LEVEL II SCOUR ANALYSIS FOR BRIDGE 53 (CHESTH01180053) on TOWN HIGHWAY 118, crossing the WILLIAMS RIVER, CHESTER, VERMONT

Open-File Report 97-769

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

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By LORA K. STRIKER AND LAURA MEDALIE

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Pembroke, New Hampshire

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U.S. DEPARTMENT OF THE INTERIOR
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Box 25286
Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	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 53 (CHESTH01180053) ON TOWN HIGHWAY 118, CROSSING THE WILLIAMS RIVER, CHESTER, VERMONT

By **Lora K. Striker and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHESTH01180053 on Town Highway 118 crossing the Williams River, Chester, 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 New England Upland section of the New England physiographic province in southeastern Vermont. The 20.8-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly suburban while the right bank upstream is pasture. There is a house on the right bank downstream and VT 103 runs parallel to the river along the left bank.

In the study area, the Williams River has an incised, straight channel with a slope of approximately 0.005 ft/ft, an average channel top width of 64 ft and an average bank height of 7 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 58.0 mm (0.190 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 17, 1996, indicated that the reach was stable.

The Town Highway 118 crossing of the Williams River is a 43-ft-long, one-lane bridge consisting of one 40-foot steel-beam span (Vermont Agency of Transportation, written communication, April 6, 1995). The opening length of the structure parallel to the bridge face is 37.6 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 5 degrees to the opening while the computed opening-skew-to-roadway is 10 degrees.

A scour hole 0.5 ft deeper than the mean thalweg depth was observed at both abutments during the Level I assessment. Scour protection measures at the site include: type-3 stone fill (less than 48 inches diameter) along the left bank upstream and downstream and type-2 stone fill (less than 36 inches diameter) along the entire base length of the upstream left wingwall, at the upstream end of the left abutment, and at the upstream end of the downstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is determined and analyzed as another potential worst-case scour scenario. 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 was 0.0 ft. Abutment scour ranged from 5.8 to 6.8 ft at the left abutment and 9.4 to 14.4 ft at the right abutment. The worst-case abutment scour occurred at the incipient roadway-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and 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.

Chester, VT. Quadrangle, 1:24,000, 1972

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 CHESTH01180053 ***Stream*** Williams River

County Windsor ***Road*** TH 118 ***District*** 2

Description of Bridge

Bridge length 43 ***ft*** ***Bridge width*** 11.5 ***ft*** ***Max span length*** 40 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 09/17/96

Description of stone fill Type-2, at the upstream end of the left abutment, along the entire base length of the upstream left wingwall, and at the upstream end of the downstream left wingwall.

Abutments and wingwalls are concrete. There is 0.5 ft of channel scour on the left and right abutments. The right abutment footing is exposed 0.5 ft at the upstream end.

Yes

Is bridge skewed to flood flow according to - survey? 5 ***Angle*** No

09/17/96

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	0	0	09/17/
Level II	96	0	0

Potential for debris Low. There is evidence of ice jams due to minor scraping of bark on trees upstream of the bridge.

Describe any features near or at the bridge that may affect flow (include observation date) None, 09/17/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a flat flood plain and steep valley wall on the left bank.

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

Date of inspection 09/17/96

DS left: Steep channel bank to a narrow flood plain

DS right: Steep channel bank to a narrow flood plain

US left: Steep channel bank to a narrow flood plain

US right: Steep channel bank to a narrow flood plain

Description of the Channel

Average top width 64 ft ***Average depth*** 7 ft

Predominant bed material Sand- boulder ***Bank material*** Sand- boulder

The stream is equiwidth, straight, and stable with alluvial channel boundaries.

09/17/96

Vegetative co Brush to VT 103

DS left: Brush with a few trees, house, and lawn on the overbank (flood plain)

DS right: Grass and weeds to VT 103

US left: Trees and brush

US right: Yes

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

None, 09/17/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 20.8 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: There is a house on the downstream right overbank area.

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

USGS gage description Williams River near Rockingham, VT

USGS gage number 01153550

Gage drainage area 112 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 4,740 ***ft³/s*** ***Q500*** 6,950 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(20.8/21.3)exp 0.75] with discharge estimates from the Williams River upstream of Whitmore Brook. Whitmore Brook joins the Williams River downstream of this site. The WIlliams River has flood frequency estimates available from the Flood Insurance Study (FIS) for the town of Chester (Federal Emergency Management Agency, 1982). The drainage area above Whitmore Brook is 21.3 square miles. The discharges fall within range of several other empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 497.76 ft, arbitrary survey datum). RM2 is a National Geodetic Survey brass tablet located 10' DS of the bridge on the left bank between the Williams River and VT 103 in a rock halfway up the bank labelled 'L61, 1980' (elev. 505.61 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-50	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	7	1	Road Grade section
APPRO	51	2	Modelled Approach section (Templated from APTEM)
APTEM	57	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 0.040 to 0.050, and overbank "n" values ranged from 0.030 to 0.050.

The starting water surface at the exit section (EXIT1) from each modelled discharge was taken from a rating curve developed using discharges and water surface elevations at the same location from the FIS for the Town of Chester (Federal Emergency Management Agency, 1982). Since the discharges used in this model differed slightly from the FIS, the rating curve was used to calculate adjusted water surface elevations at the exit section.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.011 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 location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.8 ***ft***
Average low steel elevation 497.7 ***ft***

100-year discharge 4,740 ***ft³/s***
Water-surface elevation in bridge opening 497.7 ***ft***
Road overtopping? Yes ***Discharge over road*** 2,250 ***ft³/s***
Area of flow in bridge opening 315 ***ft²***
Average velocity in bridge opening 7.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.0 ***ft/s***

Water-surface elevation at Approach section with bridge 501.1
Water-surface elevation at Approach section without bridge 500.5
Amount of backwater caused by bridge 0.6 ***ft***

500-year discharge 6,950 ***ft³/s***
Water-surface elevation in bridge opening 497.7 ***ft***
Road overtopping? Yes ***Discharge over road*** 4,740 ***ft³/s***
Area of flow in bridge opening 315 ***ft²***
Average velocity in bridge opening 7.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.1 ***ft/s***

Water-surface elevation at Approach section with bridge 502.2
Water-surface elevation at Approach section without bridge 502.1
Amount of backwater caused by bridge 0.1 ***ft***

Incipient overtopping discharge 2,660 ***ft³/s***
Water-surface elevation in bridge opening 497.7 ***ft***
Area of flow in bridge opening 315 ***ft²***
Average velocity in bridge opening 8.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.7 ***ft/s***

Water-surface elevation at Approach section with bridge 499.1
Water-surface elevation at Approach section without bridge 498.0
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, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the 100- and 500-year scour analyses are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

At this site, the 100-year, 500-year, and incipient discharges resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146).

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144). The results are presented in Appendix F. All calculations for the estimation of contraction scour at this site resulted in 0.0 ft.

