LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (RANDTH00730039) on TOWN HIGHWAY 73, crossing the SECOND BRANCH WHITE RIVER, RANDOLPH, VERMONT

U.S. Geological Survey
Open-File Report 96-234

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

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By DONALD L. SONG and MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1996

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

U.S. GEOLOGICAL SURVEY
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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 39 (RANDTH00730039) ON TOWN HIGHWAY 73, CROSSING THE SECOND BRANCH WHITE RIVER, RANDOLPH, VERMONT

***By* Donald L. Song and Michael A. Ivanoff**

INTRODUCTION

This report provides the results of a detailed Level II analysis of scour potential at structure RANDTH00730039 on town highway 73 crossing the Second Branch White River, Randolph, 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 was 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 Randolph. The 53.7-mi^2 drainage area is in a predominantly rural basin. In the vicinity of the study site, the overbanks are covered by pasture except for the upstream right bank which is covered by brush.

In the study area, the Second Branch White River has a meandering channel with a slope of approximately 0.001 ft/ft, an average channel top width of 44 ft and an average channel depth of 6 ft. The predominant channel bed material is sand with median grain size (D_{50}) of 0.884 mm (0.0029 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 12, 1994, indicated that the reach was laterally unstable. This is because of severe cut-banks both upstream and downstream where mass wasting and block failure of bank material is evident. Furthermore, minimal erosion protection is provided by bank vegetation since woody vegetation cover is sparse.

The town highway 73 crossing of the Second Branch White River is a 42-ft-long, one-lane bridge consisting of one 40-foot span (Vermont Agency of Transportation, written communication, August 2, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The ends of the upstream left wingwall and the downstream right wingwall are protected by stone fill. However, this stone fill is slumping according to the Level I field inspection. The channel is skewed approximately 30 degrees to the opening while the opening-skew-to-roadway is 0 degrees. 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).
Total scour at a highway crossing is comprised of three components: 1) long-term aggradation or degradation; 2) contraction scour (due to reduction in flow area caused by 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 scour depths for contraction and local scour and a summary of the results follows.

Contraction scour for all modelled flows ranged from 1.9 ft to 4.6 ft and the worst-case contraction scour occurred at the incipient overtopping discharge. Abutment scour ranged from 4.0 ft to 22.5 ft and the worst-case abutment scour occurred at the 500-year discharge. Scour depths and depths to armoring are summarized on p. 14 in the section titled "Scour Results". Scour elevations, based on the calculated depths are presented in tables 1 and 2; a graph of the scour elevations is presented in figure 8 Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

For all scour presented in this report, "the scour depths adopted [by VTAOT] may differ from the equation values based on engineering judgement" (Richardson and others, 1993, p. 21, 27). It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and others, 1993, p. 48). Many factors, including historical performance during flood events, the geomorphic assessment, and the results of the hydraulic analyses, must be considered to properly assess the validity of abutment scour results.

Randolph Center, VT. Quadrangle, 1:24,000, 1981.
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 RANDTH00730039 ***Stream*** Second Branch White River

County Orange ***Road*** TH073 ***District*** 04

Description of Bridge

Bridge length 42 ***ft*** ***Bridge width*** 12.8 ***ft*** ***Max span length*** 40 ***ft***

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

Abutment type concrete ***Embankment type*** vertical

Stone fill on abutment? no ***Date of inspection*** 08/12/94

Description of stone fill type II stone fill (less than 36 inches diameter) at ends of the upstream left wingwall and downstream right wingwall. This stone fill was reported as slumped.

Abutments are concrete with wingwalls.

Brief description of piers/abutments

Y

Is bridge skewed to flood flow according to Model ***survey?*** 30 ***Angle*** Y

rate: The skew angle of the stream to the bridge is 30 degrees. Opening skew to roadway is 0 degrees and the right abutment is attacked at approximately 30 degrees.

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	08/12/94	0	0
Level II	same	-	-

Potential for debris Moderate, due to trees on the unstable banks.

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

August 12, 1994: The left abutment protrudes into the low-water channel. The floodplain at this site is significant compared to the width of the stream and may convey a significant portion high discharges.

Description of the Geomorphic Setting

General topography The bridge is in an approximately 200-300 ft-wide, flat valley over a meandering stream.

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

Date of inspection 08/12/94

DS left: wide flood plain to steep valley wall

DS right: narrow flood plain to moderately steep valley wall

US left: wide flood plain to steep valley wall

US right: steep valley wall

Description of the Channel

Average top width 44 ***ft***

Average depth 6.0 ***ft***

Predominant bed material sand

Bank material silty sand

meandering, with wide flood plains. It is alluvial and laterally unstable

08/12/94

Vegetative co pasture

DS left: pasture

DS right: pasture

US left: scattered brush and some trees

US right: N

Do banks appear stable? 08/12/94--Heavy fluvial erosion has occurred on the banks both upstream and downstream. Several bank "block failures" were observed.

date of observation.

