LEVEL II SCOUR ANALYSIS FOR BRIDGE 46 (CHELTH00680046) on TOWN HIGHWAY 68, crossing the FIRST BRANCH of the WHITE RIVER, CHELSEA, VERMONT

U.S. Geological Survey
Open-File Report 96-406

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

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By MICHAEL A. IVANOFF and DONALD L. SONG

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Pembroke, New Hampshire

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U.S. DEPARTMENT OF THE INTERIOR
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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 46 (CHELTH00680046) ON TOWN HIGHWAY 68, CROSSING THE FIRST BRANCH OF THE WHITE RIVER, CHELSEA, VERMONT

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

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHELTH00680046 on town highway 68 crossing the First Branch of the White River, Chelsea, 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). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province of central Vermont in the town of Chelsea. The 58.2-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the banks have dense woody vegetation coverage.

In the study area, the First Branch of the White River has a sinuous channel with a slope of approximately 0.0054 ft/ft, an average channel top width of 92 ft and an average channel depth of 4 ft. The predominant channel bed material is gravel and cobble (D_{50} is 52.7 mm or 0.173 ft). The geomorphic assessment at the time of the Level I and Level II site visit on November 16, 1994, indicated that the reach was stable.

The town highway 68 crossing of the First Branch of the White River is a 61-ft-long, one-lane covered bridge with a 52-foot clear-span (Vermont Agency of Transportation, written commun., August 26, 1994). The bridge is supported by vertical, stone abutments with a concrete wingwall on the downstream right. The left abutment is laid-up stone supported by concrete at the upstream and downstream ends of the laid-up stone abutment. The channel is skewed approximately 40 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed under the bridge during the Level I assessment. The scour protection measures in place at the site were type-2 stone fill (less than 36 inches diameter) at the road approach embankments except the downstream left embankment which had no protection. The upstream right road embankment, impacted by the channel bend, has an extensive covering of stone fill for erosion protection. Type-3 stone fill (less than 48 inches diameter) was noted along the right abutment. 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, 1995).
Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.9 to 2.6 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 14.3 to 24.0 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The left abutment sits atop a bedrock outcrop. The results of the calculated scour depths will be limited by the bedrock.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Chelsea, VT. Quadrangle, 1:24,000, 1981

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 CHELTH00680046 *Stream* First Branch of the White River

County Orange *Road* TH 68 *District* 04

Description of Bridge

Bridge length 61 *ft* *Bridge width* 14.6 *ft* *Max span length* 52 *ft*

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

Abutment type Vertical *Embankment type* Sloping

Stone fill on abutment? Yes, on right *Date of inspection* 11/16/94

Description of stone fill Type-2, at the road approach embankments except the downstream left embankment which had none. Type-3 stone fill was along the right abutment.

Abutments are "laid-up" stone with concrete supporting the ends of the left abutment. The left abutment sets on bedrock. The downstream right wingwall is concrete.

Yes

40 Yes

Is bridge skewed to flood flow according to The *survey?* *Angle*

bridge is at a sharp channel bend. A scour hole has developed under the bridge between bedrock and stone fill respectively at the left and right abutment.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	11/16/94	0	0
Level II	11/16/94	--	--

Potential for debris Moderate. There is some debris along the banks and trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) The left abutment sits atop a bedrock outcrop extending 14 feet into the channel -- 11/16/94.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley with irregular narrow flood plains and steep valley walls on both sides.

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

Date of inspection 11/16/94

DS left: Moderately sloped channel bank to narrow floodplain

DS right: Steep valley wall

US left: Steep valley wall

US right: Moderately sloped channel bank to narrow floodplain

Description of the Channel

Average top width 92 ***ft***

Average depth 4 ***ft***

Predominant bed material Gravel / Cobbles

Bank material Gravel/Cobbles

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

11/21/94

Vegetative co Trees and brush

DS left: Trees

DS right: Trees

US left: Trees and brush

US right: Yes

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

Stable but there is evidence of lateral movement with cut-banks upstream and downstream of the bridge. There are bedrock outcrops under the bridge and downstream along the left bank. Due to extensive stone fill protection on the upstream right embankment, there are likely historical scour problems at this impact zone.

The assessment of 11/16/94 noted flow conditions up to bank-full level are influenced by bedrock outcrops on the left bank side of the channel under the left abutment and downstream. In addition, some debris are along the channel upstream.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 58.2 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England / Green Mountain	100

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

Is there a USGS gage on the stream of interest?

USGS gage description

USGS gage number

Gage drainage area ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 7,900 ***ft³/s*** ***Q500*** 10,300 ***ft³/s***

The 100- and 500- year discharges were selected from a range defined by values compiled and graphically extrapolated from several empirical methods (Potter, 1957a&b; Johnson and Tasker, 1974; Benson, 1962; FHWA, 1983; Talbot, 1887; Richardson and others, 1993). The discharges used agreed with values in the VTAOT database values (VTAOT, written communication, May 4, 1995) for the First Branch of the White River when adjusted for drainage area.

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 square on top of the US end of the left abutment (elev. 102.44 ft, arbitrary survey datum). RM2 is a chiseled square on top of bedrock 70 feet downstream of the left abutment along the left bank (elev. 92.97ft, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-92	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	68	2	Modelled Approach section (Templated from ATEMP)
ATEMP	140	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, Appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.053 to 0.065, and overbank "n" values ranged from 0.035 to 0.085.

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 0.0054 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1966).

The surveyed approach section (ATEMP) was moved along the approach channel slope (0.0097 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 incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. Analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satifactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 103.9 *ft*
Average low steel elevation 101.4 *ft*

100-year discharge 7,900 *ft³/s*
Water-surface elevation in bridge opening 101.8 *ft*
Road overtopping? Yes *Discharge over road* 2,565 *ft³/s*
Area of flow in bridge opening 540 *ft²*
Average velocity in bridge opening 9.7 *ft/s*
Maximum WSPRO tube velocity at bridge 11.8 *ft/s*

Water-surface elevation at Approach section with bridge 103.6
Water-surface elevation at Approach section without bridge 99.9
Amount of backwater caused by bridge 3.7 *ft*

500-year discharge 10,300 *ft³/s*
Water-surface elevation in bridge opening 101.8 *ft*
Road overtopping? Yes *Discharge over road* 4,414 *ft³/s*
Area of flow in bridge opening 540 *ft²*
Average velocity in bridge opening 11.1 *ft/s*
Maximum WSPRO tube velocity at bridge 13.4 *ft/s*

Water-surface elevation at Approach section with bridge 104.7
Water-surface elevation at Approach section without bridge 101.3
Amount of backwater caused by bridge 3.4 *ft*

Incipient overtopping discharge 3,510 *ft³/s*
Water-surface elevation in bridge opening 95.5 *ft*
Area of flow in bridge opening 264 *ft²*
Average velocity in bridge opening 13.3 *ft/s*
Maximum WSPRO tube velocity at bridge 16.8 *ft/s*

Water-surface elevation at Approach section with bridge 99.5
Water-surface elevation at Approach section without bridge 96.5
Amount of backwater caused by bridge 3.0 *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, 1995). 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 the 100-year and 500-year 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, 1995, p. 32, equation 20) for the incipient road-overflow discharge. For contraction scour computations using the Laursen's equation, 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 results of Laursen's clear-water contraction scour for the 100-year and 500-year events were also computed and can be found in appendix F. In this case, the 500-year model resulted in the worst case contraction scour with a scour depth of 2.6 ft. It was also the worst case total scour. The results of the streambed armoring computations suggest that the depth of contraction scour will not be limited by armoring.