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 length to depth ratio of the embankment blocking flow exceeded 25 for the 100- and 500-year discharges at both abutments. Although the HIRE equation (Richardson and others, 1993, p. 50, equation 25) generally is applicable when this ratio exceeds 25, the results from the HIRE equation were not used. Hydraulic Engineering Circular 18 recommends that the field conditions be similar to those from which the HIRE equation was derived (Richardson and others, 1993). Since the equation was developed from Army Corp. of Engineers' data obtained for spurs dikes in the Mississippi River, the HIRE equation was not adopted for the narrow, incised, upland valley at this site.

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	0.0	0.0
Depth to armoring	0.8	0.3	1.3
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	5.8	6.5	6.8
Right abutment	9.4	10.4	14.4
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	1.2	1.0	1.4
Right abutment	1.2	1.0	1.4
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

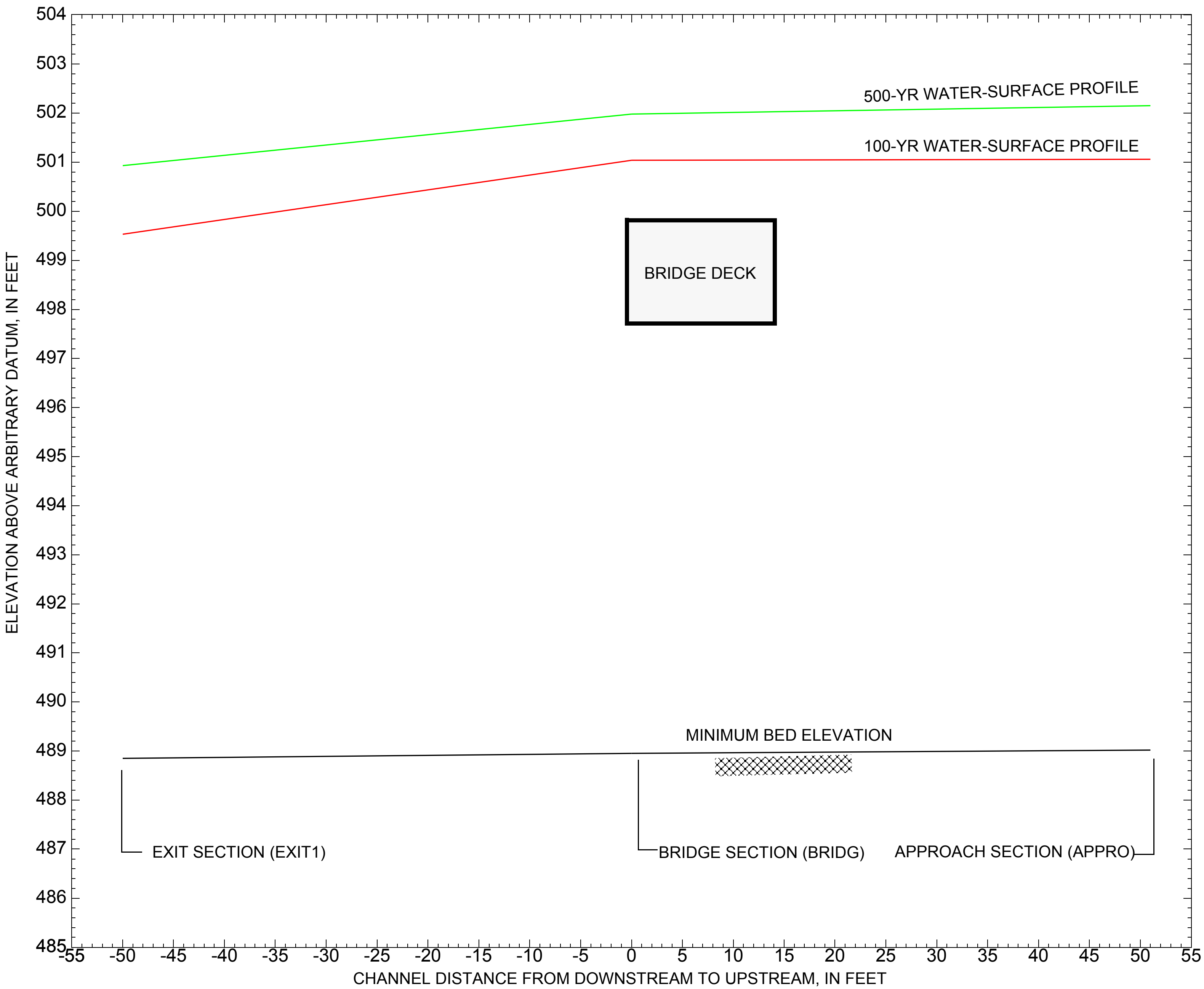

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure CHESTH01180053 on Town Highway 118, crossing the Williams River, Chester, Vermont.

