LEVEL II SCOUR ANALYSIS FOR BRIDGE 16 (CHESVT01030016) on STATE ROUTE 103, crossing the WILLIAMS RIVER, CHESTER, VERMONT

U.S. Geological Survey
Open-File Report 97-581

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

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By MICHAEL A. IVANOFF AND ROBERT E. HAMMOND

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Pembroke, New Hampshire

1997

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

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Gordon P. Eaton, Director

For additional information write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

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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 16 (CHESVT01030016) ON STATE ROUTE 103, CROSSING THE WILLIAMS RIVER, CHESTER, VERMONT

By **Michael A. Ivanoff and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHESVT01030016 on State Route 103 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 15.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture except for the downstream right overbank which is forested.

In the study area, the Williams River has an incised, straight channel with a slope of approximately 0.008 ft/ft, an average channel top width of 56 ft and an average bank height of 6 ft. The channel bed material ranges from gravel to cobbles with a median grain size (D_{50}) of 67.5 mm (0.222 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 16, 1996, indicated that the reach was stable.

The State Route 103 crossing of the Williams River is a 162-ft-long, two-lane bridge consisting of three steel-beam spans (Vermont Agency of Transportation, written communication, March 13, 1995). The opening length of the structure parallel to the bridge face is 157.7 ft.The bridge is supported by vertical, concrete abutments and piers with no wingwalls. The channel is skewed approximately 55 degrees to the opening while the opening-skew-to-roadway is also 55 degrees.

The scour protection measures at the site included type-4 stone fill (less than 60 inches diameter) along the upstream left bank. There was type-3 stone fill (less than 48 inches diameter) along the upstream right bank and both spill-through embankments and both downstream banks. There was type-1 stone fill (less than 12 inches diameter) along the upstream right and downstream left road embankments. 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). 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. Abutment scour ranged from 6.4 to 9.0 ft. The worst-case abutment scour occurred at the 500-year discharge. Pier scour ranged from 7.9 to 10.1 ft. The worst-case pier scour occurred at the incipient-overtopping discharge for both piers. 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.

Andover, VT. Quadrangle, 1:24,000, 1972 and 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 CHESVT01030016 ***Stream*** Williams River

County Windsor ***Road*** VT 103 ***District*** 3

Description of Bridge

Bridge length 162 ***ft*** ***Bridge width*** 35.2 ***ft*** ***Max span length*** 87 ***ft***

Alignment of bridge to road (on curve or straight) Straight, left; curved, right

Abutment type Spill-through ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 9/16/96

Description of stone fill Type-4, along the upstream left bank. Type-3, along the upstream right bank, both spill-through embankments, and the downstream banks. Type-1, at the upstream right and downstream left road embankments.

Abutments and piers are concrete. There is stone fill between the abutments and piers forming a spill-through embankment to the stream channel.

Yes

Is bridge skewed to flood flow according to survey? 55 ***Angle*** No

9/16/96

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	9/16/
Level II	96	0	0

Potential for debris Moderate. There is some debris caught on boulders and trees leaning over the channel upstream.

None as of 9/16/96.

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.

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

Date of inspection 9/16/96

DS left: Moderately sloped overbank.

DS right: Steep channel bank to a moderately sloped overbank.

US left: Steep channel bank and valley wall.

US right: Moderately sloped channel bank to a narrow flood plain.

Description of the Channel

Average top width 56 *ft* ***Average depth*** 6 *ft*

Predominant bed material Gravel / Cobbles ***Bank material*** Gravel/Cobbles

Straight and stable

with semi-alluvial channel boundaries.

9/16/96

Vegetative co Trees and brush.

DS left: Trees and brush.

DS right: Trees and brush.

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 noted 9/16/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 15.1 ***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***: -

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

USGS gage description Williams River at Brockways Mills, VT

USGS gage number 01153500

Gage drainage area 103 ***mi²***

Is there a lake/p - No

-

Calculated Discharges

Q100 3,910 ***ft³/s*** ***Q500*** 5,740 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates available in the Flood Insurance Study for Chester, VT (Federal Emergency Management Agency, 1982). These values are within a range defined by several empirical flood frequency curves (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 Add 330.8 ft. to the USGS arbitrary survey datum to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a State of Vermont brass tablet on top of the right end of the downstream curb (elev. 497.33 ft, arbitrary survey datum). RM2 is a chiseled X on top of the left end of the downstream curb (elev. 499.76 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-153	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	29	1	Road Grade section
APPRO	149	2	Modelled Approach section (Templated from APTEM)
APTEM	221	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 0.045 to 0.050, and overbank “n” values ranged from 0.035 to 0.070.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.008 ft/ft, which was the slope of the 100-year water surface profile from the Flood Insurance Study for the Town of Chester (Federal Emergency Management Agency, 1982).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0083 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 498.9 ***ft***
Average low steel elevation 493.7 ***ft***

100-year discharge 3,910 ft^3/s
Water-surface elevation in bridge opening 491.9 ***ft***
Road overtopping? No ***Discharge over road*** -- ft^3/s
Area of flow in bridge opening 452 ft^2
Average velocity in bridge opening 8.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.5 ***ft/s***

Water-surface elevation at Approach section with bridge 493.0
Water-surface elevation at Approach section without bridge 493.1
Amount of backwater caused by bridge N/A ***ft***

500-year discharge 5,740 ft^3/s
Water-surface elevation in bridge opening 493.7 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,327 ft^3/s
Area of flow in bridge opening 522 ft^2
Average velocity in bridge opening 8.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.3 ***ft/s***

Water-surface elevation at Approach section with bridge 496.0
Water-surface elevation at Approach section without bridge 494.9
Amount of backwater caused by bridge 1.1 ***ft***

Incipient overtopping discharge 5,420 ft^3/s
Water-surface elevation in bridge opening 492.7 ***ft***
Area of flow in bridge opening 506 ft^2
Average velocity in bridge opening 10.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.3 ***ft/s***

Water-surface elevation at Approach section with bridge 494.1
Water-surface elevation at Approach section without bridge 494.0
Amount of backwater caused by bridge 0.1 ***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 scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the 100-year and incipient-overtopping discharges were computed by use of the live-bed contraction scour equation (Richardson and others, 1995, p. 30, equation 17). At this site, the 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 500-year discharge was computed by use of the Chang equation (Richardson and others, 1995,p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For the discharge resulting in orifice flow, estimates of contraction scour were also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, since this discharge resulted in unsubmerged orifice flow, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution is provided in Appendix F.

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. At the 100-year discharge, there is no computed abutment scour because the bridge abutments do not constrict the flow.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the scour depths were applied for the entire spill-through embankment below the elevation at the toe of each embankment in figure 8.

Pier scour was computed by use of the Colorado State University pier scour equation (Richardson and others, 1995, p. 36, equation 21). Variables for the Colorado State University pier scour equation include the Froude number of the flow approaching the pier, pier width ratio to the depth of flow, pier length, and correction factors for the pier nose shape, angle of attack of flow, bed condition, and armoring by bed material size. The angle of repose depicted in figure 8 is arbitrary.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	0.0	--	0.0
Clear-water scour	--	0.0	--
Depth to armoring	3.4	3.7	13.9
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	0.0	7.2	7.0
Right abutment	0.0	9.0	6.4
Pier scour			
Pier 1	7.9	8.6	10.1
Pier 2	7.9	8.6	10.1
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.6	1.6	2.1
Right abutment	1.6	1.6	2.1
Piers:			
Pier 1	1.4	1.4	2.1
Pier 2	1.4	1.4	2.1
	--	--	--

