LEVEL II SCOUR ANALYSIS FOR BRIDGE 52 (CHESTH00100052) on TOWN HIGHWAY 10, crossing the SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT

Open-File Report 98-012

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

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By EMILY C. WILD and MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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 52 (CHESTH00100052) ON TOWN HIGHWAY 10, CROSSING THE SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT

By **Emily C. Wild and Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHESTH00100052 on Town Highway 10 crossing the South Branch 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 (FHWA, 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 4.05-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream and downstream of the bridge.

In the study area, the South Branch Williams River has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 35 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 82.1 mm (0.269 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 21, 1996, indicated that the reach was unstable, as a result of the moderate bank erosion.

The Town Highway 10 crossing of the South Branch Williams River is a 32-ft-long, one-lane bridge consisting of a 29-foot steel-stringer span (Vermont Agency of Transportation, written communication, March 31, 1995). The opening length of the structure parallel to the bridge face is 27.6 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway is 20 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed at the downstream end of the right abutment during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the upstream left and right banks, the upstream end of the upstream right wingwall and the entire base length of the upstream 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 Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was 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 ranged from 0.0 to 0.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 5.2 to 10.8 ft. The worst-case abutment scour also 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.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and Davis, 1995, p. 46). 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.

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number CHESTH00100052 ***Stream*** South Branch Williams River

County Windsor ***Road*** TH10 ***District*** 2

Description of Bridge

Bridge length 32 ***ft*** ***Bridge width*** 17.3 ***ft*** ***Max span length*** 29 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** None

Stone fill on abutment? No ***Date of inspection*** 8/21/96

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

Abutments the upstream right wingwall are concrete. There is a one foot deep scour hole in front of the downstream end of the right abutment.

Yes

25 Yes

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

is a moderate channel bend in the upstream reach. The scour hole has developed in the location where the flow impacts the downstream end of the 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	8/21/96	0	0
Level II	8/21/96	0	0

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

None, 8/21/96.

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

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with little or no flood plains.

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

Date of inspection 8/21/96

DS left: Moderately sloped overbank.

DS right: Moderately sloped overbank to a steep valley wall.

US left: Moderately sloped overbank.

US right: Steep valley wall.

Description of the Channel

Average top width 35 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material Cobbles/Boulders ***Bank material*** Cobbles/Boulders

Sinuous with non-alluvial channel boundaries.

8/21/96

Vegetative co

DS left: Trees

DS right: Trees

US left: Trees

US right: Trees

Do banks appear stable? No ***If not, describe location and type of instability and date of observation.***

There are cut-banks upstream and downstream of the bridge.

None, 8/21/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 4.05 ***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***: None.

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,550 ***ft³/s*** ***Q500*** 2,200 ***ft³/s***

The 100-year discharge is from the flood frequency estimates available from the VTAOT database. The 500-year discharge was extrapolated graphically from these estimates. The values used were within a range defined by flood frequency curves developed from several 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 upstream end of the right abutment (elev. 498.88 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 498.62 ft, arbitrary survey datum). RM3 is a chiseled X on top of the upstream end of the left abutment (elev. 500.15 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	-27	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APPR1	49	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 were 0.065, and overbank "n" values ranged from 0.065 to 0.070.

Normal depth at the exit section (EXIT1) 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 0.0283 ft/ft, which was estimated from the 100-year discharge water surface slope downstream of the bridge in the Flood Insurance Study for Chester, VT (FEMA, February 1982).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0474 ft/ft) to establish the modelled approach section (APPR1), 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.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 502.4 ***ft***
Average low steel elevation 499.6 ***ft***

100-year discharge 1,550 ***ft^3/s***
Water-surface elevation in bridge opening 500.3 ***ft***
Road overtopping? Yes ***Discharge over road*** 100 ***ft^3/s***
Area of flow in bridge opening 177 ***ft^2***
Average velocity in bridge opening 8.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.8 ***ft/s***

Water-surface elevation at Approach section with bridge 501.4
Water-surface elevation at Approach section without bridge 498.5
Amount of backwater caused by bridge 2.9 ***ft***

500-year discharge 2,200 ***ft^3/s***
Water-surface elevation in bridge opening 500.3 ***ft***
Road overtopping? Yes ***Discharge over road*** 425 ***ft^3/s***
Area of flow in bridge opening 177 ***ft^2***
Average velocity in bridge opening 10.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.3 ***ft/s***

Water-surface elevation at Approach section with bridge 502.8
Water-surface elevation at Approach section without bridge 499.5
Amount of backwater caused by bridge 3.3 ***ft***

Incipient overtopping discharge 1,040 ***ft^3/s***
Water-surface elevation in bridge opening 496.4 ***ft***
Area of flow in bridge opening 95 ***ft^2***
Average velocity in bridge opening 11.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.4 ***ft/s***

Water-surface elevation at Approach section with bridge 499.8
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 2.2 ***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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The 100-year and 500-year discharges resulted in an unsubmerged orifice flow solution. 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 pressure-flow scour equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, estimates of contraction scour also were computed for the discharges resulting in orifice flow by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results of these computations are presented in appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions also are provided in appendix F.

Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 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.

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	0.8	0.3
Depth to armoring	12.8 8.4	14.2	--
Left overbank	--	--	--
Right overbank	--	--	7.3 8.7

Local scour:			
Abutment scour	5.2	10.3	10.8
Left abutment	9.6–	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	2.0	2.4
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	1.6	2.0	2.4
Left abutment	1.6	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--		
Pier 2			