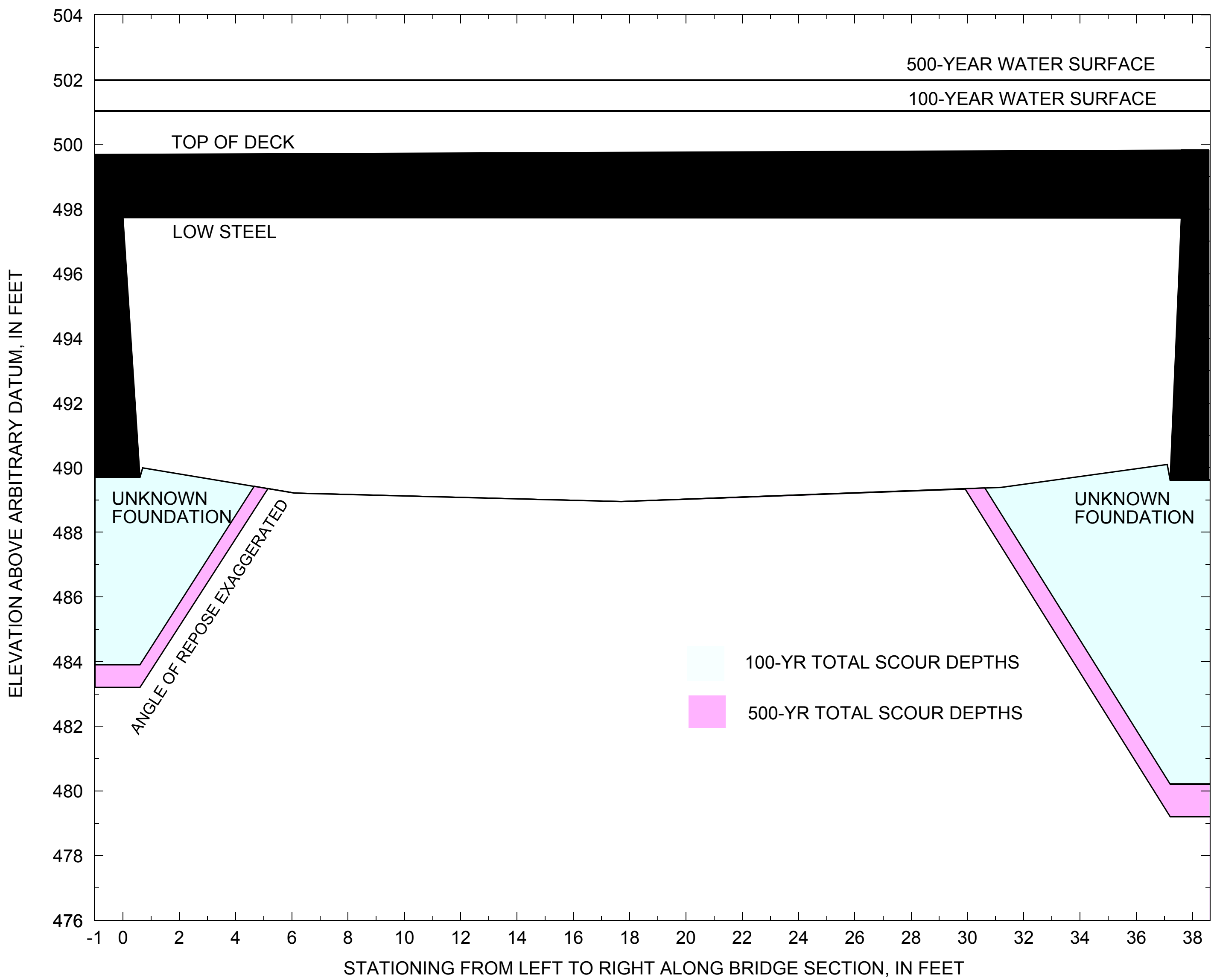

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure CHESTH01180053 on Town Highway 118, crossing the Williams River, Chester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHESTH01180053 on Town Highway 118, crossing the Williams River, Chester, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 4,740 cubic-feet per second											
Left abutment	0.0	--	497.7	--	489.7	0.0	5.8	--	5.8	483.9	--
Right abutment	37.6	--	497.7	--	489.6	0.0	9.4	--	9.4	480.2	--

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 CHESTH01180053 on Town Highway 118, crossing the Williams River, Chester, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 6,950 cubic-feet per second											
Left abutment	0.0	--	497.7	--	489.7	0.0	6.5	--	6.5	483.2	--
Right abutment	37.6	--	497.7	--	489.6	0.0	10.4	--	10.4	479.2	--

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, 1972, Chester, 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 ches053.wsp
T2        Hydraulic analysis for structure CHESTH 0118005   Date: 01-APR-97
T3        Bridge is local resident bridge connecting TH118 with VT 103, LKS
*
J1           * * 0.002
J3          6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4740.0   6950.0  2660.00
WS          499.53   500.93  497.51
*
XS   EXIT1   -50       0.
GR          -51.1, 507.33    -38.6, 500.34     -5.4, 498.61      0.0, 496.27
GR           10.4, 491.32     15.7, 490.01     21.6, 489.61     26.9, 488.85
GR           35.9, 489.35     43.1, 490.02     49.9, 492.43     62.2, 497.55
GR           96.5, 499.00    228.5, 499.99    358.5, 509.99
*
N           0.030    0.045         0.050
SA               -5.4       62.2
*
*
XS   FULLV      0    * * * 0.0038
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.73       0.0
GR            0.0, 497.73      0.6, 489.99      0.6, 489.70      6.1, 489.21
GR           17.7, 488.95     22.0, 489.05     31.2, 489.39     37.2, 489.61
GR           37.2, 490.10     37.6, 497.72      0.0, 497.73
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      21.6 * *     65.9      3.0
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      7      11.5     2
GR          -57.0, 509.71    -43.0, 500.75      0.0, 499.68     37.2, 499.82
GR           73.7, 498.87    251.0, 500.09    351.0, 510.09
*
*
XT   APTEM     57
GR          -64.3, 509.47    -46.1, 504.83    -40.7, 500.72     -6.1, 499.09
GR            0.0, 496.98     12.3, 490.21     13.2, 489.09     19.5, 489.77
GR           28.7, 489.69     37.3, 489.85     39.7, 490.24     46.5, 492.06
GR           54.8, 498.20    247.6, 500.87    347.6, 510.87
*
AS   APPRO     51 * * * 0.0111
GT
N           0.030     0.050     0.030
SA                -6.1     54.8
*
HP 1 BRIDG   497.73 1 497.73
HP 2 BRIDG   497.73 * * 2488
HP 2 RDWAY   501.04 * * 2249
HP 1 APPRO   501.06 1 501.06
HP 2 APPRO   501.06 * * 4740
*
HP 1 BRIDG   497.73 1 497.73
HP 2 BRIDG   497.73 * * 2224
HP 2 RDWAY   501.98 * * 4735
HP 1 APPRO   502.15 1 502.15
HP 2 APPRO   502.15 * * 6950
*
HP 1 BRIDG   497.73 1 497.73
HP 2 BRIDG   497.73 * * 2660
HP 1 APPRO   499.14 1 499.14
HP 2 APPRO   499.14 * * 2660
*
EX
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File ches053.wsp
      Hydraulic analysis for structure CHESTH 0118005   Date: 01-APR-97
      Bridge is local resident bridge connecting TH118 with VT 103, LKS
         *** RUN DATE & TIME: 08-20-97  15:45
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      315     26928      0     90                            0
 497.73           315     26928      0     90  1.00      0     38        0


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

       WSEL     LEW     REW    AREA        K        Q    VEL
     497.73     0.0    37.6   314.7   26928.    2488.   7.91

X STA.        0.0        3.4        5.5        7.3        9.0       10.7
  A(I)            25.4       17.0       15.4       14.5       14.7
  V(I)            4.90       7.33       8.07       8.57       8.46

X STA.       10.7       12.3       13.9       15.5       17.1       18.7
  A(I)            14.1       14.3       13.9       13.8       13.8
  V(I)            8.84       8.71       8.97       9.04       9.01

X STA.       18.7       20.3       21.9       23.5       25.2       26.8
  A(I)            14.0       13.9       14.0       14.1       14.4
  V(I)            8.90       8.93       8.88       8.83       8.65

X STA.       26.8       28.6       30.4       32.2       34.3       37.6
  A(I)            14.7       14.9       15.4       17.1       25.4
  V(I)            8.46       8.34       8.08       7.28       4.90

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       7.