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

The left abutment sits atop a bedrock outcrop. The results of the calculated scour depths may be limited by the bedrock.

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	0.9	2.6	2.1
Depth to armoring	3.0	6.9	N/A
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	23.5	24.0	14.3
Right abutment	20.8	19.2	20.2
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.9	2.5	2.4
Right abutment	1.9	2.5	2.4
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

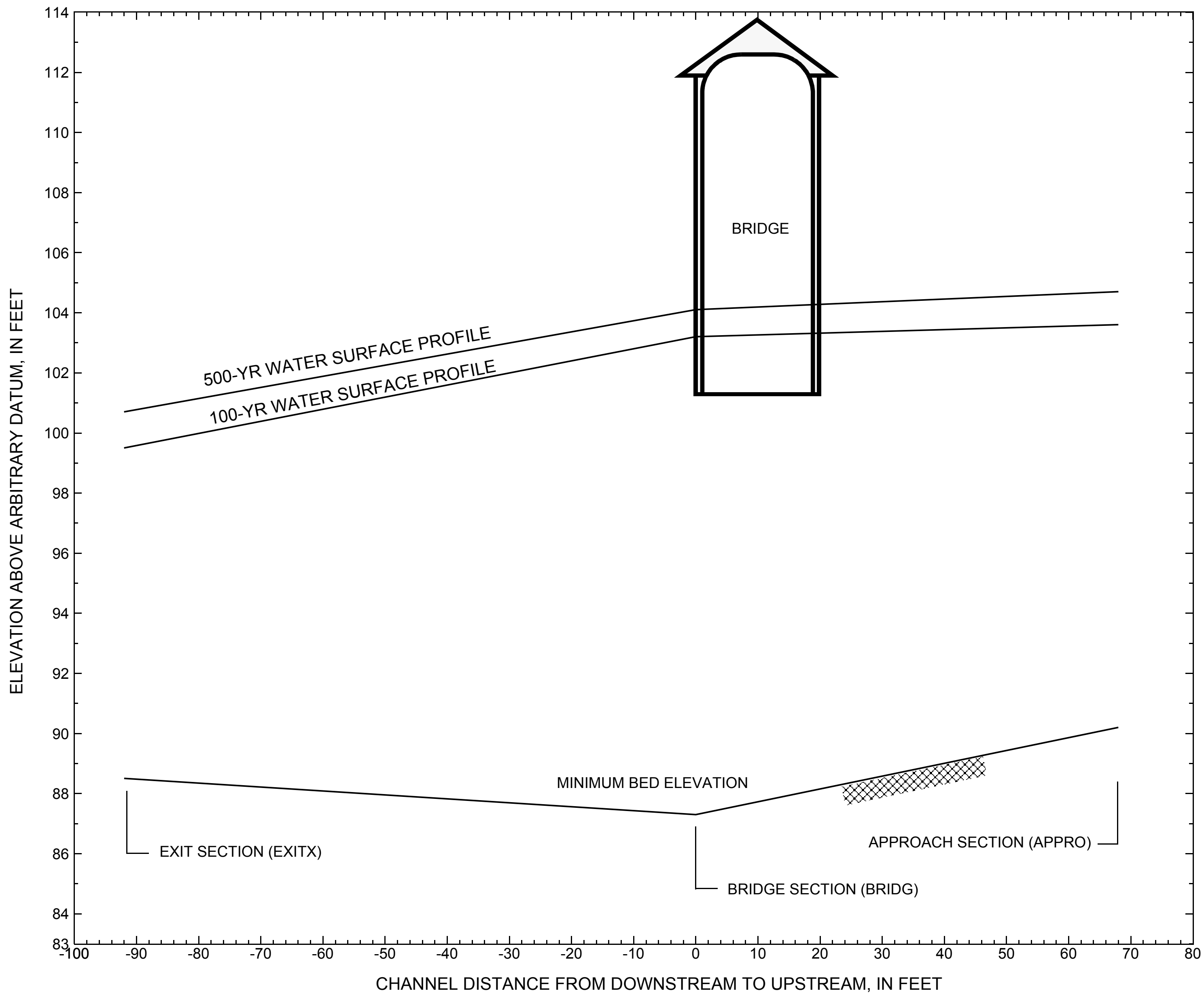

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHELTH00680046 on town highway 68, crossing First Branch of the White River, Chelsea, Vermont.