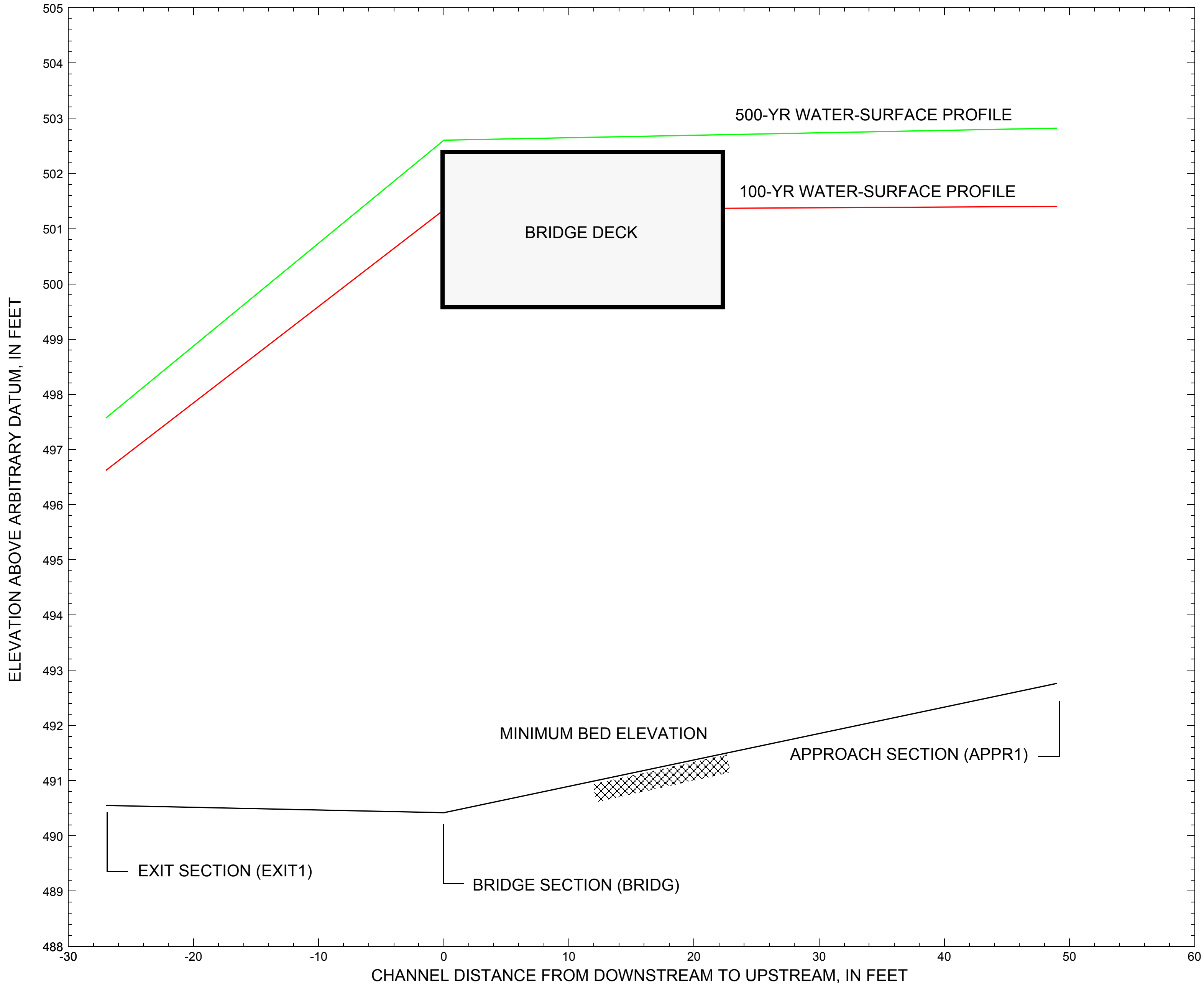

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHESTH00100052 on Town Highway 10, crossing the South Branch Williams River, Chester, Vermont.

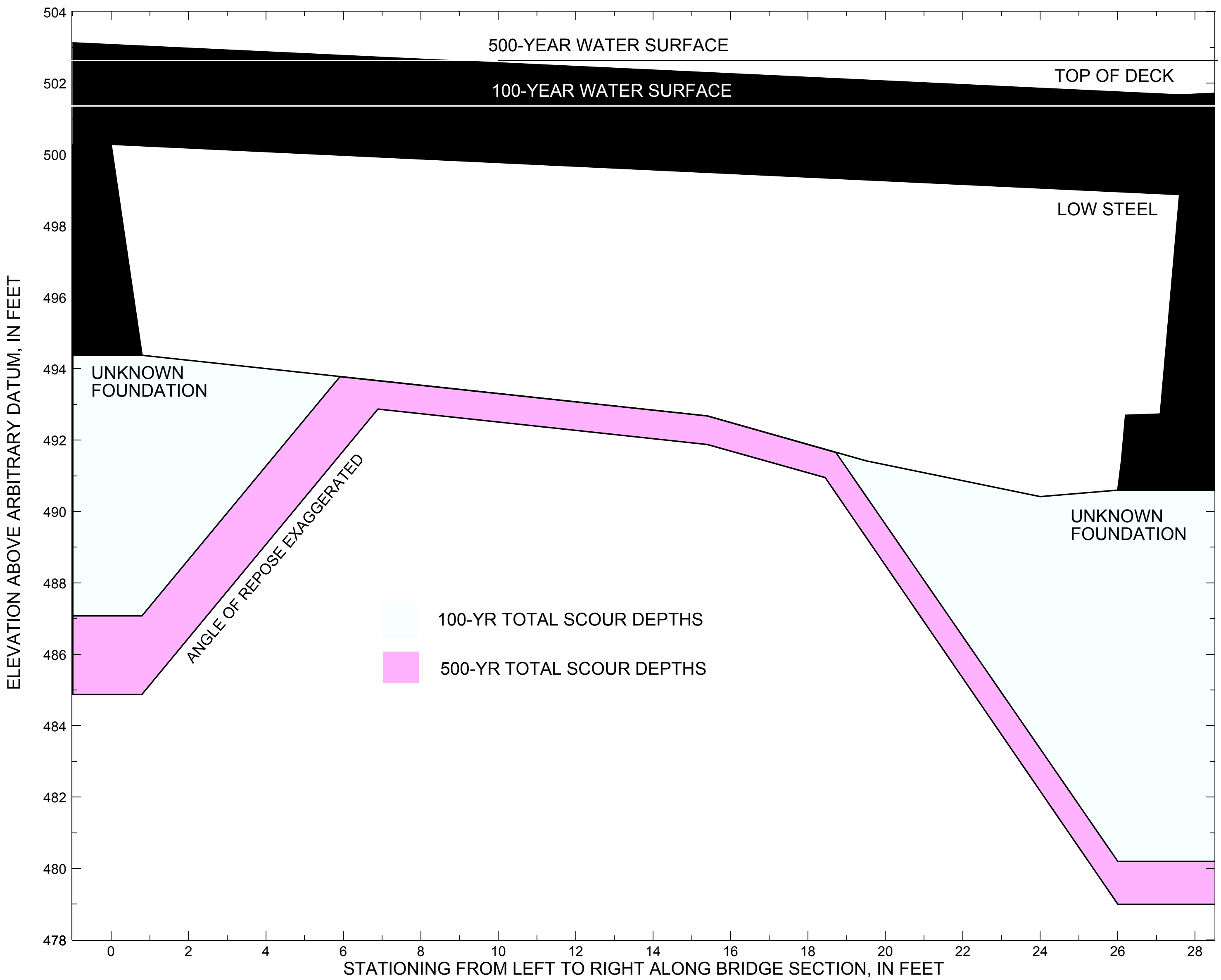

Figure 8. Scour elevations for the 100- and 500-yr discharges at structure CHESTH00100052 on Town Highway 10, crossing the South Branch Williams River, Chester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure CHESTH00100052 on Town Highway 10, crossing the South Branch 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,550 cubic-feet per second											
Left abutment	0.0	--	500.3	--	494.4	0.0	7.3	--	7.3	487.1	--
Right abutment	27.6	--	498.9	--	490.6	0.0	10.3	--	10.3	480.3	--

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-yr discharge at structure CHESTH00100052 on Town Highway 10, crossing the South Branch 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,200 cubic-feet per second											
Left abutment	0.0	--	500.3	--	494.4	0.8	8.7	--	9.5	484.9	--
Right abutment	27.6	--	498.9	--	490.6	0.8	10.8	--	11.6	479.0	--

1.Measured along the face of the most constricting side of the bridge.

