LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (BETHTH00380032) on TOWN HIGHWAY 38, crossing CAMP BROOK, BETHEL, VERMONT

U.S. Geological Survey
Open-File Report 96-192

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

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By MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1996

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (BETHTH00380032) ON TOWN HIGHWAY 38, CROSSING CAMP BROOK, BETHEL, VERMONT

***By* Michael A. Ivanoff**

INTRODUCTION

This report provides the results of a detailed Level II analysis of scour potential at structure BETHTH00380032 on town highway 38 crossing Camp Brook, Bethel, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). A Level I study is included in Appendix E of this report. A Level I study provides a qualitative geomorphic characterization of the study site. Information on the bridge available from VTAOT files were compiled prior to conducting Level I and Level II analyses and can be found in Appendix D.

The site is in the Green Mountain physiographic province of central Vermont in the town of Bethel. The 7.57-mi^2 drainage area is predominantly rural and forested. In the vicinity of the study site, the banks have dense woody vegetation coverage.

In the study area, Camp Brook is an incised, mildly sinuous channel with a slope of approximately 0.018 ft/ft, an average channel top width of 50 ft and an average channel depth of 4 ft. The predominant channel bed material is gravel and cobble (D_{50} is 66.4 mm or 0.218 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 29, 1994, indicated that the reach was stable.

The town highway 38 crossing of Camp Brook is a 32-ft-long, one-lane bridge consisting of one 29-foot span steel beam with timber deck (Vermont Agency of Transportation, written commun., August 23, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 5 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

The scour protection measures at the site include type-1 stone fill (less than 12 inches) at both of the US wingwalls, type-2 stone fill (less than 36 inches) at the US and DS right and DS left road approaches. The US right bank is protected by an artificial levee with a mix of stone fill. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The scour analysis results are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Bethel, VT. Quadrangle, 1:24,000, 1980

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 BETHTH00380032 ***Stream*** Camp Brook

County Windsor ***Road*** TH038 ***District*** 04

Description of Bridge

Bridge length 32.0 ***ft*** ***Bridge width*** 14.3 ***ft*** ***Max span length*** 29.0 ***ft***

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

Abutment type vertical ***Embankment type*** N/A

Stone fill on abutment? no ***Date of inspection*** 09/29/94

Description of stone fill Type-1 stone fill protects both of the US wingwalls. Type-2 stone fill protects the US and DS right and DS left road approaches.

Concrete abutments with wingwalls.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 5

There is a moderate bend in the channel upstream of its approach to the bridge. The left bank is impacted by flood flows.

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	09/29/94	0	0
Level II	09/29/94	-	-

Potential for debris Moderate

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

09/29/94 -- There is a man made levee of gravel, cobbles, and boulders along the upstream right bank. Also there is a stream elevation change under the bridge with a point bar running from mid channel upstream to the middle of the right abutment.

Description of the Geomorphic Setting

General topography The channel has flat to slightly irregular terraces with steep valley walls on both sides.

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

Date of inspection 10/18/95

DS left: Moderate channel bank slope to a narrow terrace

DS right: Steep channel bank

US left: Moderate channel bank slope to a narrow terrace

US right: Steep channel bank

Description of the Channel

Average top width 50 ft ***Average depth*** 4 ft

Predominant bed material gravel/cobbles ***Bank material*** cobbles

Narrow, incised channel with only slight sinuosity.

09/29/94

Vegetative co forested

DS left: forested

DS right: forested

US left: forested

US right: forested

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

09/29/94--A minor cut bank and point bar were noted within the reach, and a stream elevation change under the bridge with a ridge of stones running from mid-channel upstream to the middle of the right abutment. However, the overall reach was considered stable.

09/29/94--Mid-channel bar at upstream bridge face with a ridge of stones continuing under the bridge to the middle of the right abutment.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 7.57 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province	*Percent of drainage area*
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/ No

Calculated Discharges

Q100 1,950 ***ft³/s*** ***Q500*** 2,650 ***ft³/s***

The 100- and 500-year discharges are from an extrapolation of flood frequency values from VTAOT files for this bridge site (VTAOT, written communication, May 1995). The values were within an acceptable range defined by several empirical methods (Talbot, 1887; Federal Highway Administration, 1983; Johnson and Tasker, 1974; Potter, 1957 a &b).