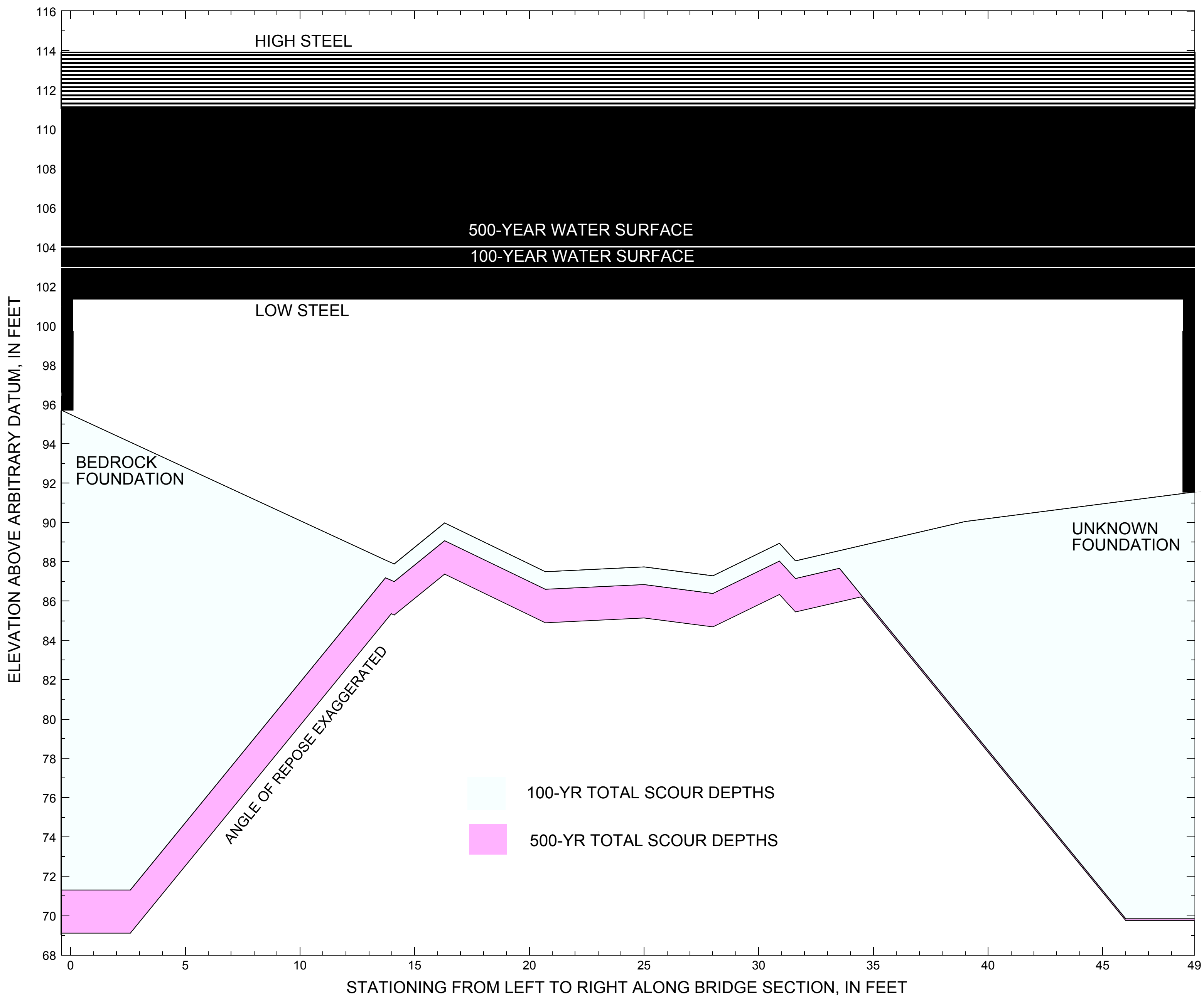

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CHELTH00680046 on town highway 68, crossing First Branch of the White River, Chelsea, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHELTH00680046 on Town Highway 68, crossing the First Branch of the White River, Chelsea, 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 7,900 cubic-feet per second											
Left abutment	0.0	--	101.8	--	95.7	0.9	23.5	--	24.4	71.3	--
Right abutment	48.7	--	101.0	--	91.6	0.9	20.8	--	21.7	69.9	--

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 CHELTH00680046 on Town Highway 68, crossing the First Branch of the White River, Chelsea, 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 10,300 cubic-feet per second											
Left abutment	0.0	--	101.8	--	95.7	2.6	24.0	--	26.6	69.1	--
Right abutment	48.7	--	101.0	--	91.6	2.6	19.2	--	21.8	69.8	--

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. Geological Survey, 1981, Chelsea, 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 chel046.wsp
T2        Hydraulic analysis for structure CHELTH00680046   Date: 02-MAY-96
T3        Hydraulic Analysis for Chelsea bridge 46 over 1st Branch White by MAI
Q           7900.0  10300.0 3510
SK         0.0054  0.0054  0.0054
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -92
GR         -150.3, 108.72   -103.6, 102.93    -66.3,  99.60    -50.6,  97.16
GR          -46.8,  94.90    -43.8,  91.44    -31.2,  92.05    -16.8,  90.93
GR           -3.4,  92.31      0.0,  91.38      4.6,  89.87      5.4,  89.23
GR           10.8,  88.53     33.2,  88.89     47.0,  88.96     55.9,  89.89
GR           61.4,  90.77     65.8,  95.37     68.3,  97.76     91.8,  99.48
GR          106.5, 106.65
N           0.035  0.053  0.085
SA              -66.3   68.3
*
XS   FULLV      0  * * *  0.0054
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    101.39      15.0
GR            0.0, 101.76      0.1,  95.71     14.1,  87.89     16.3,  89.98
GR           20.7,  87.50     25.0,  87.74     28.0,  87.29     30.9,  88.94
GR           31.6,  88.05     39.0,  90.05     48.5,  91.55     48.7, 101.02
GR            0.0, 101.76
*        BRTYPE  BRWDTH
CD           1      19
N           0.065
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      14.5     2
GR         -175.0, 109.95   -157.9, 108.58   -144.4, 107.62    -58.6, 103.75
GR            0.0, 104.14      0.0, 111.60     50.2, 110.95     50.2, 103.60
GR           93.2, 100.24    129.2,  99.31    188.9, 101.67    228.6, 104.94
*
XT   ATEMP    140
GR          -76.8, 108.63    -66.3, 105.90    -47.3, 105.10    -30.8,  96.80
GR           -7.3,  96.58     -2.8,  94.57     -1.9,  91.40      0.0,  90.94
GR           28.4,  90.89     60.8,  90.98     63.8,  91.32     70.0,  94.28
GR           82.4,  94.53     95.6,  98.45    124.5, 101.15    153.2, 102.55
GR          161.5, 108.25
*
AS   APPRO     68
GT             -0.70
N           0.048  0.058  0.070
SA             -7.3    95.6
*
HP 1 BRIDG   101.76 1 101.76
HP 2 BRIDG   101.76 * * 5256
HP 2 RDWAY   103.18 * * 2565
HP 1 APPRO   103.64 1 103.64
HP 2 APPRO   103.64 * * 7900
*
HP 1 BRIDG   101.76 1 101.76
HP 2 BRIDG   101.76 * * 5997
HP 2 RDWAY   104.13 * * 4414
HP 1 APPRO   104.66 1 104.66
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File chel046.wsp
        Hydraulic analysis for structure CHELTH00680046   Date: 02-MAY-96
        Hydraulic Analysis for Chelsea bridge 46 over 1st Branch White by MAI
           *** RUN DATE & TIME: 05-15-96  09:16
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      540     34841      0    114                     36441924
   101.76           540     34841      0    114  1.00      0     49 36441924

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       101.76     0.0    48.7   539.8   34841.    5256.   9.74

X STA.         0.0         6.0         9.2        11.6        13.7        15.7
  A(I)            44.3        30.4        27.8        25.9        25.4
  V(I)            5.93        8.66        9.46       10.13       10.34

X STA.        15.7        18.0        19.9        21.6        23.3        25.0
  A(I)            25.8        24.0        22.8        22.5        22.4
  V(I)           10.18       10.96       11.52       11.66       11.76

X STA.        25.0        26.6        28.3        30.1        32.2        34.1
  A(I)            22.2        22.6        23.4        25.0        23.7
  V(I)           11.82       11.65       11.25       10.52       11.07

X STA.        34.1        36.2        38.5        41.1        44.0        48.7
  A(I)            24.8        26.0        27.4        29.4        44.1
  V(I)           10.59       10.09        9.60        8.94        5.96

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.
         WSEL     LEW     REW    AREA        K        Q    VEL
       103.18    55.6   207.2   352.3   11244.    2565.   7.28

X STA.        55.6        81.5        89.6        95.6       100.8       105.5
  A(I)            26.3        18.8        17.3        15.8        15.3
  V(I)            4.87        6.81        7.43        8.11        8.38

X STA.       105.5       110.2       114.5       118.5       122.5       126.3
  A(I)            15.3        14.7        14.4        14.6        14.1
  V(I)            8.37        8.72        8.90        8.78        9.09

X STA.       126.3       130.0       133.9       138.1       142.7       147.7
  A(I)            14.2        14.8        14.9        15.8        16.2
  V(I)            9.05        8.67        8.61        8.13        7.91

X STA.       147.7       153.4       159.9       167.9       178.8       207.2
  A(I)            17.3        18.3        19.9        23.1        31.2
  V(I)            7.42        7.01        6.45        5.55        4.12

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      68.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      236     23857     38     40                         3322
             2     1228    160514    103    107                        24078
             3      205      9799     60     61                         2147
   103.64          1669    194169    202    208  1.14    -45    156    25479

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      68.

