LEVEL II SCOUR ANALYSIS FOR BRIDGE 63 (MTHOTH00120063) on TOWN HIGHWAY 12, crossing RUSSELL BROOK, MOUNT HOLLY, VERMONT

Open-File Report 98-159

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 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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Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 63 (MTHOTH00120063) ON TOWN HIGHWAY 12, CROSSING RUSSELL 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 MTHOTH00120063 on Town Highway 12 crossing Russell 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 3.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream and downstream of the bridge.

In the study area, Russell Brook has an incised, sinuous channel with a slope of approximately 0.0263 ft/ft, an average channel top width of 29 ft and an average bank height of 3 ft. The channel bed material ranges from cobbles to boulders with a median grain size (D_{50}) of 97.1 mm (0.318 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 4, 1995, indicated that the reach was stable.

The Town Highway 12 crossing of Russell Brook is a 29-ft-long, one-lane bridge consisting of a 26-foot steel-stringer span (Vermont Agency of Transportation, written communication, March 21, 1995). The opening length of the structure parallel to the bridge face is 23.5 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening while the computed opening-skew-to-roadway is 35 degrees.

During the Level I assessment, it was observed that the upstream left wingwall footing was exposed 0.2 ft, in reference to the mean thalweg depth, and the upstream end of the left abutment was exposed 0.1 ft. The scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the upstream end of the upstream left 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 0.0 to 0.1 ft. The worst-case contraction scour occurred at the 100-year discharge. Left abutment scour ranged from 4.4 to 5.7 ft. Right abutment scour ranged from 11.3 to 12.2 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.

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 MTHOTH00120063 ***Stream*** Russell Brook

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

Description of Bridge

Bridge length 29 ***ft*** ***Bridge width*** 18.5 ***ft*** ***Max span length*** 26 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 10/4/95

Description of stone fill Type-2, around the upstream end of the upstream left wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete.

Is bridge skewed to flood flow according to Level I survey? No ***Angle*** Yes 40

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

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	10/4/95	0	0
Level II	10/4/95	0	0

Potential for debris Moderate. Debris was present upstream of the bridge. Several large trees were leaning and have fallen over or into the channel.

Describe any features near or at the bridge that may affect flow (include observation date) Approximately 60 feet downstream of the bridge, Russell Brook enters Freeman Brook (10/4/95).

Description of the Geomorphic Setting

General topography The channel is located within a little flood plain with in moderate relief valley settings.

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

Date of inspection 10/4/95

DS left: Steep valley wall

DS right: Moderately sloped overbank

US left: Steep valley wall

US right: Moderately sloped overbank

Description of the Channel

Average top width 29 ***ft*** ***Average depth*** 3 ***ft***

Predominant bed material Cobbles ***Bank material*** Cobbles

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

Vegetative co... 10/4/95

Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right:

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

None, 10/4/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 3.6 ***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***:

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 740 ***ft³/s*** ***Q500*** 1,040 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(3.6/2.6)exp 0.67] with flood frequency estimates available from the VTAOT database (written communication, May 1995) for bridge number 25 in Shrewsbury. Bridge number 25 in Shrewsbury is located above the Freeman Brook/ Russell Brook confluence, and the drainage area above bridge number 25 is 2.6 square miles. These area adjusted values were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream left end of the concrete curb on the bridge deck (elev. 501.36 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the upstream right wingwall (elev. 498.56 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	-37	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPR2	43	2	Modelled Approach section (Templated from APTEM)
APTEM	51	1	Approach section as surveyed (Used as a template)

[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 0.055 to 0.065, and overbank "n" values ranged from 0.045 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 0.0263 ft/ft, which was calculated from thalweg points surveyed downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0390 ft/ft) to establish the modelled approach section (APPR2), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 500.6 *ft*
Average low steel elevation 498.3 *ft*

100-year discharge 740 *ft³/s*
Water-surface elevation in bridge opening 495.0 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 69 *ft²*
Average velocity in bridge opening 10.8 *ft/s*
Maximum WSPRO tube velocity at bridge 14.3 *ft/s*

Water-surface elevation at Approach section with bridge 498.1
Water-surface elevation at Approach section without bridge 496.3
Amount of backwater caused by bridge 1.8 *ft*

500-year discharge 1,040 *ft³/s*
Water-surface elevation in bridge opening 498.4 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 133 *ft²*
Average velocity in bridge opening 7.8 *ft/s*
Maximum WSPRO tube velocity at bridge 10.0 *ft/s*

Water-surface elevation at Approach section with bridge 500.0
Water-surface elevation at Approach section without bridge 497.2
Amount of backwater caused by bridge 2.8 *ft*

Incipient overtopping discharge -- *ft³/s*
Water-surface elevation in bridge opening -- *ft*
Area of flow in bridge opening -- *ft²*
Average velocity in bridge opening -- *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for this discharge was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Additional estimates of contraction scour, for the 500-year discharge, were also computed by use of Laursen's clear-water scour equation (Richardson and Davis, 1995, p. 32, equation 20) and Umbrell's pressure-flow scour equation (Richardson and Davis, 1995, p. 144-146). Since the 500-year discharge resulted in unsubmerged orifice flow, contraction scour was computed by substituting an alternative estimate for the depth of flow at the downstream face in the contraction scour equations. The results, with respect to these computations, are presented in appendix F.

