LEVEL II SCOUR ANALYSIS FOR BRIDGE 67 (MTHOTH00120067) on TOWN HIGHWAY 12, crossing FREEMAN BROOK, MOUNT HOLLY, VERMONT

Open-File Report 98-401

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 67 (MTHOTH00120067) on TOWN HIGHWAY 12, crossing FREEMAN BROOK, MOUNT HOLLY, VERMONT

By EMILY C. WILD and TIMOTHY SEVERANCE

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 67 (MTHOTH00120067) ON TOWN HIGHWAY 12, CROSSING FREEMAN BROOK, MOUNT HOLLY, VERMONT

By **Emily C. Wild and Timothy Severance**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MTHOTH00120067 on Town Highway 12 crossing Freeman Brook, Mount Holly, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in south-central Vermont. The 11.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forested.

In the study area, Freeman Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 51 ft and an average bank height of 6 ft. The channel bed material ranges from sand to boulders with a median grain size (D_{50}) of 55.7 mm (0.183 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 5, 1995, indicated that the reach was stable.

The Town Highway 12 crossing of Freeman Brook is a 34-ft-long, two-lane bridge consisting of a 30-foot prestressed concrete-slab span (Vermont Agency of Transportation, written communication, March 15, 1995). The opening length of the structure parallel to the bridge face is 29.5 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 50 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

Along the upstream right wingwall, the right abutment and the downstream right wingwall, a scour hole approximately 1.0 to 2.0 ft deeper than the mean thalweg depth was observed during the Level I assessment. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the downstream end of the downstream right wingwall; type-2 stone fill (less than 36 inches diameter) along the upstream left wingwall, the left abutment, the downstream left wingwall and the upstream left and right banks; type-3 stone fill (less than 48 inches diameter) along the downstream left and right banks; and type-4 stone fill (less than 60 inches diameter) along the upstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 2.6 to 3.9 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 7.9 to 10.0 ft. Right abutment scour ranged from 12.7 to 15.2 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Mount Holly, 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 MTHOTH00120067 ***Stream*** Freeman Brook

County Rutland ***Road*** TH 12 ***District*** 3

Description of Bridge

Bridge length 34 ***ft*** ***Bridge width*** 25.2 ***ft*** ***Max span length*** 30 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 10/5/95

Description of stone fill Type-1, along the downstream end of the downstream right wingwall. Type-2, along the upstream left wingwall, left abutment and downstream left wingwall. Type-4 along the upstream right wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a 1.1 foot deep scour hole in front of the right abutment, and the right abutment footing is exposed.

Yes

Is bridge skewed to flood flow according to Level I survey? 50 ***Angle*** Yes

There is a moderate channel bend through the bridge. The scour hole has developed in the location where the flow impacts the right abutment.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	10/5/95	0	0
Level II	10/5/95	0	0

Potential for debris Moderate. There is some debris in the upstream reach.

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

None, 10/5/95.

Description of the Geomorphic Setting

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

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

Date of inspection 10/5/95

DS left: There is a steep channel bank and a narrow flood plain.

DS right: The channel bank and overbank are moderately sloped (road embankment).

US left: There is a steep channel bank and a narrow flood plain.

US right: The channel bank and overbank are moderately sloped.

Description of the Channel

Average top width 51 ft ***Average depth*** 6 ft

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

Sinuous but stable with non-alluvial channel boundaries and a narrow flood plain.

10/5/95

Vegetative co Trees, brush and shrub

DS left: Trees and brush and Town Highway 12

DS right: Trees, shrub, brush and Town Highway 12

US left: Trees, brush and grass

US right:

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

None, 10/5/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 11.4 ***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 2,550 ***ft***^{3}***/s*** ***Q500*** 3,500 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database (Vermont Agency of Transportation, written communication, May 1995). These values were selected due to the central tendency of the discharge frequency curve with others which were developed from empirical relationships (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year discharge.

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 To obtain VTAOT datum, add 21.3 ft to USGS arbitrary survey datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 498.73 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the upstream left wingwall (elev. 492.91 ft, arbitrary survey datum). RM3 is a chiseled X on top of the downstream end of the left abutment (elev. 499.83 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-46	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPR3	59	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 0.055, and overbank "n" values ranged from 0.060 to 0.070.

Normal depth at the exit section (EXIT1) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0104 ft/ft, which was calculated from thalweg points surveyed downstream of the bridge.

The modelled approach section (APPR3) was surveyed one bridge length upstream of the upstream face, as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

For the 100-year and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing the supercritical and subcritical profiles for each discharge, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.7 *ft*
Average low steel elevation 496.9 *ft*

100-year discharge 2,550 *ft^3/s*
Water-surface elevation in bridge opening 489.6 *ft*
Road overtopping? No *Discharge over road* -- *ft^3/s*
Area of flow in bridge opening 179 *ft^2*
Average velocity in bridge opening 14.2 *ft/s*
Maximum WSPRO tube velocity at bridge 18.5 *ft/s*

Water-surface elevation at Approach section with bridge 493.3
Water-surface elevation at Approach section without bridge 490.5
Amount of backwater caused by bridge 2.8 *ft*

500-year discharge 3,500 *ft^3/s*
Water-surface elevation in bridge opening 491.1 *ft*
Road overtopping? No *Discharge over road* -- *ft^3/s*
Area of flow in bridge opening 221 *ft^2*
Average velocity in bridge opening 15.8 *ft/s*
Maximum WSPRO tube velocity at bridge 20.8 */s*

Water-surface elevation at Approach section with bridge 495.6
Water-surface elevation at Approach section without bridge 491.6
Amount of backwater caused by bridge 4.0 *ft*

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8. Bottom of footing elevations shown in figure 8 were taken from the bridge construction plans available from the VTAOT.

Contraction scour for the 100-year and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). Variables for the Laursen clear-water contraction scour equation include the discharge through the bridge, the width of the channel at the bridge, and the median grain size of the channel bed material.

Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.6	3.9	--
Depth to armoring	N/A	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	7.9	10.0	--
Right abutment	12.7	15.2	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.6	3.3	--
Right abutment	2.6	3.3	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

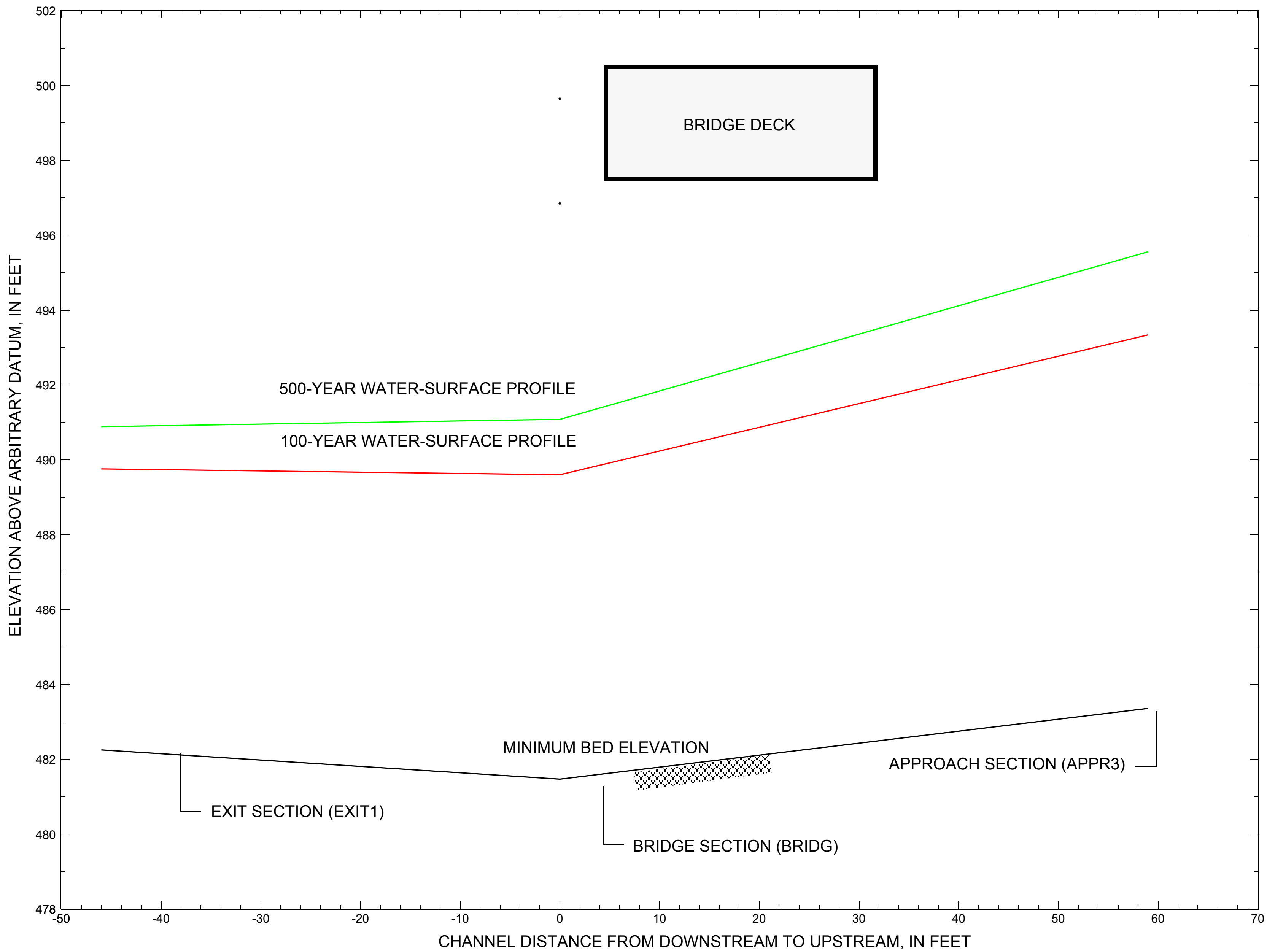

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure MTHOTH00120067 on Town Highway 12, crossing Freeman Brook, Mount Holly, Vermont.