         WSEL     LEW     REW    AREA        K        Q    VEL
       103.64   -45.8   155.8  1669.5  194169.    7900.   4.73

X STA.       -45.8       -23.4       -12.1        -1.1         4.4         9.6
  A(I)           112.3        87.2        97.3        73.2        70.1
  V(I)            3.52        4.53        4.06        5.40        5.63

X STA.         9.6        14.8        19.8        24.8        29.8        34.8
  A(I)            68.7        67.4        68.0        67.2        67.2
  V(I)            5.75        5.86        5.81        5.88        5.88

X STA.        34.8        39.9        45.1        50.1        55.3        60.6
  A(I)            68.6        68.6        66.9        70.8        69.9
  V(I)            5.75        5.76        5.90        5.58        5.65

X STA.        60.6        66.2        74.2        82.8        96.3       155.8
  A(I)            72.6        83.7        85.3       103.4       201.1
  V(I)            5.44        4.72        4.63        3.82        1.96
```

```
       U.S. Geological Survey WSPRO Input File chel046.wsp
       Hydraulic analysis for structure CHELTH00680046   Date: 02-MAY-96
       Hydraulic Analysis for Chelsea bridge 46 over 1st Branch White by MAI
          *** RUN DATE & TIME: 05-15-96  09:16
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      540     34841      0    114                     36441924
  101.76           540     34841      0    114  1.00      0     49 36441924

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      101.76     0.0    48.7   539.8   34841.    5997.  11.11

X STA.         0.0         6.0         9.2        11.6        13.7        15.7
  A(I)            44.3        30.4        27.8        25.9        25.4
  V(I)            6.77        9.88       10.79       11.56       11.80

X STA.        15.7        18.0        19.9        21.6        23.3        25.0
  A(I)            25.8        24.0        22.8        22.5        22.4
  V(I)           11.62       12.50       13.15       13.30       13.42

X STA.        25.0        26.6        28.3        30.1        32.2        34.1
  A(I)            22.2        22.6        23.4        25.0        23.7
  V(I)           13.49       13.29       12.83       12.00       12.63

X STA.        34.1        36.2        38.5        41.1        44.0        48.7
  A(I)            24.8        26.0        27.4        29.4        44.1
  V(I)           12.09       11.52       10.95       10.20        6.81

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.
        WSEL     LEW     REW    AREA        K        Q    VEL
      104.13   -67.0   218.8   518.3   18981.    4414.   8.52

X STA.       -67.0        74.4        84.3        91.3        97.2       102.6
  A(I)            48.2        27.8        24.4        22.8        22.0
  V(I)            4.58        7.94        9.06        9.69       10.02

X STA.       102.6       107.7       112.6       117.2       121.7       126.1
  A(I)            21.2        21.2        20.7        20.6        20.5
  V(I)           10.41       10.41       10.65       10.70       10.77

X STA.       126.1       130.5       135.0       139.8       145.1       151.0
  A(I)            20.9        21.1        21.6        23.0        23.7
  V(I)           10.57       10.47       10.21        9.60        9.30

X STA.       151.0       157.3       164.9       173.6       185.1       218.8
  A(I)            24.3        26.9        28.2        32.7        46.4
  V(I)            9.09        8.19        7.82        6.75        4.76

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      68.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      277     27658     46     48                         3856
            2     1333    184021    103    107                        27230
            3      267     14943     62     63                         3155
  104.66          1878    226622    211    218  1.16    -52    157    29532

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      68.

        WSEL     LEW     REW    AREA        K        Q    VEL
      104.66   -53.5   157.3  1877.6  226622.   10300.   5.49

X STA.       -53.5       -23.1       -12.0        -1.0         4.7         9.9
  A(I)           139.9        96.1       109.7        81.0        75.9
  V(I)            3.68        5.36        4.69        6.36        6.79

X STA.         9.9        15.2        20.4        25.6        30.8        36.0
  A(I)            76.4        75.0        75.6        74.7        74.7
  V(I)            6.74        6.87        6.81        6.89        6.90

X STA.        36.0        41.2        46.5        51.8        57.1        62.5
  A(I)            76.0        75.9        76.7        76.0        77.3
  V(I)            6.78        6.79        6.71        6.77        6.66

X STA.        62.5        69.1        77.3        86.3       104.2       157.3
  A(I)            86.1        90.9        96.0       132.7       211.2
  V(I)            5.98        5.66        5.36        3.88        2.44
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File chel046.wsp
        Hydraulic analysis for structure CHELTH00680046   Date: 02-MAY-96
        Hydraulic Analysis for Chelsea bridge 46 over 1st Branch White by MAI
           *** RUN DATE & TIME: 05-15-96  09:16
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      264     17154     46     55                         3568
    95.51           264     17154     46     55  1.00      0     49     3568

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
        95.51     0.5    48.6   263.9   17154.    3510.  13.30

X STA.         0.5        9.6       12.3       14.2       16.5       18.7
  A(I)            22.7       15.2       13.3       14.2       13.2
  V(I)            7.73      11.54      13.22      12.34      13.30

X STA.        18.7       20.4       21.8       23.2       24.6       26.0
  A(I)            11.7       11.2       10.5       10.6       10.6
  V(I)           15.00      15.73      16.77      16.54      16.56

X STA.        26.0       27.3       28.7       30.3       32.1       33.8
  A(I)            10.5       10.6       11.6       12.4       11.3
  V(I)           16.75      16.59      15.19      14.13      15.56

X STA.        33.8       35.7       37.8       40.3       43.5       48.6
  A(I)            12.1       12.5       13.4       15.2       21.4
  V(I)           14.50      14.09      13.14      11.56       8.21

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      68.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       93      6042     30     31                          931
             2      800     78585    103    107                        12661
             3       16       309     19     19                           85
    99.48           910     84936    152    157  1.06    -37    114    12290

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      68.
         WSEL     LEW     REW    AREA        K        Q    VEL
        99.48   -37.5   114.1   909.5   84936.    3510.   3.86

X STA.       -37.5      -14.3       -0.6        4.0        8.4       12.6
  A(I)            68.3       64.0       42.6       40.0       39.5
  V(I)            2.57       2.74       4.12       4.38       4.44