On 08/12/94, there were several scattered logs in the channel within the reach. This debris was not obstructing flow at the time of the inspection.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 53.7 ***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***: None

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 7,910 ***ft³/s*** ***Q500*** 11,100 ***ft³/s***

The 100-yr discharge was determined from a drainage area relationship [(53.7/46.0) to the 0.7 power] with an upstream site. The upstream site had a drainage area of 46 square miles and a 100-yr discharge, determined from a previous study, of 7100 cfs. (Landry, D., oral communication, March 1995). The 500-yr discharge was determined in the same manner after the 500-yr discharge from the upstream site was found by extrapolating available flood frequency estimates graphically. Incipient road overflow discharge was determined to be 1,880 cfs.

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 N/A

Description of reference marks used to determine USGS datum. RM1 is the center of a chiseled "L" in the top of the downstream end of the left abutment; the arbitrary survey elevation is 497.79 feet.

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	0	1	Exit section
FULLV	23	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	23	1	Bridge section
RDWAY	29.5	1	Road Grade section
APPRO	81	1	Approach section

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analysis reported herein reflects 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, 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 0.035 to 0.043, and overbank "n" values ranged from 0.035 to 0.046.

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 0.0008 ft/ft which was measured from water-surface profiles for the Second Branch White River in the Flood Insurance Study for the Town of Randolph (Federal Emergency Management Agency, 1991).

Bridge Hydraulics Summary

Average bridge embankment elevation 497.5 *ft*
Average low steel elevation 494.9 *ft*

100-year discharge 7,910 *ft³/s*
Water-surface elevation in bridge opening 495.0 *ft*
Road overtopping? Y *Discharge over road* 5,506 *ft³/s*
Area of flow in bridge opening 296 *ft²*
Average velocity in bridge opening 8.1 *ft/s*
Maximum WSPRO tube velocity at bridge 9.4 *ft/s*

Water-surface elevation at Approach section with bridge 498.6
Water-surface elevation at Approach section without bridge 497.1
Amount of backwater caused by bridge 1.5 *ft*

500-year discharge 11,100 *ft³/s*
Water-surface elevation in bridge opening 495.0 *ft*
Road overtopping? Y *Discharge over road* 8,950 *ft³/s*
Area of flow in bridge opening 296 *ft²*
Average velocity in bridge opening 7.8 *ft/s*
Maximum WSPRO tube velocity at bridge 9.1 *ft/s*

Water-surface elevation at Approach section with bridge 499.6
Water-surface elevation at Approach section without bridge 498.3
Amount of backwater caused by bridge 1.3

Incipient overtopping discharge 1,876 *ft³/s*
Water-surface elevation in bridge opening 493.4 *ft*
Area of flow in bridge opening 248 *ft²*
Average velocity in bridge opening 7.6 *ft/s*
Maximum WSPRO tube velocity at bridge 9.2 *ft/s*

Water-surface elevation at Approach section with bridge 494.3
Water-surface elevation at Approach section without bridge 493.8
Amount of backwater caused by bridge 0.5 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 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 live-bed contraction scour equation (Richardson and others, 1993, p. 33, equation 16). 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. The 100-year and 500-year discharges resulted in submerged orifice flow. The results of Chang's contraction scour (Richardson and others, 1995, p. 145-146) for these two events were also computed and can be found in appendix F. Because the Chang equation for pressure flow scour was derived solely with data for clear-water scour, it is not currently understood how well it would predict in live-bed conditions. Therefore, although pressure flow conditions exist for the 100-year and 500-year flows, the reported scour depths were computed using Laursen's live-bed contraction scour equation.

Abutment scour for the right abutment 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 at the left abutment was computed by use of the HIRE equation (Richardson and others, 1993, p. 50, equation 25) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	3.3	1.9	4.6
Clear-water scour	--	--	--
Depth to armoring	--	--	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour	5.9	6.0	4.0
Left abutment	19.7–	22.5-	10.3-
Right abutment			
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:	1.4	1.3	1.2
Left abutment	1.4	1.3	1.2
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