2.Arbitrary datum for this study.

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ches052.wsp
T2        Hydraulic analysis for structure CHESTH00100052   Date: 03-DEC-97
T3        TOWN HIGHWAY 10, SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT   ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1550.0   2200.0   1040.0
SK          0.0283   0.0283   0.0283
*
XS   EXIT1    -27           0.
GR          -67.6, 510.07    -28.4, 500.74      0.0, 497.15      4.6, 492.42
GR           16.7, 491.33     17.6, 490.85     22.9, 490.55     25.3, 491.34
GR           35.0, 493.12     38.9, 495.10     48.7, 496.34     57.2, 498.46
GR           71.7, 498.52    109.9, 517.35
*
N           0.070        0.065
SA                 0.0
*
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    499.58      20.0
GR            0.0, 500.29      0.8, 494.38     15.4, 492.68     19.5, 491.42
GR           24.0, 490.42     26.0, 490.60     26.1, 491.44     26.2, 492.70
GR           27.1, 492.73     27.6, 498.88      0.0, 500.29
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      24.6 * *     45.0     2.6
N           0.065
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      17.3     2
GR          -69.7, 509.96    -55.4, 504.08    -41.9, 503.01    -20.9, 502.75
GR           -2.3, 502.48     -2.2, 503.17      0.0, 503.08     28.7, 501.67
GR           30.5, 501.59     30.7, 500.69     51.5, 499.79     68.2, 509.94
*
*
XT   APTEM     57           0.
GR          -68.9, 510.30    -51.6, 503.35    -40.4, 503.01    -14.3, 502.49
GR           -5.4, 497.79      7.4, 496.83      8.6, 494.25     14.8, 493.91
GR           16.4, 493.22     18.7, 493.14     25.7, 493.26     27.7, 493.71
GR           38.1, 500.33     76.3, 525.88
*
AS   APPR1     49  * * * 0.0474
GT
N           0.065        0.065
SA                -14.3
*
HP 1 BRIDG 500.29 1 500.29
HP 2 BRIDG 500.29 * * 1450
HP 1 BRIDG 497.61 1 497.61
HP 2 RDWAY 501.34 * * 109
HP 1 APPR1 501.40 1 501.40
HP 2 APPR1 501.40 * * 1550
*
HP 1 BRIDG 500.29 1 500.29
HP 2 BRIDG 500.29 * * 1778
HP 1 BRIDG 498.80 1 498.80
HP 2 RDWAY 502.60 * * 425
HP 1 APPR1 502.82 1 502.82
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File ches052.wsp
       Hydraulic analysis for structure CHESTH00100052   Date: 03-DEC-97
       TOWN HIGHWAY 10, SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT   ECW
          *** RUN DATE & TIME: 12-09-97  11:55

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     177.    7868.     0.    65.                           0.
  500.29          177.    7868.     0.    65.  1.00     0.    28.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.29     0.0    27.6   176.6    7868.    1450.   8.21

X STA.        0.0        3.8        5.3        6.7        8.0        9.3
  A(I)           19.2        8.2        8.2        7.8        8.0
  V(I)           3.77       8.86       8.80       9.26       9.05

X STA.        9.3       10.7       11.9       13.2       14.4       15.6
  A(I)            8.0        7.8        7.7        7.8        7.7
  V(I)           9.03       9.24       9.44       9.29       9.47

X STA.       15.6       16.8       17.9       18.9       19.9       20.9
  A(I)            7.8        7.6        7.4        7.4        7.2
  V(I)           9.30       9.50       9.76       9.85      10.13

X STA.       20.9       21.8       22.7       23.6       24.4       27.6
  A(I)            7.1        7.2        7.0        6.7       20.8
  V(I)          10.24      10.08      10.39      10.84       3.49

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     126.    6746.    25.    35.                        1587.
  497.61          126.    6746.    25.    35.  1.00     0.    27.   1587.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.34    30.6    54.1    24.9     578.     109.   4.38

X STA.       30.6       33.9       35.8       37.3       38.7       39.9
  A(I)            2.4        1.5        1.4        1.3        1.3
  V(I)           2.28       3.61       3.89       4.21       4.29

X STA.       39.9       41.0       42.1       43.1       44.0       44.8
  A(I)            1.2        1.2        1.1        1.1        1.0
  V(I)           4.52       4.61       4.83       4.92       5.41

X STA.       44.8       45.6       46.4       47.2       48.0       48.8
  A(I)            1.0        1.1        1.1        1.1        1.1
  V(I)           5.37       4.91       5.05       5.05       5.18

X STA.       48.8       49.5       50.2       50.8       51.5       54.1
  A(I)            1.0        1.1        1.0        1.0        2.0
  V(I)           5.29       5.15       5.46       5.41       2.76

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            2     288.   19127.    53.    58.                        3804.
  501.40          288.   19127.    53.    58.  1.00   -13.    40.   3804.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.40   -13.0    40.3   288.1   19127.    1550.   5.38

X STA.      -13.0        0.0        3.5        6.6        9.5       11.0
  A(I)           37.8       15.7       14.9       18.5       11.1
  V(I)           2.05       4.93       5.19       4.19       7.01

X STA.       11.0       12.4       13.9       15.3       16.6       17.8
  A(I)           11.0       11.1       11.2       11.0       10.3
  V(I)           7.01       6.99       6.94       7.02       7.50

X STA.       17.8       19.1       20.4       21.7       23.0       24.3
  A(I)           11.0       11.3       11.3       11.1       11.1
  V(I)           7.05       6.84       6.89       6.96       7.01

X STA.       24.3       25.6       26.9       28.3       30.1       40.3
  A(I)           10.9       11.4       11.2       12.6       33.6
  V(I)           7.13       6.82       6.91       6.13       2.31
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        U.S. Geological Survey WSPRO Input File ches052.wsp
        Hydraulic analysis for structure CHESTH00100052   Date: 03-DEC-97
        TOWN HIGHWAY 10, SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT   ECW
           *** RUN DATE & TIME: 12-09-97  11:55
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     177.    7868.     0.    65.                          0.
   500.29          177.    7868.     0.    65.  1.00     0.    28.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.29     0.0    27.6   176.6    7868.    1778.  10.07