       WSEL     LEW     REW    AREA        K        Q    VEL
     501.04   -43.5   260.5   426.5   17084.    2249.   5.27

X STA.      -43.5      -10.8        4.6       21.5       38.9       53.1
  A(I)            22.4       19.4       22.1       21.8       20.6
  V(I)            5.03       5.80       5.09       5.16       5.47

X STA.       53.1       63.4       72.4       80.7       89.3       98.4
  A(I)            18.2       18.3       17.9       17.9       18.5
  V(I)            6.19       6.16       6.28       6.27       6.07

X STA.       98.4      108.0      118.3      129.4      141.1      154.1
  A(I)            18.9       19.4       20.3       20.4       21.7
  V(I)            5.95       5.79       5.53       5.52       5.19

X STA.      154.1      168.3      184.4      203.3      225.0      260.5
  A(I)            22.3       23.6       25.3       26.2       31.5
  V(I)            5.05       4.76       4.44       4.29       3.57

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1       42      2377     35     35                          264
           2      542     65881     61     66                         9181
           3      307     20628    195    195                         2186
 501.06           892     88886    291    297  1.22    -40    250     8031

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

       WSEL     LEW     REW    AREA        K        Q    VEL
     501.06   -41.2   250.2   891.8   88886.    4740.   5.32

X STA.      -41.2        2.8        9.2       13.1       16.0       18.8
  A(I)            75.1       47.5       40.4       34.2       32.8
  V(I)            3.16       4.99       5.86       6.93       7.22

X STA.       18.8       21.6       24.4       27.1       29.8       32.5
  A(I)            31.6       32.0       31.0       30.7       30.6
  V(I)            7.51       7.42       7.65       7.73       7.76

X STA.       32.5       35.3       38.0       41.1       44.6       49.6
  A(I)            31.6       31.4       32.9       35.1       42.4
  V(I)            7.50       7.55       7.21       6.75       5.58

X STA.       49.6       66.1       86.3      111.7      146.4      250.2
  A(I)            57.7       53.1       58.7       65.9       97.2
  V(I)            4.10       4.46       4.04       3.60       2.44
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File ches053.wsp
       Hydraulic analysis for structure CHESTH 0118005   Date: 01-APR-97
       Bridge is local resident bridge connecting TH118 with VT 103, LKS
          *** RUN DATE & TIME: 08-20-97  15:45
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      315     26928      0     90                            0
  497.73           315     26928      0     90  1.00      0     38        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.73     0.0    37.6   314.7   26928.    2224.   7.07

X STA.         0.0        3.4        5.5        7.3        9.0       10.7
  A(I)             25.4       17.0       15.4       14.5       14.7
  V(I)             4.38       6.55       7.22       7.66       7.56

X STA.        10.7       12.3       13.9       15.5       17.1       18.7
  A(I)             14.1       14.3       13.9       13.8       13.8
  V(I)             7.91       7.78       8.01       8.08       8.06

X STA.        18.7       20.3       21.9       23.5       25.2       26.8
  A(I)             14.0       13.9       14.0       14.1       14.4
  V(I)             7.95       7.99       7.94       7.89       7.73

X STA.        26.8       28.6       30.4       32.2       34.3       37.6
  A(I)             14.7       14.9       15.4       17.1       25.4
  V(I)             7.56       7.45       7.23       6.51       4.38

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       7.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.98   -44.9   269.9   717.3   39927.    4735.   6.60

X STA.       -44.9      -22.2       -8.3        6.5       22.0       38.4
  A(I)             32.1       26.8       33.1       34.9       35.8
  V(I)             7.37       8.84       7.16       6.79       6.62

X STA.        38.4       52.5       64.3       75.2       85.7       96.8
  A(I)             33.6       31.9       32.8       32.0       33.3
  V(I)             7.04       7.42       7.22       7.39       7.11

X STA.        96.8      108.3      120.6      133.4      146.7      161.3
  A(I)             33.5       34.6       35.3       35.1       37.4
  V(I)             7.07       6.83       6.70       6.74       6.34

X STA.       161.3      176.9      193.6      212.0      232.7      269.9
  A(I)             38.4       39.0       41.0       43.2       53.6
  V(I)             6.17       6.08       5.78       5.48       4.42

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       81      6833     37     37                          690
            2      609     79865     61     66                        10918
            3      526     48761    206    206                         4767
  502.15          1216    135458    304    309  1.10    -42    261    13189

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

        WSEL     LEW     REW    AREA        K        Q    VEL
      502.15   -42.7   261.1  1216.1  135458.    6950.   5.71

X STA.       -42.7       -6.2        7.2       12.4       16.3       19.9
  A(I)             81.0       77.5       55.8       49.7       46.5
  V(I)             4.29       4.49       6.23       6.99       7.48

X STA.        19.9       23.6       27.1       30.6       34.1       37.7
  A(I)             45.0       44.2       43.6       44.4       44.2
  V(I)             7.72       7.86       7.97       7.82       7.86

X STA.        37.7       41.6       46.2       57.5       72.8       89.4
  A(I)             45.9       50.4       72.5       59.5       60.5
  V(I)             7.57       6.89       4.79       5.84       5.75

X STA.        89.4      108.8      130.6      157.2      193.0      261.1
  A(I)             66.2       67.9       74.0       84.1      103.2
  V(I)             5.25       5.12       4.69       4.13       3.37
```

```
        U.S. Geological Survey WSPRO Input File ches053.wsp
        Hydraulic analysis for structure CHESTH 0118005   Date: 01-APR-97
        Bridge is local resident bridge connecting TH118 with VT 103, LKS
           *** RUN DATE & TIME: 08-20-97  15:45
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      315     26928      0     90                            0
   497.73           315     26928      0     90  1.00      0     38        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.73     0.0    37.6   314.7   26928.    2660.   8.45

X STA.         0.0        3.4        5.5        7.3        9.0       10.7
  A(I)             25.4       17.0       15.4       14.5       14.7
  V(I)             5.23       7.84       8.63       9.16       9.04

X STA.        10.7       12.3       13.9       15.5       17.1       18.7
  A(I)             14.1       14.3       13.9       13.8       13.8
  V(I)             9.45       9.31       9.59       9.66       9.64

X STA.        18.7       20.3       21.9       23.5       25.2       26.8
  A(I)             14.0       13.9       14.0       14.1       14.4
  V(I)             9.51       9.55       9.49       9.44       9.24

X STA.        26.8       28.6       30.4       32.2       34.3       37.6
  A(I)             14.7       14.9       15.4       17.1       25.4
  V(I)             9.04       8.91       8.64       7.78       5.24

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1        0         1      2      2                            0
             2      425     43950     61     66                         6378
             3       37      1150     73     73                          147
   499.14           462     45101    136    141  1.09     -8    127     4618

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.14    -8.6   127.5   462.0   45101.    2660.   5.76

X STA.        -8.6        7.8       11.4       14.0       16.0       18.1
  A(I)             41.4       27.1       24.3       20.5       19.7
  V(I)             3.22       4.91       5.48       6.50       6.74

X STA.        18.1       20.1       22.1       24.0       26.0       27.9
  A(I)             19.6       18.5       18.3       18.2       18.2
  V(I)             6.78       7.17       7.25       7.32       7.31

X STA.        27.9       29.8       31.6       33.5       35.5       37.5
  A(I)             17.9       17.9       18.0       18.6       18.3
  V(I)             7.42       7.44       7.38       7.16       7.28

X STA.        37.5       39.6       41.9       44.7       48.7      127.5
  A(I)             19.3       20.5       22.1       27.1       56.6
  V(I)             6.90       6.48       6.02       4.90       2.35
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ches053.wsp
        Hydraulic analysis for structure CHESTH 0118005   Date: 01-APR-97
        Bridge is local resident bridge connecting TH118 with VT 103, LKS
           *** RUN DATE & TIME: 08-20-97  15:45