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 Not applicable.

Description of reference marks used to determine USGS datum. RM1 is a chiseled 'X' on the top of the upstream end of the left abutment near the junction with the wingwall (elev. 499.69 feet, arbitrary datum). RM2 is a chiseled 'X' on the top of the downstream end of the right abutment near the junction with the wingwall (elev. 499.65 feet, arbitrary datum)

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-58	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
APPRO	48	2	Modelled Approach section (Templated from ATEMP)
APTEM	74	1	Approach section as surveyed (Used as a template)

[1] For location of cross-sections see plan-view plot 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). 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, Jr. and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.050, and overbank "n" values ranged from 0.030 to 0.080.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the User's manual for WSPRO (Shearman, 1990). The slope used was 0.0185 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1980) and surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.055 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

For the 100 year discharge, WSPRO assumes critical depth at the bridge section. Further analysis in which the water surface is shown to pass through critical depth in the bridge, suggests that the critical depth assumption at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.8 *ft*
Average low steel elevation 496.8 *ft*

100-year discharge 1,950 *ft^3/s*
Water-surface elevation in bridge opening 492.6 *ft*
Road overtopping? N *Discharge over road* - *s*
Area of flow in bridge opening 148 *ft^2*
Average velocity in bridge opening 13.2 *ft/s*
Maximum WSPRO tube velocity at bridge 15.7 *ft/s*

Water-surface elevation at Approach section with bridge 495.6
Water-surface elevation at Approach section without bridge 493.2
Amount of backwater caused by bridge 2.4 *t*

500-year discharge 2,650 *ft^3/s*
Water-surface elevation in bridge opening 496.8 *ft*
Road overtopping? N *Discharge over road* - */s*
Area of flow in bridge opening 263 *ft^2*
Average velocity in bridge opening 10.2 *ft/s*
Maximum WSPRO tube velocity at bridge 11.8 */s*

Water-surface elevation at Approach section with bridge 499.4
Water-surface elevation at Approach section without bridge 494.1
Amount of backwater caused by bridge 5.3

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 -- *t*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1993, p. 35, equation 18) for the 100-year discharge. Contraction scour was computed by use of the Chang pressure-flow scour equation (Richardson and others, 1995, p. 145-146) for the 500-year discharge, where orifice occurred at the bridge. 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). The results of Laursen's clear-water contraction scour equation (Richardson and others, 1993, p. 35, equation 18) were also computed for the 500-year discharge and can be found in appendix F. For contraction scour computations, the average depth in the contracted section (AREA/ TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). The Froehlich equation gives "excessively conservative estimates of scour depths" (Richardson and others, 1993, p. 48). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.8	0.7	--
Depth to armoring	43.0	3.1	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	14.9	14.2	--
Right abutment	8.5	12.8	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Rock Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(D_{50} in feet)		
Abutments:			
Left abutment	2.3	2.0	--
Right abutment	2.3	2.0	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

