurement included the cement curbing, which is 0.9 feet wide both upstream and downstream.

The RBDS erosion noted previously is road wash eroding a gully in the fill material behind the right abutment.

Only the left abutment has an upstream wingwall.

The gap between the bridge seat and low steel elevations at the upstream face of the bridge opening are 0.24 feet at the right abutment and 1.01 feet at the left abutment.

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
49.0	**10.0**			**12.0**	**3**	**3**	**543**	**543**	**2**	**2**

23. Bank width **20.0**   24. Channel width **25.0**   25. Thalweg depth **90.0**   29. Bed Material **543**

30 .Bank protection type: LB **52** RB **2**   31. Bank protection condition: LB **2** RB **2**

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.):

The left bank protection is a cement wall from the end of the wingwall (0 feet US) to 50 feet US along the top of the bank. The cement wall continues along the bottom of the bank from 55 feet US to 110 feet US. Beyond 110 feet upstream to 135 feet US the stone wall is slumped bank protection.

The right bank protection is dumped stone from 0 feet US to 45 feet US. From 45 feet US to 90 feet US, a stone wall extends along the top of the bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **175** 35. Mid-bar width: **30**

36. Point bar extent: **125** feet **US** (US, UB) to **220** feet **US** (US, UB, DS) positioned **75** %LB to **100** %RB

37. Material: **453**

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

This side bar is at the same location as a bedrock exposure at the surface across the channel upstream. The bedrock surface is slightly higher on the right bank side than the left. Approximately 20% of the side bar area is covered by grass and shrubs.

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: **135** 42. Cut bank extent: **140** feet **US** (US, UB) to **110** 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.):

The bank protection has failed within the extent of this cut-bank.

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

Scour exists at the bedrock control which extends from 230 feet US to 170 feet US. The scour depth is 5 feet, assuming a thalweg of 2 feet.

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
41.5		2.0		2	7	7	-

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **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.):

543

The footings and wingwalls of the LABUT have been eroded.

There is no abutment protection. However dumped stone protects all four corners on the banks.

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

70. Debris and Ice Comments:

2

There is a small amount of debris in the form of branches and tree litter along the banks.
The abutments constrict channel. However, low cord is high above the river.
Ice scaring in the tree bark is evident generally about 6 feet above the present water surface.

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	3	0	3	90.0
RABUT	1	0	90			2	3	48.0

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
5
1

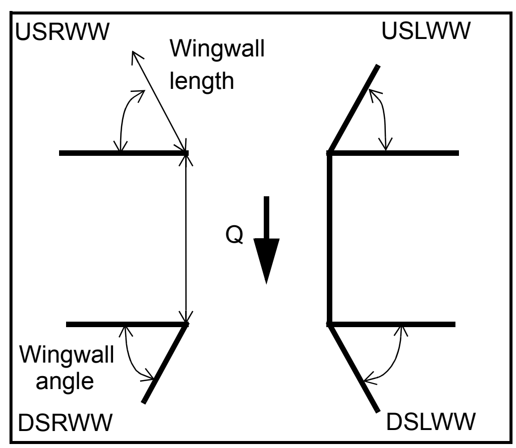
There is up to 0.5 feet of penetration under the right abutment footing and 3.0 feet of penetration under the left abutment footing.

The under bridge channel is more pooled than the rest of the channel.
There is a scour hole on the left bank at the upstream bridge face. The scour depth is 1.0 foot, assuming a thalweg of 2 feet measured elsewhere in the reach.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						48.0	
USRWW:	Y		1		2	2.5	
DSLWW:	0		3		N	27.0	
DSRWW:	-		-		-	27.5	

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	-	2	N	-	2	-	-	-
Condition	Y	0	-	-	1	-	-	-
Extent	1	2	-	2	-	0	0	-

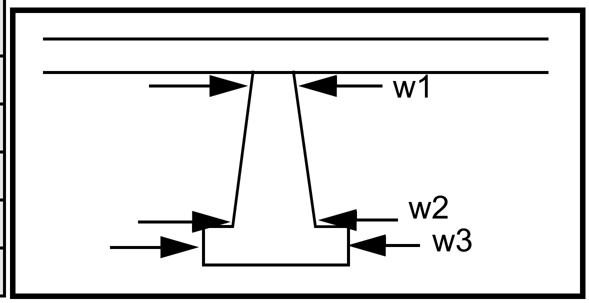
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **All** *(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**	**24.5**	-
Pier 2		**7.0**	-	**50.0**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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 (Amb) - Thalweg depth (Amb) - 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

3
2
543
543
1

101. Is a drop structure present? **2** *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

103. Drop: - feet 104. Structure material: **543** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
2
2
2
2
The left bank protection is dumped stone from downstream bridge face to 50 feet downstream.
The right bank protection is dumped stone, as well as a stone wall along the top of the bank.