X STA.         0.0         3.8         5.3         6.7         8.0         9.3
  A(I)             19.2         8.2         8.2         7.8         8.0
  V(I)             4.62       10.87       10.79       11.35       11.10

X STA.         9.3        10.7        11.9        13.2        14.4        15.6
  A(I)              8.0         7.8         7.7         7.8         7.7
  V(I)            11.07       11.33       11.57       11.39       11.61

X STA.        15.6        16.8        17.9        18.9        19.9        20.9
  A(I)              7.8         7.6         7.4         7.4         7.2
  V(I)            11.40       11.65       11.96       12.08       12.42

X STA.        20.9        21.8        22.7        23.6        24.4        27.6
  A(I)              7.1         7.2         7.0         6.7        20.8
  V(I)            12.56       12.36       12.74       13.29        4.28

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     156.    9268.    26.    38.                       2187.
   498.80          156.    9268.    26.    38.  1.00     0.    28.   2187.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.60   -10.6    56.1    66.9    1895.     425.   6.35

X STA.       -10.6        34.9        36.0        37.2        38.3        39.4
  A(I)             19.6         2.5         2.5         2.4         2.4
  V(I)             1.08        8.49        8.55        8.68        8.78

X STA.        39.4        40.4        41.4        42.4        43.3        43.8
  A(I)              2.4         2.4         2.3         2.3         1.1
  V(I)             8.92        9.02        9.21        9.22       18.65

X STA.        43.8        44.4        45.5        46.5        47.5        48.5
  A(I)              1.6         2.7         2.7         2.6         2.6
  V(I)            13.15        7.77        7.95        8.10        8.11

X STA.        48.5        49.5        50.4        51.3        52.3        56.1
  A(I)              2.5         2.6         2.4         2.6         4.5
  V(I)             8.43        8.32        8.69        8.11        4.69

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      12.     148.    32.    32.                         43.
             2     367.   27326.    57.    63.                       5291.
   502.82          379.   27474.    89.    95.  1.05   -47.    42.   4327.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.82   -46.6    42.4   379.0   27474.    2200.   5.81

X STA.       -46.6        -3.0         0.3         3.4         6.3         9.3
  A(I)             52.7        18.8        18.7        17.7        22.6
  V(I)             2.09        5.86        5.89        6.21        4.88

X STA.         9.3        10.9        12.5        14.0        15.6        17.0
  A(I)             14.4        14.4        14.4        14.4        14.3
  V(I)             7.63        7.65        7.66        7.65        7.72

X STA.        17.0        18.4        19.9        21.3        22.8        24.2
  A(I)             14.3        14.4        14.5        14.4        13.9
  V(I)             7.67        7.65        7.58        7.66        7.91

X STA.        24.2        25.6        27.0        28.6        30.6        42.4
  A(I)             13.9        14.2        15.3        16.2        45.6
  V(I)             7.89        7.77        7.20        6.78        2.41
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        U.S. Geological Survey WSPRO Input File ches052.wsp
        Hydraulic analysis for structure CHESTH00100052   Date: 03-DEC-97
        TOWN HIGHWAY 10, SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT   ECW
           *** RUN DATE & TIME: 12-09-97  11:55

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      95.    4423.    25.    33.                        1044.
   496.39           95.    4423.    25.    33.  1.00     1.    27.   1044.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.39     0.5    27.4    94.9    4423.    1040.  10.96

X STA.         0.5         5.7         7.8         9.5        11.1        12.5
  A(I)            10.9         5.2         4.8         4.5         4.4
  V(I)            4.76       10.10       10.91       11.51       11.76

X STA.        12.5        13.8        15.0        16.2        17.2        18.1
  A(I)             4.3         4.1         4.1         4.0         3.7
  V(I)           12.19       12.73       12.62       13.13       13.88

X STA.        18.1        19.0        19.8        20.6        21.3        22.0
  A(I)             3.8         3.8         3.8         3.6         3.6
  V(I)           13.72       13.85       13.70       14.51       14.57

X STA.        22.0        22.7        23.3        23.9        24.5        27.4
  A(I)             3.6         3.5         3.4         3.4        12.6
  V(I)           14.61       14.79       15.31       15.44        4.12

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     205.   11767.    48.    52.                        2420.
   499.76          205.   11767.    48.    52.  1.00   -10.    38.   2420.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      49.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.76    -9.8    37.8   205.4   11767.    1040.   5.06

X STA.        -9.8         3.9         8.9        10.2        11.5        12.8
  A(I)            30.4        18.1         7.9         7.9         7.9
  V(I)            1.71        2.87        6.57        6.58        6.56

X STA.        12.8        14.1        15.4        16.5        17.6        18.6
  A(I)             7.8         8.0         7.9         7.5         7.0
  V(I)            6.66        6.51        6.61        6.97        7.38

X STA.        18.6        19.7        20.9        22.0        23.2        24.3
  A(I)             7.7         8.2         8.0         7.9         8.0
  V(I)            6.76        6.37        6.51        6.58        6.47

X STA.        24.3        25.5        26.6        27.9        29.4        37.8
  A(I)             7.7         7.9         8.3         8.8        22.4
  V(I)            6.71        6.61        6.29        5.88        2.32
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       U.S. Geological Survey WSPRO Input File ches052.wsp
       Hydraulic analysis for structure CHESTH00100052   Date: 03-DEC-97
       TOWN HIGHWAY 10, SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT   ECW
          *** RUN DATE & TIME: 12-09-97  11:55
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT1:XS   ******     1.     178.  1.19 *****  497.81  496.04   1550.  496.62
      -27. ******    50.    9210.  1.00 ***** *******    0.81    8.73

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "FULLV"     KRATIO =  1.44

FULLV:FV      27.    -4.     230.  0.71  0.53  498.33 *******   1550.  497.61
        0.    27.    54.   13248.  1.01  0.00   -0.01    0.60    6.75
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.07     498.34     498.49
 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   497.11     525.50    0.50
 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   497.11     525.50     498.49
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPR1"
                  WSBEG,WSEND,CRWS =   498.49     525.50     498.49

APPR1:AS      49.    -7.     148.  1.72 *****  500.20  498.49   1550.  498.49
       49.    49.    36.    7265.  1.00 ***** *******    1.00   10.50
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   501.37       0.00     497.53     499.79
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===225 NO ENERGY BALANCE IN 15 ITERATIONS.
                   FLOW,Q =    4      1123.
             WS1,WSSD,WS3 =   499.05       0.00     497.38
 ===235 CONTINUE FLOW CLASS 4 COMPUTATIONS.
                   ITER,QRD =    3       427.
             WS,WSMIN,WSMAX =   503.00     499.79     506.22
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   497.38     500.57     501.10     499.58
 ===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      27.     0.     177.  1.05 *****  501.34  497.32   1450.  500.29
        0. ******    28.    7868.  1.00 ***** *******    0.57    8.21
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.454  0.000  499.58 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG      11.    32.  0.21  0.45  501.64    0.01    109.  501.34