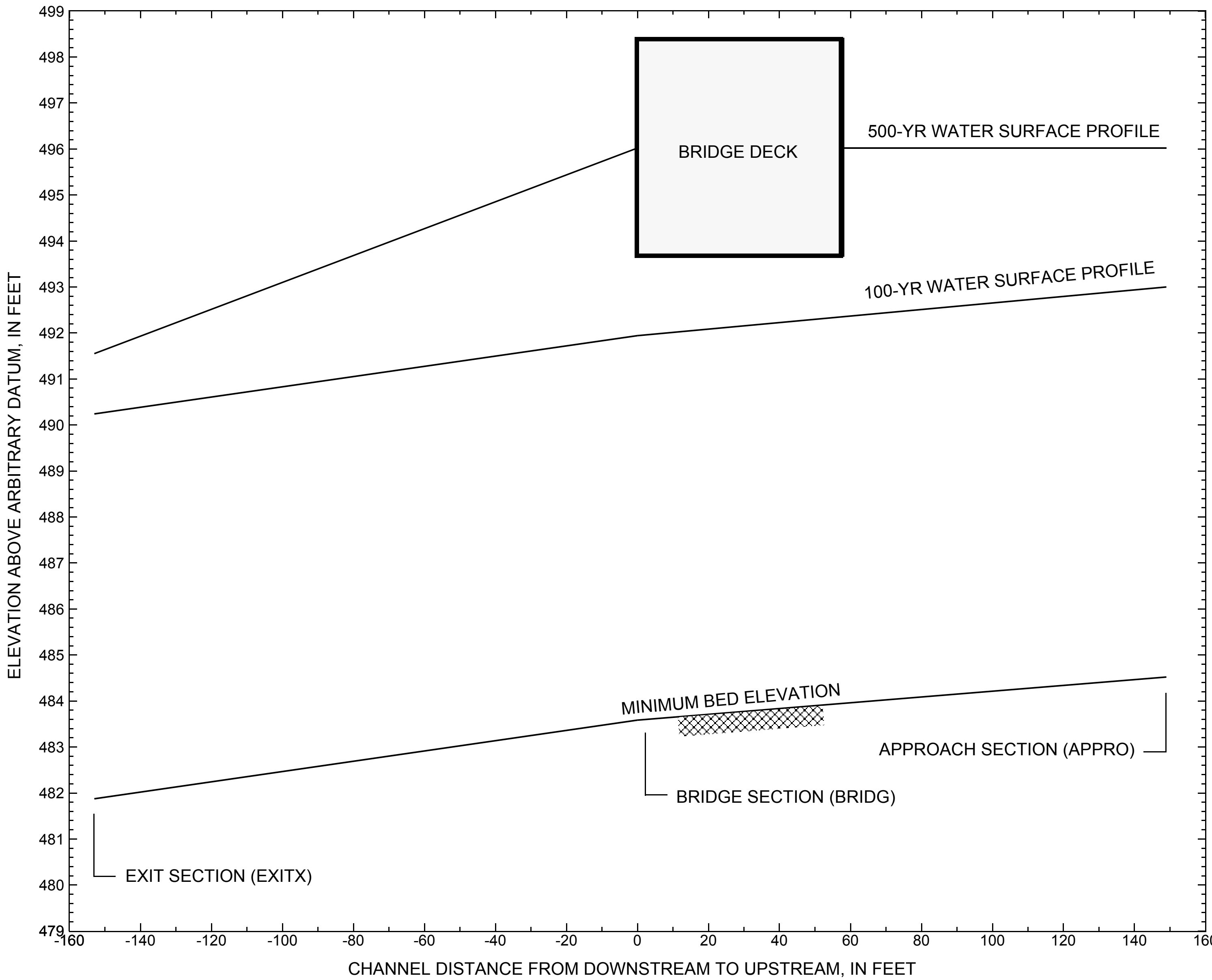

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHESVT01030016 on State Route 103, crossing the Williams River, Chester, Vermont.

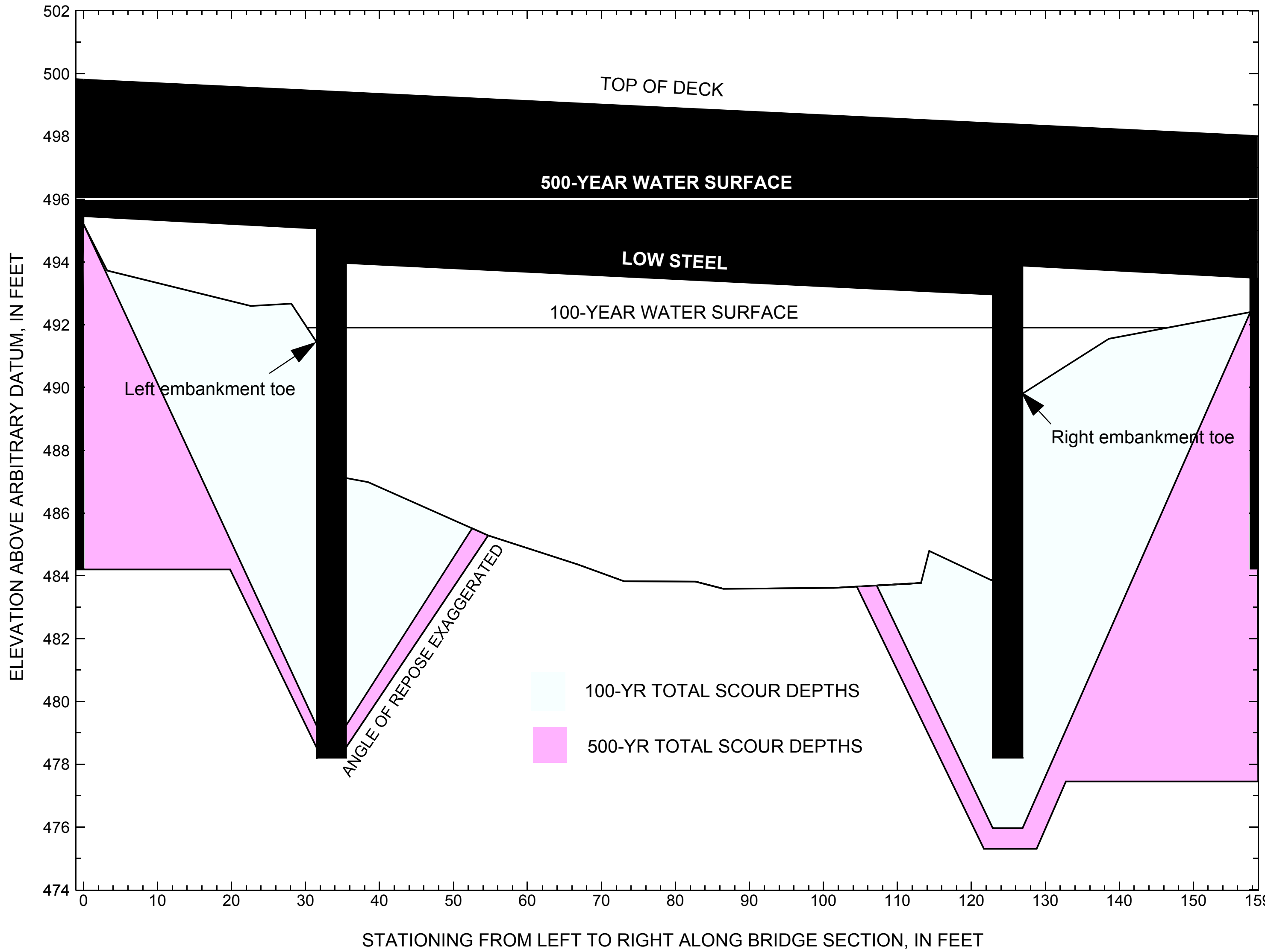

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CHESVT01030016 on State Route 103, crossing the Williams River, Chester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHESVT01030016 on State Route 103, crossing the Williams River, Chester, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum bridge seat 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 3,910 cubic-feet per second											
Left abutment	0.0	495.2	495.4	484.2	492.3	0.0	--	--	0.0	--	0.0
Left embankment toe	31.5	--	--	--	491.4	0.0	0.0	--	0.0	491.4	--
Pier 1	33.5	--	--	478.2	487.1	0.0	--	7.9	7.9	479.2	1.0
Pier 2	124.9	--	--	478.2	483.9	0.0	--	7.9	7.9	476.0	-2.2
Right embankment toe	126.9	--	--	--	486.4	0.0	0.0	--	0.0	486.4	--
Right abutment	157.7	493.3	493.5	484.2	491.0	0.0	--	--	0.0	--	0.0

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 CHESVT01030016 on State Route 103, crossing the Williams River, Chester, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum bridge seat 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 5,740 cubic-feet per second											
Left abutment	0.0	495.2	495.4	484.2	492.3	0.0	--	--	0.0	--	0.0
Left embankment toe	31.5	--	--	--	491.4	0.0	7.2	--	7.2	484.2	--
Pier 1	33.5	--	--	478.2	487.1	0.0	--	8.6	8.6	478.5	0.3
Pier 2	124.9	--	--	478.2	483.9	0.0	--	8.6	8.6	475.3	-2.9
Right embankment toe	126.9	--	--	--	486.4	0.0	9.0	--	9.0	477.4	--
Right abutment	157.7	493.3	493.5	484.2	491.0	0.0	--	--	0.0	--	-6.8vp