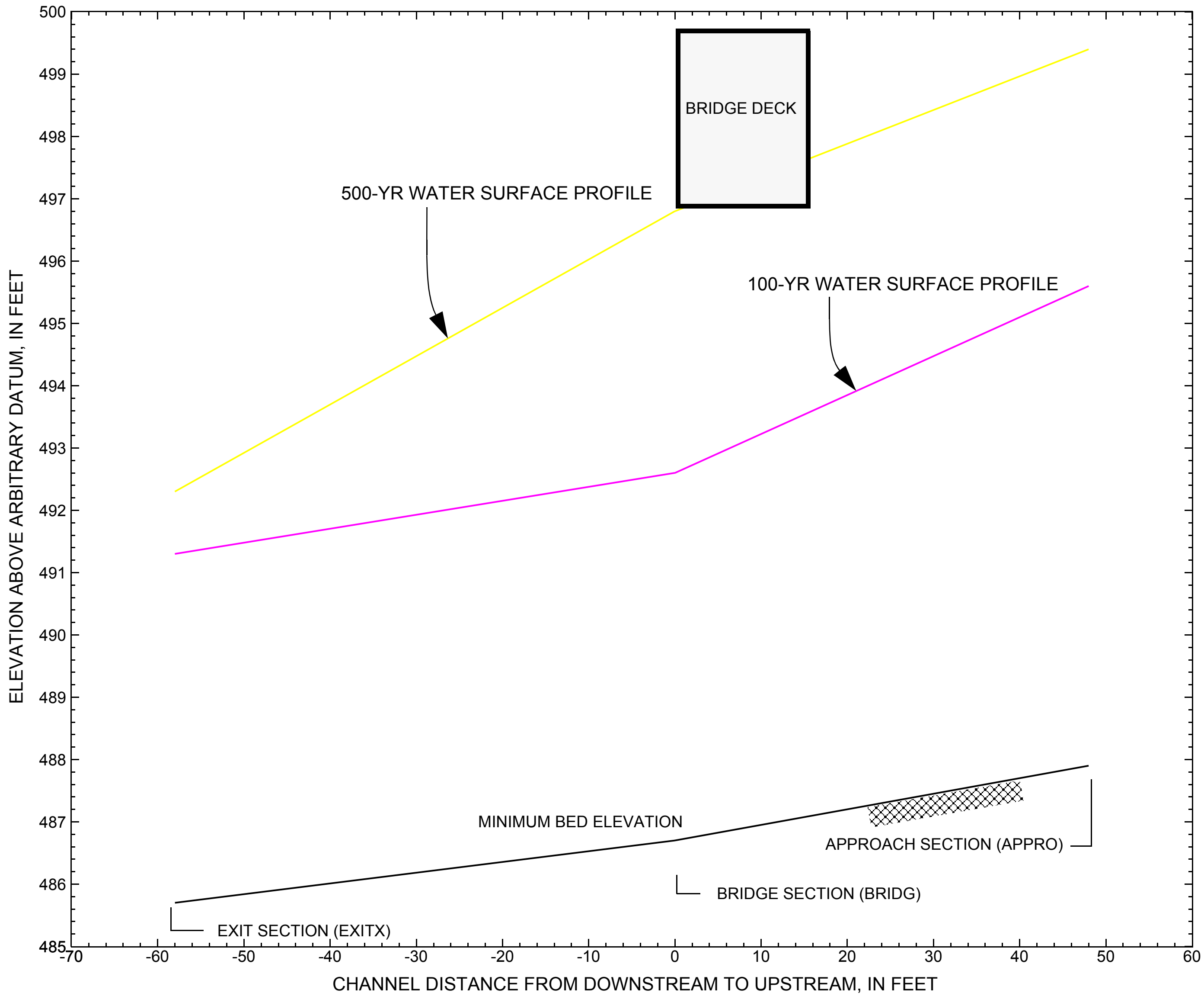

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BETHTH00380032 on town highway 38, crossing Camp Brook, Bethel, Vermont.

