LEVEL II SCOUR ANALYSIS FOR BRIDGE 31 (ALBATH00380031) on TOWN HIGHWAY 38, crossing the BLACK RIVER, ALBANY, VERMONT

U.S. Geological Survey
Open-File Report 96-196

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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By Erick M. Boehmler

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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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CONTENTS

FIGURES

TABLES

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 31 (ALBATH00380031) ON TOWN HIGHWAY 38, CROSSING THE BLACK RIVER, ALBANY, VERMONT

By **Erick M. Boehmler**

INTRODUCTION

This report provides the results of a detailed Level II analysis of scour potential at structure ALBATH00380031 on town highway 38 crossing the Black River, Albany, 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, gleaned 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 New England Upland physiographic province of North-central Vermont in the town of Albany. The 47.5-mi^2 drainage area is in a rural, forested basin. In the vicinity of the study site, the immediate banks have mainly shrub and brush vegetation. The overbank areas are pasture, except for the upstream right bank which is forested.

In the study area, the Black River has a meandering channel with a slope of approximately 0.0009 ft/ft, an average channel top width of 57 ft and an average channel depth of 3 ft. The predominant channel bed material is gravel (D_{50} is 35.4 mm or 0.116 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 5, 1994, indicated that the reach was stable.

The town highway 38 crossing of the Black River is a 50-ft-long, one-lane bridge consisting of one 47-foot span concrete T-beam type superstructure (Vermont Agency of Transportation, written commun., August 3, 1994). The bridge is supported by vertical abutments with wingwalls. The left abutment is constructed of concrete while the right is mortared, granite stone blocks. The channel is skewed approximately 30 degrees to the opening while the opening-skew-to-roadway is 10 degrees.

A scour hole, 1.5 ft deeper than the mean thalweg depth, was observed during the level I assessment along the left side of the channel under the bridge. The only scour protection measure at the site was type-3 stone fill (less than 48 inches diameter) along the left bank under the bridge. 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.

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 ALBATH00380031 ***Stream*** Black River

County Orleans ***Road*** TH 38 ***District*** 09

Description of Bridge

Bridge length 50 ***ft*** ***Bridge width*** 14.3 ***ft*** ***Max span length*** 47 ***ft***

Alignment of bridge to road (on curve or straight) Left, Straight; Right, Curve

Abutment type Vertical ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 10/05/94

Description of stone fill Type-3, along the left bank under the bridge also protects the left abutment.

Left abutment is concrete with no wingwalls, the right abutment and its wingwalls are mortared, granite stone blocks.

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

There is a mild channel bend in the upstream reach.

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	10/05/94	0	0
Level II	10/05/94	--	--

Potential for debris Moderate. While there is significant tree coverage on the right bank upstream, the banks upstream are more stable than downstream.

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

The large pile of stone fill on the left abutment significantly constricts the channel and may be inducing the channel scour evident under the bridge noted on 10/05/94.

Description of the Geomorphic Setting

General topography The channel is located within a 600 foot-wide, flat to slightly irregular flood plain with moderately sloping valley walls on both sides.

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

Date of inspection 10/05/94

DS left: Moderately sloping channel bank to a gently sloping, irregular flood plain.

DS right: Gently sloping bank to gently sloping, irregular flood plain.

US left: Gently sloping bank to gently sloping, irregular flood plain.

US right: Gently sloping bank to narrow, gently sloping flood plain.

Description of the Channel

Average top width 57 ***ft*** ***Average depth*** 2.5 ***ft***

Predominant bed material Gravel ***Bank material*** Silt and Clay

meandering but stable with semi-alluvial to alluvial channel boundaries and a wide flood plain.

10/05/94

Vegetative co Shrubs and brush

DS left: Shrubs and brush

DS right: Grass

US left: Forest with shrubs and brush undergrowth.

US right: Y

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

The assessment of 10/05/94 noted flow through the bridge is significantly influenced by the pile of stone fill on the left abutment.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 47.5 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province	***Percent of drainage area***
New England Upland	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None.

Is there a USGS gage on the stream of interest? Yes

USGS gage description Black River at Coventry, VT

USGS gage number 04296000

Gage drainage area 122 ***mi²***

Is there a lake/p _ No

Calculated Discharges

Q100 2600 ***ft³/s*** ***Q500*** 3530 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(47.5/122.)exp 0.5] with the gaged area above Coventry, VT. The exponent in the drainage relationship was computed based on gaged records and VTAOT database values of the Q100 at bridge 23 in Craftsbury. The drainage area used above bridge number 23 is 30.9 square miles.

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 DS end of the left abutment (elev. 101.51 ft, arbitrary datum). RM2 is a chiseled "X" on top of the US end of the right abutment (elev. 101.61 ft, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-47	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	59	1	Approach section

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

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). 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 were 0.040, and overbank "n" values ranged from 0.030 to 0.090.