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 ches016.wsp
T2        Hydraulic analysis for structure CHESVT01030016   Date: 26-FEB-97
T3        Bridge # 16 on VT 103 over the Williams River in Chester, VT  by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3910.0   5740.0    5420.0
SK          0.0080   0.0080    0.0080
*
XS   EXITX   -153
GR         -241.6, 498.22   -167.9, 493.69    -90.6, 492.63    -11.2, 487.77
GR           -8.0, 488.11      0.0, 488.40     12.7, 482.50     20.2, 482.11
GR           31.4, 481.87     38.0, 482.40     44.3, 482.74     51.5, 483.55
GR           55.6, 487.69    116.2, 490.72    130.1, 494.18    180.6, 495.01
GR          256.5, 494.08    334.7, 499.57
N           0.040        0.070        0.050        0.070         0.035
SA                 -90.6        0.0          55.6          130.1
*
XS   FULLV      0  * * *  0.0110
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    493.68      55.0
GR            0.0, 495.45      0.0, 495.20      2.8, 492.31      3.2, 493.72
GR           15.0, 493.02     22.6, 492.59     28.1, 492.67     31.3, 491.45
GR           33.5, 490.18     35.0, 487.13     38.5, 486.98     54.7, 485.28
GR           66.8, 484.36     73.1, 483.82     82.7, 483.81     86.5, 483.58
GR          101.4, 483.61    113.2, 483.77    114.3, 484.79    122.7, 483.86
GR          127.1, 486.36    157.7, 490.96    157.7, 493.50    124.9, 494.26
GR          124.9, 493.35     33.5, 494.00     33.5, 495.13      0.0, 495.45
*         BRTYPE  BRWDTH  EMBSS  EMBELV
CD           3      58.2    5.0   498.9
PW          483.9,4 487.1,4 487.1,8 493.1,8 493.1,6 493.8,6 493.8,4 494.0,4
PW          494.0,2 494.9,2 494.9,0
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     29      35.2     1
GR         -221.2, 503.82   -145.1, 500.45    -16.5, 499.80    -16.4, 500.66
GR            0.0, 500.59    156.2, 498.91    171.1, 498.70    171.3, 498.02
GR          218.3, 497.03    250.8, 496.29    255.8, 495.03    400.3, 493.87
GR          463.6, 508.95
*
XT   APTEM    221
GR            0.0, 498.25      9.9, 495.89     39.5, 493.71     45.6, 487.93
GR           50.6, 486.00     55.2, 485.12     65.7, 485.40     72.2, 485.69
GR           78.8, 486.06     82.9, 488.01     90.1, 490.25     96.7, 494.07
GR          112.7, 494.14    222.8, 495.73    280.6, 495.73    360.3, 510.22
*
AS   APPRO    149  * * *  0.0083
GT
N           0.040        0.050        0.050
SA                  39.5         96.7
*
HP 1 BRIDG   491.94 1 491.94
HP 2 BRIDG   491.94 * * 3910
HP 2 BRIDG   492.54 * * 3910
HP 1 APPRO   493.00 1 493.00
HP 2 APPRO   493.00 * * 3910
HP 1 BRIDG   493.68 1 493.68
HP 2 BRIDG   493.68 * * 4406
HP 1 BRIDG   492.77 1 492.77
HP 2 RDWAY   496.02 * * 1327
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ches016.wsp
        Hydraulic analysis for structure CHESVT01030016   Date: 26-FEB-97
        Bridge # 16 on VT 103 over the Williams River in Chester, VT  by MAI
           *** RUN DATE & TIME: 04-16-97  10:34

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     452.  47608.    73.    80.                          6376.
   491.94          452.  47608.    73.    80.  1.00    30.   158.   6376.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       491.94    30.0   157.7   452.2   47608.    3910.   8.65

X STA.        30.0        45.6        52.7        58.5        63.7        68.4
  A(I)             36.0        24.7        22.2        21.3        20.3
  V(I)             5.43        7.93        8.79        9.17        9.64

X STA.        68.4        72.7        76.8        80.8        84.8        88.7
  A(I)             19.5        19.3        18.7        18.8        18.6
  V(I)            10.04       10.13       10.46       10.38       10.48

X STA.        88.7        92.7        96.6       100.6       104.6       108.8
  A(I)             18.8        18.8        19.0        19.2        20.1
  V(I)            10.40       10.41       10.30       10.19        9.75

X STA.       108.8       113.2       118.7       123.9       132.9       157.7
  A(I)             20.7        23.5        23.5        28.9        40.4
  V(I)             9.45        8.32        8.33        6.77        4.84


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.54     2.6   157.7   496.4   54628.    3910.   7.88

X STA.         2.6        45.3        52.5        58.6        63.8        68.6
  A(I)             40.5        27.6        25.4        23.0        22.4
  V(I)             4.82        7.08        7.71        8.50        8.72

X STA.        68.6        72.9        77.2        81.3        85.4        89.4
  A(I)             21.5        21.2        20.5        20.7        20.5
  V(I)             9.11        9.23        9.53        9.44        9.56

X STA.        89.4        93.4        97.4       101.4       105.6       109.8
  A(I)             20.5        20.5        20.7        21.3        21.5
  V(I)             9.53        9.54        9.44        9.16        9.10

X STA.       109.8       114.8       119.9       125.7       135.0       157.7
  A(I)             24.4        23.8        27.2        30.5        42.7
  V(I)             8.01        8.21        7.18        6.42        4.57

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     149.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     347.  33024.    56.    61.                          4884.
   493.00          347.  33024.    56.    61.  1.00    40.    96.   4884.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     149.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.00    39.6    95.9   346.7   33024.    3910.  11.28

X STA.        39.6        47.5        50.4        52.5        54.5        56.2
  A(I)             28.5        19.8        16.7        15.8        14.8
  V(I)             6.85        9.86       11.69       12.41       13.21

X STA.        56.2        58.0        59.7        61.4        63.2        64.9
  A(I)             14.9        14.5        14.2        14.5        14.4
  V(I)            13.15       13.48       13.77       13.53       13.60

X STA.        64.9        66.6        68.5        70.3        72.2        74.2
  A(I)             14.4        14.7        15.0        15.0        15.7
  V(I)            13.61       13.32       13.04       13.04       12.44

X STA.        74.2        76.2        78.5        81.1        85.0        95.9
  A(I)             15.8        17.0        18.8        21.5        30.9
  V(I)            12.38       11.52       10.40        9.07        6.34
```

```
        U.S. Geological Survey WSPRO Input File ches016.wsp
        Hydraulic analysis for structure CHESVT01030016   Date: 26-FEB-97
        Bridge # 16 on VT 103 over the Williams River in Chester, VT  by MAI
           *** RUN DATE & TIME: 04-16-97  10:34
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     586.  52729.    58.   131.                       10563.
   493.68          586.  52729.    58.   131.  1.00     1.   158.  10563.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.68     1.5   157.7   586.3   52729.    4406.   7.52

X STA.         1.5       43.7       50.9       56.8       61.8       66.2
  A(I)            55.0       31.5       28.0       24.8       23.3
  V(I)            4.00       6.99       7.86       8.89       9.47

X STA.        66.2       70.4       74.3       78.0       82.8       87.7
  A(I)            22.7       21.6       21.4       27.3       27.6
  V(I)            9.70      10.22      10.32       8.08       7.99

X STA.        87.7       92.5       97.2      102.1      107.1      112.1
  A(I)            27.5       27.3       27.5       28.2       28.3
  V(I)            8.02       8.06       8.00       7.80       7.78

X STA.       112.1      118.2      123.9      130.4      138.6      157.7
  A(I)            31.6       30.0       28.3       29.0       45.3
  V(I)            6.98       7.34       7.77       7.59       4.87

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      29.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.02   251.9   409.3   238.5   13371.    1327.   5.56

X STA.       251.9      269.9      282.8      293.9      304.0      313.0
  A(I)            16.7       14.9       13.9       13.5       12.8
  V(I)            3.96       4.46       4.79       4.90       5.20