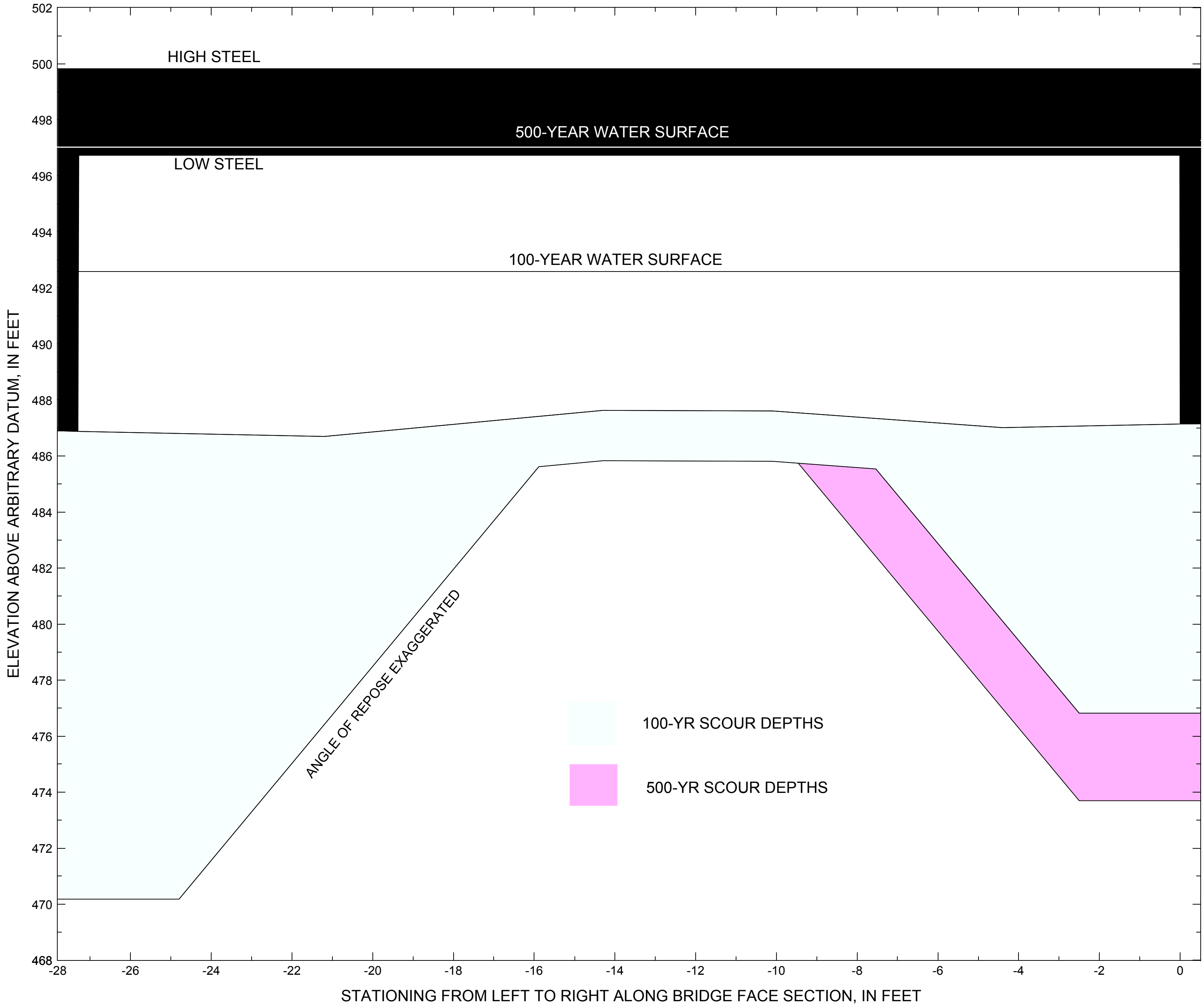

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BETHTH00380032 on town highway 38, crossing Camp Brook, Bethel, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BETHTH00380032 on Town highway 38, crossing Camp Brook, Bethel, 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 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-yr. discharge is 1,950 cubic-feet per second											
Left abutment	-27.3	--	496.8	--	486.9	1.8	14.9	--	16.7	470.2	--
Right abutment	0.0	--	496.8	--	487.2	1.8	8.5	--	10.3	476.9	--

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 BETHTH00380032 on Town highway 38, crossing Camp Brook, Bethel, 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 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-yr. discharge is 2,650 cubic-feet per second											
Left abutment	-27.3	--	496.8	--	486.9	0.7	14.2	--	14.9	472.0	--
Right abutment	0.0	--	496.8	--	487.2	0.7	12.8	--	13.5	473.7	--