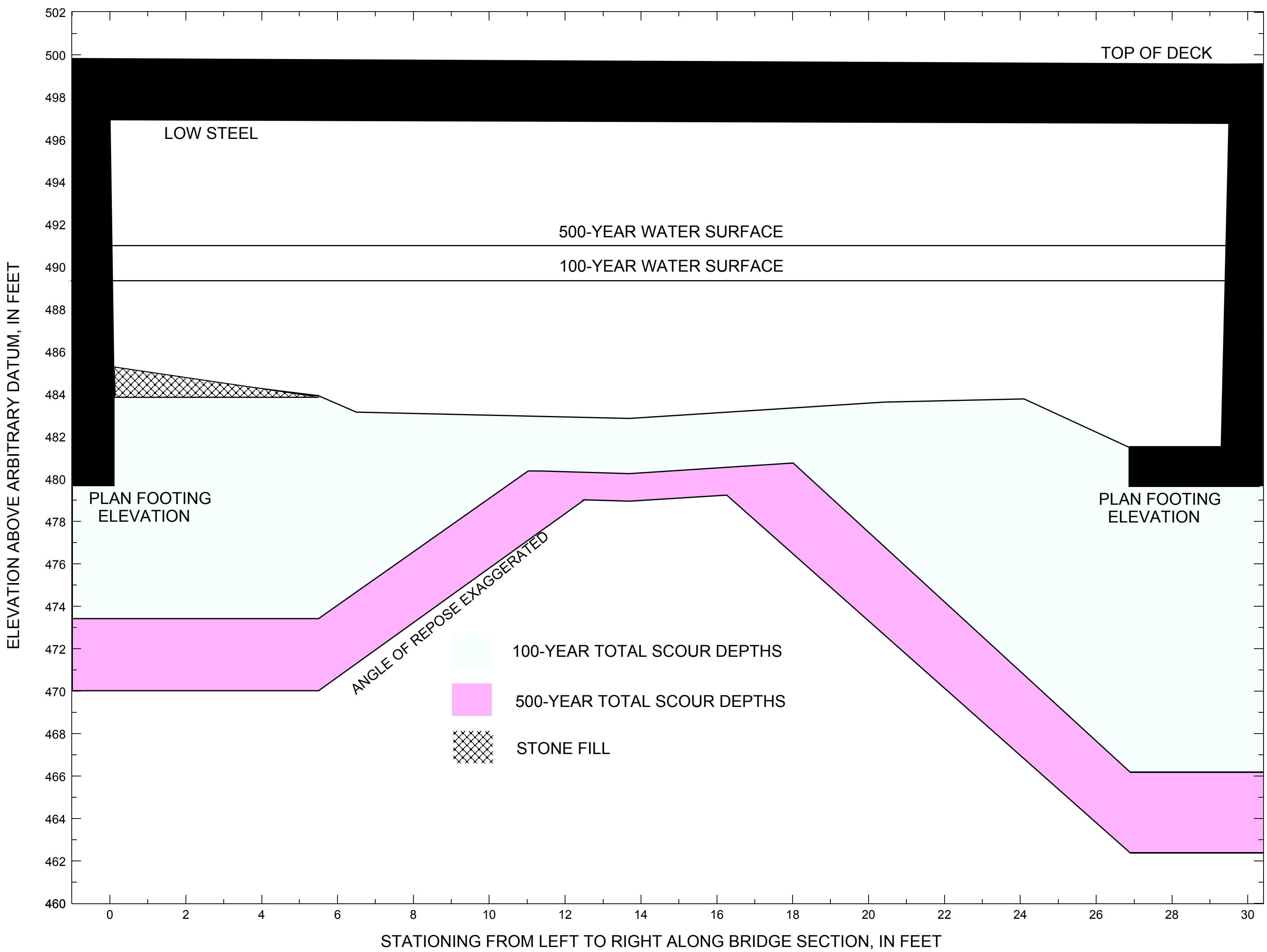

Figure 8. Scour elevations for the 100- and 500-year discharges at structure MTHOTH00120067 on Town Highway 12, crossing Freeman Brook, Mount Holly, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MTHOTH00120067 on Town Highway 12, crossing Freeman Brook, Mount Holly, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation[2] (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 2,550 cubic-feet per second											
Left abutment	0.0	497.0	496.9	479.7	483.9	2.6	7.9	--	10.5	473.4	-6.3
Right abutment	29.5	496.7	496.8	479.7	481.5	2.6	12.7	--	15.3	466.2	-13.5

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 MTHOTH00120067 on Town Highway 12, crossing Freeman Brook, Mount Holly, 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 3,500 cubic-feet per second											
Left abutment	0.0	497.0	496.9	479.7	483.9	3.9	10.0	--	13.9	470.0	-9.7
Right abutment	29.5	496.7	496.8	479.7	481.5	3.9	15.2	--	19.1	462.4	-17.3

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, 1986, Wallingford, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File mtho067.wsp
T2        Hydraulic analysis for structure MTHOTH00120067   Date: 05-FEB-98
T3        Town Highway 12, Freeman Brook, Mount Holly, Vermont         ECW
*              * * This file was generated by AWISPP v2.5 * *
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2550.0   3500.0
SK          0.0104   0.0104
*
XS   EXIT1    -46           0.
GR          -90.2, 508.52    -60.7, 495.43    -46.2, 494.68    -40.3, 493.06
GR          -16.4, 492.31    -11.7, 487.43      0.0, 487.43      8.7, 483.00
GR           13.5, 483.38     14.0, 482.29     17.6, 482.25     26.0, 482.61
GR           34.6, 482.85     36.2, 483.34     48.4, 489.37     66.7, 498.45
GR          104.5, 498.49    126.6, 497.38    143.0, 509.92
*
N            0.070        0.050        0.060
SA                 -16.4        66.7
*
XS   FULLV      0  * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.85      15.0
GR            0.0, 496.93      0.0, 485.12      5.5, 483.92      6.5, 483.15
GR           11.4, 482.97     13.7, 482.85     20.4, 483.62     24.1, 483.77
GR           26.9, 481.47     29.3, 481.51     29.5, 496.76      0.0, 496.93
*
N            0.045
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      43.0 * *     45.2     16.3
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     15      25.2     2
GR          -41.8, 499.99      0.0, 499.80     28.7, 499.55     51.3, 499.01
GR           92.9, 498.29    100.9, 503.33    110.5, 512.31
*
*
AS   APPR3     59           0.
GR         -125.7, 510.77   -108.8, 500.51    -81.9, 500.14    -54.1, 500.47
GR          -22.7, 499.99     -9.0, 498.27     -6.0, 492.46      7.7, 484.48
GR           12.2, 484.31     14.2, 483.73     17.6, 483.70     23.4, 483.76
GR           25.7, 483.36     28.4, 483.55     30.7, 484.30     41.3, 491.15
GR           56.8, 495.77     66.2, 496.75     74.0, 499.56     94.1, 512.25
*
N            0.060           0.055           0.070
SA                 -9.0            56.8
*
HP 1 BRIDG 489.60 1 489.60
HP 2 BRIDG 489.60 * * 2550
HP 1 APPR3 493.34 1 493.34
HP 2 APPR3 493.34 * * 2550
*
HP 1 BRIDG 491.08 1 491.08
HP 2 BRIDG 491.08 * * 3500
HP 1 APPR3 495.56 1 495.56
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File mtho067.wsp
        Hydraulic analysis for structure MTHOTH00120067   Date: 05-FEB-98
        Town Highway 12, Freeman Brook, Mount Holly, Vermont         ECW
           *** RUN DATE & TIME: 02-23-98  09:31