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.     4.    13.    17.   0.2   0.1   3.3  13.0   0.6   2.7
   RT:    109.    23.    31.    54.   1.5   1.1   5.1   4.4   1.4   2.9

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPR1:AS      24.   -13.     288.  0.45  0.38  501.85  498.49   1550.  501.40
       49.    26.    40.   19140.  1.00  1.35    0.01    0.41    5.38
       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     -27.     1.     50.   1550.    9210.     178.    8.73  496.62
   FULLV:FV       0.    -4.     54.   1550.   13248.     230.    6.75  497.61
   BRIDG:BR       0.     0.     28.   1450.    7868.     177.    8.21  500.29
   RDWAY:RG      11.*******     0.    109.       0.*********    2.00  501.34
   APPR1:AS      49.   -13.     40.   1550.   19140.     288.    5.38  501.40

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  ***********************

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    496.04    0.81  490.55  517.35************  1.19  497.81  496.62
   FULLV:FV  ********    0.60  490.55  517.35  0.53  0.00  0.71  498.33  497.61
   BRIDG:BR    497.32    0.57  490.42  500.29************  1.05  501.34  500.29
   RDWAY:RG  ****************  499.79  509.96  0.21******  0.45  501.64  501.34
   APPR1:AS    498.49    0.41  492.76  525.50  0.38  1.35  0.45  501.85  501.40
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File ches052.wsp
        Hydraulic analysis for structure CHESTH00100052   Date: 03-DEC-97
        TOWN HIGHWAY 10, SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT   ECW
           *** RUN DATE & TIME: 12-09-97  11:55

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

 EXIT1:XS   ******    -3.     227.  1.46 *****  499.04  497.03   2200.  497.57
      -27. ******    54.   13065.  1.01 ***** *******    0.86    9.68

 FULLV:FV      27.   -13.     311.  0.81  0.57  499.61 *******   2200.  498.80
        0.    27.    72.   17422.  1.04  0.00    0.00    0.67    7.08
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     1.00     499.46     499.46

  ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   498.30     525.50    0.50

  ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   498.30     525.50     499.46

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPR1"     KRATIO =  0.61

 APPR1:AS      49.    -9.     191.  2.05  1.28  501.52  499.46   2200.  499.46
       49.    49.    37.   10627.  1.00  0.62    0.00    1.00   11.49
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   503.21       0.00     498.83     499.79

  ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   498.27     501.73     502.29     499.58

  ===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      27.     0.     177.  1.58 *****  501.87  498.01   1778.  500.29
        0. ******    28.    7868.  1.00 ***** *******    0.70   10.07

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   5.  0.492  0.000  499.58 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      11.    32.  0.20  0.55  503.17    0.00    425.  502.60

             Q   WLEN    LEW     REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:     23.    15.   -11.     16.   0.3   0.1   3.4  14.2   0.7   2.7
    RT:    402.    40.    16.     56.   2.8   1.6   6.9   6.1   2.2   3.1

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

 APPR1:AS      24.   -47.     379.  0.55  0.47  503.37  499.46   2200.  502.82
       49.    26.    42.   27474.  1.05  1.36    0.00    0.51    5.81

        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     -27.    -3.    54.   2200.   13065.     227.    9.68  497.57
    FULLV:FV       0.   -13.    72.   2200.   17422.     311.    7.08  498.80
    BRIDG:BR       0.     0.    28.   1778.    7868.     177.   10.07  500.29
    RDWAY:RG      11.*******    23.    425.       0.*********    2.00  502.60
    APPR1:AS      49.   -47.    42.   2200.   27474.     379.    5.81  502.82

  SECOND USER DEFINED TABLE.

     XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO  VHD      EGL    WSEL
    EXIT1:XS     497.03    0.86  490.55  517.35************  1.46  499.04  497.57
    FULLV:FV   ********    0.67  490.55  517.35  0.57  0.00  0.81  499.61  498.80
    BRIDG:BR     498.01    0.70  490.42  500.29************  1.58  501.87  500.29
    RDWAY:RG   ****************  499.79  509.96  0.20******  0.55  503.17  502.60
    APPR1:AS     499.46    0.51  492.76  525.50  0.47  1.36  0.55  503.37  502.82
```
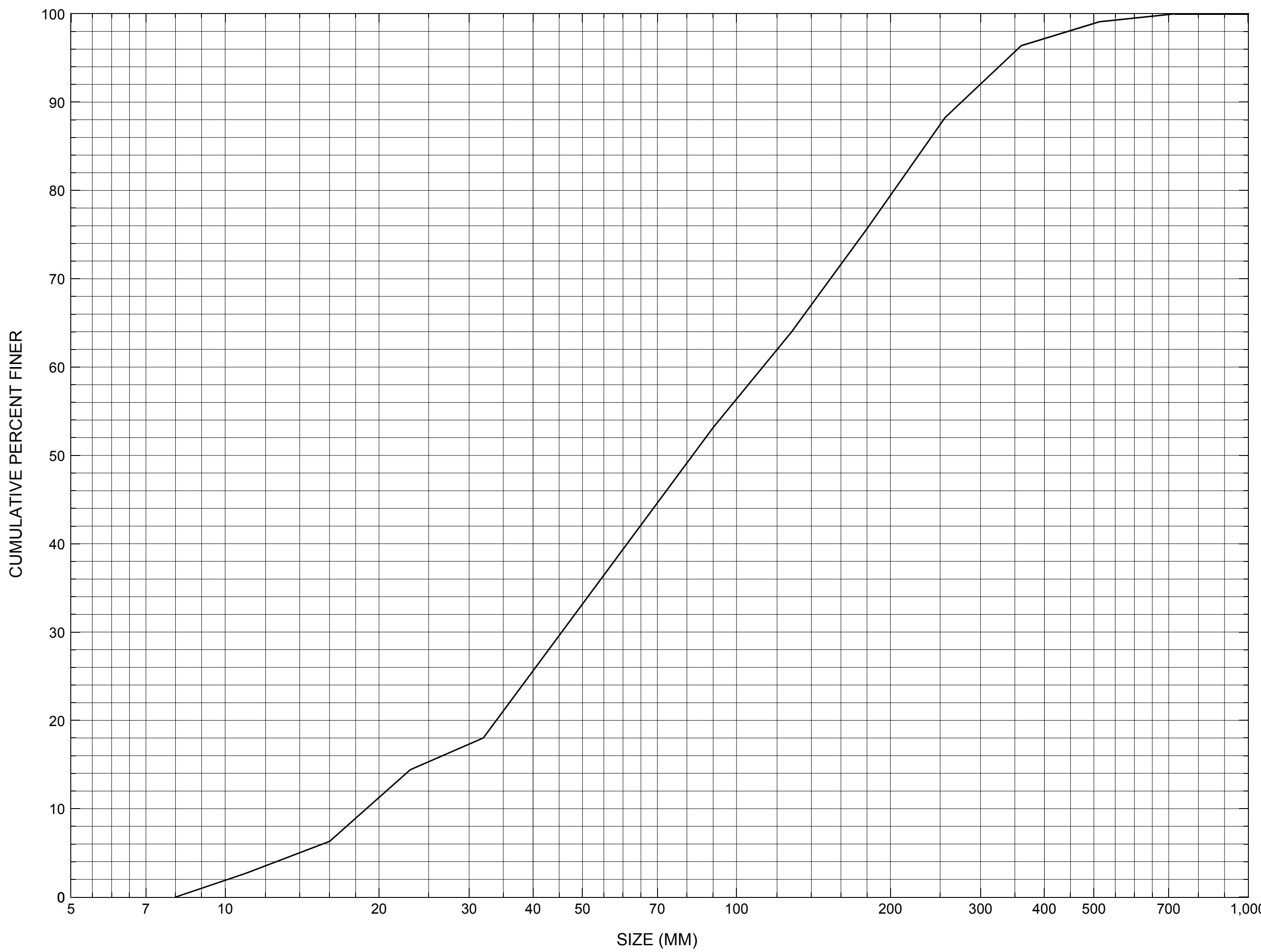