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

Scour Results

Contraction scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.1	0.0	--
Depth to armoring	14.6 N/	A	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	4.4	5.7	--
Right abutment	11.3–	12.2–	---
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	1.5	1.9	--
Right abutment	1.5	1.9	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

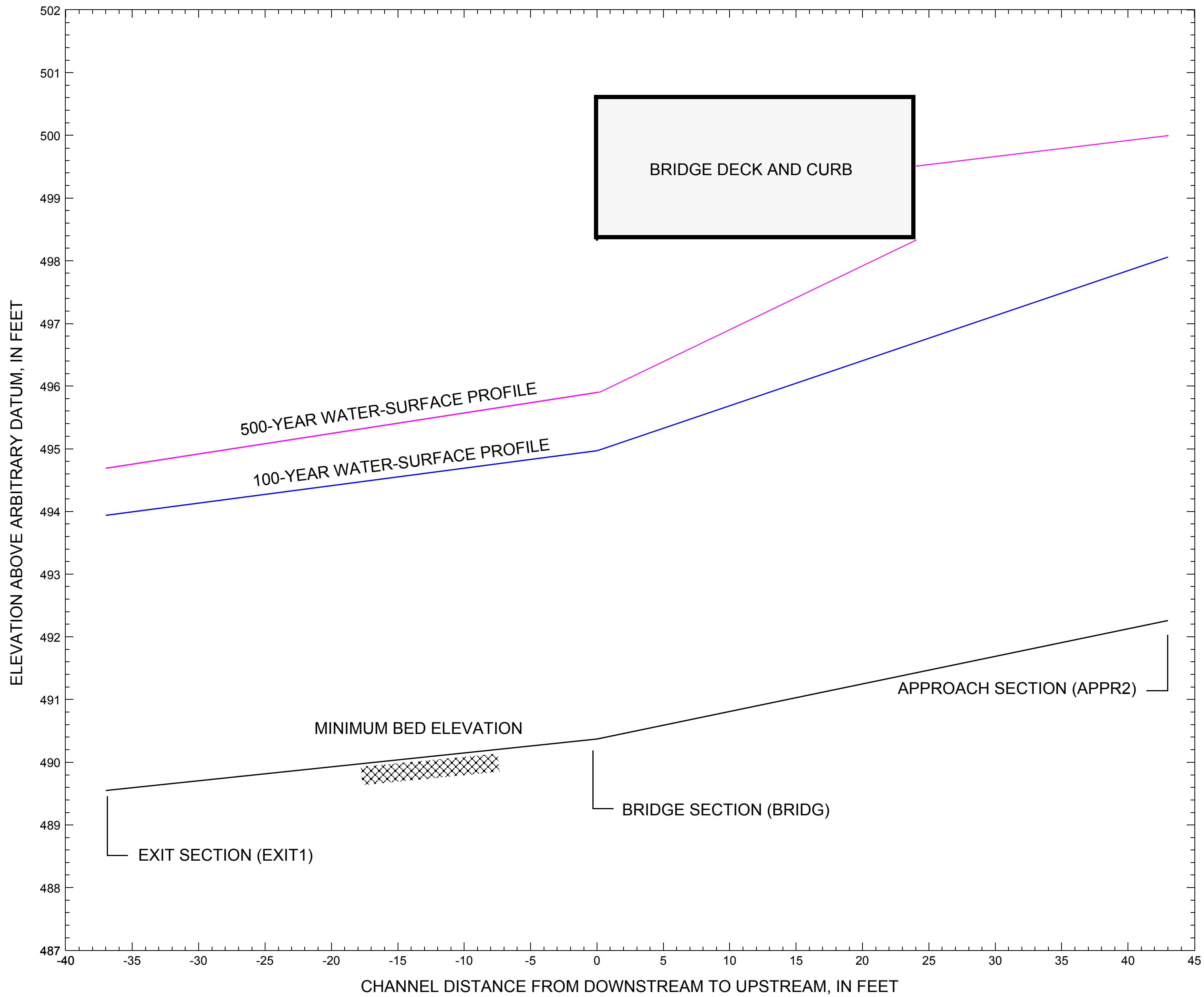

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure MTHOTH00120063 on Town Highway 12, crossing Russell Brook, Mount Holly, Vermont.