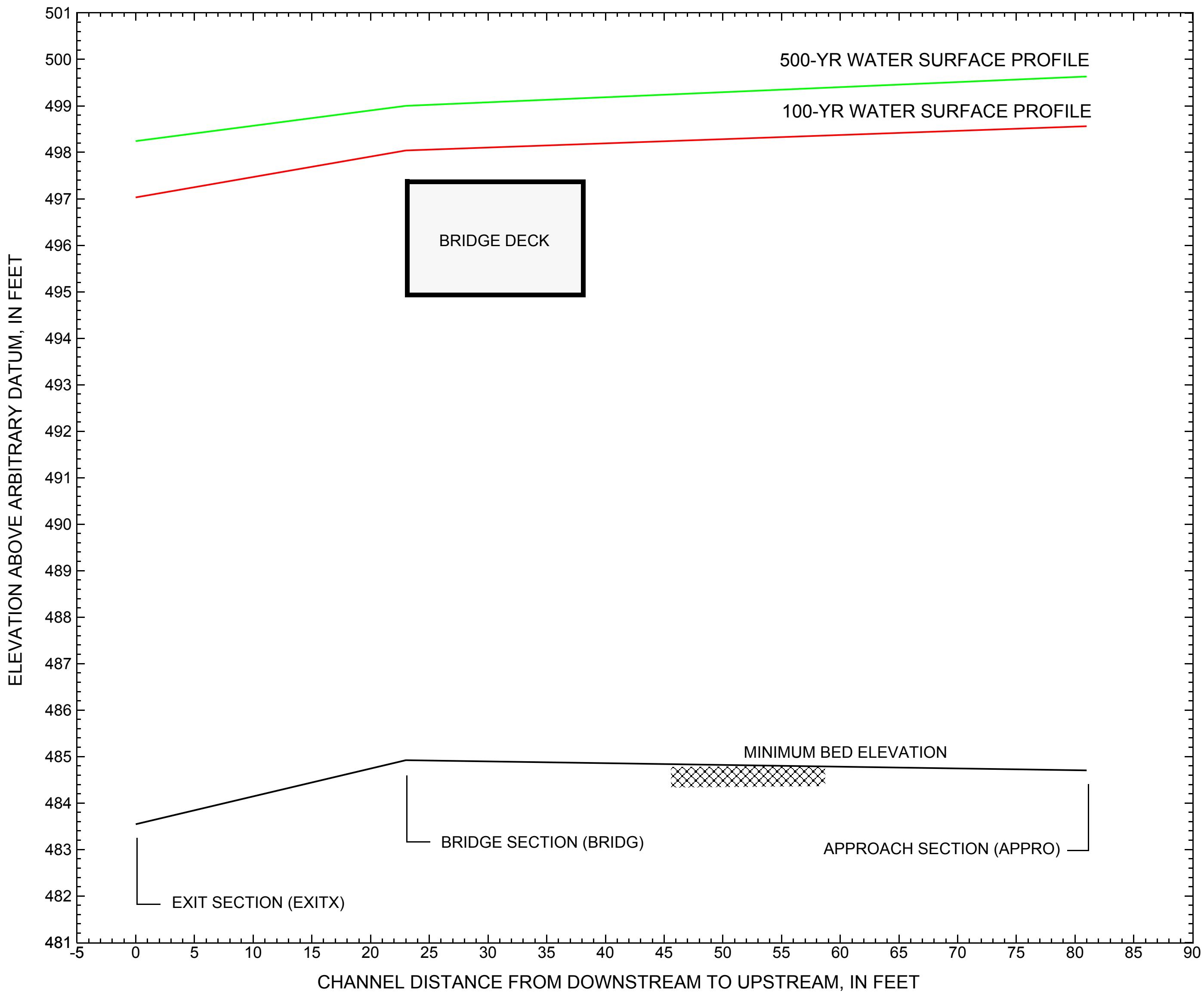

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RANDTH00730039 on town highway 73, crossing the Second Branch White River, Randolph, Vermont.