```
        U.S. Geological Survey WSPRO Input File ches052.wsp
        Hydraulic analysis for structure CHESTH00100052   Date: 03-DEC-97
        TOWN HIGHWAY 10, SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT   ECW
           *** RUN DATE & TIME: 12-09-97  11:55

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

EXIT1:XS   ******     2.     130.  1.00 *****  496.58  494.98   1040.  495.58
      -27. ******    43.    6181.  1.00 ***** *******    0.79    8.00

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.44

FULLV:FV      27.     1.     173.  0.56  0.53  497.09 *******   1040.  496.53
        0.    27.    49.    8872.  1.00  0.00   -0.02    0.56    6.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.10     497.41     497.60

 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.03     525.50    0.50

 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.03     525.50     497.60

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPR1"
                  WSBEG,WSEND,CRWS =   497.60     525.50     497.60

APPR1:AS      49.    -6.     111.  1.37 *****  498.98  497.60   1040.  497.60
       49.    49.    34.    4736.  1.00 ***** *******    1.00    9.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1040.      496.39

            <<<<<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      27.     1.      95.  1.87 *****  498.26  496.39   1040.  496.39
        0.    27.    27.    4420.  1.00 ***** *******    1.00   10.96

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  499.58 ****** ****** ******

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

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

APPR1:AS      24.   -10.     206.  0.40  0.54  500.16  497.60   1040.  499.76
       49.    26.    38.   11785.  1.00  1.36    0.00    0.43    5.06

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.330  0.053   11155.     3.    30.   499.52

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -27.     2.    43.   1040.    6181.     130.    8.00  495.58
   FULLV:FV       0.     1.    49.   1040.    8872.     173.    6.01  496.53
   BRIDG:BR       0.     1.    27.   1040.    4420.      95.   10.96  496.39
   RDWAY:RG      11.**************      0.*****************    2.00********
   APPR1:AS      49.   -10.    38.   1040.   11785.     206.    5.06  499.76

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       3.    30.   11155.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    494.98    0.79  490.55  517.35************  1.00  496.58  495.58
   FULLV:FV  ********    0.56  490.55  517.35  0.53  0.00  0.56  497.09  496.53
   BRIDG:BR    496.39    1.00  490.42  500.29************  1.87  498.26  496.39
   RDWAY:RG  ****************  499.79  509.96********************************
   APPR1:AS    497.60    0.43  492.76  525.50  0.54  1.36  0.40  500.16  499.76
  ER

NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESTH00100052, in Chester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHESTH00100052

General Location Descriptive

Data collected by *(First Initial, Full last name)* L. MEDALIE

Date *(MM/DD/YY)* 03 / 31 / 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)* 000000

Waterway *(I - 6)* SO BR OF WILLIAMS R

Road Name *(I - 7):* -

Route Number TH010

Vicinity *(I - 9)* 0.25 MI TO JCT W C3 TH63

Topographic Map Saxtons River

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43138

Longitude *(i - 17; nnnnn.n)* 72401

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10140700521407

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

Maximum span length *(I - 48; nnnn)* 0029

Year built *(I - 27; YYYY)* 1939

Structure length *(I - 49; nnnnnn)* 000032

Average daily traffic, ADT *(I - 29; nnnnnn)* 000060

Deck Width *(I - 52; nn.n)* 173

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

Channel & Protection *(I - 61; n)* 4

Opening skew to Roadway *(I - 34; nn)* 20

Waterway adequacy *(I - 71; n)* 5

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*) 29

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

Vertical clearance from streambed (*nnn.n ft*) 6.5

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

Waterway of full opening (*nnn.n* ft^2) 188.5

Comments:

The structural inspection report states the structure is a steel stringer type bridge with a concrete deck. The right abutment and wingwalls have some horizontal cracks with heavy leakage reported at each end. A few minor spalls are noted in these cracked areas. The left abutment has a few minor cracks with faint stains. The footings are exposed along both abutment walls. The downstream half of the right abutment is undermined. A stick can penetrate below the footing roughly two feet. The upstream end of left abutment has some minor erosion of the concrete. There is some localized scour at the downstream end of the right abutment. The river makes a moderate to sharp turn through the structure. **(Continued, page 33)**

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: 4.0

Terrain character: Hilly, forested

Stream character & type: -

Streambed material: Stone and gravel with some random boulders

Discharge Data *(cfs)*: $Q_{2.33}$ 400 Q_{10} 800 Q_{25} 1050

Q_{50} 1300 Q_{100} 1550 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*): 1 %

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} (*ft^3/ sec*): -

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

Upstream distance (*miles*): 2600' Town: Chester Year Built: -

Highway No. : TH92 Structure No. : 46 Structure Type: I-beam, wood

Clear span (*ft*): 19 Clear Height (*ft*): 6 Full Waterway (*ft^2*): 144

Downstream distance (*miles*): **1600’** Town: **Chester** Year Built: **1965**

Highway No. : **TH63** Structure No. : **49** Structure Type: **I-beam, wood**

Clear span (*ft*): **20** Clear Height (*ft*): **6.5** Full Waterway (*ft*^{2}): **130**

Comments:

The upstream bridge (46) washed out in the 1973 flood. The downstream bridge (49) was rebuilt in 1965. All of the flow is presently on the right abutment side of the channel directly in front of the undermined footing. The banks are fairly well protected with stone fill. Channel scour is severe along the right abutment. The bank upstream from the right abutment is well protected with boulders.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **4.05** mi^2 Lake/pond/swamp area **0.05** mi^2