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT1:XS   ******    -22      577  1.27 *****  500.80  497.24    4740  499.53
       -49 ******    167    63819  1.20 ***** *******    0.91    8.22

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.91     499.88     497.43

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   499.03     510.18    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   499.03     510.18     497.43

FULLV:FV       50    -25      610  1.18  0.26  501.07  497.43    4740  499.88
         0     50    189    66723  1.26  0.00    0.01    0.91    7.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       51    -36      728  0.82  0.24  501.30 *******    4740  500.48
        51     51    224    70764  1.24  0.00   -0.01    0.77    6.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   499.88     497.73

            <<<<<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       50      0      315  0.97 *****  498.70  494.46    2488  497.73
         0 ******     38    26928  1.00 ***** *******    0.48    7.91

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.73 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       7.    40.  0.11  0.54  501.48    0.00   2249.  501.04

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    304.    62.   -43.    19.   1.4   1.0   5.2   5.0   1.4   2.9
   RT:   1945.   242.    19.   261.   2.2   1.5   6.2   5.3   2.0   2.9

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

APPRO:AS       29    -40      891  0.54  0.19  501.59  497.70    4740  501.06
        51     35    250    88769  1.22  0.00    0.00    0.59    5.32

      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
   EXIT1:XS     -50.   -23.   167.   4740.   63819.     577.    8.22  499.53
   FULLV:FV       0.   -26.   189.   4740.   66723.     610.    7.77  499.88
   BRIDG:BR       0.     0.    38.   2488.   26928.     315.    7.91  497.73
   RDWAY:RG       7.*******   304.   2249.******************    2.00  501.04
   APPRO:AS      51.   -41.   250.   4740.   88769.     891.    5.32  501.06

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    497.24    0.91  488.85  509.99************  1.27  500.80  499.53
   FULLV:FV    497.43    0.91  489.04  510.18  0.26  0.00  1.18  501.07  499.88
   BRIDG:BR    494.46    0.48  488.95  497.73************  0.97  498.70  497.73
   RDWAY:RG  ****************  498.87  510.09  0.11******  0.54  501.48  501.04
   APPRO:AS    497.70    0.59  489.02  510.80  0.19  0.00  0.54  501.59  501.06
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ches053.wsp
        Hydraulic analysis for structure CHESTH 0118005   Date: 01-APR-97
        Bridge is local resident bridge connecting TH118 with VT 103, LKS
           *** RUN DATE & TIME: 08-20-97  15:45

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

EXIT1:XS   ******    -39      936  1.30 *****  502.23  500.44    6950  500.93
       -49 ******    241    97569  1.51 ***** *******    0.88    7.42

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.81     501.32     500.63

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   500.43     510.18    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   500.43     510.18     500.63

FULLV:FV       50    -39      978  1.19  0.24  502.46  500.63    6950  501.27
         0     50    243   102113  1.52  0.00   -0.01    0.83    7.11
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       51    -42     1186  0.59  0.18  502.64 *******    6950  502.05
        51     51    260   130760  1.10  0.00    0.00    0.55    5.86
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   501.27     497.73

            <<<<<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       50      0      315  0.78 *****  498.51  494.09    2224  497.73
         0 ******     38    26928  1.00 ***** *******    0.43    7.07

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.73 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       7.    40.  0.10  0.56  502.60    0.00   4735.  501.98

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    753.    64.   -45.    19.   2.3   1.9   7.1   6.3   2.5   3.0
   RT:   3982.   251.    19.   270.   3.1   2.4   7.9   6.7   3.0   3.0

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

APPRO:AS       29    -42     1216  0.56  0.23  502.71  500.92    6950  502.15
        51     40    261   135506  1.10  0.00    0.00    0.53    5.71

       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
   EXIT1:XS     -50.   -40.   241.   6950.   97569.     936.    7.42  500.93
   FULLV:FV       0.   -40.   243.   6950.  102113.     978.    7.11  501.27
   BRIDG:BR       0.     0.    38.   2224.   26928.     315.    7.07  497.73
   RDWAY:RG       7.*******   753.   4735.******************    2.00  501.98
   APPRO:AS      51.   -43.   261.   6950.  135506.    1216.    5.71  502.15