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 0.0009 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed approach section was approximately 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.

The modeled 100- and 500-year discharges overtop the roadway embankments but not the bridge deck. The incipient roadway overtopping discharge was 2,496 cfs.

Bridge Hydraulics Summary

Average bridge embankment elevation 101.6 *ft*
Average low steel elevation 99.2 *ft*

100-year discharge 2,600 *ft³/s*
Water-surface elevation in bridge opening 99.2 *ft*
Road overtopping? Y *Discharge over road* 218 *ft³/s*
Area of flow in bridge opening 356 *ft²*
Average velocity in bridge opening 6.7 *ft/s*
Maximum WSPRO tube velocity at bridge 8.0 *ft/s*

Water-surface elevation at Approach section with bridge 100.1 *ft*
Water-surface elevation at Approach section without bridge 98.2 *ft*
Amount of backwater caused by bridge 1.9 *ft*

500-year discharge 3,530 *ft³/s*
Water-surface elevation in bridge opening 99.2 *ft*
Road overtopping? Y *Discharge over road* 633 *ft³/s*
Area of flow in bridge opening 356 *ft²*
Average velocity in bridge opening 8.2 *ft/s*
Maximum WSPRO tube velocity at bridge 9.8 *ft/s*

Water-surface elevation at Approach section with bridge 100.7 *ft*
Water-surface elevation at Approach section without bridge 98.9 *ft*
Amount of backwater caused by bridge 1.8 *ft*

Incipient overtopping discharge 2,496 *ft³/s*
Water-surface elevation in bridge opening 97.5 *ft*
Area of flow in bridge opening 287 *ft²*
Average velocity in bridge opening 8.7 *ft/s*
Maximum WSPRO tube velocity at bridge 10.8 *ft/s*

Water-surface elevation at Approach section with bridge 99.2 *ft*
Water-surface elevation at Approach section without bridge 98.1 *ft*
Amount of backwater caused by bridge 1.1 *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.

The 100-year and 500-year discharges 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). Therefore, contraction scour for these two discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1993, p. 35, equation 18) for the incipient road-overflow discharge. 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. In this case, the incipient road-overflow model resulted in the worst case contraction scour with a scour depth of 0.6 ft. However, it was not the worst case total scour.

Abutment scour for the right abutment at all modelled discharges 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 for all modeled discharges 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	--	--	--
Clear-water scour	0.0	0.5	0.6
Depth to armoring	0.5	2.1	4.2
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	11.7	12.4	12.1
Right abutment	8.7	9.0	9.8
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	0.9	1.3	2.0
Right abutment	0.9	1.3	2.0
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