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     179.  15544.    28.    42.                        2551.
   489.60          179.  15544.    28.    42.  1.00     0.    29.   2551.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       489.60     0.0    29.4   179.1   15544.    2550.  14.24

X STA.        0.0        4.4        5.9        7.1        8.2        9.3
  A(I)           20.9        8.1        7.6        6.9        7.3
  V(I)           6.09      15.84      16.84      18.48      17.48

X STA.        9.3       10.5       11.6       12.7       13.8       14.9
  A(I)            7.0        7.1        7.2        7.2        7.2
  V(I)          18.10      17.90      17.62      17.67      17.81

X STA.       14.9       16.0       17.2       18.3       19.6       20.8
  A(I)            7.0        7.1        7.1        7.4        7.2
  V(I)          18.22      18.02      17.84      17.34      17.62

X STA.       20.8       22.1       23.4       24.8       25.9       29.4
  A(I)            7.2        7.3        8.0        7.7       26.5
  V(I)          17.63      17.40      15.97      16.59       4.81

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR3;  SRD =      59.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     353.  30988.    55.    60.                        5063.
   493.34          353.  30988.    55.    60.  1.00    -6.    49.   5063.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR3;  SRD =      59.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.34    -6.5    48.6   352.7   30988.    2550.   7.23

X STA.       -6.5        4.8        6.9        8.5       10.1       11.6
  A(I)           43.4       16.4       14.5       13.8       14.0
  V(I)           2.94       7.80       8.82       9.23       9.09

X STA.       11.6       13.2       14.6       16.1       17.5       19.0
  A(I)           14.1       13.7       14.0       13.9       13.9
  V(I)           9.05       9.28       9.10       9.20       9.20

X STA.       19.0       20.4       21.8       23.2       24.6       25.9
  A(I)           13.7       13.7       13.3       13.7       13.2
  V(I)           9.31       9.33       9.56       9.34       9.63

X STA.       25.9       27.3       28.6       30.0       31.7       48.6
  A(I)           13.2       12.9       13.5       15.1       58.7
  V(I)           9.65       9.86       9.42       8.47       2.17
```

```
U.S. Geological Survey WSPRO Input File mtho067.wsp
Hydraulic analysis for structure MTHOTH00120067   Date: 05-FEB-98
Town Highway 12, Freeman Brook, Mount Holly, Vermont         ECW
   *** RUN DATE & TIME: 02-23-98  09:31

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

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     221.   21116.    28.    45.                         3499.
491.08          221.   21116.    28.    45.  1.00     0.    29.   3499.

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

     WSEL     LEW     REW    AREA        K        Q    VEL
   491.08     0.0    29.4   221.1   21116.    3500.  15.83

X STA.         0.0        4.5        5.9        7.1        8.2        9.3
  A(I)            28.1        9.4        8.9        8.6        8.4
  V(I)            6.23      18.64      19.60      20.34      20.84

X STA.         9.3       10.4       11.5       12.6       13.7       14.8
  A(I)             8.7        8.6        8.5        8.8        8.8
  V(I)           20.04      20.33      20.52      19.91      19.98

X STA.        14.8       15.9       17.0       18.1       19.3       20.5
  A(I)             8.5        8.6        8.5        8.6        8.8
  V(I)           20.58      20.27      20.69      20.35      19.98

X STA.        20.5       21.7       22.9       24.1       25.4       29.4
  A(I)             8.5        8.6        8.8        9.8       35.7
  V(I)           20.54      20.39      19.89      17.88       4.91

CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR3;  SRD =      59.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          2     485.   47385.    64.    71.                         7583.
495.56          485.   47385.    64.    71.  1.00    -8.    56.   7583.

VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR3;  SRD =      59.

     WSEL     LEW     REW    AREA        K        Q    VEL
   495.56    -7.6    56.1   484.5   47385.    3500.   7.22

X STA.        -7.6        3.0        5.5        7.5        9.2       10.9
  A(I)            53.9       22.6       20.8       18.9       18.8
  V(I)            3.25       7.73       8.42       9.25       9.32

X STA.        10.9       12.6       14.2       15.8       17.4       19.0
  A(I)            18.9       19.2       19.0       18.8       18.8
  V(I)            9.28       9.12       9.23       9.33       9.33

X STA.        19.0       20.5       22.0       23.5       25.0       26.5
  A(I)            17.9       17.8       18.0       18.1       17.4
  V(I)            9.79       9.81       9.71       9.66      10.03