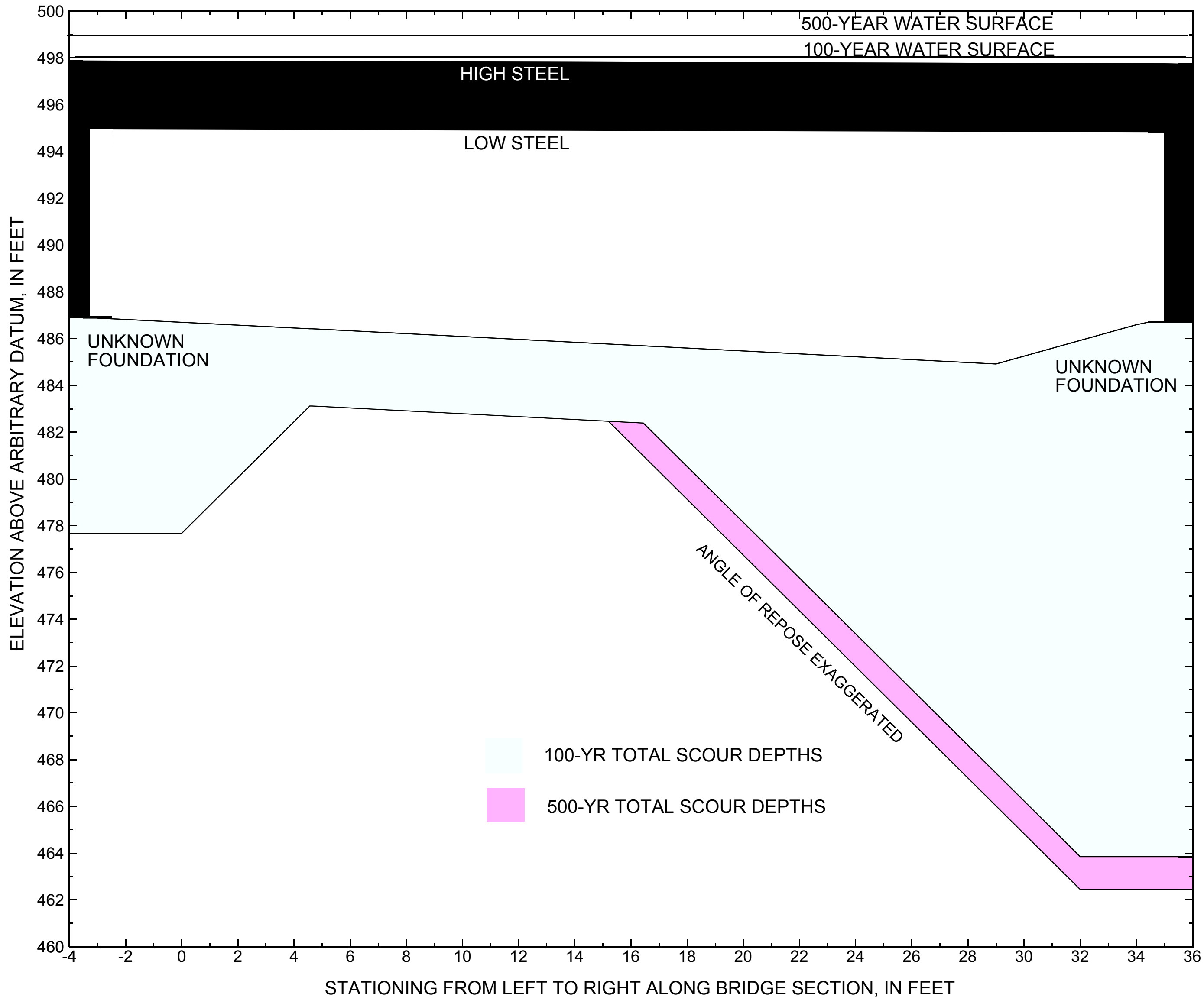

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RANDTH00730039 on town highway 73, crossing the Second Branch White River, Randolph, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RANDTH00730039 on Town Highway 73, crossing the Second Branch White River, Randolph, 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 7,910 cubic-feet per second											
Left abutment	-3	--	495.0	--	486.9	3.3	5.9	--	9.2	477.7	--
Right abutment	35	--	494.8	--	486.8	3.3	19.7	--	23.0	463.8	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure RANDTH00730039 on Town Highway 73, crossing the Second Branch White River, Randolph, 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 11,100 cubic-feet per second											
Left abutment	-3	--	495.0	--	486.9	1.9	6.0	--	7.9	479.0	--
Right abutment	35	--	494.8	--	486.8	1.9	22.5	--	24.4	462.4	--

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

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

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U.S. Geological Survey, 1981, Randolph Center, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE rand039.wsp
T2        CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
T3        SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
J1         * * 0.001
*
Q          7910 11100 1876
SK         0.0008 0.0008 0.0008
*
XS   EXITX     0
GR          -402., 502.81    -375., 494.11    -363., 492.17    -338., 492.06
GR          -292., 490.91    -259., 492.73    -199., 492.83    -128., 492.55
GR           -51., 492.49      -7., 492.49       0., 486.56      13., 486.97
GR            28., 483.54      36., 485.68      39., 491.93      60., 493.71
GR            75., 496.88      89., 497.90     105., 503.71
N             0.036       0.043       0.037
SA                 -7.         39.
*
XS   FULLV   23 * 0.8 * 0.014
*
BR   BRIDG   23 494.9 30
GR            -3., 495.01      -3., 486.88       0., 486.70      29., 484.92
GR            34., 486.59      35., 486.85      35., 494.80      -3., 495.01
CD           1 20.6 * * 42.5 6.6
N           0.035
*
XR   RDWAY   29.5 12.8 2 2.8
GR          -346., 504.08    -328., 499.69    -296., 497.85    -226., 495.52
GR          -156., 494.80     -98., 494.24     -41., 494.84       0., 497.39
GR            43., 497.73      73., 500.28      96., 503.02     117., 504.53
BP           0
*
AS   APPRO          81
GR          -315., 504.91    -295., 500.27    -262., 497.41    -187., 495.31
GR          -148., 493.63     -82., 493.21     -51., 493.11     -34., 492.89
GR           -21., 492.98      -7., 492.29      -4., 486.52       0., 484.99
GR             6., 484.70      30., 486.81      34., 490.70      63., 491.36
GR            92., 495.10     106., 496.65     118., 498.41     126., 501.31
GR           136., 503.62
N           0.035       0.041       0.046
SA                  -7          34
BP           -4 34 32 53
*
HP 1 APPRO 498.56 1 498.56
HP 2 APPRO 498.56 * * 7910
HP 2 RDWAY 498.04 * * 5506
HP 1 BRIDG 495.01 1 495.01
HP 2 BRIDG 495.01 * * 2407
HP 1 APPRO 499.63 1 499.63
HP 2 APPRO 499.63 * * 11100
HP 2 RDWAY 499.00 * * 8950
HP 1 BRIDG 495.01 1 495.01
HP 2 BRIDG 495.01 * * 2314
HP 1 APPRO 494.34 1 494.34
HP 2 APPRO 494.34 * * 1876
HP 1 BRIDG 493.43 1 493.43
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE rand039.wsp
        CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
        SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73
           *** RUN DATE & TIME: 07-11-95 14:24
    CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD =      81.
     WSEL SA#     AREA        K   TOPW   WETP ALPH    LEW    REW     QCR
            1    1089.  118002.   268.   268.                     12457.
            2     508.   90796.    41.    46.                     10132.
            3     423.   39956.    84.    85.                      5372.
   498.56         2020.  248754.   394.   400.  1.23  -275.   118.  23392.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      81.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.56  -275.3   118.4  2019.8  248754.    7910.   3.92