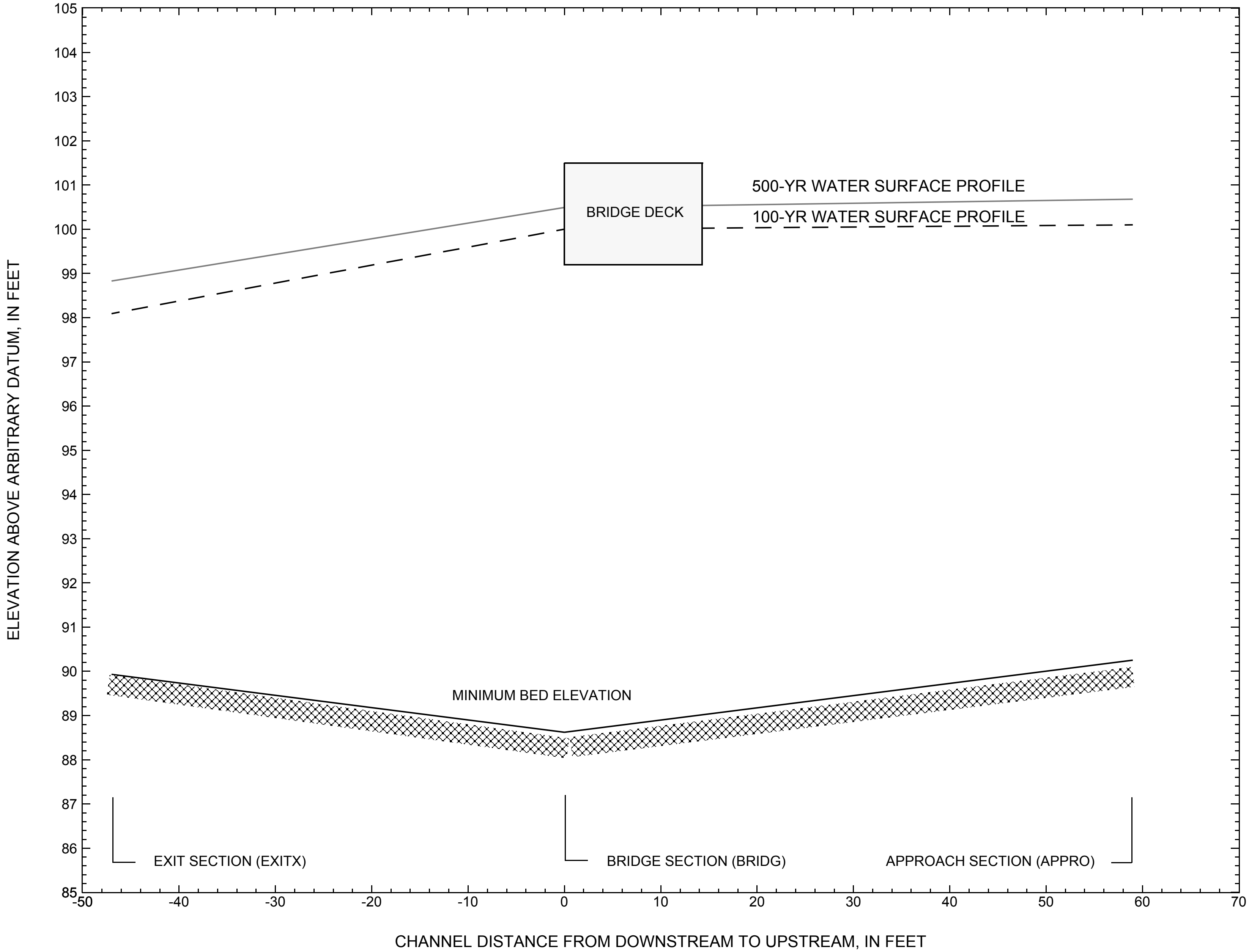

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ALBATH00380031 on town highway 38, crossing the Black River, Albany, Vermont.