X STA.        26.5       27.9       29.5       31.1       33.0       56.1
  A(I)            17.8       18.0       18.3       20.5       91.1
  V(I)            9.84       9.71       9.57       8.52       1.92
```

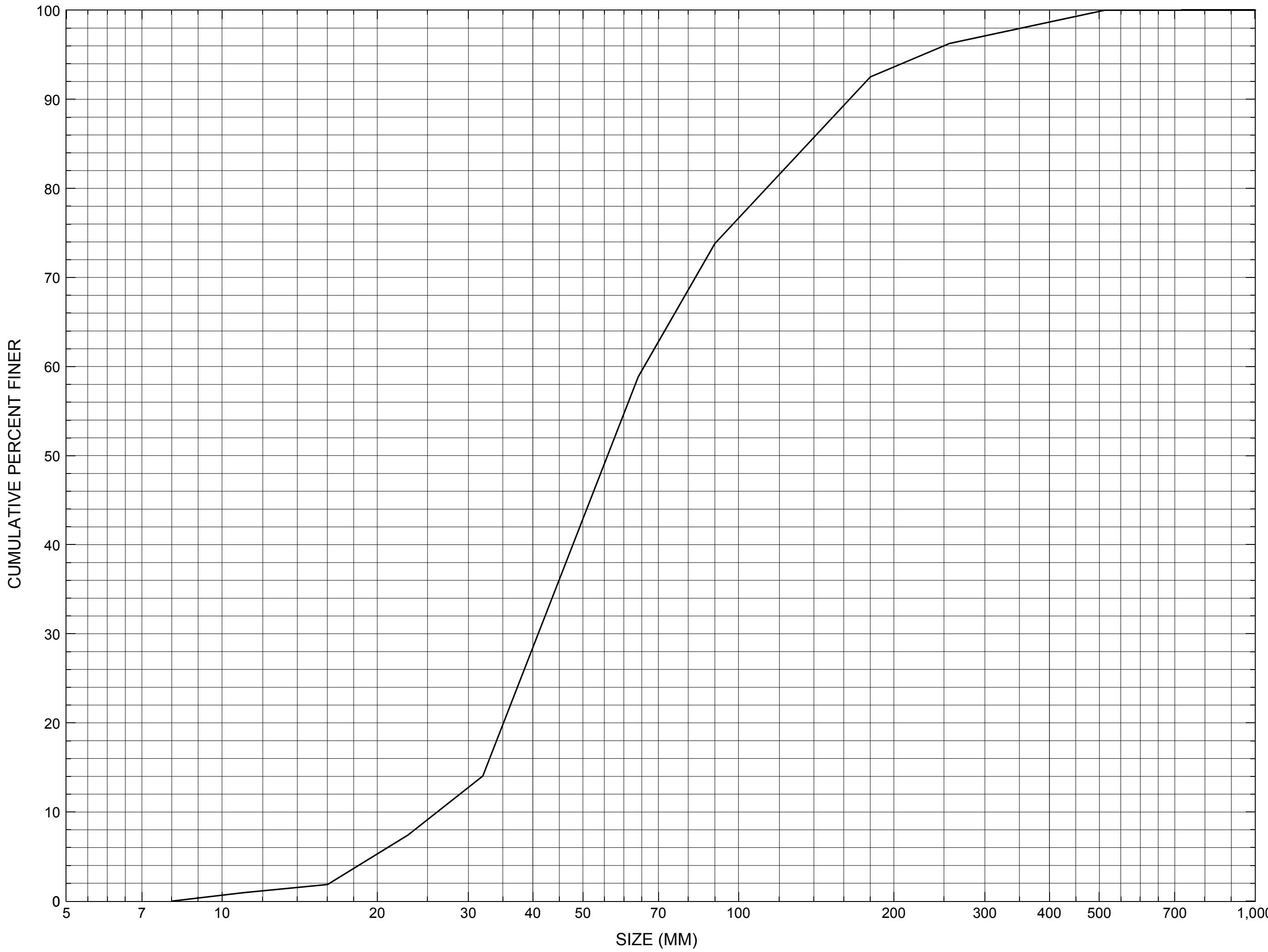
```
        U.S. Geological Survey WSPRO Input File mtho067.wsp
        Hydraulic analysis for structure MTHOTH00120067   Date: 05-FEB-98
        Town Highway 12, Freeman Brook, Mount Holly, Vermont         ECW
           *** RUN DATE & TIME: 02-23-98  09:31

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

EXIT1:XS   ******   -14.     306.  1.08 *****  490.84  488.51   2550.  489.76
      -46. ******    49.   24983.  1.00 ***** *******    0.67    8.33

FULLV:FV      46.   -15.     346.  0.84  0.40  491.24 *******   2550.  490.39
        0.    46.    50.   30038.  1.00  0.00   -0.01    0.56    7.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR3":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.95     490.49     490.27

 ===110 WSEL NOT FOUND AT SECID "APPR3":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   489.89     512.25    0.50

 ===115 WSEL NOT FOUND AT SECID "APPR3":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   489.89     512.25     490.27

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPR3"     KRATIO =  0.53

APPR3:AS      59.    -3.     214.  2.21  0.80  492.71  490.27   2550.  490.50
       59.    59.    40.   15998.  1.00  0.68    0.00    0.94   11.92
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    2550.     489.60

            <<<<<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      46.     0.     179.  3.16 *****  492.75  489.60   2550.  489.60
        0.    46.    29.   15528.  1.00 ***** *******    1.00   14.25

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.85 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR3:AS      16.    -6.     353.  0.81  0.24  494.15  490.27   2550.  493.34
       59.    18.    49.   31001.  1.00  1.16    0.01    0.50    7.23

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.315  0.001   30922.     5.    34.   493.11

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXIT1:XS     -46.   -14.    49.   2550.   24983.     306.    8.33  489.76
   FULLV:FV       0.   -15.    50.   2550.   30038.     346.    7.36  490.39
   BRIDG:BR       0.     0.    29.   2550.   15528.     179.   14.25  489.60
   RDWAY:RG      15.**************      0.******************    2.00********
   APPR3:AS      59.    -6.    49.   2550.   31001.     353.    7.23  493.34

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR3:AS       5.    34.   30922.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    488.51    0.67  482.25  509.92************ 1.08  490.84  489.76
   FULLV:FV  ********    0.56  482.25  509.92  0.40  0.00  0.84  491.24  490.39
   BRIDG:BR    489.60    1.00  481.47  496.93************ 3.16  492.75  489.60
   RDWAY:RG  ****************  498.29  512.31********************************
   APPR3:AS    490.27    0.50  483.36  512.25  0.24  1.16  0.81  494.15  493.34
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File mtho067.wsp
        Hydraulic analysis for structure MTHOTH00120067   Date: 05-FEB-98
        Town Highway 12, Freeman Brook, Mount Holly, Vermont         ECW
           *** RUN DATE & TIME: 02-23-98  09:31

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

EXIT1:XS   ******   -15.     379.  1.33 *****  492.22  489.47   3500.  490.89
      -46. ******    51.   34307.  1.00 ***** *******    0.68    9.23

FULLV:FV      46.   -16.     424.  1.06  0.41  492.62 *******   3500.  491.56
        0.    46.    53.   40435.  1.00  0.00   -0.01    0.59    8.26
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR3":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     1.01     491.51     491.57

 ===110 WSEL NOT FOUND AT SECID "APPR3":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   491.06     512.25    0.50