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    500.44    0.88  488.85  509.99************  1.30  502.23  500.93
   FULLV:FV    500.63    0.83  489.04  510.18  0.24  0.00  1.19  502.46  501.27
   BRIDG:BR    494.09    0.43  488.95  497.73************  0.78  498.51  497.73
   RDWAY:RG  ****************  498.87  510.09  0.10******  0.56  502.60  501.98
   APPRO:AS    500.92    0.53  489.02  510.80  0.23  0.00  0.56  502.71  502.15
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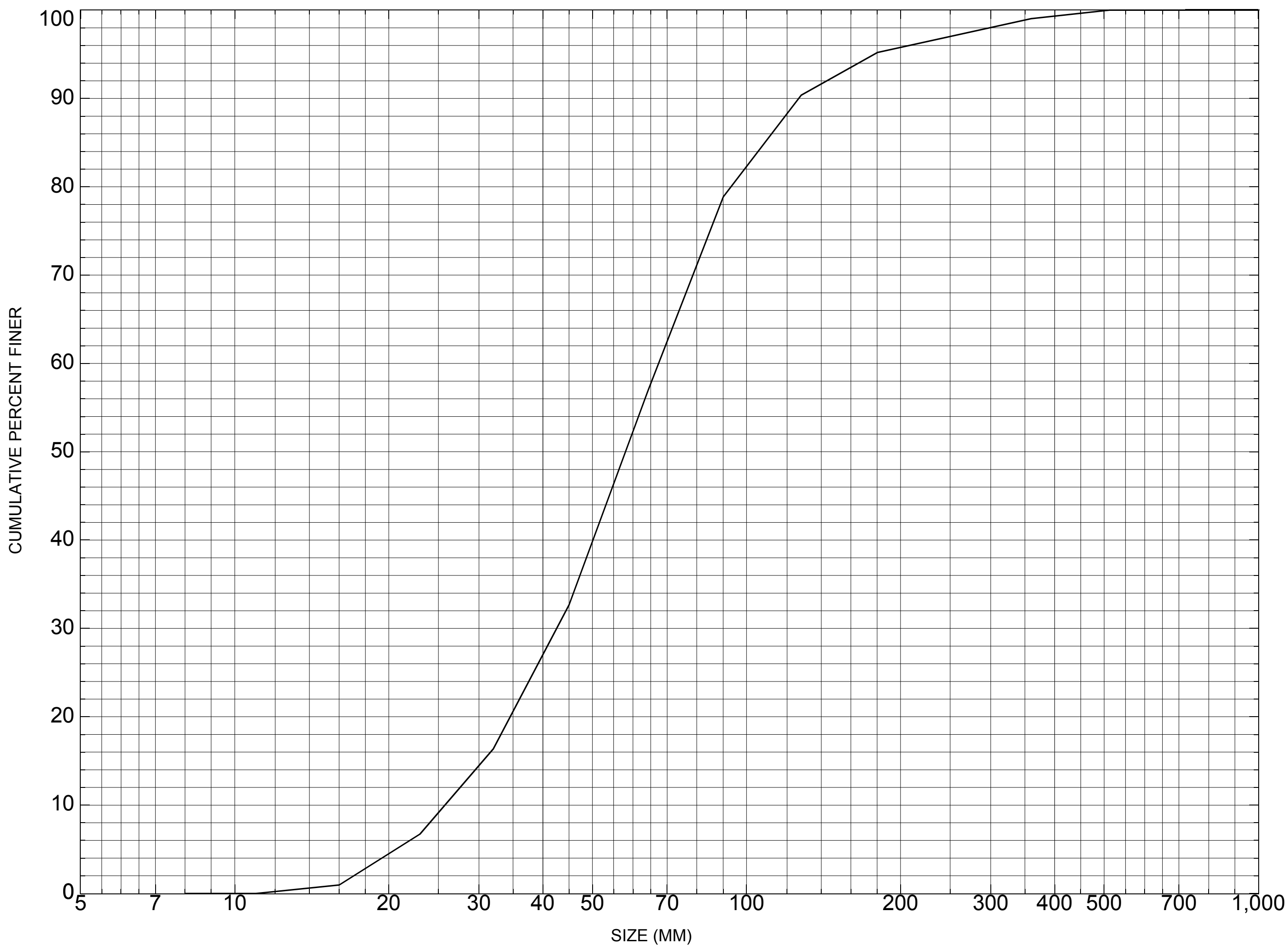
```
        U.S. Geological Survey WSPRO Input File ches053.wsp
        Hydraulic analysis for structure CHESTH 0118005   Date: 01-APR-97
        Bridge is local resident bridge connecting TH118 with VT 103, LKS
           *** RUN DATE & TIME: 08-20-97  15:45

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

EXIT1:XS   ******     -2      372  0.80 *****  498.31  495.08    2660  497.51
       -49 ******     62    38187  1.00 ***** *******    0.53    7.15

FULLV:FV       50     -2      377  0.77  0.24  498.56 *******    2660  497.79
         0     50     63    39023  1.00  0.00    0.01    0.52    7.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       51     -2      358  0.86  0.27  498.87 *******    2660  498.01
        51     51     55    34122  1.00  0.04    0.00    0.53    7.43
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   497.79     497.73

            <<<<<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       50      0      315  1.11 *****  498.84  494.69    2655  497.73
         0 ******     38    26928  1.00 ***** *******    0.51    8.44

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   3.  0.800  0.000  497.73 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       7.        <<<<<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       29     -8      462  0.56  0.19  499.70  495.40    2660  499.14
        51     33    127    45092  1.09  0.00    0.00    0.58    5.76

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.00

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -50.    -3.    62.   2660.   38187.     372.    7.15  497.51
   FULLV:FV       0.    -3.    63.   2660.   39023.     377.    7.05  497.79
   BRIDG:BR       0.     0.    38.   2655.   26928.     315.    8.44  497.73
   RDWAY:RG       7.**************      0.       0.       0.    2.00********
   APPRO:AS      51.    -9.   127.   2660.   45092.     462.    5.76  499.14

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO   VHD      EGL    WSEL
   EXIT1:XS    495.08    0.53  488.85  509.99************  0.80  498.31  497.51
   FULLV:FV  ********    0.52  489.04  510.18  0.24  0.00  0.77  498.56  497.79
   BRIDG:BR    494.69    0.51  488.95  497.73************  1.11  498.84  497.73
   RDWAY:RG  ****************  498.87  510.09************  0.56  499.57********
   APPRO:AS    495.40    0.58  489.02  510.80  0.19  0.00  0.56  499.70  499.14
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESTH01180053, in Chester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHESTH01180053

General Location Descriptive

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

Date *(MM/DD/YY)* 04 / 06 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 13675

Mile marker *(I - 11; nnn.nnn)* 300000

Waterway *(I - 6)* WILLIAMS RIVER

Road Name *(I - 7):* -

Route Number TH118

Vicinity *(I - 9)* 0.01 MI TO JCT W VT103

Topographic Map Chester

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43174

Longitude *(i - 17; nnnnn.n)* 72363

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10140700531407

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

Maximum span length *(I - 48; nnnn)* 0040

Year built *(I - 27; YYYY)* 1919

Structure length *(I - 49; nnnnnn)* 000043

Average daily traffic, ADT *(I - 29; nnnnnn)* 000020

Deck Width *(I - 52; nn.n)* 115

Year of ADT *(I - 30; YY)* 94

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

Opening skew to Roadway *(I - 34; nn)* 00

Waterway adequacy *(I - 71; n)* 6

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 8.0

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

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

Comments:

The structural inspection report of 09/23/95 indicates the structure is a single span, steel beam type bridge with a concrete deck. Both concrete abutment faces have very minor stains noted. There is a section of footing in view at the upstream end of the right abutment. The streambed is flush with the top of the footing. The waterway has a fairly straight alignment through the structure. The streambed consists of stone and gravel with some random boulders.

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: -

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

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

Upstream distance (*miles*): 0.25 Town: Chester Year Built: 1930

Highway No. : TH 17 Structure No. : 75 Structure Type: 302

Clear span (*ft*): 56.0 Clear Height (*ft*): 12.0 Full Waterway (*ft²*): -

Downstream distance (*miles*): **2.0** Town: **Chester** Year Built: **1931**

Highway No. : **VT 103** Structure No. : **12** Structure Type: **104**

Clear span (*ft*): **87.0** Clear Height (*ft*): **13.5** Full Waterway (ft^2): **680.0**

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **20.82** mi^2

Lake/pond/swamp area **0.03** mi^2

Watershed storage *(ST)* **0.1** %

Bridge site elevation **640** ft

Headwater elevation **2882** ft

Main channel length **12.49** mi

10% channel length elevation **680** ft

85% channel length elevation **1660** ft

Main channel slope *(S)* **104.65** 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:

There is no benchmark information available.

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:

There is no foundation material information available.

Comments:

There are no bridge plans available.

Cross-sectional Data

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

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

Comments: **The measurements are in feet.**

Station	**217**	**234**	**255**	-	-	-	-	-	-	-	-
Feature	**LAB**		**RAB**	-	-	-	-	-	-	-	-
Low chord elevation	**630.9**	**630.9**	**630.9**	-	-	-	-	-	-	-	-
Bed elevation	**622.3**	**622.8**	**623.5**	-	-	-	-	-	-	-	-
Low chord-bed	**8.6**	**8.1**	**7.4**	-	-	-	-	-	-	-	-

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 10/15/96
Computerized by: RB Date: 10/16/96
Reviewd by: LKS Date: 08/20/97

Structure Number CHESTH01180053