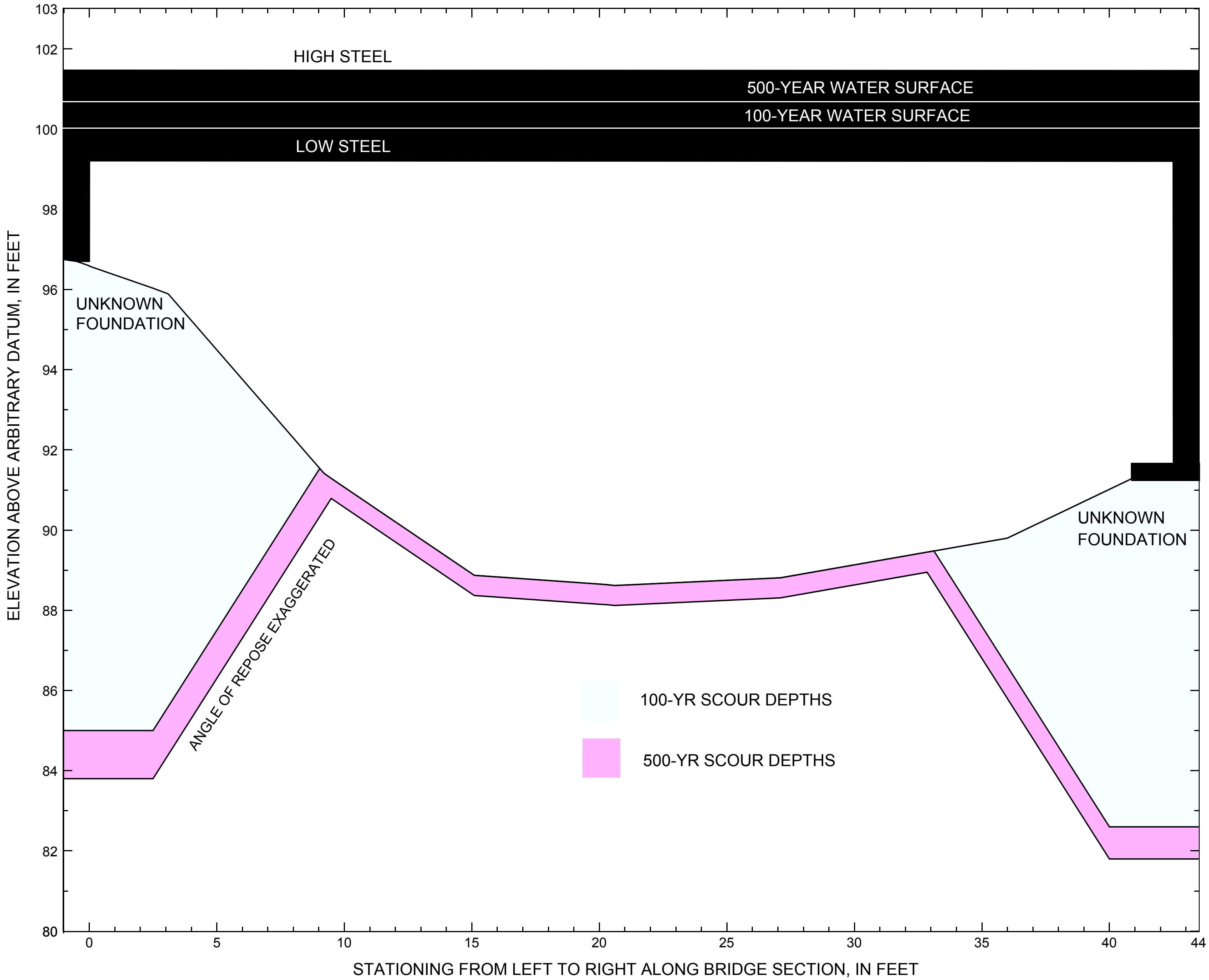

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ALBATH00380031 on town highway 38, crossing the Black River, Albany, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ALBATH00380031 on Town Highway 38, crossing the Black River, Albany, 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 2,600 cubic-feet per second											
Left abutment	0.0	--	99.2	--	96.7	0.0	11.7	--	11.7	85.0	--
Right abutment	42.5	--	99.2	--	91.3	0.0	8.7	--	8.7	82.6	--

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 ALBATH00380031 on Town Highway 38, crossing the Black River, Albany, 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 3,530 cubic-feet per second											
Left abutment	0.0	--	99.2	--	96.7	0.5	12.4	--	12.9	83.8	--
Right abutment	42.5	--	99.2	--	91.3	0.5	9.0	--	9.5	81.8	--

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. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File alba031.wsp
T2        Hydraulic analysis for structure ALBATH00380031   Date: 25-JAN-96
T3        Town Highway 38 Bridge Crossing the Black River, Albany, VT        EMB
Q           2600.0,   3530.0,  2496.0
SK          0.0009,   0.0009,  0.0009
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -47
GR         -298.0, 114.85   -269.8, 100.43   -146.0,  97.69    -67.8,  95.98
GR          -16.9,  95.74     -3.4,  94.96      0.0,  92.28     10.8,  91.55
GR           17.1,  90.33     25.1,  89.93     37.0,  90.11     53.5,  91.52
GR           60.6,  93.67     80.5,  95.21    158.7,  97.52    293.1,  99.15
*
N             0.035       0.040         0.035
SA                  -3.4          60.6
*
*            The exit channel points only were lowered by 1.34 feet due to
*            channel scouring at the bridge section.
XS   FULLV      0
GR         -298.0, 114.85   -269.8, 100.43   -146.0,  97.69    -67.8,  95.98
GR          -16.9,  95.74     -3.4,  94.96      0.0,  90.94     10.8,  90.20
GR           17.1,  88.98     25.1,  88.58     37.0,  88.76     53.5,  90.18
GR           60.6,  92.32     80.5,  95.21    158.7,  97.52    293.1,  99.15
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0      99.2      10.0
GR            0.0,  99.24      0.1,  96.72      3.1,  95.89      9.2,  91.42
GR           15.1,  88.87     20.6,  88.62     27.1,  88.81     36.0,  89.80
GR           41.0,  91.32     41.5,  91.55     42.3,  91.65     42.5,  99.16
GR            0.0,  99.24
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      22.6 * *     19.5     8.2
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      14.3     2
GR         -336.0, 112.19   -255.2, 102.06   -164.9,  99.51    -80.9,  99.19
GR          -42.2, 100.08      0.0, 101.49     24.5, 101.71     48.9, 101.45
GR           78.0, 101.09    111.4, 100.35    139.5, 100.25    209.2, 102.30
*
AS   APPRO     59
GR         -384.3, 109.71   -367.6, 101.41   -208.5,  98.58   -141.2,  96.16
GR            0.0,  94.71     15.5,  91.56     17.5,  91.01     25.1,  90.63
GR           30.6,  90.25     36.2,  90.29     48.9,  91.41     50.3,  93.17
GR           88.0,  99.50    135.9, 100.64    212.0, 102.45
*
N           0.030        0.040        0.090
SA                   0.0          50.3
*
HP 1 BRIDG    99.24 1  99.24
HP 2 BRIDG    99.24 * * 2395
HP 2 RDWAY    99.99 * *  218
HP 1 APPRO   100.10 1 100.10
HP 2 APPRO   100.10 * * 2600
*
HP 1 BRIDG    99.24 1  99.24
HP 2 BRIDG    99.24 * * 2937
HP 2 RDWAY   100.49 * *  633
HP 1 APPRO   100.68 1 100.68
HP 2 APPRO   100.68 * * 3530
*
HP 1 BRIDG    97.49 1  97.49
HP 2 BRIDG    97.49 * * 2496
HP 1 APPRO    99.21 1  99.21
HP 2 APPRO    99.21 * * 2496
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