X STA.       313.0      321.6      329.5      336.8      343.7      350.3
  A(I)            12.7       12.1       11.8       11.6       11.3
  V(I)            5.21       5.46       5.63       5.72       5.89

X STA.       350.3      356.5      362.4      368.1      373.5      378.8
  A(I)            11.1       10.7       10.7       10.4       10.2
  V(I)            6.00       6.21       6.23       6.36       6.49

X STA.       378.8      383.9      388.7      393.6      398.5      409.3
  A(I)            10.2        9.8       10.2       10.4       13.6
  V(I)            6.49       6.78       6.51       6.41       4.88

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     149.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      55.   2883.    33.    33.                         404.
             2     519.  63968.    57.    62.                        8877.
             3     279.  10779.   189.   189.                        1924.
   496.02          853.  77630.   279.   283.  1.55     7.   285.   6809.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     149.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.02     6.8   285.5   853.1   77630.    5740.   6.73

X STA.         6.8       43.0       47.9       51.0       53.7       56.2
  A(I)            70.6       40.3       32.1       29.2       28.2
  V(I)            4.06       7.12       8.94       9.84      10.18

X STA.        56.2       58.5       60.9       63.2       65.7       68.1
  A(I)            26.6       27.3       26.7       27.2       27.0
  V(I)           10.78      10.53      10.75      10.56      10.64

X STA.        68.1       70.6       73.1       75.7       78.5       81.7
  A(I)            27.7       27.4       28.4       29.4       31.7
  V(I)           10.36      10.47      10.12       9.75       9.06

X STA.        81.7       85.9       92.5      121.9      166.6      285.5
  A(I)            35.5       43.0       78.4       90.2      126.2
  V(I)            8.08       6.68       3.66       3.18       2.27
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     514.  55277.    80.    88.                        7413.
   492.77          514.  55277.    80.    88.  1.00     2.   158.   7413.
```

```
        U.S. Geological Survey WSPRO Input File ches016.wsp
        Hydraulic analysis for structure CHESVT01030016   Date: 26-FEB-97
        Bridge # 16 on VT 103 over the Williams River in Chester, VT  by MAI
           *** RUN DATE & TIME: 04-16-97  10:28
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      505     54509     78     86                         7300
   492.66           505     54509     78     86  1.00      2    158     7300

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.66     2.5   157.7   505.5   54509.    5420.  10.72

X STA.         2.5       46.5       53.9       60.0       65.2       70.0
  A(I)            46.4       29.4       26.1       24.1       22.9
  V(I)            5.84       9.23      10.40      11.24      11.86

X STA.        70.0       74.3       78.5       82.7       86.7       90.6
  A(I)            21.8       21.3       21.1       20.4       20.6
  V(I)           12.42      12.73      12.86      13.29      13.13

X STA.        90.6       94.6       98.5      102.5      106.6      110.8
  A(I)            20.5       20.5       20.7       20.9       21.9
  V(I)           13.20      13.21      13.07      12.96      12.39

X STA.       110.8      115.7      120.6      126.5      135.7      157.7
  A(I)            23.9       23.4       27.2       30.0       42.4
  V(I)           11.32      11.56       9.96       9.05       6.40

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.47     1.7   157.7   572.0   57964.    5420.   9.48

X STA.         1.7       45.4       53.4       59.4       64.8       69.5
  A(I)            57.3       35.0       28.5       26.9       24.7
  V(I)            4.73       7.74       9.50      10.07      10.97

X STA.        69.5       73.9       78.0       82.1       86.0       89.9
  A(I)            24.0       22.9       22.7       21.8       22.1
  V(I)           11.31      11.84      11.96      12.42      12.24

X STA.        89.9       93.8       97.7      101.6      105.7      110.4
  A(I)            22.0       22.0       22.3       22.9       26.5
  V(I)           12.30      12.31      12.17      11.81      10.24

X STA.       110.4      117.0      123.0      130.3      139.2      157.7
  A(I)            34.7       32.2       31.7       30.3       41.5
  V(I)            7.81       8.42       8.54       8.95       6.53

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     149.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1        7       162     14     14                           28
             2      411     43249     57     62                         6242
             3       21       335     56     56                           75
   494.12           439     43746    127    131  1.10     26    153     4407

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     149.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.12    25.8   152.7   438.8   43746.    5420.  12.35

X STA.        25.8       46.7       49.7       52.0       54.1       56.0
  A(I)            38.6       23.0       20.1       18.9       18.2
  V(I)            7.02      11.76      13.50      14.31      14.86

X STA.        56.0       57.8       59.7       61.5       63.3       65.2
  A(I)            17.9       17.5       17.1       17.4       17.3
  V(I)           15.15      15.52      15.85      15.56      15.64

X STA.        65.2       67.1       69.0       71.0       73.0       75.1
  A(I)            17.7       17.5       18.2       18.2       18.6
  V(I)           15.32      15.46      14.90      14.89      14.54

X STA.        75.1       77.3       79.7       82.8       87.1      152.7
  A(I)            19.6       20.5       23.2       26.0       53.2
  V(I)           13.82      13.23      11.69      10.44       5.09
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ches016.wsp
        Hydraulic analysis for structure CHESVT01030016   Date: 26-FEB-97
        Bridge # 16 on VT 103 over the Williams River in Chester, VT  by MAI
           *** RUN DATE & TIME: 04-16-97  10:34

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

EXITX:XS   ******   -52.     523.  1.25 *****  491.49  489.08   3910.  490.24
     -153. ******   107.   43711.  1.44 ***** *******    0.87    7.48

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.97     491.50     490.77

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   489.74     501.25    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   489.74     501.25     490.77

FULLV:FV     153.   -45.     459.  1.53  1.40  493.03  490.77   3910.  491.50
        0.   153.    98.   38338.  1.35  0.14    0.00    0.97    8.52
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     149.    40.     350.  1.94  1.77  495.00 *******   3910.  493.07
      149.   149.    96.   33538.  1.00  0.20    0.00    0.79   11.16
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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     153.    30.     452.  1.16  1.62  493.10  490.52   3910.  491.94
        0.   153.   158.   47619.  1.00  0.00    0.02    0.61    8.65

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.000  0.114  493.68 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG       29.        <<<<<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      91.    40.     347.  1.98  1.27  494.98  492.04   3910.  493.00
      149.    91.    96.   33043.  1.00  0.60    0.00    0.80   11.27

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      0.000  0.000   33027.     7.   134.   491.41


  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q         K      AREA     VEL    WSEL
   EXITX:XS     -153.   -52.   107.   3910.   43711.     523.    7.48  490.24
   FULLV:FV        0.   -45.    98.   3910.   38338.     459.    8.52  491.50
   BRIDG:BR        0.    30.   158.   3910.   47619.     452.    8.65  491.94
   RDWAY:RG       29.**************      0.******************    1.00********
   APPRO:AS      149.    40.    96.   3910.   33043.     347.   11.27  493.00

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       7.   134.   33027.