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, 1980, Bethel, 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 beth032.wsp
T2        CREATED ON 28-NOV-95 FOR BRIDGE BETHTH00380032 USING FILE beth032.ndca
T3        Hydrologic analysis of Bethel bridge 32 by MAI
*
Q          1950.0,    2650.0
SK         0.0185   0.0185
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXIT1    -58
GR         -109.6, 498.33   -108.2, 497.99    -68.2, 495.63    -51.1, 494.18
GR          -44.9, 491.12    -40.9, 492.98    -31.7, 488.75    -19.9, 485.85
GR          -11.6, 485.70     -3.4, 486.38      0.0, 487.25      6.9, 487.72
GR            9.9, 487.37     13.8, 490.18     16.6, 490.91     24.0, 491.89
GR           27.0, 494.66     60.6, 494.34     71.1, 499.89
N           0.050   0.080
SA               27.0
*
XS   FULLV       0  * * *   0.0175
*
BR   BRIDG   0     496.75
GR          -27.3, 496.75    -27.3, 486.90    -21.2, 486.70    -14.3, 487.63
GR          -10.1, 487.61     -4.8, 487.06     -4.4, 487.01      0.0, 487.15
GR            0.0, 496.76    -12.3, 496.83    -27.3, 496.75
N           0.040
CD           4 21 1 499.8 55
*
XT   ATEMP     74
GR         -139.7, 504.12   -134.3, 500.46   -103.8, 500.74    -77.0, 500.25
GR          -55.9, 499.77    -51.8, 499.49    -45.8, 495.52    -40.0, 491.24
GR          -31.3, 490.05    -17.7, 489.80     -7.6, 489.56     -2.0, 489.50
GR            0.0, 489.33      2.4, 490.47      6.0, 493.67      9.1, 494.93
GR           13.9, 497.16     28.2, 496.77     41.8, 497.53     45.5, 498.02
GR           51.3, 499.27     57.9, 502.11
AS   APPRO  48
GT         -1.43
N          0.030     0.05     0.080
SA                -51.8    13.9
*
HP 1 BRIDG   492.58 1 492.58
HP 2 BRIDG   492.58 * * 1950
HP 1 APPRO   495.62 1 495.62
HP 2 APPRO   495.62 * * 1950
*
HP 1 BRIDG   496.83 1 496.83
HP 2 BRIDG   496.83 * * 2650
HP 1 APPRO   499.35 1 499.35
HP 2 APPRO   499.35 * * 2650
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE beth032.wsp
       CREATED ON 28-NOV-95 FOR BRIDGE BETHTH00380032 USING FILE beth032.ndca
       Hydrologic analysis of Bethel bridge 32 by MAI
          *** RUN DATE & TIME: 12-07-95  08:59
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     148.   13476.    27.    39.                         1949.
   492.58          148.   13476.    27.    39.  1.00   -27.     0.   1949.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       492.58   -27.3     0.0   147.7   13476.    1950.  13.21

X STA.       -27.3      -24.9      -23.6      -22.3      -21.2      -20.1
  A(I)            13.5        8.0        7.0        6.7        6.4
  V(I)            7.23      12.16      13.86      14.49      15.32

X STA.       -20.1      -19.0      -17.8      -16.7      -15.5      -14.2
  A(I)             6.3        6.4        6.2        6.2        6.4
  V(I)           15.53      15.21      15.62      15.66      15.20

X STA.       -14.2      -12.9      -11.6      -10.3       -9.0       -7.7
  A(I)             6.5        6.5        6.4        6.5        6.5
  V(I)           15.03      15.01      15.35      14.95      15.00

X STA.        -7.7       -6.5       -5.2       -3.9       -2.4        0.0
  A(I)             6.7        6.8        7.1        8.1       13.3
  V(I)           14.56      14.24      13.70      12.01       7.31

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     356.   32645.    62.    66.                         4848.
             3       2.      11.    15.    15.                            5.
   495.62          358.   32656.    77.    81.  1.01   -48.    33.   4356.
VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.62   -48.1    33.2   358.1   32656.    1950.   5.45
X STA.       -48.1      -38.9      -35.7      -33.0      -30.6      -28.3
  A(I)            29.5       19.6       17.8       16.8       16.2
  V(I)            3.30       4.97       5.48       5.81       6.02