           *** RUN DATE & TIME: 02-14-96  10:58

  T1        U.S. Geological Survey WSPRO Input File alba031.wsp
  T2        Hydraulic analysis for structure ALBATH00380031   Date: 25-JAN-96
  T3        Town Highway 38 Bridge Crossing the Black River, Albany, VT        EMB

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
             1      356     31799     0    96                            0
   99.24            356     31799     0    96  1.00      0     43        0

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
        99.24     0.0    42.5   356.1   31799.    2395.   6.73
X STA.         0.0        7.8       10.7       12.9       14.8       16.4
  A(I)            31.6       22.1       19.2       17.5       16.5
  V(I)            3.79       5.41       6.25       6.84       7.28

X STA.        16.4       17.9       19.4       20.9       22.4       23.8
  A(I)            15.7       15.6       15.2       15.0       14.9
  V(I)            7.64       7.68       7.89       7.99       8.02

X STA.        23.8       25.3       26.7       28.2       29.7       31.3
  A(I)            15.0       14.9       15.0       15.3       15.6
  V(I)            7.99       8.02       7.99       7.85       7.70

X STA.        31.3       33.0       34.7       36.6       38.8       42.5
  A(I)            15.9       16.5       17.0       19.4       28.4
  V(I)            7.55       7.25       7.03       6.18       4.21

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.
         WSEL     LEW     REW    AREA        K        Q    VEL
        99.99  -181.9   -46.1    71.8    1996.     218.   3.04
X STA.      -181.9     -161.6     -153.6     -146.6     -140.1     -134.0
  A(I)             5.7        4.1        3.8        3.6        3.6
  V(I)            1.92       2.67       2.91       2.99       3.04

X STA.      -134.0     -128.5     -123.1     -118.2     -113.4     -108.8
  A(I)             3.3        3.4        3.2        3.2        3.1
  V(I)            3.26       3.22       3.42       3.38       3.50

X STA.      -108.8     -104.4     -100.2      -96.1      -92.1      -88.1
  A(I)             3.1        3.1        3.0        3.0        3.0
  V(I)            3.54       3.57       3.65       3.58       3.59

X STA.       -88.1      -84.1      -80.1      -75.4      -68.7      -46.1
  A(I)             3.1        3.2        3.4        4.0        5.8
  V(I)            3.53       3.40       3.19       2.71       1.87

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
     WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
             1      907     95527   294   294                         9046
             2      433     66518    50    52                         7202
             3      150      4383    63    63                         1308
   100.10          1490    166428   407   409  1.27   -293    113    14357

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
         WSEL     LEW     REW    AREA        K        Q    VEL
       100.10  -294.0   113.2  1489.6  166428.    2600.   1.75
X STA.      -294.0     -168.2     -139.1     -118.0      -99.8      -82.9
  A(I)           155.4      101.4       85.8       78.0       75.4
  V(I)            0.84       1.28       1.51       1.67       1.72

X STA.       -82.9      -67.8      -53.7      -40.3      -28.0      -16.4
  A(I)            69.5       67.0       65.8       62.1       59.8
  V(I)            1.87       1.94       1.97       2.09       2.17

X STA.       -16.4       -5.1        6.2       14.3       20.4       25.8
  A(I)            59.6       64.6       61.0       53.7       51.0
  V(I)            2.18       2.01       2.13       2.42       2.55

X STA.        25.8       30.8       35.9       41.1       46.9      113.2
  A(I)            48.3       50.2       49.6       53.0      178.2
  V(I)            2.69       2.59       2.62       2.45       0.73
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    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      356     31799      0     96                            0
    99.24           356     31799      0     96  1.00      0     43        0

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
        99.24     0.0    42.5   356.1   31799.    2937.   8.25
X STA.         0.0        7.8       10.7       12.9       14.8       16.4
  A(I)             31.6       22.1       19.2       17.5       16.5
  V(I)             4.65       6.63       7.67       8.39       8.93

X STA.        16.4       17.9       19.4       20.9       22.4       23.8
  A(I)             15.7       15.6       15.2       15.0       14.9
  V(I)             9.37       9.42       9.68       9.80       9.84

X STA.        23.8       25.3       26.7       28.2       29.7       31.3
  A(I)             15.0       14.9       15.0       15.3       15.6
  V(I)             9.80       9.84       9.79       9.62       9.44

X STA.        31.3       33.0       34.7       36.6       38.8       42.5
  A(I)             15.9       16.5       17.0       19.4       28.4
  V(I)             9.26       8.89       8.63       7.58       5.17

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.
         WSEL     LEW     REW    AREA        K        Q    VEL
       100.49  -199.6   147.7   155.1    5859.     633.   4.08
X STA.      -199.6     -169.5     -160.7     -153.0     -145.9     -139.4
  A(I)             12.8        8.4        7.8        7.3        7.0
  V(I)             2.48       3.78       4.06       4.33       4.51

X STA.      -139.4     -133.0     -127.0     -121.2     -115.5     -110.1
  A(I)              7.0        6.7        6.6        6.5        6.4
  V(I)             4.53       4.75       4.80       4.86       4.92