X STA.        12.6       16.7       20.8       25.0       29.1       33.2
  A(I)            38.0       38.2       38.5       38.1       38.1
  V(I)            4.62       4.60       4.56       4.61       4.61

X STA.        33.2       37.4       41.5       45.7       50.1       54.4
  A(I)            38.6       38.6       39.0       40.3       39.8
  V(I)            4.54       4.55       4.50       4.36       4.41

X STA.        54.4       58.8       63.6       70.2       79.7      114.1
  A(I)            40.6       43.2       49.1       54.8       80.3
  V(I)            4.32       4.06       3.57       3.21       2.19
```

```
      U.S. Geological Survey WSPRO Input File chel046.wsp
       Hydraulic analysis for structure CHELTH00680046   Date: 02-MAY-96
       Hydraulic Analysis for Chelsea bridge 46 over 1st Branch White by MAI
          *** RUN DATE & TIME: 05-15-96  09:16

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

EXITX:XS   ******    -62     1022  0.95 *****  100.04   95.77    7900   99.09
       -91 ******     86   107403  1.02 ***** *******    0.53    7.73

FULLV:FV       92    -62     1022  0.95  0.50  100.54 *******    7900   99.59
         0     92     87   107468  1.02  0.00    0.00    0.53    7.73
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       68    -37      981  1.08  0.42  101.02 *******    7900   99.94
        68     68    119    94565  1.07  0.06    0.00    0.59    8.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   106.24       0.00      99.49      99.31

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =    99.56     103.02     103.37     101.39

 ===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       92      0      540  1.47 *****  103.23   97.20    5256  101.76
         0 ******     49    34841  1.00 ***** *******    0.52    9.74

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.434  0.000  101.39 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    54.  0.09  0.40  103.95   -0.01   2565.  103.18

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.    40.   -64.   -24.   0.2   0.1   4.4  26.5   1.0   2.8
   RT:  2565.   152.    56.   207.   3.9   2.3   8.2   7.3   3.1   3.1

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

APPRO:AS       49    -45     1669  0.40  0.35  104.04   97.54    7900  103.64
        68     54    156   194108  1.14  0.41   -0.01    0.31    4.73

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -92.   -63.    86.   7900.  107403.    1022.    7.73   99.09
   FULLV:FV       0.   -63.    87.   7900.  107468.    1022.    7.73   99.59
   BRIDG:BR       0.     0.    49.   5256.   34841.     540.    9.74  101.76
   RDWAY:RG      10.*******     0.   2565.       0.*********    2.00  103.18
   APPRO:AS      68.   -46.   156.   7900.  194108.    1669.    4.73  103.64

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS     95.77    0.53   88.53  108.72************  0.95  100.04   99.09
   FULLV:FV  ********    0.53   89.03  109.22  0.50  0.00  0.95  100.54   99.59
   BRIDG:BR     97.20    0.52   87.29  101.76************  1.47  103.23  101.76
   RDWAY:RG  ****************   99.31  111.60  0.09******  0.40  103.95  103.18
   APPRO:AS     97.54    0.31   90.19  107.93  0.35  0.41  0.40  104.04  103.64
```

WSPRO OUTPUT FILE (continued)

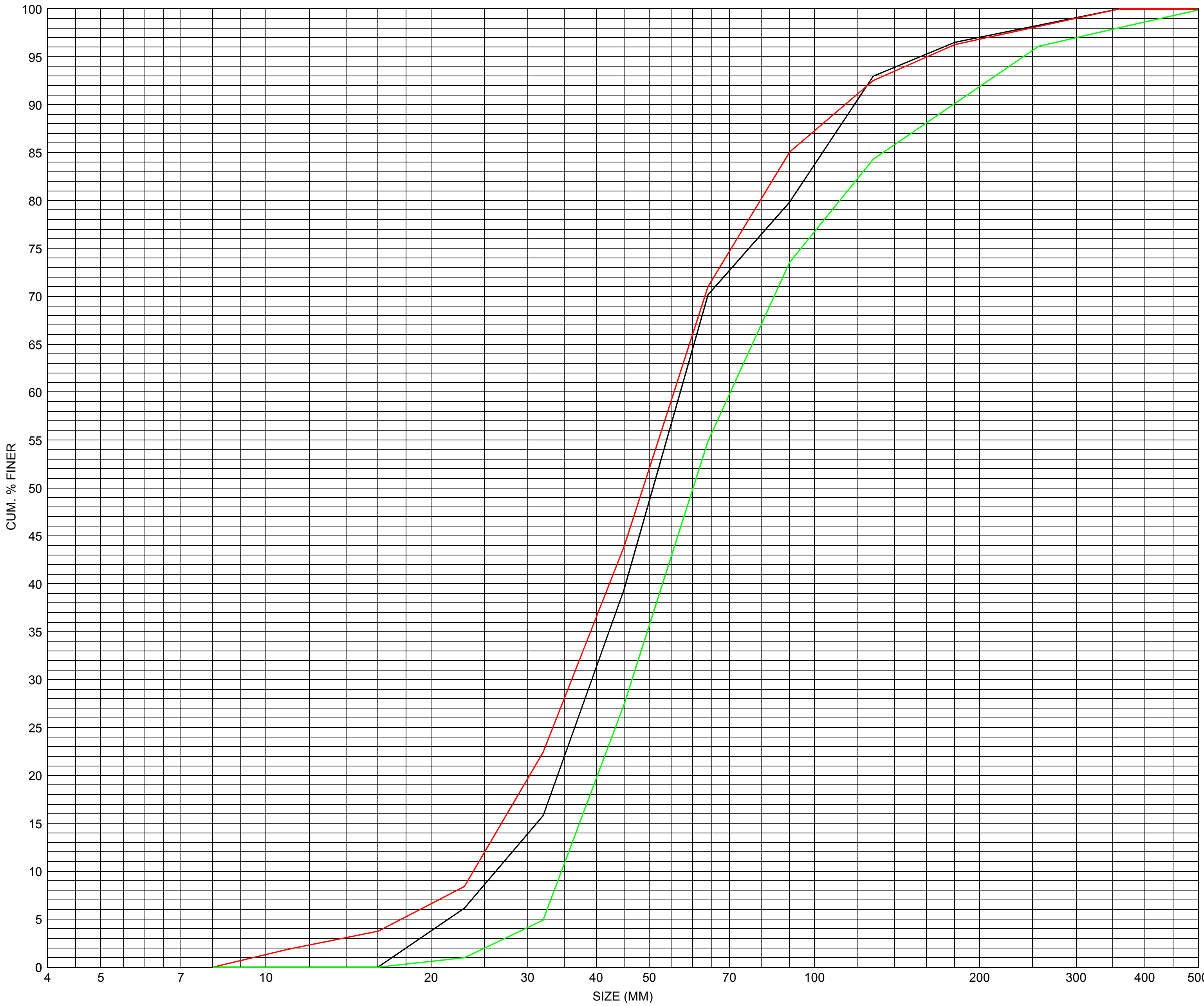
```
       U.S. Geological Survey WSPRO Input File chel046.wsp
        Hydraulic analysis for structure CHELTH00680046   Date: 02-MAY-96
        Hydraulic Analysis for Chelsea bridge 46 over 1st Branch White by MAI
           *** RUN DATE & TIME: 05-15-96  09:16