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 09 / 17 / 1996
2. Highway District Number 02 Mile marker 300000
County WINDSOR (027) Town CHESTER (13675)
Waterway *(I - 6)* WILLIAMS RIVER Road Name -
Route Number TH118 Hydrologic Unit Code: 01080107
3. Descriptive comments:
The bridge is located 0.01 miles from the junction of VT 103. A local resident stated that the bridge was not overtopped in the flood of 1973.

B. Bridge Deck Observations

4. Surface cover... LBUS 2 RBUS 4 LBDS 2 RBDS 2 Overall 2
*(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 1 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 43 *(feet)* Span length 40 *(feet)* Bridge width 11.5 *(feet)*

Road approach to bridge:

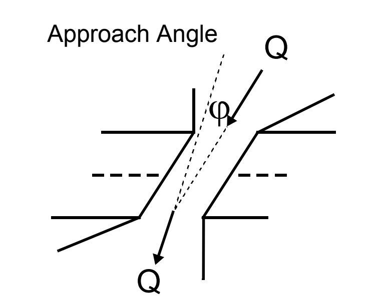
8. LB 0 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

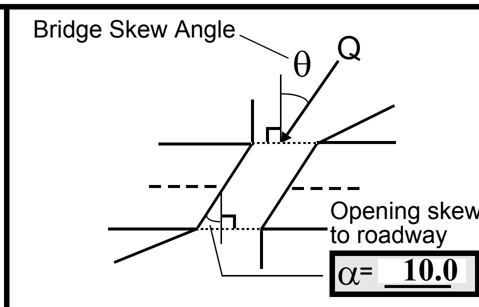
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	2	1
RBDS	0	-	0	-
LBDS	2	2	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 5





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 78 feet US *(US, UB, DS)* to 38 feet DS
Channel impact zone 2: Exist? N *(Y or N)*
Where? - *(LB, RB)* Severity -
Range? - feet - *(US, UB, DS)* to - feet -

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

18. Bridge Type: **1a**

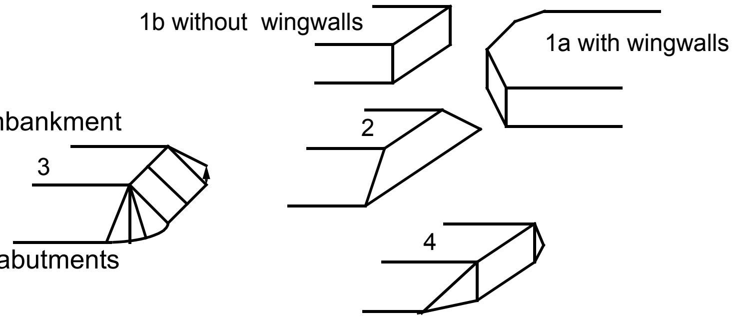
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. The right bank has trees along the bank and lawn beyond the trees and a house DS.
7. The bridge measurement values are from the VTAOT files. Measured bridge width is 11.6 ft., bridge span is 38 ft, and bridge length is 43 ft.
8. VT 103 is crowned so that the center of the road is slightly higher than the bridge and the sides of the road are slightly lower.
9. For the left road approach, there is a 5 ft dirt section after the end of the bridge and then VT 103.
11. On the left bank DS there is a laid-up stone wall beyond the end of the wingwall that is slumped at the DS end. A small patch of asphalt was poured off the side of VT 103 with some loose gravel on both sides of it on the left bank DS for road wash drainage.
17. The most severe impact and greatest amount of protection is at 38 ft US on the left bank.

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
46.0	**9.0**			**6.0**	**1**	**4**	**352**	**342**	**1**	**1**

23. Bank width **25.0** 24. Channel width **35.0** 25. Thalweg depth **61.0** 29. Bed Material **34**

30 .Bank protection type: LB **3** RB **0** 31. Bank protection condition: LB **1** 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. On the left bank, the boulders are added protection and not bank material because of VT 103 at the top of the bank.
30. The left bank protection is not continuous, but patchy. It is placed where needed from the US bridge face to 87 ft US.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **66** 35. Mid-bar width: **5**

36. Point bar extent: **45** feet **US** (US, UB) to **83** feet **US** (US, UB, DS) positioned **75** %LB to **100** %RB

37. Material: **34**

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

-

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

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

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

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

There are no cut-banks upstream at this site.

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.):

There is no channel scour upstream at this site. However, there is some very minor scour in the vicinity of a large boulder in the center of the channel at 90 ft upstream.

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):

There are no major confluences upstream at this site.

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
34.0		**0.5**		**2**	**7**	**7**	**-**

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

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

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

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

3452

63. The bed material grades from sand and gravel at the left side of the channel, to cobbles in mid-channel, and back to gravel and sand at the right side of the channel. In addition to the sand and gravel there are a couple of random boulders.

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

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

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

70. Debris and Ice Comments:

1

There is minor scraping of the bark on the US sides of the trees.

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		5	90	2	1	0.5	-	90.0
RABUT	1	0	90			2	2	37.0

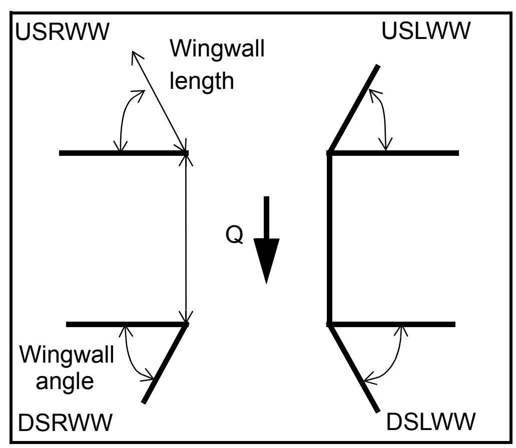
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

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

0.5
0.5
1
74. There is a small scour hole near the left abutment under the bridge that is 9 ft long and 4 ft wide.
76. The right abutment footing is exposed 0.5 ft at the US end. There is also a 1.5 ft square chunk eroded from the bottom DS end of the right abutment.
75. A minor 2 ft round scour hole is in the sand at the corner of the US right wingwall and right abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						37.0	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	11.5	
DSRWW:	1		2		0.5	15.5	



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	0.5	0	N	-	1	-	2	-
Condition	Y	-	-	-	1	-	2	-
Extent	1	-	-	2	0	2	0	--

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

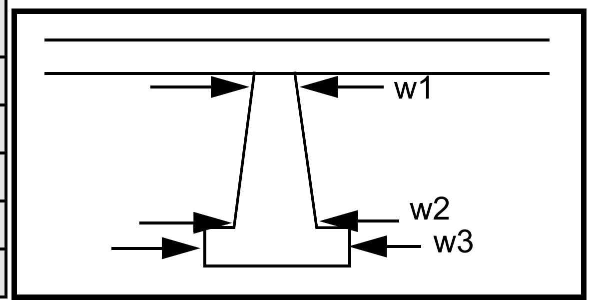
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
2
2
2
-
-
-

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				**95.0**	**11.0**	**35.0**
Pier 2	**8.5**	**9.0**	**9.5**	**90.0**	**10.0**	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**then**	**the**	**at the**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**DS**	**turn**	**end.**	**DS**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**left**	**s**	**The**	**end.**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**wing**	**into**	**US**	**The**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wall**	**a**	**right**	**US**	*Y- yes; N- no*
91. Attack ∠ (BF)	**is**	**stone**	**wing**	**right**	
92. Pushed	**con-**	**wall**	**wall**	**wing**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**crete**	**that**	**foot-**	**wall**	
95. Cross-members	**for**	**is**	**ing is**	**exte**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**the**	**slum**	**only**	**nds**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**first**	**ped**	**expo**	**out**	