X STA.      -110.1     -104.7      -99.6      -94.4      -89.3      -84.3
  A(I)              6.4        6.3        6.4        6.4        6.4
  V(I)             4.94       5.02       4.98       4.93       4.92

X STA.       -84.3      -79.2      -73.3      -65.9      -55.2      147.7
  A(I)              6.5        7.0        7.7        8.9       16.6
  V(I)             4.85       4.51       4.10       3.55       1.91

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     1087    120399    327    327                        11259
             2      462     74160     50     52                         7942
             3      193      5404     87     88                         1629
   100.68          1742    199963    464    466  1.29   -326    138    16878

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
         WSEL     LEW     REW    AREA        K        Q    VEL
       100.68  -326.6   137.6  1742.3  199963.    3530.   2.03
X STA.      -326.6     -184.3     -150.9     -129.0     -109.5      -92.3
  A(I)            185.3      119.1       98.4       92.2       84.9
  V(I)             0.95       1.48       1.79       1.91       2.08

X STA.       -92.3      -76.6      -62.0      -48.3      -35.3      -23.1
  A(I)             80.0       77.0       73.9       72.0       69.3
  V(I)             2.21       2.29       2.39       2.45       2.55

X STA.       -23.1      -11.5       -0.5       10.5       17.8       23.7
  A(I)             67.4       64.6       76.9       65.3       57.5
  V(I)             2.62       2.73       2.29       2.70       3.07

X STA.        23.7       29.4       34.9       40.6       46.6      137.6
  A(I)             58.3       56.6       58.6       58.3      226.6
  V(I)             3.03       3.12       3.01       3.03       0.78
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WSPRO OUTPUT FILE (continued)

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    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      287     33918     42     51                         4264
    97.49           287     33918     42     51  1.00      0     42     4264

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
        97.49     0.1    42.5   286.7  33918.   2496.   8.71
X STA.        0.1        9.3       11.9       14.0       15.6       17.1
  A(I)           27.2       17.3       15.3       13.7       12.8
  V(I)           4.59       7.20       8.17       9.14       9.73

X STA.       17.1       18.5       19.9       21.3       22.6       24.0
  A(I)           12.5       12.1       11.8       11.6       11.5
  V(I)          10.02      10.32      10.61      10.77      10.81

X STA.       24.0       25.3       26.7       28.1       29.5       31.0
  A(I)           11.6       11.6       12.0       11.9       12.2
  V(I)          10.73      10.78      10.37      10.45      10.27

X STA.       31.0       32.6       34.2       36.1       38.3       42.5
  A(I)           12.7       13.3       14.2       16.2       25.3
  V(I)           9.84       9.41       8.81       7.70       4.93

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      668     64936    244    244                         6273
             2      388     55449     50     52                         6113
             3      109      3723     36     36                         1071
    99.21          1165    124107    330    332  1.24   -243     86    11136

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
         WSEL     LEW     REW    AREA        K        Q    VEL
        99.21  -243.9    86.3  1164.6  124107.   2496.   2.14
X STA.     -243.9     -146.8     -122.5     -102.7      -85.2      -68.9
  A(I)          118.3       75.6       66.0       62.1       60.4
  V(I)           1.05       1.65       1.89       2.01       2.07

X STA.      -68.9      -54.4      -40.9      -28.0      -16.1       -5.0
  A(I)           56.0       54.2       53.5       50.7       48.9
  V(I)           2.23       2.30       2.33       2.46       2.55

X STA.       -5.0        6.4       13.9       19.4       24.2       28.9
  A(I)           55.1       49.4       43.8       40.3       40.2
  V(I)           2.26       2.53       2.85       3.09       3.11

X STA.       28.9       33.2       37.7       42.3       47.4       86.3
  A(I)           38.6       40.1       39.6       41.7      130.0
  V(I)           3.23       3.11       3.15       2.99       0.96
  EX

+++ BEGINNING PROFILE CALCULATIONS --   3

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

EXITX:XS   ******   -163      919  0.19 *****   98.28   94.95    2600   98.09
       -46 ******    206    86633  1.50 ***** *******    0.39    2.83

FULLV:FV       47   -166     1043  0.15  0.03   98.31 *******    2600   98.16
         0     47    212   109698  1.56  0.00    0.00    0.33    2.49
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       59   -197      858  0.18  0.04   98.37 *******    2600   98.19
        59     59     80    84134  1.26  0.01    0.00    0.34    3.03
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =     99.39       0.00      97.57      99.19

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =    97.58      99.31      99.38      99.20

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
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WSPRO OUTPUT FILE (continued)

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           <<<<<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       47      0      356  0.70 *****   99.94   95.03    2395   99.24
         0 ******     43    31799  1.00 ***** *******    0.41    6.73