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

EXITX:XS   ******    -75     1238  1.14 *****  101.57   96.83   10300  100.44
       -91 ******     94   140065  1.05 ***** *******    0.56    8.32

FULLV:FV       92    -75     1239  1.13  0.50  102.07 *******   10300  100.94
         0     92     94   140152  1.05  0.00    0.00    0.56    8.32
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       68    -40     1208  1.25  0.41  102.54 *******   10300  101.29
        68     68    142   125818  1.10  0.06    0.00    0.61    8.53
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===230 REJECTED FLOW CLASS 1 SOLUTION.
              WS1,WSSD,WS3 =   107.93       0.00     101.06
                      CRWS =    98.56   ********     101.06
                      YMAX =   107.93   ********     101.76

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   101.76     104.42     104.84     101.39

 ===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       92      0      540  1.92 *****  103.68   97.86    5997  101.76
         0 ******     49    34841  1.00 ***** *******    0.59   11.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.464  0.000  101.39 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    54.  0.11  0.54  105.09    0.01   4414.  104.13

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    231.    65.   -67.    -2.   0.4   0.2   4.6  18.7   1.2   2.9
   RT:   4183.   169.    50.   219.   4.8   3.0   9.4   8.3   4.0   3.1

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

APPRO:AS       49    -52     1878  0.54  0.45  105.20   98.56   10300  104.66
        68     54    157   226622  1.16  0.48    0.01    0.35    5.49

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -92.   -76.    94.  10300.  140065.    1238.    8.32  100.44
   FULLV:FV       0.   -76.    94.  10300.  140152.    1239.    8.32  100.94
   BRIDG:BR       0.     0.    49.   5997.   34841.     540.   11.11  101.76
   RDWAY:RG      10.*******   231.   4414.       0.*********    2.00  104.13
   APPRO:AS      68.   -53.   157.  10300.  226622.    1878.    5.49  104.66

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     96.83    0.56   88.53  108.72************  1.14  101.57  100.44
   FULLV:FV  ********    0.56   89.03  109.22  0.50  0.00  1.13  102.07  100.94
   BRIDG:BR     97.86    0.59   87.29  101.76************  1.92  103.68  101.76
   RDWAY:RG  ****************   99.31  111.60  0.11******  0.54  105.09  104.13
   APPRO:AS     98.56    0.35   90.19  107.93  0.45  0.48  0.54  105.20  104.66
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File chel046.wsp
        Hydraulic analysis for structure CHELTH00680046   Date: 02-MAY-96
        Hydraulic Analysis for Chelsea bridge 46 over 1st Branch White by MAI
           *** RUN DATE & TIME: 05-15-96  09:16

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

EXITX:XS   ******    -47      586  0.56 *****   96.15   93.45    3510   95.59
       -91 ******     66    47756  1.00 ***** *******    0.47    5.99

FULLV:FV       92    -47      586  0.56  0.50   96.65 *******    3510   96.09
         0     92     66    47802  1.00  0.00    0.00    0.47    5.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       68    -31      504  0.78  0.48   97.24 *******    3510   96.46
        68     68     91    36224  1.03  0.11    0.00    0.62    6.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =     99.48       0.00      95.51      99.31

 ===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       92      0      264  2.98  1.38   98.49   95.46    3510   95.51
         0     92     49    17157  1.08  0.96    0.00    1.02   13.30

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.961 ******  101.39 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<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       49    -37      910  0.24  0.45   99.73   94.70    3510   99.48
        68     53    114    85007  1.06  0.79    0.01    0.29    3.86

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.605  0.405   50415.     8.    56. ********

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW        Q         K     AREA     VEL    WSEL
   EXITX:XS      -92.   -48.    66.   3510.   47756.     586.    5.99   95.59
   FULLV:FV        0.   -48.    66.   3510.   47802.     586.    5.99   96.09
   BRIDG:BR        0.     0.    49.   3510.   17157.     264.   13.30   95.51
   RDWAY:RG      10.**************       0.        0.       0.    2.00********
   APPRO:AS       68.   -38.   114.   3510.   85007.     910.    3.86   99.48