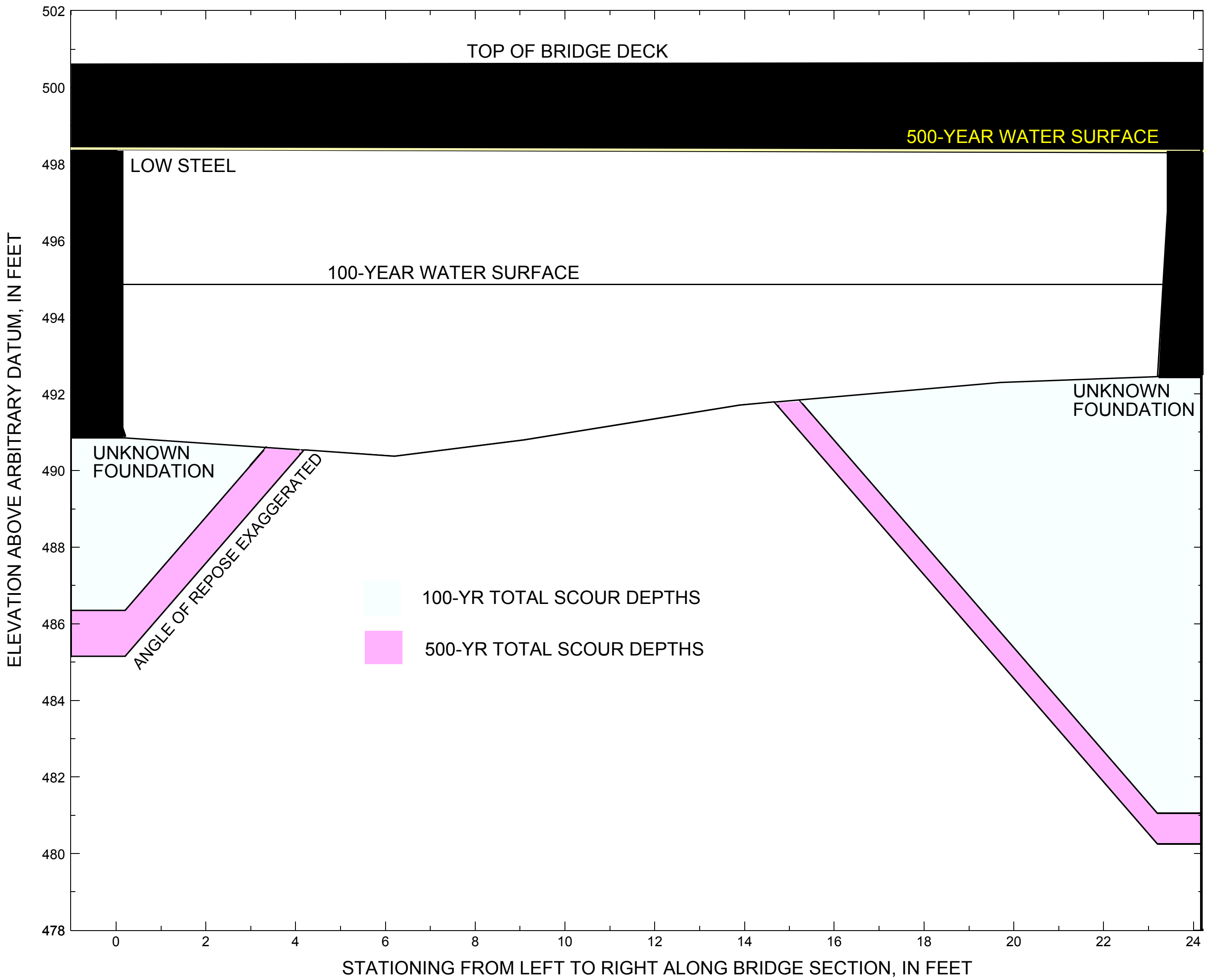

Figure 8. Scour elevations for the 100- and 500-year discharges at structure MTHOTH00120063 on Town Highway 12, crossing Russell Brook, Mount Holly, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MTHOTH00120063 on Town Highway 12, crossing Russell 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)
100-year discharge is 740 cubic-feet per second											
Left abutment	0.0	--	498.4	--	490.9	0.1	4.4	--	4.5	486.4	--
Right abutment	23.5	--	498.3	--	492.5	0.1	11.3	--	11.4	481.1	--

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 MTHOTH00120063 on Town Highway 12, crossing Russell 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 1,040 cubic-feet per second											
Left abutment	0.0	--	498.4	--	490.9	0.0	5.7	--	5.7	485.2	--
Right abutment	23.5	--	498.3	--	492.5	0.0	12.2	--	12.2	480.3	--

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, Mount Holly, 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 mtho063.wsp
T2        Hydraulic analysis for structure MTHOTH00120063   Date: 26-FEB-98
T3        Town Highway 12, Russell Brook, Mount Holly, Vermont          ECW
*
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q            740.0   1040.0
SK          0.0263   0.0263
*
XS   EXIT1    -37           0.
GR          -63.2, 512.27    -47.0, 499.97    -23.6, 499.36     -5.0, 497.34
GR            0.0, 494.33      5.3, 491.08      9.3, 490.30     10.7, 490.02
GR           14.4, 489.75     18.6, 489.55     21.9, 489.82     22.1, 490.30
GR           23.5, 491.84     27.7, 492.30     33.1, 494.90     88.9, 497.06
GR          119.5, 498.09    129.6, 501.31    176.5, 501.45    203.0, 502.54
*
N           0.045        0.055        0.070
SA                 -5.0         33.1
*
XS   FULLV      0  * * *   0.0246
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.34      35.0
GR            0.0, 498.38      0.0, 491.20      0.1, 490.85      2.4, 490.69
GR            6.2, 490.37      9.1, 490.80     11.7, 491.27     13.9, 491.71
GR           19.7, 492.30     23.2, 492.45     23.5, 498.30      0.0, 498.38
*
*        BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      27.9 * *     51.3      3.6
N           0.055
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     12      18.5     2
GR          -64.4, 513.50    -51.7, 506.80    -43.1, 500.26    -17.5, 500.37
GR            0.0, 500.61      1.8, 500.61      2.1, 501.45     29.9, 501.43
GR           29.9, 500.65     30.1, 500.65     72.0, 501.25    188.1, 502.91
GR          360.6, 510.69
*
*
*
XT   APTEM     51           0.
GR          -79.6, 516.35    -59.8, 503.26    -27.5, 502.44    -16.1, 500.91
GR           -9.7, 497.98      0.0, 497.09      8.4, 492.57     10.8, 492.84
GR           20.2, 493.11     23.5, 492.57     27.2, 492.82     31.2, 493.30
GR           34.0, 495.26     38.5, 495.71     48.4, 499.46     75.6, 501.26
*
AS   APPR2     43    * * * 0.0390
GT
N           0.070        0.065        0.065
SA                 -16.1        48.4
*
HP 1 BRIDG 494.97 1 494.97
HP 2 BRIDG 494.97 * * 740
HP 1 APPR2 498.06 1 498.06
HP 2 APPR2 498.06 * * 740
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File mtho063.wsp
       Hydraulic analysis for structure MTHOTH00120063   Date: 26-FEB-98
       Town Highway 12, Russell Brook, Mount Holly, Vermont          ECW
          *** RUN DATE & TIME: 03-02-98  08:54

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      69.    3585.    19.    26.                          741.
   494.97           69.    3585.    19.    26.  1.00     0.    23.    741.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.97     0.0    23.3    68.8    3585.     740.  10.76