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.371  0.000   99.20 ****** ****** ******

   XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
  RDWAY:RG       8.    45.  0.01  0.06  100.15    0.01    218.   99.99

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
  LT:    218.   136.  -182.   -46.   0.8   0.5   3.5   3.0   0.7   2.8
  RT:      0.    24.   118.   142.   0.1   0.0   2.0   9.3   0.3   2.6

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

APPRO:AS       36   -293     1491  0.06  0.05  100.16   96.38    2600  100.10
        59     46    113   166599  1.27  0.13    0.01    0.18    1.74
       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

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

  FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
  EXITX:XS     -47.  -164.   206.   2600.   86633.     919.    2.83   98.09
  FULLV:FV       0.  -167.   212.   2600.  109698.    1043.    2.49   98.16
  BRIDG:BR       0.     0.    43.   2395.   31799.     356.    6.73   99.24
  RDWAY:RG       8.*******   218.    218.*********       0.    2.00   99.99
  APPRO:AS      59.  -294.   113.   2600.  166599.    1491.    1.74  100.10

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

 SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
  EXITX:XS     94.95    0.39   89.93  114.85************  0.19   98.28   98.09
  FULLV:FV  ********    0.33   88.58  114.85  0.03  0.00  0.15   98.31   98.16
  BRIDG:BR     95.03    0.41   88.62   99.24************  0.70   99.94   99.24
  RDWAY:RG  ****************   99.19  112.19  0.01******  0.06  100.15   99.99
  APPRO:AS     96.38    0.18   90.25  109.71  0.05  0.13  0.06  100.16  100.10

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

EXITX:XS   ******   -197     1228  0.20 *****   99.03   96.33    3530   98.83
       -46 ******    267   117621  1.52 ***** *******    0.38    2.87

FULLV:FV       47   -199     1356  0.17  0.03   99.06 *******    3530   98.90
         0     47    272   142525  1.60  0.00    0.00    0.34    2.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       59   -227     1071  0.21  0.05   99.13 *******    3530   98.92
        59     59     85   112050  1.24  0.02    0.00    0.35    3.30
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   100.87       0.00      98.11      99.19

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =    98.56     100.45     100.52      99.20

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

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
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 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR       47      0      356  1.06 *****  100.30   95.80    2937   99.24
         0 ******     43    31799  1.00 ***** *******    0.50    8.25

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.432  0.000   99.20 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    45.  0.01  0.08  100.75    0.01    633.  100.49

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    603.   169.  -199.   -30.   1.3   0.9   4.7   4.1   1.1   3.0
   RT:     30.    42.   105.   148.   0.2   0.2   2.6   4.6   0.4   2.7

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

APPRO:AS       36   -325     1741  0.08  0.08  100.76   96.84    3530  100.68
        59     48    137   199836  1.29  0.12    0.01    0.21    2.03

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -47.  -198.   267.   3530.  117621.    1228.    2.87   98.83
   FULLV:FV       0.  -200.   272.   3530.  142525.    1356.    2.60   98.90
   BRIDG:BR       0.     0.    43.   2937.   31799.     356.    8.25   99.24
   RDWAY:RG       8.*******   603.    633.*****************    2.00  100.49
   APPRO:AS      59.  -326.   137.   3530.  199836.    1741.    2.03  100.68

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     96.33    0.38   89.93  114.85************  0.20   99.03   98.83
   FULLV:FV  ********    0.34   88.58  114.85  0.03  0.00  0.17   99.06   98.90
   BRIDG:BR     95.80    0.50   88.62   99.24************  1.06  100.30   99.24
   RDWAY:RG  ****************   99.19  112.19  0.01******  0.08  100.75  100.49
   APPRO:AS     96.84    0.21   90.25  109.71  0.08  0.12  0.08  100.76  100.68


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

EXITX:XS   ******   -159      883  0.19 *****   98.18   94.83    2496   97.99
       -46 ******    198    83120  1.50 ***** *******    0.39    2.83

FULLV:FV       47   -162     1006  0.15  0.03   98.21 *******    2496   98.06
         0     47    203   105942  1.55  0.00    0.00    0.33    2.48
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       59   -194      830  0.18  0.04   98.27 *******    2496   98.09
        59     59     80    80527  1.27  0.01    0.00    0.34    3.01
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =     99.21       0.00      97.49      99.19

 ===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       47      0      287  1.62  0.10   99.11   95.18    2496   97.49
         0     47     42    33896  1.37  0.83    0.00    0.69    8.71
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     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.853 ******   99.20 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<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       36   -243     1165  0.09  0.07   99.30   96.32    2496   99.21
       59     46     86   124123  1.24  0.12    0.00    0.22    2.14