 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN     YMAX     HF    HO   VHD      EGL    WSEL
   EXITX:XS     489.08    0.87  481.87  499.57************  1.25  491.49  490.24
   FULLV:FV     490.77    0.97  483.55  501.25  1.40  0.14  1.53  493.03  491.50
   BRIDG:BR     490.52    0.61  483.58  495.45  1.62  0.00  1.16  493.10  491.94
   RDWAY:RG   ****************  493.87  508.95**********************************
   APPRO:AS     492.04    0.80  484.52  509.62  1.27  0.60  1.98  494.98  493.00
```

WSPRO OUTPUT FILE (continued)

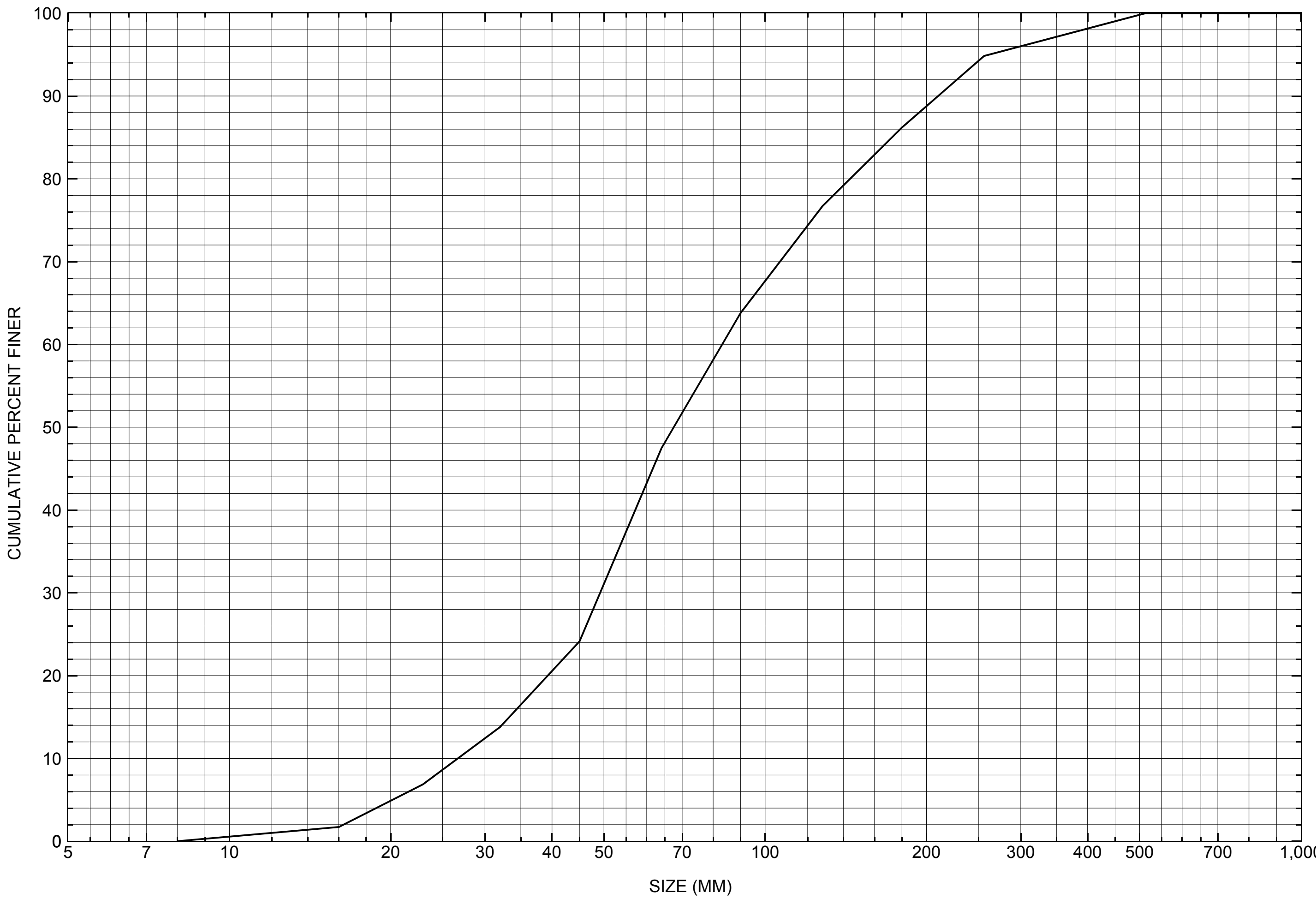
```
        U.S. Geological Survey WSPRO Input File ches016.wsp
        Hydraulic analysis for structure CHESVT01030016   Date: 26-FEB-97
        Bridge # 16 on VT 103 over the Williams River in Chester, VT  by MAI
           *** RUN DATE & TIME: 04-16-97  10:34

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

EXITX:XS   ******   -73.     755.  1.45 *****  493.00  490.82   5740.  491.55
     -153. ******   120.   64131.  1.61 ***** *******    0.86    7.61
 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.00     492.76     492.50
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.05     501.25    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.05     501.25     492.50

FULLV:FV     153.   -65.     668.  1.80  1.40  494.57  492.50   5740.  492.77
        0.   153.   118.   56175.  1.57  0.18    0.00    0.99    8.60
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.30     494.20     494.90
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.27     509.62    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.27     509.62     494.90
 ===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 "APPRO"
                  WSBEG,WSEND,CRWS =   494.90     509.62     494.90

APPRO:AS     149.    15.     563.  2.10 *****  497.00  494.90   5740.  494.90
      149.   149.   207.   54308.  1.30 ***** *******    1.20   10.19
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===230 REJECTED FLOW CLASS 1 SOLUTION.
             WS1,WSSD,WS3 =   494.90       0.00     492.38
                     CRWS =   494.90   ********     492.03
                     YMAX =   509.62   ********     495.45
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   499.11         1.      5739.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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     153.     1.     522.  1.11 *****  494.79  490.98   4406.  493.68
        0. ******   158.   52729.  1.00 ***** *******    0.82    8.44

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   5.  0.496  0.110  493.68 ****** ****** ******

   XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
  RDWAY:RG      29.   114.  0.62  1.09  496.48    0.00   1327.  496.02

               Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
  LT:       0.   193.  -136.    91.   0.8   0.3   5.8  19.0   1.6   3.0
  RT:    1327.   154.   256.   409.   2.1   1.5   6.5   5.6   2.0   3.0

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

APPRO:AS      91.     7.     852.  1.09  0.59  497.11  494.90   5740.  496.02
      149.    93.   285.   77507.  1.55  0.00    0.00    0.85    6.74

  FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW       Q         K      AREA     VEL    WSEL
  EXITX:XS    -153.   -73.   120.   5740.   64131.      755.    7.61  491.55
  FULLV:FV       0.   -65.   118.   5740.   56175.      668.    8.60  492.77
  BRIDG:BR       0.     1.   158.   4406.   52729.      522.    8.44  493.68
  RDWAY:RG      29.*******     0.   1327.        0.*********    1.00  496.02
  APPRO:AS     149.     7.   285.   5740.   77507.      852.    6.74  496.02

 SECOND USER DEFINED TABLE.

   XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
  EXITX:XS     490.82    0.86  481.87  499.57************  1.45  493.00  491.55
  FULLV:FV     492.50    0.99  483.55  501.25  1.40  0.18  1.80  494.57  492.77
  BRIDG:BR     490.98    0.82  483.58  495.45************  1.11  494.79  493.68
  RDWAY:RG   ****************  493.87  508.95  0.62******  1.09  496.48  496.02
  APPRO:AS     494.90    0.85  484.52  509.62  0.59  0.00  1.09  497.11  496.02
        U.S. Geological Survey WSPRO Input File ches016.wsp
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ches016.wsp
        Hydraulic analysis for structure CHESVT01030016   Date: 26-FEB-97
        Bridge # 16 on VT 103 over the Williams River in Chester, VT  by MAI
           *** RUN DATE & TIME: 04-16-97  10:28

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

EXITX:XS   ******    -69      716  1.42 *****  492.76  490.50    5420  491.34
      -152 ******    119    60561  1.60 ***** *******    0.86    7.57

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
           FNTEST,FR#,WSEL,CRWS =  0.80    1.00     492.56     492.18

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   490.84     499.90    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   490.84     499.90     492.18

FULLV:FV      153    -61      632  1.77  1.40  494.34  492.18    5420  492.57
         0    153    117    52995  1.55  0.17    0.00    1.00    8.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
           FNTEST,FR#,WSEL,CRWS =  0.80    1.23     494.03     494.01

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   492.07     509.62    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   492.07     509.62     494.01

APPRO:AS      149     27      428  2.71  1.93  496.74  494.01    5420  494.03
       149    149    147    42734  1.09  0.47    0.00    1.23   12.67
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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      153      2      506  1.81  1.70  494.48  491.78    5420  492.66
         0    153    158    54479  1.02  0.02    0.01    0.75   10.72

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.992  0.113  493.68 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      29.        <<<<<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       91     26      438  2.62  1.45  496.74  494.01    5420  494.12
       149     94    152    43698  1.10  0.81    0.01    1.23   12.37


       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.000   43614.     0.   155.   492.36

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -153.   -70.   119.   5420.   60561.     716.    7.57  491.34
   FULLV:FV      0.   -62.   117.   5420.   52995.     632.    8.58  492.57
   BRIDG:BR      0.     2.   158.   5420.   54479.     506.   10.72  492.66
   RDWAY:RG      29.**************      0.*****************    1.00********
   APPRO:AS     149.    26.   152.   5420.   43698.     438.   12.37  494.12