X STA.         0.0         2.6         3.4         4.1         4.8         5.5
  A(I)            9.1         2.6         2.7         2.7         2.6
  V(I)           4.08       14.30       13.86       13.88       14.34

X STA.         5.5         6.2         7.0         7.7         8.5         9.3
  A(I)            2.6         2.7         2.7         2.8         2.8
  V(I)          13.98       13.87       13.58       13.34       13.30

X STA.         9.3        10.1        11.0        11.9        12.9        14.0
  A(I)            2.7         2.8         2.9         2.9         3.0
  V(I)          13.63       13.30       12.76       12.83       12.18

X STA.        14.0        15.2        16.5        17.8        19.3        23.3
  A(I)            3.1         3.2         3.3         3.3         8.5
  V(I)          12.05       11.71       11.28       11.24        4.35

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR2;  SRD =      43.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     197.   10110.    56.    59.                         2090.
   498.06          197.   10110.    56.    59.  1.00   -11.    46.   2090.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR2;  SRD =      43.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.06   -10.6    45.5   196.7   10110.     740.   3.76

X STA.       -10.6         7.8         9.1        10.4        11.7        13.0
  A(I)           34.5         7.4         7.3         7.4         7.4
  V(I)           1.07        4.99        5.06        5.02        5.00

X STA.        13.0        14.4        15.8        17.3        18.7        20.1
  A(I)            7.5         7.4         7.8         7.6         7.6
  V(I)           4.92        4.97        4.76        4.86        4.89

X STA.        20.1        21.6        23.0        24.3        25.7        27.0
  A(I)            7.9         7.7         7.8         7.7         7.5
  V(I)           4.68        4.78        4.77        4.83        4.90

X STA.        27.0        28.4        29.8        31.4        33.7        45.5
  A(I)            7.6         7.7         7.9         9.7        23.3
  V(I)           4.84        4.82        4.68        3.83        1.59
```

```
        U.S. Geological Survey WSPRO Input File mtho063.wsp
        Hydraulic analysis for structure MTHOTH00120063   Date: 26-FEB-98
        Town Highway 12, Russell Brook, Mount Holly, Vermont          ECW
           *** RUN DATE & TIME: 03-02-98  08:54
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     133.    6794.     0.    52.                    6332471.
   498.38          133.    6794.     0.    52.  1.00     0.    24.6332471.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.38     0.0    23.5   133.4    6794.    1040.   7.79

X STA.        0.0        2.7        3.5        4.4        5.2        6.0
  A(I)            16.8        5.3        5.3        5.4        5.2
  V(I)            3.09       9.84       9.89       9.61       9.98

X STA.        6.0        6.8        7.7        8.5        9.4       10.3
  A(I)             5.3        5.5        5.4        5.5        5.6
  V(I)            9.84       9.52       9.66       9.41       9.32

X STA.       10.3       11.3       12.2       13.2       14.3       15.4
  A(I)             5.5        5.6        5.8        5.8        5.7
  V(I)            9.42       9.36       9.02       9.04       9.16

X STA.       15.4       16.5       17.6       18.8       20.0       23.5
  A(I)             5.8        5.9        6.0        6.0       16.2
  V(I)            8.98       8.87       8.64       8.68       3.20

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      87.    5085.    19.    28.                       1058.
   495.94           87.    5085.    19.    28.  1.00     0.    23.   1058.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR2;  SRD =      43.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     314.   20255.    63.    66.                       3964.
             3       5.      71.    13.    13.                         20.
   500.00          319.   20326.    76.    79.  1.02   -15.    61.   3664.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR2;  SRD =      43.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.00   -14.8    61.3   319.1   20326.    1040.   3.26

X STA.      -14.8        4.0        6.4        8.2        9.8       11.4
  A(I)            49.9       14.5       13.1       12.1       12.0
  V(I)            1.04       3.60       3.97       4.29       4.34

X STA.       11.4       13.0       14.7       16.4       18.1       19.8
  A(I)            12.2       12.3       12.2       12.4       12.4
  V(I)            4.27       4.24       4.25       4.18       4.21

X STA.       19.8       21.5       23.2       24.8       26.4       28.1
  A(I)            12.7       12.8       12.5       12.3       12.4
  V(I)            4.08       4.06       4.16       4.23       4.19