Watershed storage *(ST)* **1.2** %

Bridge site elevation **1342** ft Headwater elevation **2303** ft

Main channel length **3.87** mi

10% channel length elevation **1496** ft 85% channel length elevation **1759** ft

Main channel slope *(S)* **90.48** 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 chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 1/24/97
Computerized by: RB Date: 4/24/97
Reviewd by: EW Date: 12/16/97

Structure Number CHESTH00100052

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 08 / 21 / 1996
2. Highway District Number 02 Mile marker 0000
County 027 Windsor Town 13675 Chester
Waterway *(I - 6)* South Branch Williams River Road Name -
Route Number TH 10 Hydrologic Unit Code: 01080107
3. Descriptive comments:
Located 0.25 miles to junction with TH 63.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 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 2 DS 2 *(**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 32 *(feet)* Span length 29 *(feet)* Bridge width 17.3 *(feet)*

Road approach to bridge:

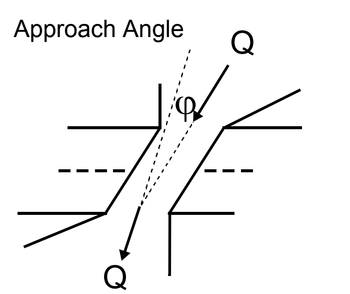
8. LB 0 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope *(run / rise in feet / foot)*:
US left -- US right --

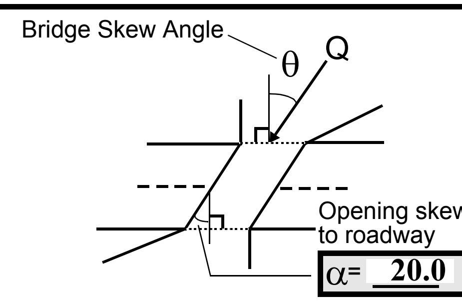
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	5	1	0	-
RBUS	0	-	0	-
RBDS	5	1	0	-
LBDS	5	1	0	-

*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: 15 16. Bridge skew: 25





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 30 feet US *(US, UB, DS)* to 5 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**

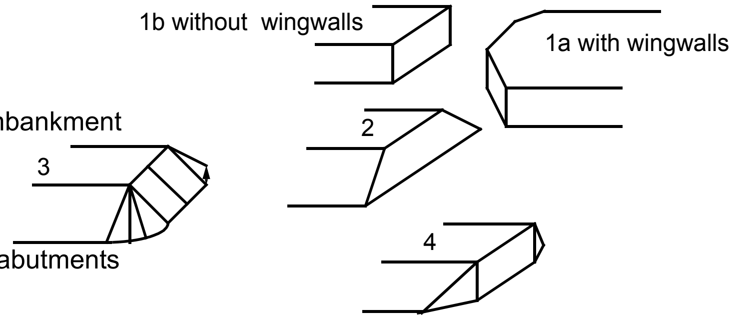
1a- Vertical abutments with wingwalls

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.)

7. Values are from the VT AOT files. Measured bridge dimensions are the same.
11. Protection for the road approaches consists of the concrete wingwalls and laid-up stone wall extensions of the wingwalls that also extend above the concrete. The wingwalls are parallel to the road.
18. Only the US right wingwall is not parallel to the road.

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
34.0	**2.5**			**6.5**	**4**	**4**	**54**	**54**	**1**	**1**

23. Bank width **55.0**   24. Channel width **30.0**   25. Thalweg depth **30.5**   29. Bed Material **543**

30 .Bank protection type: LB **2** RB **2**   31. Bank protection condition: LB **2** RB **1**

*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.):

30. The right bank protection extends 20 ft from the bridge face. The left bank protection extends 4 ft from the US end of the left abutment along the road approach at the base of the US left wingwall.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **0US** 35. Mid-bar width: **26**

36. Point bar extent: **160** feet **US** (US, UB) to **40** feet **DS** (US, UB, DS) positioned **0** %LB to **80** %RB

37. Material: **452**

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

This mid bar of this point bar is at the US bridge face.

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: **70** 42. Cut bank extent: **18** feet **US** (US, UB) to **80** 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.):

The right bank is cut from 100 ft to 180 ft US.

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
19.0		0.5		2	7	7	0

58. Bank width (BF) **-** 59. Channel width **-** 60. Thalweg depth **90.0** 63. Bed Material **0**

*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.):

453

-

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? **1** ___ *(Y or N)* Ice Blockage Potential **N** ____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

There is some debris on the banks with the trees leaning into the channel.

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		**0**	**85**	**2**	**2**	**0**	**1.5**	**90.0**
RABUT	**1**	**15**	**85**			**2**	**3**	**26.0**

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.):

0.2

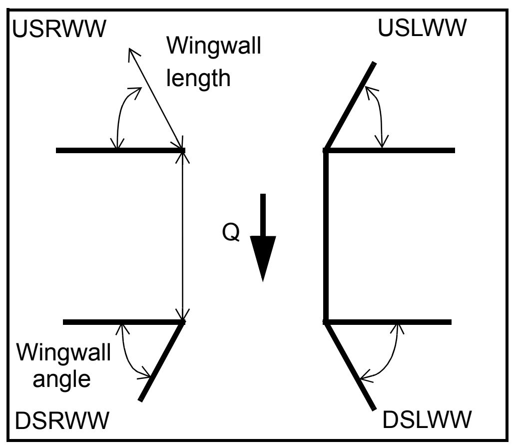
2.0

1

The right abutment footing is undermined the entire length. The footing is only exposed 1.5 ft at the US end.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**26.0**	
USRWW:	**Y**		**1**		**0**	**1.0**	
DSLWW:	**-**		**-**		**Y**	**21.5**	
DSRWW:	**1**		**2**		**0**	**23.5**	



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	**1**	**0**	**Y**	**0**	**1**	**1**	**-**	**-**
Condition	**Y**	**-**	**1**	**2**	**1**	**2**	**-**	**-**
Extent	**1**	**-**	**2**	**2**	**2**	**0**	**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

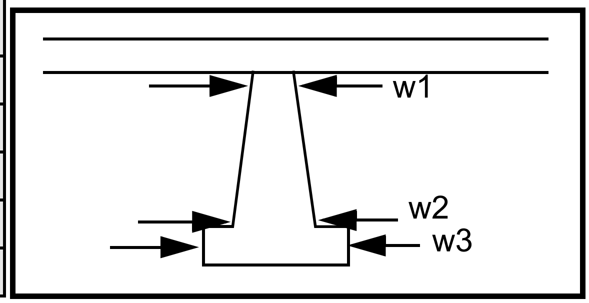
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? _\-___ *(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	**0.0**		**4.0**	**5.0**	**95.0**	**15.0**
Pier 2	**9.0**		-	**0.0**	**10.5**	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)		-	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		-	-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material		-	-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		-	-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		-	-	-	*Y- yes; N- no*
91. Attack ∠ (BF)		-	-	-	
92. Pushed		-	-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		-	-	-	
95. Cross-members		-	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition		-	-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**N**	-	-	-	
98. Exposure depth	-	-	-	-	

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

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
-	-			-	-	NO	PIE	RS		

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.):

4
3
543
543
2
1
543
0
0
-
-
The bed and banks consist of boulders, cobble and gravel.