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.845  0.703   36849.   -13.    30. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -47.  -160.   198.   2496.   83120.     883.    2.83   97.99
   FULLV:FV       0.  -163.   203.   2496.  105942.    1006.    2.48   98.06
   BRIDG:BR       0.     0.    42.   2496.   33896.     287.    8.71   97.49
   RDWAY:RG       8.**************      0.       0.       0.    2.00********
   APPRO:AS      59.  -244.    86.   2496.  124123.    1165.    2.14   99.21

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -13.    30.   36849.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO   VHD      EGL    WSEL
   EXITX:XS     94.83    0.39   89.93  114.85************  0.19    98.18   97.99
   FULLV:FV  ********    0.33   88.58  114.85  0.03  0.00  0.15    98.21   98.06
   BRIDG:BR     95.18    0.69   88.62   99.24  0.10  0.83  1.62    99.11   97.49
   RDWAY:RG  ****************   99.19  112.19  0.02******  0.09    99.28********
   APPRO:AS     96.32    0.22   90.25  109.71  0.07  0.12  0.09    99.30   99.21
  ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```
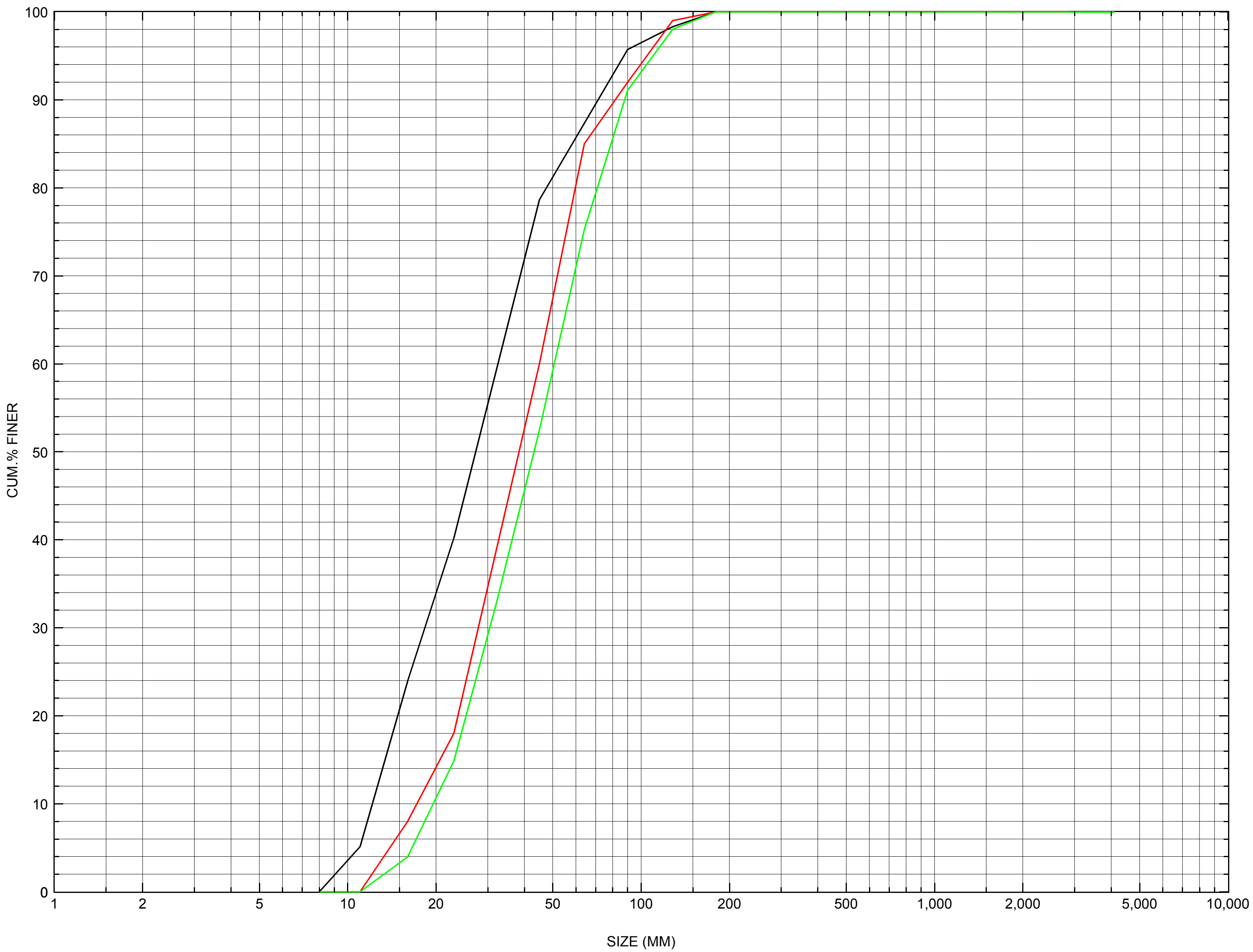

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure ALBATH00380031, in Albany, Vermont.

APPENDIX D:

HISTORICAL DATA FORM