X STA.       28.1       29.8       31.7       34.4       37.6       61.3
  A(I)            12.6       12.7       15.8       15.5       36.7
  V(I)            4.13       4.08       3.30       3.34       1.42
```

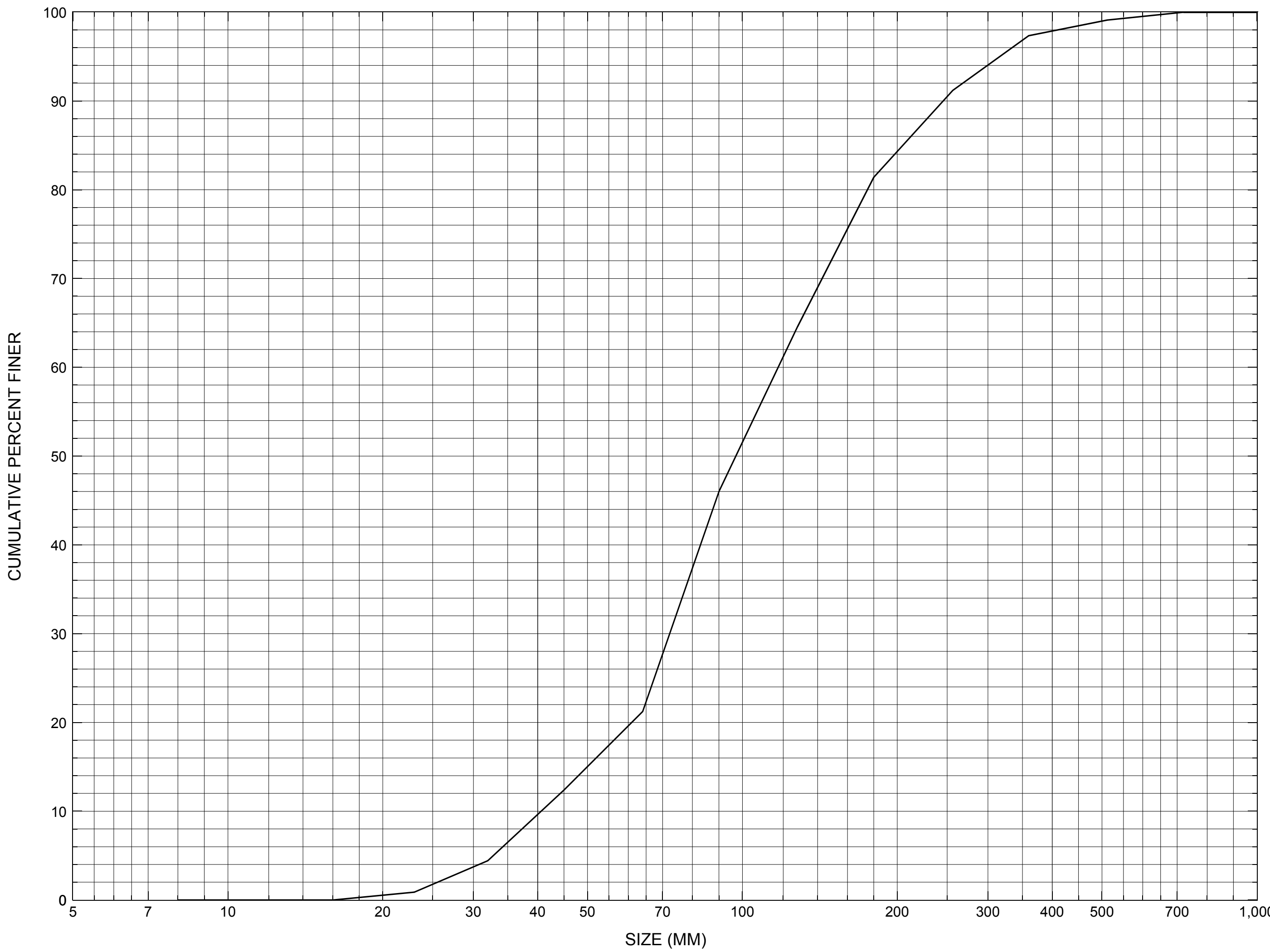
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File mtho063.wsp
        Hydraulic analysis for structure MTHOTH00120063   Date: 26-FEB-98
        Town Highway 12, Russell Brook, Mount Holly, Vermont          ECW
           *** RUN DATE & TIME: 03-02-98  08:54

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

 EXIT1:XS   ******     1.      88.  1.11 *****  495.05  493.67    740.  493.94
      -37. ******     31.    4563.  1.00 ***** *******    0.88    8.45

  ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.84     494.96     494.58

  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.44     513.18    0.50

  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.44     513.18     494.58

 FULLV:FV      37.     0.      91.  1.03  0.92  495.99  494.58    740.  494.97
         0.    37.    31.    4822.  1.00  0.00    0.02    0.83    8.13
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPR2:AS      43.     1.     113.  0.67  0.97  496.98 *******    740.  496.31
        43.    43.    41.    5023.  1.00  0.00    0.01    0.69    6.54
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =     740.     494.97

             <<<<<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      37.     0.      69.  1.80 *****  496.77  494.97    740.  494.97
         0.    37.    23.    3578.  1.00 ***** *******    1.00   10.77

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  1.000 ******  498.34 ****** ****** ******

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

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

 APPR2:AS      15.   -11.     197.  0.22  0.32  498.28  495.59    740.  498.06
        43.    21.    46.   10112.  1.00  1.19    0.00    0.35    3.76

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.418  0.137    8732.    10.    33.   497.93

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXIT1:XS     -37.     1.    31.    740.    4563.      88.    8.45  493.94
    FULLV:FV       0.     0.    31.    740.    4822.      91.    8.13  494.97
    BRIDG:BR       0.     0.    23.    740.    3578.      69.   10.77  494.97
    RDWAY:RG      12.**************      0.******************    2.00********
    APPR2:AS      43.   -11.    46.    740.   10112.     197.    3.76  498.06

     XSID:CODE   XLKQ   XRKQ       KQ
    APPR2:AS      10.    33.    8732.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    EXIT1:XS    493.67    0.88  489.55  512.27************  1.11  495.05  493.94
    FULLV:FV    494.58    0.83  490.46  513.18  0.92  0.00  1.03  495.99  494.97
    BRIDG:BR    494.97    1.00  490.37  498.38************  1.80  496.77  494.97
    RDWAY:RG  ****************  500.26  513.50**********************************
    APPR2:AS    495.59    0.35  492.26  516.04  0.32  1.19  0.22  498.28  498.06
```

```
        U.S. Geological Survey WSPRO Input File mtho063.wsp
        Hydraulic analysis for structure MTHOTH00120063   Date: 26-FEB-98
        Town Highway 12, Russell Brook, Mount Holly, Vermont          ECW
           *** RUN DATE & TIME: 03-02-98  08:54

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

 EXIT1:XS   ******    -1.     111.  1.36 *****  496.05  494.44   1040.  494.69
      -37. ******    33.    6408.  1.00 ***** *******    0.90    9.34

  ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.86     495.72     495.35

  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.19     513.18    0.50

  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.19     513.18     495.35

 FULLV:FV      37.    -1.     116.  1.26  0.92  496.99  495.35   1040.  495.73
        0.    37.    33.    6766.  1.00  0.00    0.02    0.86    8.98
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPR2:AS      43.    -5.     151.  0.74  0.95  497.94 *******   1040.  497.20
       43.    43.    43.    7242.  1.00  0.00    0.00    0.68    6.88
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.88     499.13     499.40     498.34

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

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

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

 BRIDG:BR      37.     0.     133.  0.98 *****  499.36  495.94   1059.  498.38
        0. ******    24.    6794.  1.00 ***** *******    0.59    7.94

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.466 ******  498.34 ****** ****** ******

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

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

 APPR2:AS      15.   -15.     319.  0.17  0.16  500.17  496.23   1040.  500.00
       43.    21.    61.   20321.  1.02  1.21    0.02    0.28    3.26

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.93

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

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -37.    -1.    33.   1040.    6408.     111.    9.34  494.69
   FULLV:FV       0.    -1.    33.   1040.    6766.     116.    8.98  495.73
   BRIDG:BR       0.     0.    24.   1059.    6794.     133.    7.94  498.38
   RDWAY:RG      12.**************      0.*********       0.    2.00********