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 **N** feet **-** *(US, UB, DS)* positioned **NO** %LB to **DR** %RB

Material: **OP**

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

STRUCTURE

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

Cut bank extent: **120** feet **24** *(US, UB, DS)* to **70** feet **DS** *(US, UB, DS)*

Bank damage: **190** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
20
100
345

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

Scour dimensions: Length **point** Width **bar** Depth: **is** Positioned **opp** %LB to **osit** %RB

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

e a severe cut bank on the DS left bank.

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

Confluence 1: Distance **100** Enters on **0** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **170** Enters on **DS** *(LB or RB)* Type **2** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

From 80 ft to 170 ft DS the cut bank is severe. The right bank is also cut from 10 ft DS to 40 ft DS with a mid-bank distance of 25 ft. It is eroded.

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)*:

Y
11
12
8
1
30
95
Scour is located at the DS end of the right abutment.

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: CHESTH00100052 Town: CHESTER
Road Number: TH 10 County: WINDSOR
Stream: SOUTH BRANCH WILLIAMS RIVER

Initials ECW Date: 12/8/97 Checked: RLB

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	1550	2200	1040
Main Channel Area, ft2	288	367	205
Left overbank area, ft2	0	12	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	53	57	48
Top width L overbank, ft	0	32	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.269	0.269	0.269
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.4	6.4	4.3
y1, average depth, LOB, ft	ERR	0.4	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	19127	27474	11767
Conveyance, main channel	19127	27326	11767
Conveyance, LOB	0	148	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1550.0	2188.1	1040.0
Ql, discharge, LOB, cfs	0.0	11.9	0.0
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	5.4	6.0	5.1
Vl, mean velocity, LOB, ft/s	ERR	1.0	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.6	9.9	9.2
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	1550	2200	1040
(Q) discharge thru bridge, cfs	1450	1778	1040
Main channel conveyance	7868	7868	4423
Total conveyance	7868	7868	4423
Q2, bridge MC discharge,cfs	1450	1778	1040
Main channel area, ft2	177	177	95
Main channel width (normal), ft	25.9	25.9	25.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	25.9	25.9	25.3
y_bridge (avg. depth at br.), ft	6.83	6.83	3.75
Dm, median (1.25*D50), ft	0.33625	0.33625	0.33625
y2, depth in contraction,ft	5.32	6.34	4.08
ys, scour depth (y2-ybridge), ft	-1.51	-0.49	**0.33**

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	1450	1778	1040
Main channel area (DS), ft2	126	156	95
Main channel width (normal), ft	25.9	25.9	25.3
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	25.9	25.9	25.3
D90, ft	0.9026	0.9026	0.9026
D95, ft	1.1138	1.1138	1.1138
Dc, critical grain size, ft	0.7618	0.6766	0.7832
Pc, Decimal percent coarser than Dc	0.152	0.195	0.142
Depth to armoring, ft	12.75	8.38	14.20

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	1550	2200	1040
Q, thru bridge MC, cfs	1450	1778	1040
Vc, critical velocity, ft/s	9.59	9.87	9.22
Va, velocity MC approach, ft/s	5.38	5.96	5.07
Main channel width (normal), ft	25.9	25.9	25.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	25.9	25.9	25.3
qbr, unit discharge, ft2/s	56.0	68.6	41.1
Area of full opening, ft2	177.0	177.0	95.0
Hb, depth of full opening, ft	6.83	6.83	3.75
Fr, Froude number, bridge MC	0.57	0.7	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	126	156	N/A
**Hb, depth at downstream face, ft	4.86	6.02	N/A
**Fr, Froude number at DS face	0.92	0.82	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	499.58	499.58	0
Elevation of Bed, ft	492.75	492.75	-3.75
Elevation of Approach, ft	501.4	502.82	0
Friction loss, approach, ft	0.38	0.47	0
Elevation of WS immediately US, ft	501.02	502.35	0.00
ya, depth immediately US, ft	8.27	9.60	3.75
Mean elevation of deck, ft	502.38	502.38	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.91	1.00
**Cc, for downstream face (<=1.0)	0.842888	0.871947	ERR
Ys, scour w/Chang equation, ft	**-0.71**	**0.78**	N/A
Ys, scour w/Umbrell equation, ft	-0.40	0.98	N/A

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

**Ys, scour w/Chang equation, ft	2.06	1.95	N/A

**Ys, scour w/Umbrell equation, ft	1.57	1.79	ERR

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	5.32	6.34	4.08
WSEL at downstream face, ft	497.61	498.80	--
Depth at downstream face, ft	4.86	6.02	N/A
Ys, depth of scour (Laursen), ft	0.46	0.32	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	1550	2200	1040	1550	2200	1040
a', abut.length blocking flow, ft	13.8	47.4	11.1	13.6	15.7	11.2
Ae, area of blocked flow ft2	41.39	69.95	24.63	50.81	60.1	39.5
Qe, discharge blocked abut.,cfs	95.21	--	42.13	--	--	156
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.30	3.19	1.71	4.13	4.41	3.95
ya, depth of f/p flow, ft	3.00	1.48	2.22	3.74	3.83	3.53
--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	70	70	70	110	110	110
K2	0.97	0.97	0.97	1.03	1.03	1.03
Fr, froude number f/p flow	0.234	0.448	0.202	0.349	0.344	0.371
ys, scour depth, ft	7.29	8.72	5.23	10.28	10.83	9.57

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)	13.8	47.4	11.1	13.6	15.7	11.2
y1 (depth f/p flow, ft)	3.00	1.48	2.22	3.74	3.83	3.53
a'/y1	4.60	32.12	5.00	3.64	4.10	3.18
Skew correction (p. 49, fig. 16)	0.93	0.93	0.93	1.04	1.04	1.04
Froude no. f/p flow	0.23	0.45	0.20	0.35	0.34	0.37
Ys w/ corr. factor K1/0.55:						
vertical	ERR	7.66	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	6.28	ERR	ERR	ERR	ERR
spill-through	ERR	4.21	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	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.92	0.82	1	0.92	0.82	1
y, depth of flow in bridge, ft	4.86	6.02	3.75	4.86	6.02	3.75
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	1.99	2.38	1.57	1.99	2.38	1.57