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      0.   155.   43614.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    490.50    0.86  481.87  498.22************  1.42  492.76  491.34
   FULLV:FV    492.18    1.00  483.55  499.90  1.40  0.17  1.77  494.34  492.57
   BRIDG:BR    491.78    0.75  483.58  495.45  1.70  0.02  1.81  494.48  492.66
   RDWAY:RG  ****************  495.03  508.95**********************************
   APPRO:AS    494.01    1.23  484.52  509.62  1.45  0.81  2.62  496.74  494.12
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESVT01030016, in Chester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHESVT01030016

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 03 / 13 / 95

Highway District Number *(I - 2; nn)* 03

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

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

Mile marker *(I - 11; nnn.nnn)* 009560

Waterway *(I - 6)* WILLIAMS RIVER

Road Name *(I - 7):* -

Route Number VT103

Vicinity *(I - 9)* 1.7 MI N JCT. VT.10

Topographic Map Chester

Hydrologic Unit Code:

Latitude *(I - 16; nnnn.n)* 43207

Longitude *(i - 17; nnnnn.n)* 72374

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20002500161407

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0087

Year built *(I - 27; YYYY)* 1962

Structure length *(I - 49; nnnnnn)* 000162

Average daily traffic, ADT *(I - 29; nnnnnn)* 004470

Deck Width *(I - 52; nn.n)* 352

Year of ADT *(I - 30; YY)* 92

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

Opening skew to Roadway *(I - 34; nn)* 55

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

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*) 87.8

Number of spans *(I - 45; nnn)* 003

Vertical clearance from streambed (*nnn.n ft*) 10.0

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

Waterway of full opening (*nnn.n* ft^2) 450.0

Comments:

The structural inspection report of 9/22/93 indicates the structure is a three span, rolled steel beam type bridge. The left abutment wall and its wingwalls are in good condition with the exception of some minor concrete cracking and scaling. Both piers are solid shaft type piers with some minor areas of concrete staining and cracking. The right abutment wall and its wingwalls are in good condition. The channel is straight and passes entirely through the middle span. There is some minor streambank erosion noted. Both abutment walls are protected by stone fill. The abutments are the spill-through type. Vegetation is noted on both banks up- and downstream of the bridge.

Bridge Hydrologic Data

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

Terrain character: Hilly

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)* : Moderate Debris *(Heavy, Moderate, Light)*: Light

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

The stream response is (*Flashy, Not 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*): - Town: - Year Built: -

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

Clear span (*ft*): 34 Clear Height (*ft*): - Full Waterway (*ft²*): 110.5

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): 35 Clear Height (*ft*): - Full Waterway (ft^2): 140

Comments:

Some hydrologic data is found on the plans. A drainage area is given as 11,000 acres.

The area full opening is 450 square feet.
There is slight drift in the channel. The potential for ice blockage was noted as moderate.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 15.10 mi^2 Lake and pond area 0.003 mi^2
Watershed storage *(ST)* 0.02 %
Bridge site elevation 820.0 ft Headwater elevation 2882.0 ft
Main channel length 8.45 mi
10% channel length elevation 940.0 ft 85% channel length elevation 1840.0 ft
Main channel slope *(S)* 142.01 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? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 08 / 1960

Project Number F 025 1(8) Minimum channel bed elevation: 815

Low superstructure elevation: USLAB 827.01 DSLAB 826.01 USRAB 825.25 DSRAB 824.05

Benchmark location description:

No benchmark information is provided on the plans. Taken from the plans, on the right abutment at the downstream end there are 3 interconnected, step like, concrete posts forming the end of the guardrail. The indicated elevation on the lowest of the 3 steps, at the very end of the post toward the right bank is 830.21. The datum is unknown but probably arbitrary.

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

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

If 1: Footing Thickness 2.0 Footing bottom elevation: 809.0

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? Y *If no, type ctrl-n bi* Number of borings taken: 14

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

Briefly describe material at foundation bottom elevation or around piles:

The pier footings are set in a compact to wet, loose brown sand and coarse gravel and some cobbles. The left abutment is shown in a mica schist bedrock at least at the upstream end. The right abutment is probably set in a wet, loose, brown, coarse sand, gravel, and cobbles.

Comments:

The bottom of footing elevation shown above is that for the bottom of each pier. The bottom of each abutment footing is depicted at elev. 815.0 on the plans. The abutment footings are shown protected by the spill-through abutment stone fill on the plans. These plans are listed under the last project number which is "F025-1(8)". Opposite side of previous BM is 832.57. The low superstructure elevation for the piers are: pier 1(left) upstream end 826.70(left), 825.59(right) and downstream end 825.68(left), 824.55(right); pier 2(right) upstream end 824.75(left), 825.67(right) and downstream end 823.90(left), 824.81(right). The pier footing is 2 feet thick.

Cross-sectional Data

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

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

Comments: **The elevations and stations are measured in feet.**

Station	**432**	**464**	**468**	**524**	**562**	**566**	**598**	-	-	-	-
Feature	**LAB**	-	-	-	-	-	**RAB**	-	-	-	-
Low cord elevation	**826.1**	**826.1**	**826.1**	**826.1**	**826.1**	**826.1**	**826.1**	-	-	-	-
Bed elevation	**822.6**	**819**	**816.1**	**814.8**	**816.1**	**817.5**	**821.1**	-	-	-	-
Low cord to bed length	**3.5**	**7.1**	**10**	**11.3**	**10**	**8.6**	**5**	-	-	-	-

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

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

Comments: -

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 9/23/96
Computerized by: EW Date: 9/24/96
Reviewd by: MAI Date: 5/29/97

Structure Number CHESVT01030016

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND Date *(MM/DD/YY)* 09 / 16 / 1996

2. Highway District Number 03 Mile marker 009560

County WINDSOR (027) Town CHESTER (13675)

Waterway *(I - 6)* WILLIAMS RIVER Road Name -

Route Number VT 103 Hydrologic Unit Code: 01080107

3. Descriptive comments:

Located 1.7 miles north of the junction with Vermont 10, and at the junction with TH09 (Smokeshire road). A local resident said the 1973 flood flow overtopped Smokeshire road, and none went over Vermont 103. All of the flood water went through the bridge.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 LBDS 4 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 2 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length 162 *(feet)* Span length 87 *(feet)* Bridge width 35.2 *(feet)*

Road approach to bridge:

8. LB 0 RB 0 *(**0** even, **1**- lower, **2**- higher)*

9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*

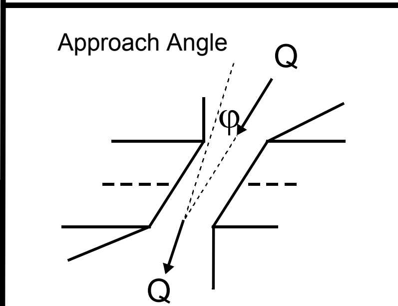
10. Embankment slope (*run / rise in feet / foot*):
US left --:1 US right --:1

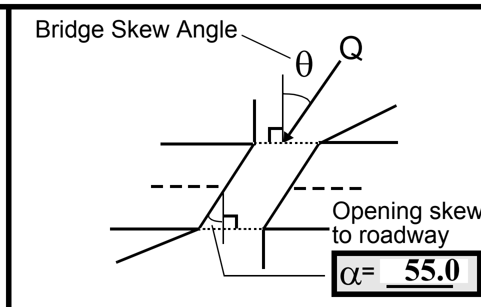
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	0	-	0	-
RBUS	1	1	2	1
RBDS	0	-	0	-
LBDS	1	1	0	-

*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: 0 16. Bridge skew: 55





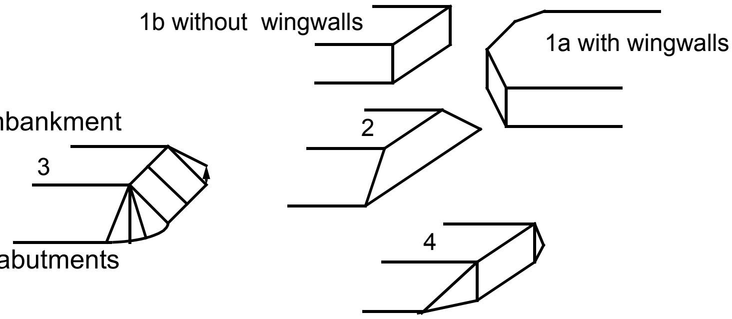
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 300 feet US *(US, UB, DS)* to 200 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 170 feet DS *(US, UB, DS)* to 350 feet DS

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

18. Bridge Type: **3**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

#4: There are lawns surrounding houses on all banks (upstream and downstream) with woods behind, except on the downstream left bank there is pasture beyond the house.
#7: The bridge dimensions are from the VTAOT database. The measured dimensions are: US bridge length = 188.8 feet; span = 155.7 feet; and deck width from the inside edges of curbs = 30.4 feet; DS bridge length = 189.6 feet; span = 157.6 feet; and deck width between outside edges of cubs = 34.8 feet.
The lengths underneath the bridge, measured perpendicular to flow between the left abutment and pier 1 is 16 feet; between pier 1 and pier 2 is 49 feet; and between pier 2 and the right abutment is 16 feet. The lengths underneath the bridge, measured parallel to bridge deck between the left abutment and pier 1 is 30 feet; between pier 1 and pier 2 is 89 feet; and between pier 2 and the right abutment is 30 feet.
#18: There is type 3 stone fill (less than 48 inches diameter) between the piers and abutments forming a spill-through embankment.