X STA.       -28.3      -26.1      -23.9      -21.7      -19.6      -17.5
  A(I)            15.5       15.8       15.3       15.3       15.3
  V(I)            6.28       6.18       6.35       6.39       6.36

X STA.       -17.5      -15.4      -13.3      -11.3       -9.2       -7.1
  A(I)            15.2       15.3       15.1       15.4       15.4
  V(I)            6.41       6.36       6.47       6.33       6.32

X STA.        -7.1       -5.0       -2.8       -0.5        2.3       33.2
  A(I)            16.1       16.4       17.7       20.2       34.0
  V(I)            6.04       5.94       5.52       4.82       2.87
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     263.   22734.     0.    74.                            0.
   496.83          263.   22734.     0.    74.  1.00   -27.     0.      0.
    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.83   -27.3     0.0   262.7   22734.    2650.  10.09
X STA.       -27.3      -24.9      -23.5      -22.2      -21.0      -19.9
  A(I)            23.3       14.2       12.8       12.1       11.7
  V(I)            5.69       9.35      10.36      10.93      11.34

X STA.       -19.9      -18.7      -17.6      -16.4      -15.2      -13.9
  A(I)            11.4       11.2       11.4       11.3       11.4
  V(I)           11.57      11.78      11.66      11.76      11.58

X STA.       -13.9      -12.7      -11.4      -10.2       -9.0       -7.7
  A(I)            11.4       11.4       11.5       11.5       11.9
  V(I)           11.66      11.65      11.51      11.54      11.17

X STA.        -7.7       -6.5       -5.2       -3.9       -2.4        0.0
  A(I)            11.6       12.1       13.0       14.5       23.1
  V(I)           11.41      10.94      10.20       9.17       5.74
```

```
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      34.     938.    83.    83.                        124.
             2     596.   73732.    66.    71.                      10199.
             3     130.    5196.    41.    41.                       1316.
   499.35          761.   79866.   190.   195.  1.29  -135.    55.   7614.
    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.35  -134.8    54.8   760.7  79866.    2650.   3.48
X STA.      -134.8      -42.0      -37.9      -34.6      -31.6      -28.8
  A(I)             79.1       38.0       33.1       31.7       30.0
  V(I)             1.67       3.49       4.01       4.18       4.42

X STA.       -28.8      -26.1      -23.4      -20.8      -18.2      -15.7
  A(I)             29.2       29.0       28.2       28.4       27.6
  V(I)             4.53       4.57       4.71       4.67       4.79

X STA.       -15.7      -13.2      -10.6       -8.2       -5.7       -3.1
  A(I)             28.1       28.2       27.7       27.7       28.8
  V(I)             4.72       4.69       4.78       4.78       4.61

X STA.        -3.1       -0.5        2.4        7.2       21.2       54.8
  A(I)             29.5       31.8       40.0       61.7      102.9
  V(I)             4.48       4.16       3.32       2.15       1.29

        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE beth032.wsp
        CREATED ON 28-NOV-95 FOR BRIDGE BETHTH00380032 USING FILE beth032.ndca
        Hydrologic analysis of Bethel bridge 32 by MAI
           *** RUN DATE & TIME: 12-07-95  08:59
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT1:XS   ******   -45.     209.  1.36 *****  492.66  490.84   1950.  491.30
      -58. ******    20.   14332.  1.00 ***** *******    0.86    9.34

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.83     492.44     491.86

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   490.80     500.91    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   490.80     500.91     491.86

FULLV:FV      58.   -45.     214.  1.29  1.04  493.70  491.86   1950.  492.41
        0.    58.    20.   14735.  1.00  0.00    0.00    0.84    9.10
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      48.   -45.     219.  1.23  0.76  494.47 *******   1950.  493.24
       48.    48.     8.   16209.  1.00  0.00    0.01    0.77    8.90
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                 SECID “BRIDG”     Q,CRWS =    1950.     492.58