X STA.      -275.3     -182.2     -150.4     -127.2     -105.5      -86.0
  A(I)           188.7      131.6      116.0      110.9      102.7
  V(I)            2.10       3.01       3.41       3.57       3.85

X STA.       -86.0      -66.9      -48.5      -31.2      -14.5       -1.4
  A(I)           102.8       99.9       96.5       94.8      104.9
  V(I)            3.85       3.96       4.10       4.17       3.77

X STA.        -1.4        3.4        7.9       12.4       17.2       22.3
  A(I)            64.9       62.1       61.3       62.9       64.5
  V(I)            6.09       6.37       6.46       6.29       6.13

X STA.        22.3       27.8       36.7       51.1       67.9      118.4
  A(I)            66.7       86.9      109.6      120.9      171.1
  V(I)            5.93       4.55       3.61       3.27       2.31

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      30.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.04  -299.3    46.6   800.6   61825.    5506.   6.88

X STA.      -299.3     -235.6     -215.4     -199.4     -184.8     -171.5
  A(I)            72.5       50.0       43.3       41.9       40.1
  V(I)            3.79       5.51       6.36       6.56       6.87

X STA.      -171.5     -159.4     -148.1     -137.5     -127.5     -118.1
  A(I)            38.1       36.9       35.6       34.8       33.6
  V(I)            7.23       7.47       7.74       7.91       8.20

X STA.      -118.1     -108.9     -100.3      -91.6      -82.8      -73.6
  A(I)            33.4       32.1       32.7       32.5       33.0
  V(I)            8.24       8.57       8.41       8.48       8.33

X STA.       -73.6      -64.1      -53.8      -43.0      -29.9       46.6
  A(I)            33.1       34.9       35.6       38.1       68.5
  V(I)            8.31       7.90       7.74       7.23       4.02

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =      23.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      296.   29612.     0.    82.                           0.
   495.01          296.   29612.     0.    82.  1.00    -3.    35.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =      23.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.01    -3.0    35.0   296.2   29612.    2407.   8.13

X STA.        -3.0        0.4        2.7        4.8        6.7        8.5
  A(I)            24.5       16.4       15.2       14.3       14.0
  V(I)            4.92       7.32       7.91       8.44       8.59

X STA.         8.5       10.3       12.0       13.7       15.4       17.0
  A(I)            13.6       13.3       13.0       13.2       12.9
  V(I)            8.82       9.05       9.26       9.13       9.32

X STA.        17.0       18.6       20.2       21.7       23.3       24.9
  A(I)            12.8       12.9       12.8       13.1       12.8
  V(I)            9.38       9.30       9.43       9.20       9.39