 ===115 WSEL NOT FOUND AT SECID "APPR3":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   491.06     512.25     491.57

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPR3"
                   WSBEG,WSEND,CRWS =   491.57     512.25     491.57

APPR3:AS      59.    -4.     262.  2.78 *****  494.35  491.57   3500.  491.57
       59.    59.    43.   20977.  1.00 ***** *******    1.00   13.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    3500.      491.08

            <<<<<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      46.     0.     221.  3.90 *****  494.98  491.08   3500.  491.08
        0.    46.    29.   21122.  1.00 ***** *******    1.00   15.83

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.85 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR3:AS      16.    -8.     485.  0.81  0.22  496.37  491.57   3500.  495.56
       59.    18.    56.   47394.  1.00  1.18    0.01    0.46    7.22

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.376  0.061   44449.     5.    34.   495.38

                          <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXIT1:XS     -46.   -15.    51.   3500.   34307.     379.    9.23  490.89
   FULLV:FV       0.   -16.    53.   3500.   40435.     424.    8.26  491.56
   BRIDG:BR       0.     0.    29.   3500.   21122.     221.   15.83  491.08
   RDWAY:RG      15.**************      0.*****************    2.00********
   APPR3:AS      59.    -8.    56.   3500.   47394.     485.    7.22  495.56

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR3:AS       5.    34.   44449.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS    489.47    0.68  482.25  509.92************  1.33  492.22  490.89
   FULLV:FV  ********    0.59  482.25  509.92  0.41  0.00  1.06  492.62  491.56
   BRIDG:BR    491.08    1.00  481.47  496.93************  3.90  494.98  491.08
   RDWAY:RG  ****************  498.29  512.31**********************************
   APPR3:AS    491.57    0.46  483.36  512.25  0.22  1.18  0.81  496.37  495.56
  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 MTHOTH00120067, in Mount Holly, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MTHOTH00120067

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 15 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 47200

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

Waterway *(I - 6)* FREEMAN BROOK

Road Name *(I - 7):* -

Route Number TH012

Vicinity *(I - 9)* 0.5 MI TO JCT W VT103

Topographic Map Mount Holly

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 43286

Longitude *(i - 17; nnnnn.n)* 72519

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10111200671112

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

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

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

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000150

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

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 501

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 030.0

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

Vertical clearance from streambed (*nnn.n ft*) 000.0

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

Waterway of full opening (*nnn.n ft*^{2}) 240.0

Comments:

The structural inspection report of 6/8/94 indicates the structure is a prestressed concrete slab type bridge. The abutment walls and wingwalls are concrete on which there are randomly distributed fine cracks. Concrete scaling is reported primarily along the bottom section of the right abutment wall. Local scour is noted along the right abutment and its downstream wingwall, which has an exposed footing. The footing concrete is noted as having heavy scaling but no undermining. Most of the channel flow is along the right abutment. Heavy riprap protection is reported in front of each upstream wingwall and along the left abutment wall. A gravel point bar is reported along the left abutment side of the **(Cont., page 31)**

Bridge Hydrologic Data

Is there hydrologic data available? **N** *if No, type ctrl-n h* VTAOT Drainage area (*mi*^{2}): **11.8**

Terrain character: -

Stream character & type:

-

Streambed material: -

Discharge Data (*cfs*): $Q_{2.33}$ - Q_{10} **1500** Q_{25} **1840**

Q_{50} **2200** Q_{100} - Q_{500} -

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

Estimated Discharge (*cfs*): - Velocity at Q **25** (*ft/s*): **12.5**

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*)	-	-	**7.8**	-	-
Velocity (*ft / sec*)	-	-	**12.5**	-	-

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 (*ft²*): -

Comments:

channel. The channel is noted as lined with stone and boulders upstream and downstream, which may provide some protection. There is very limited hydrologic data provided on an office memorandum in the hydraulics section files.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **11.38** mi^2 Lake/pond/swamp area **0.02** mi^2

Watershed storage *(ST)* **0.2** %

Bridge site elevation **1161** ft Headwater elevation **3286** ft

Main channel length **5.33** mi

10% channel length elevation **1181** ft 85% channel length elevation **2000** ft

Main channel slope *(S)* **204.77** 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)*: **11** / **1973**

Project Number **STF-9437** Minimum channel bed elevation: **505.0**

Low superstructure elevation: USLAB **518.26** DSLAB **519.21** USRAB **517.99** DSRAB **518.94**

Benchmark location description:

BM#2, a spike [in root or trunk of] a 24 in hemlock tree between a 6 in ash and 12 in poplar tree on the temporary stretch of roadway on the right bank upstream that once led to a temporary bridge. The tree is about 50 feet from the right bank of the stream and 20 feet from the centerline of the temporary roadway right bankward, elevation 518.49.

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

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **501.0**

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

If 3: Footing bottom elevation: ______

Is boring information available? **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:

-

Comments:

These plans are listed under the last project number which is STF 9437. The same hydraulic data on the bridge given in the previous section are printed on the plans. Additional reference marks that may be used are: 1) the point on the top streamward edge of the upstream right wingwall, where the slope of the concrete changes from horizontal to downward, elevation shown is 519.95; and 2) another point in the same location as in, but on the upstream left wingwall and the elevation shown is 520.22.