   APPR2:AS      43.   -15.    61.   1040.   20321.     319.    3.26  500.00

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR2:AS  ***********************

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    494.44    0.90  489.55  512.27************  1.36  496.05  494.69
   FULLV:FV    495.35    0.86  490.46  513.18  0.92  0.00  1.26  496.99  495.73
   BRIDG:BR    495.94    0.59  490.37  498.38************  0.98  499.36  498.38
   RDWAY:RG  ****************  500.26  513.50************  0.13  500.64********
   APPR2:AS    496.23    0.28  492.26  516.04  0.16  1.21  0.17  500.17  500.00
  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 MTHOTH00120063, in Mount Holly, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MTHOTH00120063

General Location Descriptive

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

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

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

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

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

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

Waterway *(I - 6)* RUSSELL BROOK

Road Name *(I - 7):* -

Route Number TH012

Vicinity *(I - 9)* 1.10 MI TO JCT W VT103

Topographic Map Mount Holly

Hydrologic Unit Code: 02010002

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

Longitude *(i - 17; nnnnn.n)* 72513

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10111200631112

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

Maximum span length *(I - 48; nnnn)* 0026

Year built *(I - 27; YYYY)* 1939

Structure length *(I - 49; nnnnnn)* 000029

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

Deck Width *(I - 52; nn.n)* 185

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 021.5

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

Vertical clearance from streambed (*nnn.n ft*) 007.4

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

Waterway of full opening (*nnn.n* ft^2) 159.0

Comments:

The structural inspection report of 6/24/94 indicates the structure is a steel stringer type bridge with a concrete deck. The abutment walls and wingwalls are concrete with some random cracking and leakage reported overall. The right abutment wall is noted as having a crack which is 1/4 inch at the top and closes toward the bottom of the wall. The left abutment footing is reported exposed at the surface with some local scour. The report indicates that there has been no undermining, however. The wingwalls of the left abutment reportedly have extensive map cracking with leakage through the cracks. The channel bed is noted as consisting mainly of stone, boulders, and gravel. There is a large gravel point **(Cont., page 31)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): bar

Comments:

noted in the report as deposited along the right abutment side of the channel under the bridge. The majority of the streamflow is directed at the left abutment. There is some brush in the channel at the upstream face of the bridge reported. Any stone fill present is noted in the report as natural protection.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **3.55** mi^2 Lake/pond/swamp area **0.002** mi^2
Watershed storage *(ST)* **0.1** %
Bridge site elevation **1221** ft Headwater elevation **2559** ft
Main channel length **4.62** mi
10% channel length elevation **1291** ft 85% channel length elevation **2028** ft
Main channel slope *(S)* **212.33** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:
NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: CG Date: 2/7/96
Computerized by: CG Date: 2/7/96
Reviewd by: EW Date: 3/6/98

Structure Number MTHOTH00120063

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. Severance Date *(MM/DD/YY)* 10 / 04 / 1995

2. Highway District Number 03 Mile marker 0

County Rutland (021) Town Mount Holly (47200)

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

Route Number TH012 Hydrologic Unit Code: 02010002

3. Descriptive comments:

The bridge is located 1.10 miles to the 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 1/2 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 29 *(feet)* Span length 26 *(feet)* Bridge width 18.5 *(feet)*

Road approach to bridge:

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

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

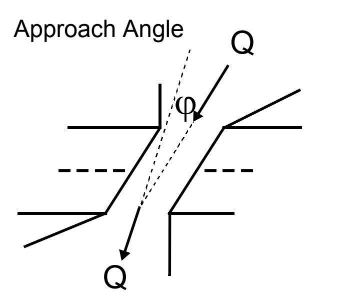
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

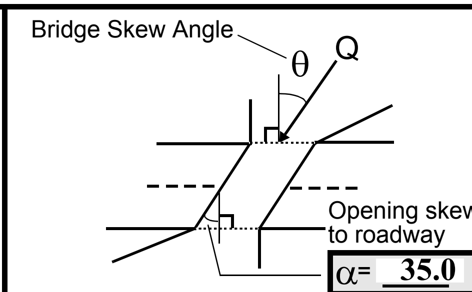
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	1	1	2	1
RBDS	1	1	2	0
LBDS	2	1	3	1

*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: 40





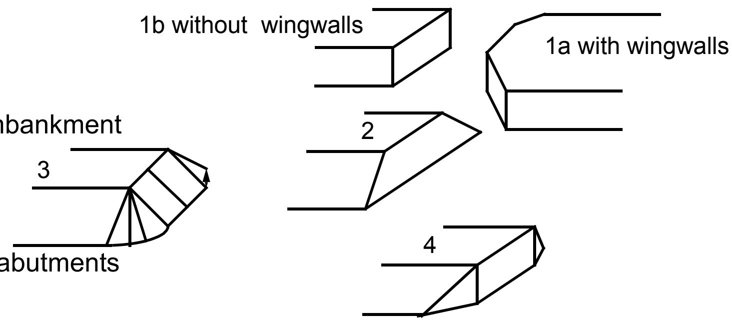
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 25 feet US *(US, UB, DS)* to 25 feet DS

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

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

18. Bridge Type: **1a**

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



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

Bridge length is 29.2 feet; span length is 26.5 feet; bridge width is 18.15 feet.
The upstream portion of the channel under the bridge is pooled, while the downstream portion is riffled.
The year 1939 is imprinted in the downstream side of the upstream curb/rail.