X STA.        24.9       26.4       28.0       29.7       31.6       35.0
  A(I)            13.0       13.5       14.4       15.7       24.7
  V(I)            9.26       8.91       8.38       7.65       4.87
```

WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE rand039.wsp
        CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
        SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73
           *** RUN DATE & TIME: 07-11-95  14:24
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      81.
     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1    1383.  170442.   281.   281.                     17423.
             2     551.  104250.    41.    46.                     11474.
             3     515.   54125.    87.    88.                      7092.
   499.63         2449.  328818.   409.   415.  1.17  -288.   121.  31490.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      81.
         WSEL     LEW     REW    AREA         K        Q     VEL
       499.63  -287.6   121.4  2449.2  328818.   11100.   4.53

X STA.      -287.6     -200.5     -165.3     -141.4     -120.2     -100.9
  A(I)           217.7      160.0      137.0      129.3      120.8
  V(I)            2.55       3.47       4.05       4.29       4.59

X STA.      -100.9      -81.5      -63.4      -45.9      -28.9      -12.4
  A(I)           123.1      116.6      114.2      113.6      111.6
  V(I)            4.51       4.76       4.86       4.89       4.97

X STA.       -12.4       -0.3        5.0       10.2       15.7       21.5
  A(I)           120.6       78.3       77.1       78.7       80.7
  V(I)            4.60       7.09       7.20       7.06       6.88

X STA.        21.5       27.6       38.3       53.2       71.2      121.4
  A(I)            81.2      112.7      128.8      145.3      202.0
  V(I)            6.84       4.93       4.31       3.82       2.75

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      30.
         WSEL     LEW     REW    AREA         K        Q     VEL
       499.00  -316.0    57.9  1146.1  103728.    8950.   7.81

X STA.      -316.0     -250.1     -227.1     -209.5     -194.1     -179.6
  A(I)            99.5       70.1       62.7       57.6       56.4
  V(I)            4.50       6.38       7.14       7.77       7.93

X STA.      -179.6     -166.0     -153.7     -141.8     -130.4     -119.7
  A(I)            54.6       51.1       51.1       49.9       48.0
  V(I)            8.20       8.75       8.75       8.96       9.32

X STA.      -119.7     -109.5      -99.5      -89.6      -79.6      -69.4
  A(I)            47.2       46.7       46.6       46.3       46.1
  V(I)            9.48       9.58       9.60       9.66       9.70

X STA.       -69.4      -58.4      -47.0      -34.3      -15.6       57.9
  A(I)            48.5       48.7       51.5       59.2      104.1
  V(I)            9.22       9.20       8.68       7.56       4.30

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =      23.
     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     296.   29612.     0.    82.                         0.
   495.01          296.   29612.     0.    82.  1.00    -3.    35.     0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =      23.

         WSEL     LEW     REW    AREA         K        Q     VEL
       495.01    -3.0    35.0   296.2   29612.    2314.   7.81

X STA.        -3.0        0.4        2.7        4.8        6.7        8.5
  A(I)            24.5       16.4       15.2       14.3       14.0
  V(I)            4.73       7.04       7.60       8.12       8.26

X STA.         8.5       10.3       12.0       13.7       15.4       17.0
  A(I)            13.6       13.3       13.0       13.2       12.9
  V(I)            8.48       8.70       8.90       8.77       8.96

X STA.        17.0       18.6       20.2       21.7       23.3       24.9
  A(I)            12.8       12.9       12.8       13.1       12.8
  V(I)            9.02       8.94       9.06       8.84       9.02

X STA.        24.9       26.4       28.0       29.7       31.6       35.0
  A(I)            13.0       13.5       14.4       15.7       24.7
  V(I)            8.90       8.57       8.05       7.36       4.68
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE rand039.wsp
        CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
        SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73
           *** RUN DATE & TIME: 07-11-95  14:24
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      81.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     168.    7471.   157.   158.                         985.
             2     334.   45321.    41.    46.                        5422.
             3     130.    7768.    52.    52.                        1171.
   494.34          633.   60560.   251.   256.  1.58  -164.    86.   4546.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      81.
         WSEL     LEW     REW    AREA        K        Q    VEL
       494.34  -164.5    86.1   633.0   60560.    1876.   2.96

X STA.      -164.5      -70.4      -22.3       -2.8       -0.1        2.2