Cross-sectional Data

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

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

Comments: **Some cross sections of the stream were generated and kept with the plans, which may be retrieved when needed. No reproducible bridge cross sections.**

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

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: CG Date: 2/09/96
Computerized by: CG Date: 2/12/96
Reviewd by: EW Date: 2/25/98

Structure Number MTHOTH00120067

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. Severance Date *(MM/DD/YY)* 10 / 05 / 1995
2. Highway District Number 03 Mile marker -
County Rutland (021) Town Mount Holly (47200)
Waterway *(I - 6)* Freeman Brook Road Name Freeman Brook Road
Route Number TH 012 Hydrologic Unit Code: 02010002
3. Descriptive comments:

The bridge is located 0.5 miles to junction with VT 103.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 6 RBDS 6 Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 2,1 DS 2,1 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 34 *(feet)* Span length 30 *(feet)* Bridge width 25.2 *(feet)*

Road approach to bridge:

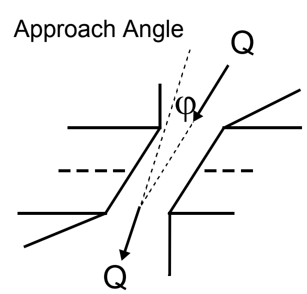
8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 2.1:1 US right 2.6:1

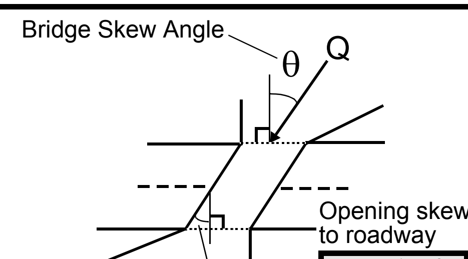
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	0	-	2	2
RBUS	0	-	2	2
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 50





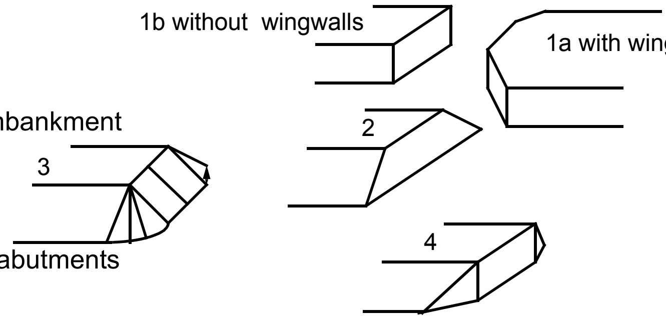
α= 15.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 5 feet US *(US, UB, DS)* to 28 feet UB
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 15 feet DS *(US, UB, DS)* to 40 feet DS

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

18. Bridge Type: **4**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



19. Bridge Deck Comments (surface cover variations, measured bridge and span lengths, bridge type variations, approach overflow width, etc.)

7: Values are from the VTAOT database. The measured bridge length equals 34 ft, span length equals 32 ft, clear span equals 30 ft, and bridge width equals 24.6 ft.
The clear span was measured from abutment edge to abutment edge.
Guard rails are along the upstream and downstream bridge deck and out onto the road approach.
The stream is in a V-notch valley.
8. The right road approach is slightly higher near the bridge than the left road approach. Then, the right road approach is lower than the bridge.

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
34.0	**8.0**			**7.0**	**1**	**2**	**342**	**342**	**0**	**0**

23. Bank width **15.0** 24. Channel width **35.0** 25. Thalweg depth **52.5** 29. Bed Material **435**

30 .Bank protection type: LB **2** RB **24** 31. Bank protection condition: LB **1** RB **1**

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

32. Comments (bank material variation, minor inflows, protection extent, etc.):
Both upstream banks are protected with boulders.
The roadway runs along/close to the left bank. Therefore the bank is made up of roadbed material consisting of cobbles, gravel and boulders.
The protection along the right bank extends upstream 114 feet. The protection from the bridge to 60 feet upsteam is type-2 and from 60 feet to 114 feet upstream is type-4.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **84** 35. Mid-bar width: **16**

36. Point bar extent: **54** feet **US** *(US, UB)* to **103** feet **US** *(US, UB, DS)* positioned **0** %LB to **60** %RB

37. Material: **435**

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

This is a point bar. The boulders have probably fallen or rolled from the upstream left bank protection. There are bars upstream along the locally braided reach (142 feet upstream to 300 feet upstream).

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: **191** 42. Cut bank extent: **135** feet **US** *(US, UB)* to **300** feet **US** *(US, UB, DS)*

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

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

The cut bank starts where the left bank protection ends. It is opposite the center of the area where the channel is braided and has bars.

45. Is channel scour present? **Y** *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: **39**

47. Scour dimensions: Length **15** Width **4** Depth : **1.2** Position **65** %LB to **80** %RB

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

There is some localized scouring in pools. The stream is riffled at the locally braided area upstream.

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
18.5		1.0		2	-	-	-

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

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

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

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

42

There is a point bar, 6 feet under the bridge to 45 feet under the bridge. The downstream end is sand and the upstream end is cobble, with gravel mixed over the entire bar. The mid-bar distance is at 20 feet under bridge. The mid-bar width is 16 feet. The channel takes up the entire width between the two abutments at the upstream bridge face. Flow is then directed at the right abutment from 5 feet to 20 feet under the bridge, across the upstream end of the under bridge point bar.

63. Bed material is cobbles with sand along the base of 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? 1___ *(Y or N)* Ice Blockage Potential N____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

The channel narrows at the bridge, but the clear span is high. The distance between the top of the footing and the low chord is 16 feet at the downstream end of the right abutment.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	0	-	-	90.0
RABUT	1	30	90			2	2	28.5

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

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

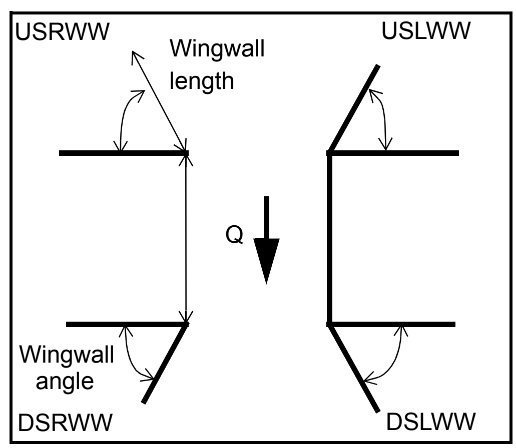
1.1
0.1
1

Just the downstream end of the right abutment has exposure depth, but the top of the footing is exposed for the entire abutment length.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						28.5	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	29.0	
DSRWW:	1		1		1	29.5	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	2	1	1	1	-
Condition	Y	-	1	0.3	1	1	1	-
Extent	1	-	2	2	3,4	2	0	-