98. Exposure depth	**7 ft**	**at**	**sed**	**from**	

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

the edge of the abutment 6.3 ft and then angles back for an additional 2 ft. At this point there are remains of a slumping stone wall for 5 ft.

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 - Thalweg depth - Bed Material -

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

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

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

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

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

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

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.):

-
-
-
-

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

Cut bank extent: no feet pie (US, UB, DS) to rs. 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.):

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

Scour dimensions: Length ____ Width 1 Depth: 3 Positioned 54 %LB to 24 %RB

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

1
0
345
3

Are there major confluences? 0 (Y or if N type ctrl-n mc) How many? 1

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

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

Confluence comments (eg. confluence name):

tion is a few large boulders in the bank from the end of the wingwall to 35 ft DS.

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

109. G. Plan View Sketch

- -

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: CHESTH01180053 Town: CHESTER
Road Number: TH 118 County: WINDSOR
Stream: WILLIAMS RIVER

Initials LKS Date: 06/30/97 Checked: EMB

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	4740	6950	2660
Main Channel Area, ft2	542	609	425
Left overbank area, ft2	42	81	0
Right overbank area, ft2	307	526	37
Top width main channel, ft	61	61	61
Top width L overbank, ft	35	37	2
Top width R overbank, ft	195	206	73
D50 of channel, ft	0.1903	0.1903	0.1903
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.9	10.0	7.0
y1, average depth, LOB, ft	1.2	2.2	0.0
y1, average depth, ROB, ft	1.6	2.6	0.5
Total conveyance, approach	88886	135458	45101
Conveyance, main channel	65881	79865	43950
Conveyance, LOB	2377	6833	1
Conveyance, ROB	20628	48761	1150
Percent discrepancy, conveyance	0.0000	-0.0007	0.0000
Qm, discharge, MC, cfs	3513.2	4097.7	2592.1
Ql, discharge, LOB, cfs	126.8	350.6	0.1
Qr, discharge, ROB, cfs	1100.0	2501.8	67.8
Vm, mean velocity MC, ft/s	6.5	6.7	6.1
Vl, mean velocity, LOB, ft/s	3.0	4.3	ERR
Vr, mean velocity, ROB, ft/s	3.6	4.8	1.8
Vc-m, crit. velocity, MC, ft/s	9.3	9.5	8.9
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	4740	6950	2660
(Q) discharge thru bridge, cfs	2488	2224	2660
Main channel conveyance	26928	26928	26928
Total conveyance	26928	26928	26928
Q2, bridge MC discharge,cfs	2488	2224	2660
Main channel area, ft2	315	315	315
Main channel width (normal), ft	37.6	37.6	37.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	37.6	37.6	37.6
y_bridge (avg. depth at br.), ft	8.37	8.37	8.37
Dm, median (1.25*D50), ft	0.237875	0.237875	0.237875
y2, depth in contraction,ft	6.78	6.16	7.18
ys, scour depth (y2-ybridge), ft	-1.59	-2.21	-1.19

Armoring
Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2488	2224	2660
Main channel area (DS), ft2	314.7	314.7	314.7
Main channel width (normal), ft	37.6	37.6	37.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	37.6	37.6	37.6
D90, ft	0.4150	0.4150	0.4150
D95, ft	0.5826	0.5826	0.5826
Dc, critical grain size, ft	0.2080	0.1662	0.2377
Pc, Decimal percent coarser than Dc	0.439	0.592	0.352
Depth to armoring, ft	**0.80**	**0.34**	**1.31**

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	4740	6950	2660
Q, thru bridge MC, cfs	2488	2224	2660
Vc, critical velocity, ft/s	9.28	9.46	8.91
Va, velocity MC approach, ft/s	6.48	6.73	6.10
Main channel width (normal), ft	37.6	37.6	37.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	37.6	37.6	37.6
qbr, unit discharge, ft2/s	66.2	59.1	70.7
Area of full opening, ft2	314.7	314.7	314.7
Hb, depth of full opening, ft	8.37	8.37	8.37
Fr, Froude number, bridge MC	0.48	0.43	0.51
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	497.73	497.73	497.73
Elevation of Bed, ft	489.36	489.36	489.36
Elevation of Approach, ft	501.06	502.15	499.14
Friction loss, approach, ft	0.19	0.23	0.19
Elevation of WS immediately US, ft	500.87	501.92	498.95
ya, depth immediately US, ft	11.51	12.56	9.59
Mean elevation of deck, ft	499.75	499.75	499.75
w, depth of overflow, ft (>=0)	1.12	2.17	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.95	0.97
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	**-0.84**	**-1.77**	**-0.16**
Ys, scour w/Umbrell equation, ft	1.24	1.68	0.04

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

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

**Ys, scour w/Umbrell equation, ft	N/A	N/A	N/A

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

y2, from Laursen's equation, ft	6.78	6.16	7.18
WSEL at downstream face, ft	--	--	--
Depth at downstream face, ft	N/A	N/A	N/A
Ys, depth of scour (Laursen), ft	N/A	N/A	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	4740	6950	2660	4740	6950	2660
a', abut.length blocking flow, ft	41.2	42.7	8.6	212.6	223.5	89.9
Ae, area of blocked flow ft2	34.31	39.4	21.71	114.16	141.66	144.68
Qe, discharge blocked abut.,cfs	--	--	69.74	--	--	658.67
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.16	4.35	3.21	4.31	5.08	4.55
ya, depth of f/p flow, ft	0.83	0.92	2.52	0.54	0.63	1.61
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.426	0.463	0.356	0.524	0.512	0.632
ys, scour depth, ft	**5.76**	**6.51**	**6.77**	**9.36**	**10.40**	**14.38**

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)	41.2	42.7	8.6	212.6	223.5	89.9
y1 (depth f/p flow, ft)	0.83	0.92	2.52	0.54	0.63	1.61
a'/y1	49.47	46.28	3.41	395.92	352.62	55.86
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.43	0.46	0.36	0.52	0.51	0.63
Ys w/ corr. factor K1/0.55:						
vertical	4.57	5.20	ERR	3.16	3.70	10.06
vertical w/ ww's	3.75	4.27	ERR	2.59	3.03	8.25
spill-through	2.51	2.86	ERR	1.74	2.03	5.53

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	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.48	0.43	0.51	0.48	0.43	0.51
y, depth of flow in bridge, ft	8.37	8.37	8.37	8.37	8.37	8.37
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.19**	**0.96**	**1.35**	**1.19**	**0.96**	**1.35**
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR