LEVEL II SCOUR ANALYSIS FOR BRIDGE 27 (ANDOTH00290027) on TOWN HIGHWAY 29, crossing MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

U.S. Geological Survey
Open-File Report 97-225

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

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By Ronda L. Burns and Emily C. Wild

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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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Box 25286
Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 27 (ANDOTH00290027) ON TOWN HIGHWAY 29, CROSSING MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

By **Ronda L. Burns and Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ANDOTH00290027 on Town Highway 29 crossing the Middle Branch Williams River, Andover, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in central Vermont. The 12.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the left bank upstream of the bridge while the immediate bank has woody vegetation. The surface cover on the upstream right bank is forest. Downstream of the bridge the left bank is pasture and the right bank has woody vegetation.

In the study area, the Middle Branch Williams River has an incised, straight channel with a slope of approximately 0.009 ft/ft, an average channel top width of 63 ft and an average bank height of 5 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 64.7 mm (0.212 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 10, 1996, indicated that the reach was stable.

The Town Highway 29 crossing of the Middle Branch Williams River is a 34-ft-long, two-lane bridge consisting of one 32-foot steel-beam span (Vermont Agency of Transportation, written communication, April 5, 1995). 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 0 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the left abutment during the Level I assessment. Scour protection measures at the site include type-2 stone fill (less than 36 inches diameter) along the upstream right bank and downstream left bank and around the upstream left and right wingwalls. Type- 3 stone fill (less than 48 inches diameter) is located along the base of the left abutment in the scour hole, at the end of the downstream left wingwall and along the upstream left bank. 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 ranged from 0.4 to 0.9 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge and the 100-year discharge. Abutment scour ranged from 10.7 to 13.6 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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, 1971

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 ANDOTH00290027 ***Stream*** Middle Branch Williams River

County Windsor ***Road*** TH29 ***District*** 2

Description of Bridge

Bridge length 34 ***ft*** ***Bridge width*** 14.4 ***ft*** ***Max span length*** 32 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 09/10/96

Description of stone fill Type-2, at the upstream end of the upstream right wingwall, and along the base of the upstream left wingwall. Type-3, along the base of the left abutment and at the downstream end of the downstream left wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a 1.5 ft. deep scour hole in front of the left abutment.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 25

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

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	09/10/96	0	0
Level II	09/10/96	0	0

Potential for debris Moderate.

Describe any features near or at the bridge that may affect flow (include observation date) The type-3 protection for the left abutment is in the scour hole along the base of the abutment. (09/10/96)

Description of the Geomorphic Setting

General topography The channel is located within a 500 foot-wide, flat to slightly irregular flood plain with steep valley walls on both sides.

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

Date of inspection 09/10/96

DS left: Moderately sloped overbank

DS right: Moderately sloped overbank

US left: Steep channel bank to a narrow terrace

US right: Moderately sloped overbank

Description of the Channel

Average top width 63 ***ft*** ***Average depth*** 5 ***ft***

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

Straight and stable with alluvial channel boundaries and a narrow flood plain.

09/10/96

Vegetative co Short grass and brush with a few trees.

DS left: Short grass.

DS right: Short grass with brush and trees along the bank.

US left: Trees and brush

US right:

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

The assessment of 09/10/96 noted low flow conditions are influenced by an irregular slope in the stream bed going from right to left at the upstream bridge face, causing the water to flow into the left abutment at a 45 degree angle.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 12.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 3,390 ***ft³/s*** ***Q500*** 4,970 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(12.7/14.8)exp 0.68] with the drainage area above the Andover Branch on the Middle Branch Williams River in Chester. This drainage area is 14.8 square miles and has flood frequency estimates available in the Flood Insurance Study for the town of Chester (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 None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 501.04 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the left abutment (elev. 500.67 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	-33	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	45	1	Approach section

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

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). 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 0.050 to 0.065, and overbank “n” values ranged from 0.035 to 0.120.

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 0.0087 ft/ft which was calculated from the surveyed thalweg points downstream of the bridge.