This stream ends/runs into Freeman Brook 60 feet downstream of the downstream bridge face.

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
28.0	**4.5**			**2.0**	**4**	**4**	**4**	**4**	**2**	**2**

23. Bank width **30.0** 24. Channel width **35.0** 25. Thalweg depth **34.0** 29. Bed Material **4**

30 .Bank protection type: LB **0** RB **0** 31. Bank protection condition: LB **-** RB **-**

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

32. Comments (bank material variation, minor inflows, protection extent, etc.):
Both banks upstream of the bridge are cut to some extent. There is a bar along the left bank. Cobbles and boulders are along both banks. Trees are leaning into the channel. Some trees have fallen into the channel. Debris is on bar and vegetation is growing on it.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **45** 35. Mid-bar width: **15**

36. Point bar extent: **25** feet **US** (US, UB) to **65** feet **US** (US, UB, DS) positioned **0** %LB to **75** %RB

37. Material: **4**

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

There is an additional point bar upstream on the left bank. It is positioned 86 feet US to 100 feet US, has a mid-bar distance of 96 feet, and a mid-bar width of 5 feet.

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

41. Mid-bank distance: **62** 42. Cut bank extent: **30** feet **US** (US, UB) to **75** 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.):

On the left bank, above the point bar, there is also cut-bank in front of the highest section of the point bar. At high flow, water passes around the left side of point bar, cutting left 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

There is localized scour at pools.

49. Are there major confluences? **Y** (Y or if N type ctrl-n mc) 50. How many? **1**

51. Confluence 1: Distance **50** 52. Enters on **RB** (LB or RB) 53. Type **2** (1- perennial; 2- ephemeral)

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

54. Confluence comments (eg. confluence name):

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
23.0		0.5		2	7	7	-

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

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

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

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

4

A bar along the right abutment extends well into channel. It starts 13 feet upstream and is 45 feet long. Mid-bar distance is 8 feet under bridge. Mid-bar width is 13 feet. The channel/flow runs along the left abutment. The left abutment footing is exposed.

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

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

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

70. Debris and Ice Comments:

1

Upstream of the bridge, there is debris scattered and several large trees leaning and fallen over or into the channel.

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		**15**	**90**	**2**	**2**	**0**	**0.1**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**0**	**19.0**

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

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

-

-

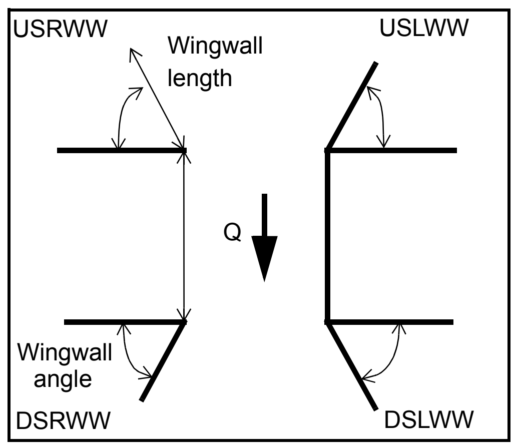
1

There are some cobbles along the left abutment. The left abutment is exposed mostly along the upstream half and is partially covered along the downstream half. The upstream left wingwall is exposed at the downstream end.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**19.0**	
USRWW:	**Y**		**1**		**2**	**1.0**	
DSLWW:	**0**		**0.2**		**Y**	**23.5**	
DSRWW:	**1**		**0**		**-**	**24.0**	

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



82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**0**	**Y**	**-**	**2**	**-**	**-**	**-**
Condition	**Y**	**-**	**1**	**-**	**2**	**-**	**-**	**-**
Extent	**1**	**-**	**0**	**2**	**0**	**0**	**0**	**-**

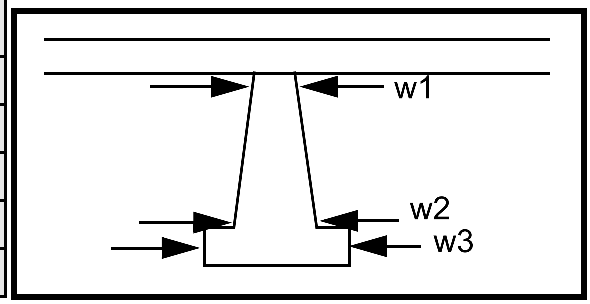
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
0
-
-

Piers:

84. Are there piers? **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		**7.5**	**8.0**	**95.0**	**5.0**	**35.0**
Pier 2	**6.5**	**6.5**	**-**	**120.0**	**-**	**-**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**LWW:**	**wing-**	**laid up**		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**Fine**	**walls**	**stone**		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**s**	**exce**	**exte**	**N**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**have**	**pt**	**ntion**	**-**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wash**	**the**	**s.**	**-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**ed**	**dow**		**-**	
92. Pushed	**out**	**nstre**		**-**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**from**	**am**		**-**	
95. Cross-members	**the**	**left**		**-**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**bank**	**wing**		**-**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**side.**	**wall**		**-**	
98. Exposure depth	**All**	**have**		**-**	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

NO PIERS

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 **4** ______ feet **4** ____ *(US, UB, DS)* positioned **4** ____ %LB to **4** ____ %RB

Material: **1** ____

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