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
153.5	**6.0**			**6.0**	**2**	**3**	**345**	**345**	**0**	**0**

23. Bank width **45.0** 24. Channel width **25.0** 25. Thalweg depth **57.5** 29. Bed Material **345**

30 .Bank protection type: LB **4** RB **3** 31. Bank protection condition: LB **1** 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.):
#27: The above values were determined from the natural bank, approximately 450 feet upstream from bridge.
#29: Bedrock exists across entire channel approximately 450 feet upstream.
#30: The left bank protection extends from 400 feet upstream to 40 feet upstream. The protection consists of large boulders along the bank to protect road which is parallel to the river. The right bank protection, which is an old stone wall, extends from 400 feet upstream to 15 feet upstream. Boulders also have been placed along the right bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **20** 35. Mid-bar width: **25**
36. Point bar extent: **40** feet **US** (US, UB) to **145** feet **DS** (US, UB, DS) positioned **0** %LB to **50** %RB
37. Material: **435**
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
This side bar is adjacent to pier 1, along the left bank.

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: **430** 42. Cut bank extent: **450** feet **US** (US, UB) to **400** 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 cut-bank is just downstream of bedrock bed, and is probably a result of turbulence caused by flow over bedrock.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **450**
47. Scour dimensions: Length **15** Width **10** Depth : **2** Position **45** %LB to **55** %RB
48. Scour comments (eg. additional scour areas, local scouring process, etc.):
Scour exists just below bedrock in channel.

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
37.5		0.5		2	5	5	0

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **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.):
435
The length of flow is 55 feet between the upstream and downstream bridge faces.

#55: There is about 2-3 feet of concrete abutment exposed between top of placed stone and bridge seat. At the abutments there is 0.2 feet difference between the bridge seat and low cord.

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 2____ (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 severe scaring on the upstream side of a tree (8 inches in diameter) in the upstream left bank impact zone. There are trees leaning over the channel upstream.

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	90	0	0	-	-	90.0
RABUT	1	0	90			0	0	90.5

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

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

-

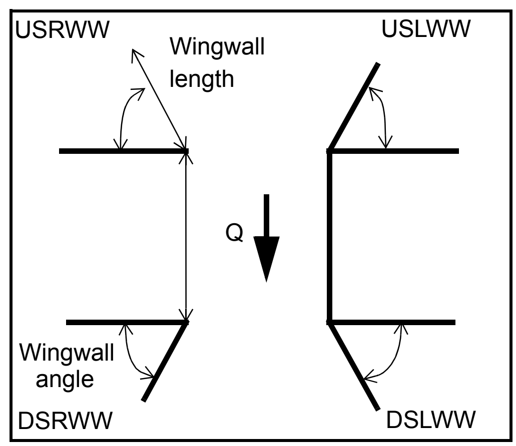
-

1

#71- #77: The values above are based on the vertical concrete abutment. There is stone fill forming a spill-through embankment between the abutments and piers, with a slope of 30 degrees.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						90.5	
USRWW:	N		-		-	0.5	
DSLWW:	-		-		N	57.0	
DSRWW:	-		-		-	59.5	



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	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	3	3	-

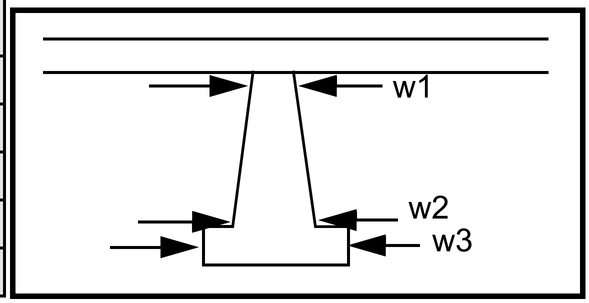
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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	-	-	-	-	-	-
Pier 2	-	4	4	-	494.00	487.13
Pier 3	-	4	4	-	493.35	485.10
Pier 4	-	-	-	-	-	-



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

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
-	-			-			Eac	h	pier	has

Bank width (BF) -   Channel width (Amb) 60.0   Thalweg depth (Amb) 56.1   Bed Material type-

Bank protection type (Qmax): LB 3 RB pro   Bank protection condition: LB tec- RB tion

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.):
surrounding the base.

4
3
7
7
0

101. Is a drop structure present? **0** *(Y or N, if N type ctrl-n ds)*   102. Distance: - feet

103. Drop: - feet   104. Structure material: **435** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
3
3
1
1
The left bank protection extends from 35 feet under bridge to 190 feet downstream. There is an old rock wall/ pile to approximately 300 feet downstream.

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

Point bar extent: **bank** feet **pro** (US, UB, DS) to **tec-** feet **tio** (US, UB, DS) positioned **n** %LB to **ext** %RB

Material: **en**

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

ds from 36 feet downstream to 145 feet downstream. There is an old rock wall/pile to 300 feet downstream.

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

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

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

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

N

-

NO DROP STRUCTURE

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

Scour dimensions: Length ______ Width ______ Depth: **N** Positioned **-** %LB to **-** %RB

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

-

-

-

-

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

Confluence 1: Distance **-** Enters on **NO** (LB or RB) Type **POI** (**1**- perennial; **2**- ephemeral)

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N

-

-

-

-

-

-

-

NO CUT BANKS

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: CHESVT01030016 Town: Chester
Road Number: VT 103 County: Windsor
Stream: Williams River

Initials MAI Date: 04/17/97 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	3910	5740	5420
Main Channel Area, ft2	346.7	519	411
Left overbank area, ft2	0	55	7
Right overbank area, ft2	0	279	21
Top width main channel, ft	56.3	57	57
Top width L overbank, ft	0	33	14
Top width R overbank, ft	0	189	56
D50 of channel, ft	0.222	0.222	0.222
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.2	9.1	7.2
y1, average depth, LOB, ft	ERR	1.7	0.5
y1, average depth, ROB, ft	ERR	1.5	0.4
Total conveyance, approach	33024	77630	43746
Conveyance, main channel	33024	63968	43249
Conveyance, LOB	0	2883	162
Conveyance, ROB	0	10779	335
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	3910.0	4729.8	5358.4
Ql, discharge, LOB, cfs	0.0	213.2	20.1
Qr, discharge, ROB, cfs	0.0	797.0	41.5
Vm, mean velocity MC, ft/s	11.3	9.1	13.0
Vl, mean velocity, LOB, ft/s	ERR	3.9	2.9
Vr, mean velocity, ROB, ft/s	ERR	2.9	2.0
Vc-m, crit. velocity, MC, ft/s	9.2	9.8	9.4
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	1	0	1
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and others, 1995, p. 30, eq. 17 and 18)

Characteristic	Approach 100 yr	500 yr	Other Q	Bridge 100 yr	500 yr	Other Q
Q1, discharge, cfs	3910	5740	5420	3910	4406	5420
Total conveyance	33024	77630	43746	47608	52729	54509
Main channel conveyance	33024	63968	43249	47608	52729	54509
Main channel discharge	3910	4730	5358	3910	4406	5420
Area - main channel, ft2	346.7	519	411	401	522	448.4
(W1) channel width, ft	56.3	57	57	58.3	72.3	72
(Wp) cumulative pier width, ft	0	0	0	8	8	8
W1, adjusted bottom width(ft)	56.3	57	57	50.3	64.3	64
D50, ft	0.222	0.222	0.222			
w, fall velocity, ft/s (p. 32)	3.85	3.85	3.85			
y, ave. depth flow, ft	6.16	9.11	7.21	7.97	8.12	7.01
S1, slope EGL	0.0133	0.0163	0.0164			
P, wetted perimeter, MC, ft	61	62	62			
R, hydraulic Radius, ft	5.592	8.371	6.629			
V*, shear velocity, ft/s	1.548	2.096	1.871			
V*/w	0.402	0.544	0.486			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.59	0.64	0.59			
y2,depth in contraction, ft	6.58	7.93	6.80			
ys, scour depth, ft (y2-y_bridge)	-1.39	-0.19	-0.21			

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	3910	5740	5420
(Q) discharge thru bridge, cfs	0	4406	0
Main channel conveyance	0	52729	0
Total conveyance	0	52729	0
Q2, bridge MC discharge,cfs	ERR	4406	ERR
Main channel area, ft2	0	522	0
Main channel width (normal), ft	0.0	72.3	0.0
Cum. width of piers in MC, ft	0.0	8.0	0.0

W, adjusted width, ft	0	64.3	0
y_bridge (avg. depth at br.), ft	ERR	8.12	ERR
Dm, median (1.25*D50), ft	0.2775	0.2775	0.2775
y2, depth in contraction,ft	ERR	6.69	ERR
ys, scour depth (y2-ybridge), ft	N/A	-1.43	N/A

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	3910	5740	5420
Q, thru bridge MC, cfs	3910	4406	5420
Vc, critical velocity, ft/s	9.19	9.81	9.43
Va, velocity MC approach, ft/s	11.28	9.11	13.04
Main channel width (normal), ft	58.3	72.3	72.0
Cum. width of piers in MC, ft	8.0	8.0	8.0
W, adjusted width, ft	50.3	64.3	64.0
qbr, unit discharge, ft2/s	77.7	68.5	84.7
Area of full opening, ft2	401.0	522.0	448.4
Hb, depth of full opening, ft	7.97	8.12	7.01
Fr, Froude number, bridge MC	0	0.82	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	455.6	N/A
**Hb, depth at downstream face, ft	N/A	7.09	N/A
**Fr, Froude number at DS face	ERR	0.64	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	493.68	0
Elevation of Bed, ft	-7.97	485.56	-7.01
Elevation of Approach, ft	0	496.02	0
Friction loss, approach, ft	0	0.59	0
Elevation of WS immediately US, ft	0.00	495.43	0.00
ya, depth immediately US, ft	7.97	9.87	7.01
Mean elevation of deck, ft	0	499.75	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.95	1.00
**Cc, for downstream face (<=1.0)	ERR	0.915705	ERR
Ys, scour w/Chang equation, ft	N/A	-0.78	N/A
Ys, scour w/Umbrell equation, ft	N/A	2.29	N/A

**=for UNsubmerged orifice flow only.

**Ys, scour w/Chang equation, ft	N/A	0.54	N/A

**Ys, scour w/Umbrell equation, ft	ERR	3.32	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	6.58	6.69	6.80
WSEL at downstream face, ft	--	492.77	--
Depth at downstream face, ft	ERR	7.21	ERR
Ys, depth of scour (Laursen), ft	N/A	-0.52	N/A

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	3910	4406	5420
Main channel area (DS), ft2	401	455.6	448.4
Main channel width (normal), ft	58.3	72.3	72.0
Cum. width of piers, ft	8.0	8.0	8.0
Adj. main channel width, ft	50.3	64.3	64.0
D90, ft	0.6900	0.6900	0.6900
D95, ft	0.8590	0.8590	0.8590
Dc, critical grain size, ft	0.3915	0.4041	0.6343
Pc, Decimal percent coarser than Dc	0.259	0.247	0.120
Depth to armoring, ft	3.37	3.70	13.90

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	3910	5740	5420	3910	5740	5420
a', abut.length blocking flow, ft	--	36.5	18.2	--	107.3	36.7
Ae, area of blocked flow ft2	--	73.1	33.6	--	166.9	29.8
Qe, discharge blocked abut.,cfs	--	304.6	236	--	--	151.6
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	ERR	4.17	7.02	ERR	2.73	5.09
ya, depth of f/p flow, ft	ERR	2.00	1.85	ERR	1.56	0.81
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	35	35	35	145	145	145
K2	0.88	0.88	0.88	1.06	1.06	1.06
Fr, froude number f/p flow	ERR	0.519	0.911	ERR	0.410	0.995
ys, scour depth, ft	0.00	7.17	7.00	0.00	8.96	6.35

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)	--	36.5	18.2	--	107.3	36.7
y1 (depth f/p flow, ft)	ERR	2.00	1.85	ERR	1.56	0.81
a'/y1	ERR	18.23	9.86	ERR	68.98	45.20
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	N/A	0.52	0.91	N/A	0.41	0.99
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	8.43	5.90
vertical w/ ww's	ERR	ERR	ERR	ERR	6.91	4.83
spill-through	ERR	ERR	ERR	ERR	4.64	3.24

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)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.61	0.64	0.75	0.61	0.64	0.75
y, depth of flow in bridge, ft	7.97	7.08	7.01	7.97	7.08	7.01
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.83	1.79	2.44	1.83	1.79	2.44
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.60	1.56	2.13	1.60	1.56	2.13
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR

Pier Scour

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)
V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	33.5	33.5	33.5
Area of WSPRO flow tube, ft2	20.5	21.4	21.8
Skewed width of flow tube, ft	2.29	2.12	2.24
y1, pier approach depth, ft	8.95	10.09	9.73
y1 in meters	2.728	3.077	2.966
V1, pier approach velocity, ft/s	9.56	10.32	12.42
a, pier width, ft	4	4	4
L, pier length, ft	60	60	60
Fr1, Froude number at pier	0.563	0.572	0.702
Pier attack angle, degrees	0	0	0
K1, shape factor	1	1	1
K2, attack factor	1.00	1.00	1.00
K3, bed condition factor	1.1	1.1	1.1
D50, ft	0.222	0.222	0.222
D50, m	0.067662	0.067662	0.067662
D90, ft	0.69	0.69	0.69
D90, m	0.210302	0.210302	0.210302
Vc50,critical velocity(D50),m/s	2.982	3.042	3.023
Vc90,critical velocity(D90),m/s	4.351	4.439	4.412
Vi,incipient velocity,m/s	1.650	1.683	1.673
Vr, velocity ratio	0.468	0.531	0.771
K4, armor factor	0.86	0.90	0.98
ys, scour depth (K4 applicable) ft	7.88	8.58	10.07

Pier 2	Q100	Q500	Qother
Pier stationing, ft	124.9	124.9	124.9
Area of WSPRO flow tube, ft2	20.5	21.4	21.8
Skewed width of flow tube, ft	2.29	2.12	2.24
y1, pier approach depth, ft	8.95	10.09	9.73
y1 in meters	2.728	3.077	2.966
V1, pier approach velocity, ft/s	9.56	10.32	12.4
a, pier width, ft	4	4	4
L, pier length, ft	60	60	60
Fr1, Froude number at pier	0.563	0.572	0.700
Pier attack angle, degrees	0	0	0
K1, shape factor	1	1	1
K2, attack factor	1.00	1.00	1.00
K3, bed condition factor	1.1	1.1	1.1

D50, ft	0.222	0.222	0.222
D50, m	0.067662	0.067662	0.067662
D90, ft	0.69	0.69	0.69
D90, m	0.210302	0.210302	0.210302
Vc50,critical velocity(D50),m/s	2.982	3.042	3.023
Vc90,critical velocity(D90),m/s	4.351	4.439	4.412
Vi,incipient velocity,m/s	1.650	1.683	1.673
Vr, velocity ratio	0.468	0.531	0.769
K4, armor factor	0.86	0.90	0.98
ys, scour depth, (K4 applicable) ft	7.88	8.58	10.06

Pier rip-rap sizing
D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	1.5
V, velocity on pier, ft/s	9.75	9.67	12.09
D50, median stone diameter, ft	1.39	1.37	2.14

Pier 2			
K, pier shape coeff.	1.5	1.5	1.5
V, velocity on pier, ft/s	9.75	9.67	12.09
D50, median stone diameter, ft	1.39	1.37	2.14