The surveyed approach section (APPRO) was one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.9 ***ft***
Average low steel elevation 498.8 ***ft***

100-year discharge 3,390 ***ft^3/s***
Water-surface elevation in bridge opening 498.8 ***ft***
Road overtopping? Y ***Discharge over road*** 1,141 ***ft^3/s***
Area of flow in bridge opening 234 ***ft^2***
Average velocity in bridge opening 9.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.5 ***ft/s***

Water-surface elevation at Approach section with bridge 501.2
Water-surface elevation at Approach section without bridge 499.1
Amount of backwater caused by bridge 2.1 ***ft***

500-year discharge 4,970 ***ft^3/s***
Water-surface elevation in bridge opening 498.8 ***ft***
Road overtopping? Y ***Discharge over road*** 2,764 ***ft^3/s***
Area of flow in bridge opening 234 ***ft^2***
Average velocity in bridge opening 9.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.8 ***ft/s***

Water-surface elevation at Approach section with bridge 501.9
Water-surface elevation at Approach section without bridge 500.1
Amount of backwater caused by bridge 1.8

Incipient overtopping discharge 1,980 ***ft^3/s***
Water-surface elevation in bridge opening 496.6 ***ft***
Area of flow in bridge opening 169 ***ft^2***
Average velocity in bridge opening 11.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.3 ***ft/s***

Water-surface elevation at Approach section with bridge 499.1
Water-surface elevation at Approach section without bridge 497.7
Amount of backwater caused by bridge 1.4 ***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 incipient road-overflow model was computed by use of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The 100-year and 500-year discharges resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Therefore, contraction scour for the 100-year and 500-year discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). In this case, the incipient road-overflow model and the 100-year flow resulted in the worst cases of contraction scour with a scour depth of 0.9 ft. However, they were not the worst case total scour.

Abutment scour for the left and right abutments were 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.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.9	0.4	0.9
Depth to armoring	4.9	3.0	14.7
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	12.7	13.6	10.7
Right abutment	11.0	11.9	11.0
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.9	1.6	2.3
Right abutment	1.9	1.6	2.3
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

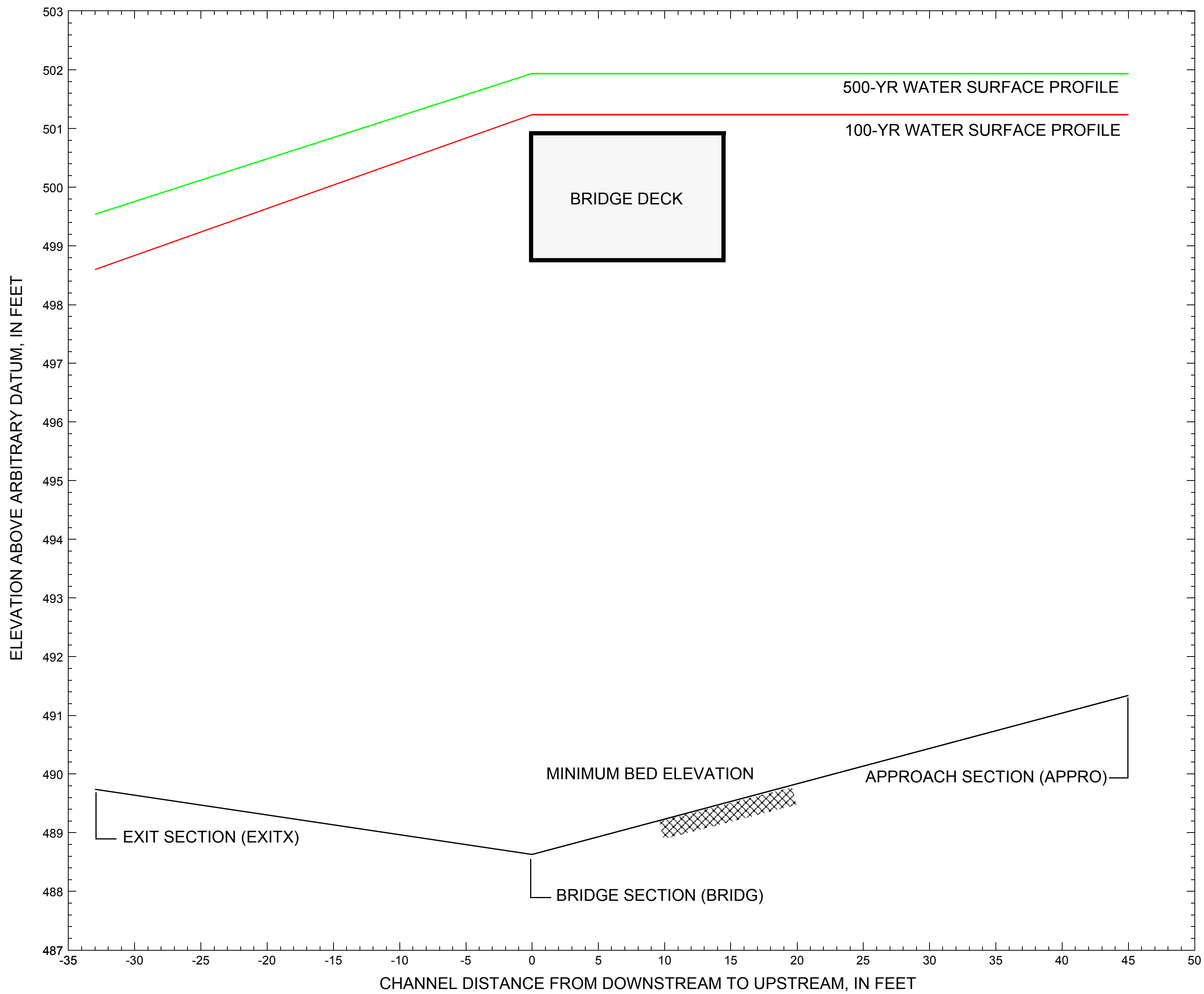

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ANDOTH00290027 on Town Highway 29, crossing Middle Branch Williams River, Andover, Vermont.