            <<<<<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      58.   -27.     148.  2.74 *****  495.32  492.58   1950.  492.58
        0.    58.     0.   13479.  1.01 ***** *******    1.01   13.20

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  0.996 ******  496.75 ****** ****** ******

    XSID:CODE     SRD   FLEN     HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      27.   -48.     358.  0.47  0.25  496.09  492.50   1950.  495.62
       48.    28.    33.   32668.  1.01  0.53    0.02    0.45    5.44

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.486  0.317   22208.   -30.    -3.   495.50
```

```
FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -58.   -45.    20.   1950.   14332.     209.    9.34  491.30
   FULLV:FV       0.   -45.    20.   1950.   14735.     214.    9.10  492.41
   BRIDG:BR       0.   -27.     0.   1950.   13479.     148.   13.20  492.58
   RDWAY:RG      11.**************      0.*****************    2.00********
   APPRO:AS      48.   -48.    33.   1950.   32668.     358.    5.44  495.62

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -30.    -3.   22208.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    490.84    0.86  485.70  499.89************  1.36  492.66  491.30
   FULLV:FV    491.86    0.84  486.72  500.91  1.04  0.00  1.29  493.70  492.41
   BRIDG:BR    492.58    1.01  486.70  496.83************  2.74  495.32  492.58
   RDWAY:RG  ****************  499.51  505.11**********************************
   APPRO:AS    492.50    0.45  487.90  502.69  0.25  0.53  0.47  496.09  495.62

        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE beth032.wsp
        CREATED ON 28-NOV-95 FOR BRIDGE BETHTH00380032 USING FILE beth032.ndca
        Hydrologic analysis of Bethel bridge 32 by MAI
           *** RUN DATE & TIME: 12-07-95  08:59
XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT1:XS   ******   -47.     270.  1.50 *****  493.76  491.86   2650.  492.26
      -58. ******    24.   19481.  1.00 ***** *******    0.87    9.82

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.84     493.38     492.87

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.76     500.91    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.76     500.91     492.87

FULLV:FV      58.   -47.     277.  1.43  1.04  494.80  492.87   2650.  493.37
        0.    58.    25.   20171.  1.00  0.00    0.01    0.84    9.57
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81     494.09     493.39

 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.87     502.69    0.50

 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.87     502.69     493.39
APPRO:AS      48.   -46.     267.  1.54  0.77  495.64  493.39   2650.  494.10
       48.    48.    10.   21564.  1.00  0.06    0.01    0.81    9.94
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.81     497.29     497.50     496.75
 ===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      58.   -27.     263.  1.63 *****  498.46  493.87   2691.  496.83
        0. ******     0.   22734.  1.00 ***** *******    0.58   10.24

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       4. ****    2.  0.465 ******  496.75 ****** ****** ******

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

APPRO:AS      27.  -135.     760.  0.24  0.11  499.59  493.39   2650.  499.35
       48.    29.    55.   79841.  1.29  0.49    0.02    0.35    3.48

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

FIRST USER DEFINED TABLE.