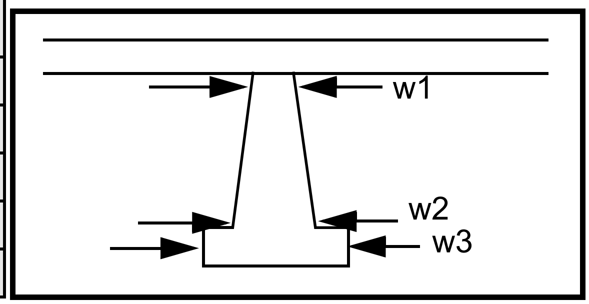
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
1
1
2
3

Piers:

84. Are there piers? DS (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				30.0	30.0	60.0
Pier 2				14.0	60.0	11.0
Pier 3			-	30.0	25.0	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	RWW-	WW-	DSLW	most	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	The	The	W-	of	1- Solid pier, 2- column, 3- bent
88. Material	upst	foot-	Ther	whic	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	ream	ing is	e is	h is	1- Round; 2- Square; 3- Pointed
90. Inclined?	end	not	pro-	alon	Y- yes; N- no
91. Attack ∠ (BF)	of	expo	tec-	g the	
92. Pushed	the	sed,	tion	dow	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	foot-	but	alon	nstre	
95. Cross-members	ing is	there	g the	am	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	expo	is	entir	end.	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	sed.	scou	e	DSR	
98. Exposure depth	USR	r.	base,	WW	

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

- There is some small protection at the downstream end. This may be slumped bank protection. The upstream end of the footing is exposed 3 feet. There is some coarse sand at the base of the center of the wingwall.

N

-

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width - Thalweg depth - Bed Material -

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB -

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: -

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

-
-
-
NO PIERS

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

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

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

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

3
2
34

Is channel scour present? **34** (Y or if N type ctrl-n cs) Mid-scour distance: **1**

Scour dimensions: Length **1** Width **4** Depth: **3** Positioned **3** %LB to **1** %RB

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

1
Bank material is cobble and gravel. The fines have been washed out in places.
There is stone protection along both downstream banks. The left bank protection extends from the downstream left wingwall to 41 feet downstream. The right bank protection extends from the downstream end of

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

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

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

Confluence comments (eg. confluence name):

ll to 80 feet downstream.
There is a bedrock outcrop 220 feet to 265 feet downstream on the left bank. A portion of this outcrop sticks

F. Geomorphic Channel Assessment

107. Stage of reach evolution **out**

__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)*:

into the channel.
There are cutbanks along both downstream banks.
There is some scattered debris.

N
-
NO DROP STRUCTURE

109. G. Plan View Sketch

-

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: MTHOTH00120067 Town: MOUNT HOLLY
Road Number: TH 12 County: RUTLAND
Stream: FREEMAN BROOK

Initials ECW Date: 2-11-98 Checked: LKS

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2550	3500	0
Main Channel Area, ft2	353	485	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	55	64	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.183	0.183	0.183
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.4	7.6	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	30988	47385	0
Conveyance, main channel	30988	47385	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	2550.0	3500.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	7.2	7.2	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	8.7	8.9	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

	100 yr	500 yr	other Q
Main Channel	0	0	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	2550	3500	0
(Q) discharge thru bridge, cfs	2550	3500	0
Main channel conveyance	15544	21116	0
Total conveyance	15544	21116	0
Q2, bridge MC discharge,cfs	2550	3500	ERR
Main channel area, ft2	179	221	0
Main channel width (normal), ft	28.4	28.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	28.4	28.4	0
y_bridge (avg. depth at br.), ft	6.30	7.78	ERR
Dm, median (1.25*D50), ft	0.22875	0.22875	0.22875
y2, depth in contraction,ft	8.91	11.69	ERR
ys, scour depth (y2-ybridge), ft	2.61	3.91	N/A

Armoring

```
 Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
 Depth to Armoring=3*(1/Pc-1)
 (Federal Highway Administration, 1993)
```

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2550	3500	N/A
Main channel area (DS), ft2	179	221	0
Main channel width (normal), ft	28.4	28.4	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	28.4	28.4	0.0
D90, ft	0.5386	0.5386	0.0000
D95, ft	0.7458	0.7458	0.0000
Dc, critical grain size, ft	0.8314	0.9456	ERR
Pc, Decimal percent coarser than Dc	0.038	0.031	0.000
Depth to armoring, ft	N/A	N/A	ERR

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 1995, p. 48, eq. 28)

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	2550	3500	0	2550	3500	0
a', abut.length blocking flow, ft	7	8.1	0	19.7	27.2	0
Ae, area of blocked flow ft2	26.88	41.19	0	84.41	136.65	0
Qe, discharge blocked abut.,cfs	78.98	133.73	0	355.18	590.63	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.94	3.25	ERR	4.21	4.32	ERR
ya, depth of f/p flow, ft	3.84	5.09	ERR	4.28	5.02	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	75	75	75	105	105	105
K2	0.98	0.98	0.98	1.02	1.02	1.02
Fr, froude number f/p flow	0.264	0.254	ERR	0.358	0.340	ERR
ys, scour depth, ft	7.85	9.98	N/A	12.67	15.23	N/A

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

a'(abut length blocked, ft)	7	8.1	0	19.7	27.2	0
y1 (depth f/p flow, ft)	3.84	5.09	ERR	4.28	5.02	ERR
a'/y1	1.82	1.59	ERR	4.60	5.41	ERR
Skew correction (p. 49, fig. 16)	0.95	0.95	0.95	1.03	1.03	1.03
Froude no. f/p flow	0.26	0.25	N/A	0.36	0.34	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	0	1	1	0
y, depth of flow in bridge, ft	6.30	7.78	0.00	6.30	7.78	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	2.63	3.25	ERR	2.63	3.25	ERR