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       8.    56.   50415.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXITX:XS      93.45    0.47   88.53  108.72************  0.56   96.15   95.59
   FULLV:FV   ********    0.47   89.03  109.22  0.50  0.00  0.56   96.65   96.09
   BRIDG:BR      95.46    1.02   87.29  101.76  1.38  0.96  2.98   98.49   95.51
   RDWAY:RG  ****************    99.31  111.60  0.09******  0.25   99.63********
   APPRO:AS      94.70    0.29   90.19  107.93  0.45  0.79  0.24   99.73   99.48
```

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 CHELTH00680046, in Chelsea, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHELTH0680046

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. IVANOFF

Date *(MM/DD/YY)* 08 / 26 / 94

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 13525

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

Waterway *(I - 6)* FIRST BRANCH WHITE RIVER

Road Name *(I - 7)*: C3068

Route Number 0.1 MI

Vicinity *(I - 9)* JCT VT110

Topographic Map Chelsea

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43574

Longitude *(i - 17; nnnnn.n)* 72278

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10090400460904

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

Maximum span length *(I - 48; nnnn)* 0052

Year built *(I - 27; YYYY)* 1886

Structure length *(I - 49; nnnnnn)* 000061

Average daily traffic, ADT *(I - 29; nnnnnn)* 000040

Deck Width *(I - 52; nn.n)* 146

Year of ADT *(I - 30; YY)* 91

Channel & Protection *(I - 61; n)* 7

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

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

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

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

Structure type *(I - 43; nnn)* 710

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 012.0

Number of approach spans *(I - 46; nnnn)* 0001

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

Comments:

Structural inspection report of 9/8/93 indicates a modified queen post thru-truss covered bridge with a gravel roadway surface. The report notes that the abutments are 'laid up' stone. The downstream end of the right abutment is reported as having settled with some stone cracking. Stone fill at the upstream end of the right abutment is in place to deter further settlement. Channel makes a sharp turn into bridge with flow on a bedrock outcrop in front of the left abutment. No channel scour or embankment erosion.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

-

Streambed material: **Stone and gravel under the bridge: stone and boulder with bedrock left**

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

-

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

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

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

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

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

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

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

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

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

Comments:

--

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 58.18 mi^2

Lake and pond area 0.07 mi^2

Watershed storage *(ST)* 0.1 %

Bridge site elevation 690 ft

Headwater elevation 1700 ft

Main channel length 11.13 mi

10% channel length elevation 760 ft

85% channel length elevation 1380 ft

Main channel slope *(S)* 74.52 ft / mi

Watershed Precipitation Data

Average site precipitation ______ in

Average headwater precipitation ______ in

Maximum 2yr-24hr precipitation event *(I24,2)* ______ in

Average seasonal snowfall *(Sn)* ______ ft

Bridge Plan Data

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

Project Number ________ Minimum channel bed elevation: ________

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

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness ________ Footing bottom elevation: ________

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

If 3: Footing bottom elevation: ________

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

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

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: MAI Date: 2/06/95
Computerized by: MAI Date: 3/15/95
Reviewd by: MAI Date: 5/15/96

Structure Number CHELTH00680046

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* D. SONG Date *(MM/DD/YY)* 11 / 16 / 1994
2. Highway District Number 04 Mile marker 0
County ORANGE (017) Town CHELSEA (13525)
Waterway *(I - 6)* FIRST BRANCH WHITE RIVER Road Name -
Route Number TH046 Hydrologic Unit Code: 01080105
3. Descriptive comments:
Located about 0.1 mile from the junction of TH 46 and VT 110.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 5 LBDS 6 RBDS 6 Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 1 DS 1 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 61 *(feet)* Span length 52 *(feet)* Bridge width 14.6 *(feet)*

Road approach to bridge:

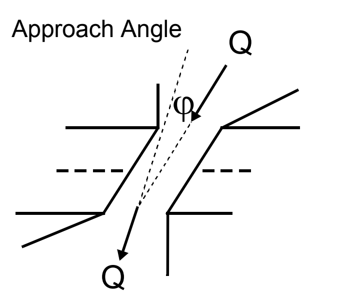
8. LB 1 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 4.5:1 US right 4.6:1

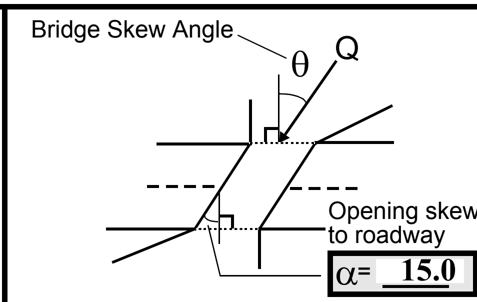
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	0
RBUS	2	1	0	0
RBDS	2	1	1	2
LBDS	0	-	-	-

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

Channel approach to bridge (BF):

15. Angle of approach: 60 16. Bridge skew: 40





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 60 feet US *(US, UB, DS)* to 0 feet US
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 3
Range? 10 feet US *(US, UB, DS)* to 30 feet DS

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

18. Level II Bridge Type: **1b**

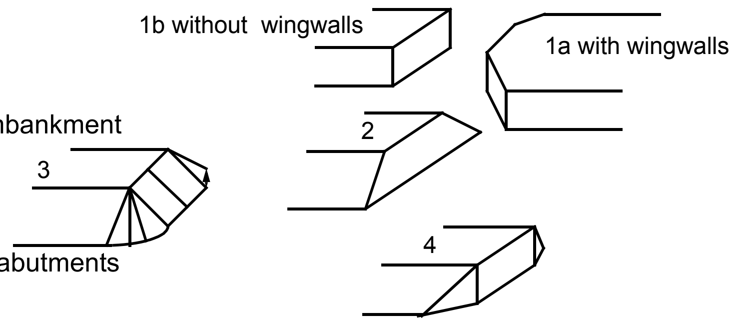
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

4. Left and Right banks upstream are forested on the immediate banks. LBDS: moderate tree coverage with little undergrowth.
7. Values from VTAOT database (VTAOT, written communication, August 26.1994). Measured bridge length: 61, span: 52, and width: 14.5 feet.
17. Zone 1: is protected by stone fill to prevent embankment erosion on the right bank. Zone 2: impact is on a bedrock control under the left abutment; causes severe contraction under the bridge; local scour.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
144.7	3.0			3.0	3	3	231	231	2	0

23. Bank width **75.0** 24. Channel width **25.0** 25. Thalweg depth **72.5** 29. Bed Material **345**

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

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

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

27. An exposed cut bank on the LB reveals fines (silt and sands) exposed to channel bottom depth.
29. Bed material gravel and cobble with some boulders.

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

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

37. Material: -

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

NO POINT BARS

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

41. Mid-bank distance: 120 42. Cut bank extent: 60 feet US (US, UB) to 150 feet US (US, UB, DS)

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

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

Cut-bank is not part of an impact zone, but is obvious from severe root exposure and falling trees. Bank may be cut at high flows.

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

47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB 2 RB ____ (**1**- natural bank; **2**- abutment; **3**- artificial levee)

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
65.5		0.5		2	6	7	-

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

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

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

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

43

Flow impacts severely on the left abutment, which is composed of stone and concrete on bedrock foundation.

63. Bed material is cobble and gravel.

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

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

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

70. Debris and Ice Comments:

2

67. Debris accumulation near the bridge.