1
4
0
0

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

Cut bank extent: **s are** feet **wa** *(US, UB, DS)* to **shed** feet **out** *(US, UB, DS)*

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

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

m banks leaving cobbles and boulders strewn along both banks.
60 feet downstream from the downstream bridge face is a major confluence (flow left to right).

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

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? **-** ____

Confluence 1: Distance **NO** Enters on **DR** *(LB or RB)* Type **OP** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

RE

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)*:

Y
29
8
25
DS
38
DS
0
45
4

109. G. Plan View Sketch

- T

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: MTHOTH00120063 Town: MOUNT HOLLY
Road Number: TH 12 County: RUTLAND
Stream: RUSSELL BROOK

Initials ECW Date: 3/2/98 Checked: MAI

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	740	1040	0
Main Channel Area, ft2	197	314	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	5	0
Top width main channel, ft	56	63	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	13	0
D50 of channel, ft	0.318	0.318	0.318
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	3.5	5.0	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	0.4	ERR
Total conveyance, approach	10110	20326	0
Conveyance, main channel	10110	20255	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	71	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	740.0	1036.4	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	3.6	ERR
Vm, mean velocity MC, ft/s	3.8	3.3	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	0.7	ERR
Vc-m, crit. velocity, MC, ft/s	9.4	10.0	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	740	1040	0
(Q) discharge thru bridge, cfs	740	1040	0
Main channel conveyance	3585	6794	0
Total conveyance	3585	6794	0
Q2, bridge MC discharge,cfs	740	1040	ERR
Main channel area, ft2	69	133	0
Main channel width (normal), ft	19.1	19.3	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.1	19.3	0
y_bridge (avg. depth at br.), ft	3.61	6.89	ERR
Dm, median (1.25*D50), ft	0.3975	0.3975	0.3975
y2, depth in contraction,ft	3.70	4.91	ERR
ys, scour depth (y2-ybridge), ft	0.09	-1.98	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	740	1040	N/A
Main channel area (DS), ft2	69	87	0
Main channel width (normal), ft	19.1	19.3	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	19.1	19.3	0.0
D90, ft	0.8057	0.8057	0.0000
D95, ft	1.0381	1.0381	0.0000
Dc, critical grain size, ft	0.7238	0.8076	ERR
Pc, Decimal percent coarser than Dc	0.130	0.099	0.000
Depth to armoring, ft	14.58	N/A	ERR

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	740	1040	0
Q, thru bridge MC, cfs	740	1040	N/A
Vc, critical velocity, ft/s	9.44	10.00	N/A
Va, velocity MC approach, ft/s	3.76	3.30	N/A
Main channel width (normal), ft	19.1	19.3	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.1	19.3	0.0
qbr, unit discharge, ft2/s	38.7	53.9	ERR
Area of full opening, ft2	69.0	133.0	0.0
Hb, depth of full opening, ft	3.61	6.89	ERR
Fr, Froude number, bridge MC	0	0.59	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	87	N/A
**Hb, depth at downstream face, ft	N/A	4.51	ERR
**Fr, Froude number at DS face	ERR	0.99	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	498.34	0
Elevation of Bed, ft	-3.61	491.45	N/A
Elevation of Approach, ft	0	500	0
Friction loss, approach, ft	0	0.16	0
Elevation of WS immediately US, ft	0.00	499.84	0.00
ya, depth immediately US, ft	3.61	8.39	N/A
Mean elevation of deck, ft	0	501.44	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.95	ERR
**Cc, for downstream face (<=1.0)	ERR	0.79	ERR
Ys, scour w/Chang equation, ft	N/A	-1.23	N/A
Ys, scour w/Umbrell equation, ft	N/A	-2.15	N/A

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

**Ys, scour w/Chang equation, ft	N/A	2.31	N/A

**Ys, scour w/Umbrell equation, ft	ERR	0.23	ERR

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

y2, from Laursen's equation, ft	3.70	4.91	0.00
WSEL at downstream face, ft	--	495.94	--
Depth at downstream face, ft	N/A	4.51	N/A
Ys, depth of scour (Laursen), ft	N/A	0.40	N/A

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	740	1040	0	740	1040	0
a', abut.length blocking flow, ft	12.7	16.9	0	24.3	39.9	0
Ae, area of blocked flow ft2	23.81	44.86	0	89.01	144.05	0
Qe, discharge blocked abut.,cfs	25.54	46.74	0	342.87	471.06	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.07	1.04	ERR	3.85	3.27	ERR
ya, depth of f/p flow, ft	1.87	2.65	ERR	3.66	3.61	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	125	125	125	55	55	55
K2	1.04	1.04	1.04	0.94	0.94	0.94
Fr, froude number f/p flow	0.138	0.113	ERR	0.355	0.303	ERR
ys, scour depth, ft	4.35	5.67	N/A	11.33	12.16	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)	12.7	16.9	0	24.3	39.9	0
y1 (depth f/p flow, ft)	1.87	2.65	ERR	3.66	3.61	ERR
a'/y1	6.77	6.37	ERR	6.63	11.05	ERR
Skew correction (p. 49, fig. 16)	1.09	1.09	1.09	0.83	0.83	0.83
Froude no. f/p flow	0.14	0.11	N/A	0.35	0.30	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	0.99	0	1	0.99	0
y, depth of flow in bridge, ft	3.61	4.51	0.00	3.61	4.51	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	1.51	1.88	ERR	1.51	1.88	ERR