  A(I)            79.9       62.4       49.8       24.6       21.5
  V(I)            1.17       1.50       1.88       3.82       4.36

X STA.         2.2        4.4        6.4        8.5       10.5       12.7
  A(I)            20.2       19.7       19.6       19.4       19.6
  V(I)            4.65       4.76       4.79       4.84       4.79

X STA.        12.7       14.9       17.2       19.6       22.1       24.7
  A(I)            19.7       20.5       20.3       20.8       21.4
  V(I)            4.77       4.58       4.62       4.50       4.39

X STA.        24.7       27.5       30.9       40.8       54.6       86.1
  A(I)            21.9       25.6       40.0       45.7       60.4
  V(I)            4.29       3.66       2.34       2.05       1.55

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =      23.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     248.   32176.    33.    46.                        3856.
   493.43          248.   32176.    33.    46.  1.00    -3.    35.   3856.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =      23.
         WSEL     LEW     REW    AREA        K        Q    VEL
       493.43    -3.0    35.0   247.7   32176.    1876.   7.57

X STA.        -3.0        1.0        3.4        5.4        7.4        9.2
  A(I)            22.9       14.4       12.5       12.0       11.1
  V(I)            4.10       6.52       7.51       7.84       8.43

X STA.         9.2       10.9       12.6       14.2       15.7       17.3
  A(I)            10.9       11.0       10.6       10.2       10.3
  V(I)            8.62       8.56       8.88       9.19       9.08

X STA.        17.3       18.8       20.3       21.7       23.2       24.7
  A(I)            10.2       10.3       10.2       10.2       10.5
  V(I)            9.22       9.12       9.23       9.17       8.97

X STA.        24.7       26.1       27.7       29.3       31.3       35.0
  A(I)            10.7       11.2       11.7       13.8       23.1
  V(I)            8.76       8.35       8.01       6.81       4.05
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WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE rand039.wsp
        CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
        SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73
           *** RUN DATE & TIME: 07-11-95  14:24

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******  -384.    2323.  0.19 *****  497.23  494.40   7910.  497.03
        0. ******    77.  279554.  1.07 ***** *******    0.28    3.41

FULLV:FV      23.  -383.    2184.  0.22  0.02  497.27 *******   7910.  497.05
       23.    23.    74.  254146.  1.08  0.02    0.00    0.30    3.62
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  0.62

APPRO:AS      58.  -249.    1449.  0.63  0.09  497.69 *******   7910.  497.06
       81.    58.   109.  158475.  1.37  0.33    0.00    0.56    5.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                     WS3N,LSEL =   497.05     494.90

            <<<<<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      23.    -3.     296.  1.03 *****  496.04  491.41   2407.  495.01
       23. ******    35.   29612.  1.00 ***** *******    0.51    8.13

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  494.90 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       30.    45.  0.05  0.29  498.80    0.00   5506.  498.04

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   5416.   319.  -299.    20.   3.8   2.5   7.8   6.8   3.2   2.9
   RT:     90.    27.    20.    47.   0.5   0.4   4.5   9.1   1.1   2.8

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS      37.  -275.    2018.  0.29  0.20  498.85  495.59   7910.  498.56
       81.    54.   118.  248511.  1.23  0.00    0.00    0.34    3.92

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW     REW       Q        K      AREA     VEL    WSEL
   EXITX:XS        0.  -384.     77.   7910.  279554.    2323.    3.41  497.03
   FULLV:FV       23.  -383.     74.   7910.  254146.    2184.    3.62  497.05
   BRIDG:BR       23.    -3.     35.   2407.   29612.     296.    8.13  495.01
   RDWAY:RG       30.******* 5416.    5506.******************    2.00  498.04
   APPRO:AS       81.  -275.    118.   7910.  248511.    2018.    3.92  498.56
 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    494.40    0.28  483.54  503.71************  0.19  497.23  497.03
   FULLV:FV  ********    0.30  483.86  504.03  0.02  0.02  0.22  497.27  497.05
   BRIDG:BR    491.41    0.51  484.92  495.01************  1.03  496.04  495.01
   RDWAY:RG  ****************  494.24  504.53  0.05******  0.29  498.80  498.04
   APPRO:AS    495.59    0.34  484.70  504.91  0.20  0.00  0.29  498.85  498.56
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE rand039.wsp
        CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
        SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73
           *** RUN DATE & TIME: 07-11-95  14:24

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******  -388.    2893.  0.24 *****  498.48  494.94  11100.  498.24
        0. ******    90.  392433.  1.05 ***** *******    0.28    3.84

FULLV:FV      23.  -387.    2749.  0.27  0.02  498.53 *******  11100.  498.26
       23.    23.    89.  362143.  1.05  0.02    0.00    0.30    4.04
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.63

APPRO:AS      58.  -272.    1905.  0.66  0.09  498.93 *******  11100.  498.27
       81.    58.   117.  228947.  1.25  0.32    0.00    0.52    5.83
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   498.26     494.90

            <<<<<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      23.     -3.     296.  0.95 *****  495.96  491.27   2314.  495.01
       23. ******    35.   29612.  1.00 ***** *******    0.49    7.81

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  494.90 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      30.    45.  0.05  0.37  499.95    0.00   8783.  499.00

             Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   8473.   336.  -316.    20.   4.8   3.3   8.9   7.7   4.2   2.9
   RT:    311.    38.    20.    58.   1.5   1.1   6.1   7.6   2.0   2.8

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS      37.  -288.    2451.  0.37  0.26  500.01  496.51  11100.  499.63
       81.    56.   121.  329091.  1.17  0.00    0.00    0.35    4.53

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW     REW       Q        K      AREA     VEL    WSEL
   EXITX:XS       0.  -388.     90.  11100.  392433.    2893.    3.84  498.24
   FULLV:FV      23.  -387.     89.  11100.  362143.    2749.    4.04  498.26
   BRIDG:BR      23.    -3.     35.   2314.   29612.     296.    7.81  495.01
   RDWAY:RG      30.*******  8473.   8783.******************    2.00  499.00
   APPRO:AS      81.  -288.    121.  11100.  329091.    2451.    4.53  499.63
 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    494.94    0.28  483.54  503.71************  0.24  498.48  498.24
   FULLV:FV  ********    0.30  483.86  504.03  0.02  0.02  0.27  498.53  498.26
   BRIDG:BR    491.27    0.49  484.92  495.01************  0.95  495.96  495.01
   RDWAY:RG  ***************  494.24  504.53  0.05******  0.37  499.95  499.00
   APPRO:AS    496.51    0.35  484.70  504.91  0.26  0.00  0.37  500.01  499.63
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WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE rand039.wsp
        CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
        SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73
           *** RUN DATE & TIME: 07-11-95  14:24

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******  -373.     856.  0.12 *****  493.87  489.97   1876.  493.75
        0. ******    60.   66280.  1.60 ***** *******    0.35    2.19

FULLV:FV      23.  -371.     722.  0.18  0.02  493.94 *******   1876.  493.76
       23.    23.    57.   54316.  1.72  0.05    0.00    0.46    2.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      58.  -152.     504.  0.33  0.08  494.14 *******   1876.  493.81
       81.    58.    82.   48782.  1.53  0.12    0.00    0.55    3.72
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   494.34       0.00     493.43     494.24

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

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

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
BRIDG:BR      23.    -3.     248.  0.96  0.04  494.39  490.56   1876.  493.43
       23.    23.    35.   32189.  1.08  0.48    0.00    0.51    7.57

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.963 ******  494.90 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      30.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS      37.  -165.     633.  0.22  0.09  494.56  490.12   1876.  494.34
       81.    52.    86.   60609.  1.58  0.07    0.01    0.41    2.96

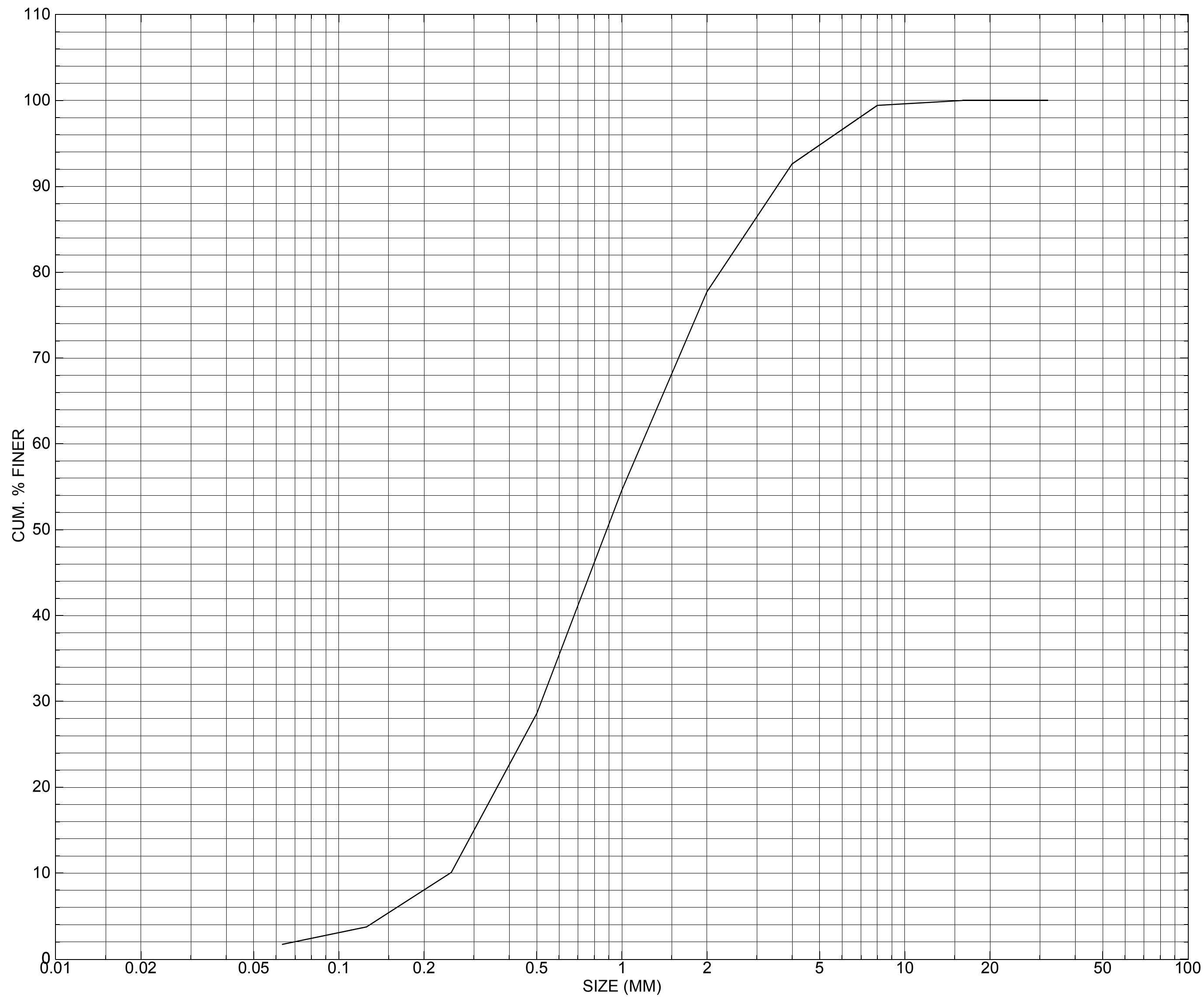
       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.838  0.250   45309.    -7.    31. ********

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS       0.  -373.    60.   1876.   66280.     856.    2.19  493.75
   FULLV:FV      23.  -371.    57.   1876.   54316.     722.    2.60  493.76
   BRIDG:BR      23.    -3.    35.   1876.   32189.     248.    7.57  493.43
   RDWAY:RG      30.**************      0.       0.       0.    2.00********
   APPRO:AS      81.  -165.    86.   1876.   60609.     633.    2.96  494.34
 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS      FR#    YMIN    YMAX    HF     HO   VHD      EGL    WSEL
   EXITX:XS    489.97     0.35  483.54  503.71************  0.12  493.87  493.75
   FULLV:FV  ********     0.46  483.86  504.03  0.02  0.05  0.18  493.94  493.76
   BRIDG:BR    490.56     0.51  484.92  495.01  0.04  0.48  0.96  494.39  493.43
   RDWAY:RG  ****************  494.24  504.53  0.04******  0.22  494.50********
   APPRO:AS    490.12     0.41  484.70  504.91  0.09  0.07  0.22  494.56  494.34
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Bed material particle-size distributions for five samples taken at the approach cross-section and combined for structure RANDTH00730039, in Randolph, Vermont

APPENDIX D:

HISTORICAL DATA FORM