68. Moderate channel gradient and the span length is 70% of the upstream bank width.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		30	90	2	0	-	-	90.0
RABUT	1	-	90			2	0	48.5

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

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

-

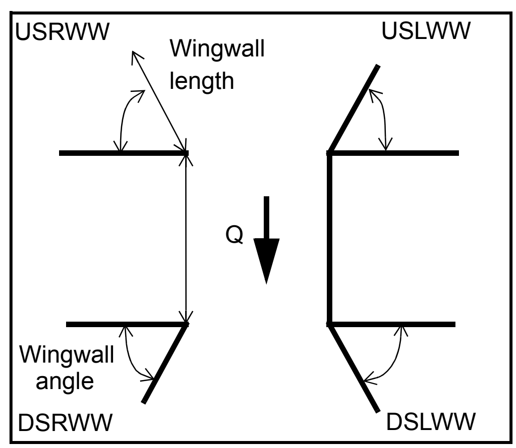
-

2

72. Left abutment is a short concrete and stone drywall, perched on a sloping bedrock foundation which will contain all of the flow at bank full conditions.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						25.0	
USRWW:	N		-		-	2.5	
DSLWW:	-		-		N	17.5	
DSRWW:	-		-		-	20.5	



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

82. **Bank / Bridge Protection**:

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

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

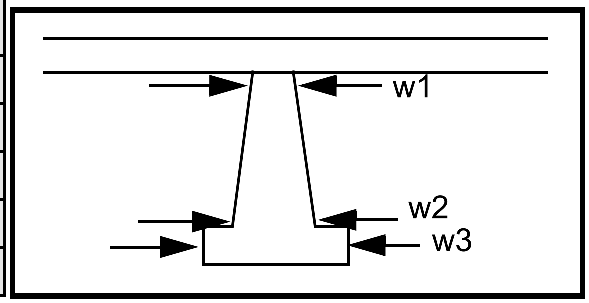
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-

-
-
-
-
-
0
-
-

Piers:

84. Are there piers? **80.** *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	**5.0**	-	-	**11.0**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**DSR**	**after**	**set-**	**RAB**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**WW**	**the**	**tle-**	**UT:**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**:**	**orig-**	**ment**	**upst**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**wing**	**inal**	**note**	**ream**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wall**	**brid**	**d on**	**right**	*Y- yes; N- no*
91. Attack ∠ (BF)	**appe**	**ge**	**the**	**abut**	
92. Pushed	**ars**	**con-**	**his-**	**ment**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**to**	**stric-**	**tori-**	**and**	
95. Cross-members	**have**	**tion;**	**cal**	**road**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**been**	**per-**	**form**	**emb**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**adde**	**haps**	**.**	**ank-**	
98. Exposure depth	**d**	**after**	**82.**	**ment**	

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

have stone fill protection in place; the same stone fill, fills channel and a deep scour hole.

N

-

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

-
-
-
-
-
-

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

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

Material: __-__

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

-
-
-
NO PIERS

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

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

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

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

3
4
451

Is channel scour present? __451__ *(Y or if N type ctrl-n cs)* Mid-scour distance: __2__

Scour dimensions: Length __1__ Width __435__ Depth: __0__ Positioned __0__ %LB to __-__ %RB

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

-
Bank material is cobble with boulders and some silt. There is a bedrock outcrop extending from the left bank 60 feet.
Bed material is cobble and gravel with some boulders and sand.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

1- *Constructed*
2- *Stable*
3- *Aggraded*
4- *Degraded*
5- *Laterally unstable*
6- *Vertically and laterally unstable*

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

N
-
NO DROP STRUCTURE

Y
100
45
120

109. G. Plan View Sketch

D

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: CHELTH00680046 Town: Chelsea
Road Number: TH 68 County: Orange
Stream: First Branch White River

Initials MAI Date: 05/09/96 Checked: SAO

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	7900	10300	3510
Main Channel Area, ft2	1228	1333	800
Left overbank area, ft2	236	277	93
Right overbank area, ft2	205	267	16
Top width main channel, ft	103	103	103
Top width L overbank, ft	38	46	30
Top width R overbank, ft	60	62	19
D50 of channel, ft	0.173	0.173	0.173
D50 left overbank, ft	0	0	
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	11.9	12.9	7.8
y1, average depth, LOB, ft	6.2	6.0	3.1
y1, average depth, ROB, ft	3.4	4.3	0.8
Total conveyance, approach	194169	226622	84936
Conveyance, main channel	160514	184021	78585
Conveyance, LOB	23857	27658	6042
Conveyance, ROB	9799	14943	309
Percent discrepancy, conveyance	-0.0005	0.0000	0.0000
Qm, discharge, MC, cfs	6530.7	8363.8	3247.5
Ql, discharge, LOB, cfs	970.7	1257.1	249.7
Qr, discharge, ROB, cfs	398.7	679.2	12.8
Vm, mean velocity MC, ft/s	5.3	6.3	4.1
Vl, mean velocity, LOB, ft/s	4.1	4.5	2.7
Vr, mean velocity, ROB, ft/s	1.9	2.5	0.8
Vc-m, crit. velocity, MC, ft/s	9.4	9.6	8.8
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	ERR
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	0.0

Results

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

	100 yr	500 yr	other Q
Main Channel	0	0	0
Left Overbank	1	1	1
Right Overbank	1	1	1

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	1228	1333	800
Main channel width, ft	103	103	103
y1, main channel depth, ft	11.92	12.94	7.77

Bridge Section			
(Q) total discharge, cfs	7900	10300	3510
(Q) discharge thru bridge, cfs	5256	5996	3510
Main channel conveyance	34841	34841	17154
Total conveyance	34841	34841	17154
Q2, bridge MC discharge,cfs	5256	5996	3510
Main channel area, ft2	540	540	264
Main channel width (skewed), ft	47.0	47.0	46.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	47	47	46.5
y_bridge (avg. depth at br.), ft	11.49	11.49	5.68
Dm, median (1.25*D50), ft	0.21625	0.21625	0.21625
y2, depth in contraction,ft	10.93	12.23	7.80
ys, scour depth (y2-ybridge), ft	-0.56	0.75	2.13
ys, scour depth (y2-y1), ft	-0.99493	-0.70824	0.0349
ys, scour depth (y2-yfullv), ft	1.24	1.19	N/A

ARMORING			
D90	0.419	0.419	0.419
D95	0.63	0.63	0.63
Critical grain size,Dc, ft	0.2831	0.3684	0.6839
Decimal-percent coarser than Dc	0.222	0.138	N/A
Depth to armoring,ft	2.98	6.90	N/A

Pressure Flow Scour (contraction scour for orifice flow conditions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10*(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richardson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	5256	5997	0
Vc, critical velocity, ft/s	9.4	9.6	0
Vc, critical velocity, m/s	2.86498	2.925937	0
Main channel width (skewed), ft	47	47	0
Cum. width of piers, ft	0	0	0

W, adjusted width, ft	47	47	0
qbr, unit discharge, ft^2/s	111.8298	127.5957	ERR
qbr, unit discharge, m^2/s	10.38831	11.85288	N/A
Area of full opening, ft^2	540	540	0
Hb, depth of full opening, ft	11.48936	11.48936	ERR
Hb, depth of full opening, m	3.501787	3.501787	N/A
Fr, Froude number MC	0.52	0.59	1
Cf, Fr correction factor (<=1.0)	1	1	1.5
Elevation of Low Steel, ft	101.391	101.391	0
Elevation of Bed, ft	89.90164	89.90164	N/A
Elevation of approach WS, ft	103.64	104.66	0
HF, bridge to approach, ft	0.35	0.45	0
Elevation of WS immediately US, ft	103.29	104.21	0
ya, depth immediately US, ft	13.38836	14.30836	N/A
ya, depth immediately US, m	4.16046	4.446352	N/A
Mean elev. of deck, ft	111.275	111.275	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	0.962673	0.945879	ERR
Ys, depth of scour (chang), ft	0.868711	2.562356	N/A

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	7900	10300	3510	7900	10300	3510
a', abut.length blocking flow, ft	46.7	54.4	38.8	108	109.4	66.3
Ae, area of blocked flow ft2	322.8	334.7	149.9	429.5	355.4	328.9
Qe, discharge blocked abut.,cfs	1325	--	423.5	--	--	1144.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	4.10	4.60	2.83	4.10	4.82	3.48
ya, depth of f/p flow, ft	6.91	6.15	3.86	3.98	3.25	4.96
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.275	0.310	0.253	0.281	0.309	0.275
ys, scour depth, ft	23.48	23.96	14.30	20.79	19.21	20.23

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

a'(abut length blocked, ft)	46.7	54.4	38.8	108	109.4	66.3
y1 (depth f/p flow, ft)	6.91	6.15	3.86	3.98	3.25	4.96
a'/y1	6.76	8.84	10.04	27.16	33.68	13.36
Skew correction (p. 49, fig. 16)	0.95	0.95	0.95	0.95	0.95	0.95
Froude no. f/p flow	0.28	0.31	0.25	0.28	0.31	0.28
Skew Correction				0.96	0.96	
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	17.35	14.62	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR

spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.52	0.59	1.02	0.52	0.59	1.02
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	11.48	11.48	5.68	11.48	11.48	5.68
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.92	2.47	ERR	1.92	2.47	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	2.39	ERR	ERR	2.39