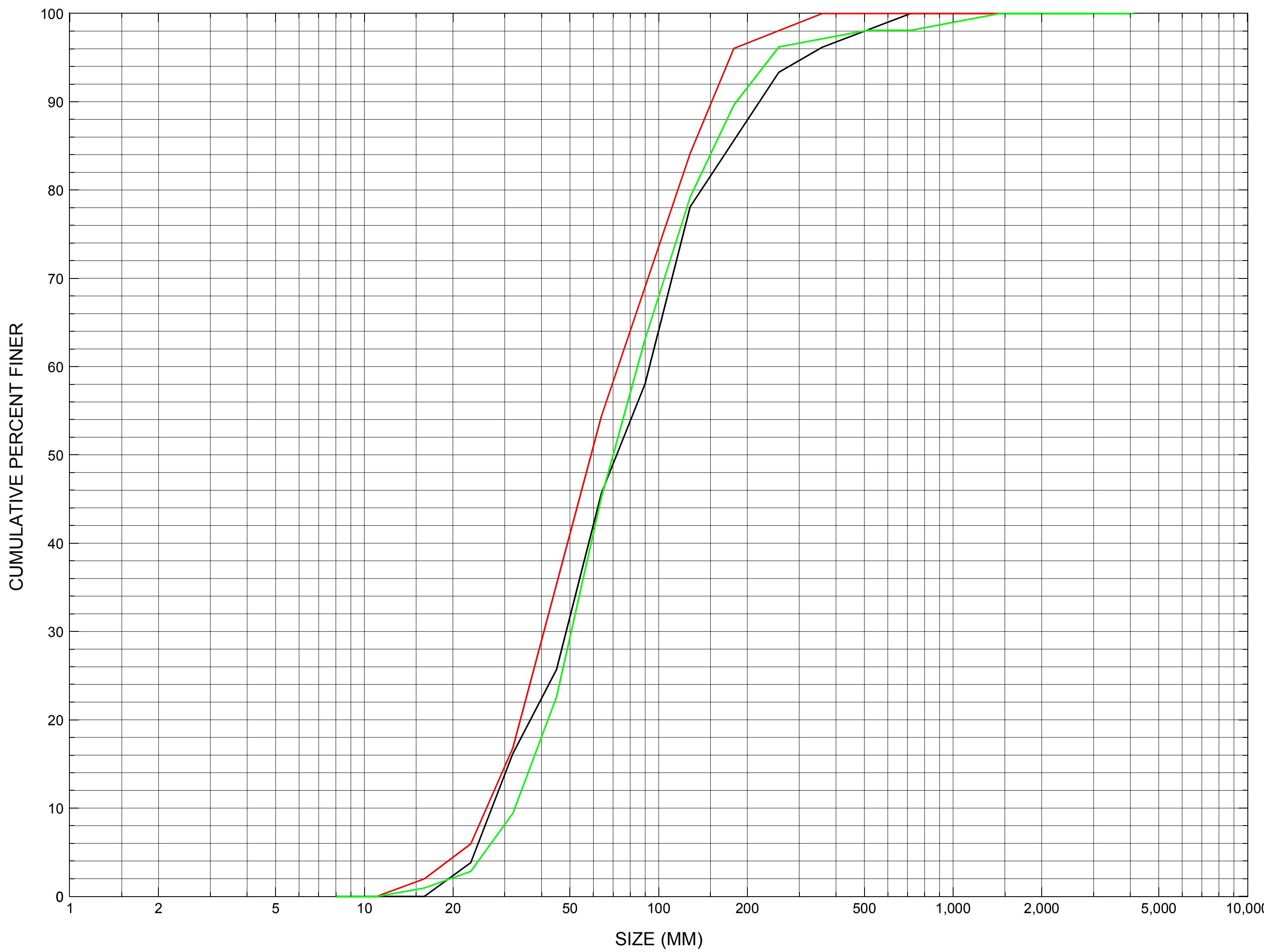
XSID:CODE	SRD	LEW	REW	Q	K	AREA	VEL	WSEL
EXIT1:XS	-58.	-47.	24.	2650.	19481.	270.	9.82	492.26
FULLV:FV	0.	-47.	25.	2650.	20171.	277.	9.57	493.37
BRIDG:BR	0.	-27.	0.	2691.	22734.	263.	10.24	496.83
RDWAY:RG	11.	*******	*******	0.	*********	0.	2.00	********
APPRO:AS	48.	-135.	55.	2650.	79841.	760.	3.48	499.35

SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
EXIT1:XS	491.86	0.87	485.70	499.89	******	******	1.50	493.76	492.26
FULLV:FV	492.87	0.84	486.72	500.91	1.04	0.00	1.43	494.80	493.37
BRIDG:BR	493.87	0.58	486.70	496.83	******	******	1.63	498.46	496.83
RDWAY:RG	**********	******	499.51	505.11	******	******	0.21	499.90	********
APPRO:AS	493.39	0.35	487.90	502.69	0.11	0.49	0.24	499.59	499.35

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure BETHTH00380032, in Bethel, Vermont.

APPENDIX D:

HISTORICAL DATA FORM