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

Point bar extent: ______ feet ____ *(US, UB, DS)* to ______ feet ____ *(US, UB, DS)* positioned ____ %LB to _____ %RB

Material: _____

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

N

Is a cut-bank present? - _____ *(Y or if N type ctrl-n cb)* Where? NO *(LB or RB)* Mid-bank distance: DR

Cut bank extent: OP feet ST *(US, UB, DS)* to RUC feet TU *(US, UB, DS)*

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

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

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

Scour dimensions: Length - Width - Depth: - Positioned - %LB to - %RB

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

-
-
-
-

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

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

Confluence 2: Distance RS 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 CUT BANKS

Y
20 DS
15

109. G. Plan View Sketch

\- 7

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:	MIDBTH00230021	Town:	Middlebury
Road Number:	TH 23	County:	Addison
Stream:	Middlebury River		

Initials EMB   Date: 7/2/97   Checked: RB   7/8/97

I. 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	6000	8500	6820
Main Channel Area, ft2	778	891	874
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	86	88	88
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.498	0.498	0.498
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.0	10.1	9.9
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	64247	78535	76312
Conveyance, main channel	64247	78535	76312
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	6000.0	8500.0	6820.0
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	7.7	9.5	7.8
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	12.8	13.1	13.0
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	6000	7413	6820
Main channel area (DS), ft2	359	449	392
Main channel width (normal), ft	41.6	41.7	41.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	41.6	41.7	41.6
D90, ft	1.4590	1.4590	1.4590
D95, ft	1.6602	1.6602	1.6602
Dc, critical grain size, ft	1.5379	1.3569	1.6001
Pc, Decimal percent coarser than Dc	0.080	0.130	0.064
Depth to armoring, ft	53.35	27.24	69.97

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	6000	8500	6820
(Q) discharge thru bridge, cfs	6000	7413	6820
Main channel conveyance	29880	41306	33914
Total conveyance	29880	41306	33914
Q2, bridge MC discharge,cfs	6000	7413	6820
Main channel area, ft2	359	449	392
Main channel width (normal), ft	41.6	41.7	41.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	41.6	41.7	41.6
y_bridge (avg. depth at br.), ft	8.63	10.77	9.42
Dm, median (1.25*D50), ft	0.6225	0.6225	0.6225
y2, depth in contraction,ft	10.05	12.02	11.21
ys, scour depth (y2-ybridge), ft	1.42	1.25	1.79

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	6000	8500	6820	6000	8500	6820
a', abut.length blocking flow, ft	22.9	23	23.1	21.2	22.8	22.8
Ae, area of blocked flow ft2	140.7	169.2	166.2	132.5	160.9	157
Qe, discharge blocked abut.,cfs	789.5	1211.2	970.5	754	--	909.3
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	5.61	7.16	5.84	5.69	7.11	5.79
ya, depth of f/p flow, ft	6.14	7.36	7.19	6.25	7.06	6.89
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	95	95	95	85	85	85
K2	1.01	1.01	1.01	0.99	0.99	0.99
Fr, froude number f/p flow	0.399	0.465	0.384	0.401	0.472	0.389
ys, scour depth, ft	17.72	21.47	19.61	19.89	23.71	21.48

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)	22.9	23	23.1	21.2	22.8	22.8
y1 (depth f/p flow, ft)	6.14	7.36	7.19	6.25	7.06	6.89
a'/y1	3.73	3.13	3.21	3.39	3.23	3.31
Skew correction (p. 49, fig. 16)	1.01	1.01	1.01	0.98	0.98	0.98
Froude no. f/p flow	0.40	0.47	0.38	0.40	0.47	0.39
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	0.89	1	1	0.89	1
y, depth of flow in bridge, ft	8.63	10.77	9.42	8.63	10.77	9.42
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	3.61	4.36	3.94	3.61	4.36	3.94