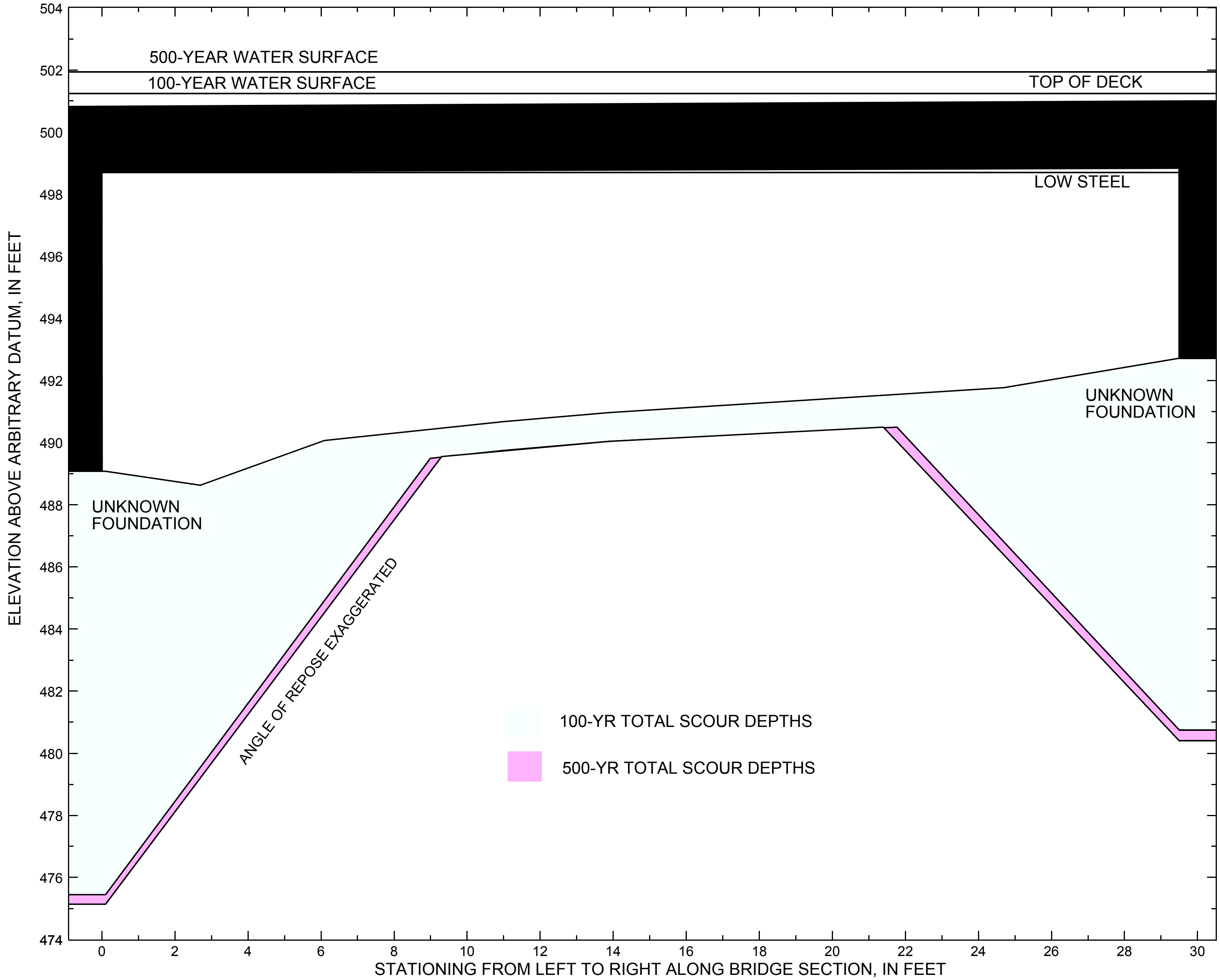

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ANDOTH00290027 on Town Highway 29, crossing Middle Branch Williams River, Andover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ANDOTH00290027 on Town Highway 29, crossing Middle Branch Williams River, Andover, 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 3,390 cubic-feet per second											
Left abutment	0.1	--	498.7	--	489.1	0.9	12.7	--	13.6	475.5	--
Right abutment	29.6	--	498.8	--	492.7	0.9	11.0	--	11.9	480.8	--

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 ANDOTH00290027 on Town Highway 29, crossing Middle Branch Williams River, Andover, 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 4,970 cubic-feet per second											
Left abutment	0.1	--	498.7	--	489.1	0.4	13.6	--	14.0	475.1	--
Right abutment	29.6	--	498.8	--	492.7	0.4	11.9	--	12.3	480.4	--

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, 1971, Andover, 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 ando027.wsp
T2        Hydraulic analysis for structure ANDOTH00290027   Date: 31-JAN-97
T3        TH029 crossing the middle branch of the williams river in Andover, VT
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3390.0   4970.0   1980.0
SK          0.0087   0.0087   0.0087
*
XS   EXITX    -33           0.
GR         -319.0, 510.59   -276.3, 506.81   -266.1, 502.24   -208.6, 500.67
GR          -77.9, 499.87     -9.4, 495.48      0.0, 490.94      5.8, 489.74
GR           12.0, 490.21     20.0, 490.45     21.6, 490.98     29.4, 492.09
GR           43.6, 493.57     54.0, 496.38     79.2, 499.25    173.4, 498.56
GR          320.7, 499.34    336.3, 504.69    369.0, 505.22    376.6, 506.91
*
N           0.035        0.065        0.045
SA                 -9.4         54.0
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.76       0.0
GR            0.0, 498.70      0.0, 490.93      0.1, 489.08      2.7, 488.63
GR            6.1, 490.07     11.0, 490.68     13.9, 490.97     24.7, 491.77
GR           29.5, 492.72     29.6, 498.81      0.0, 498.70
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      16.0      2.5    501.7     59.7
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      14.4     2
GR         -329.5, 511.04   -215.9, 502.94    -91.6, 501.53     -2.1, 500.83
GR           -2.0, 501.52      0.0, 501.56     29.8, 501.91     31.8, 501.86
GR           32.0, 501.00    144.1, 499.88    224.4, 499.62    340.4, 505.10
GR          374.5, 505.20    383.3, 507.66
*
AS   APPRO     45           0.
GR         -199.6, 514.06   -184.9, 503.38    -85.5, 502.38    -15.5, 501.61
GR           -3.9, 493.06      0.0, 491.90      8.3, 491.81     17.1, 491.71
GR           22.0, 491.34     28.8, 491.70     30.8, 491.96     38.0, 493.48
GR           45.7, 498.22    112.6, 498.18    147.3, 499.51    218.2, 499.30
GR          344.0, 504.94    379.7, 505.40    390.9, 507.13
*
N           0.040        0.060        0.120
SA                -15.5        45.7
*
HP 1 BRIDG   498.81 1 498.81
HP 2 BRIDG   498.81 * * 2313
HP 2 RDWAY   501.24 * * 1141
HP 1 APPRO   501.24 1 501.24
HP 2 APPRO   501.24 * * 3390
*
HP 1 BRIDG   498.81 1 498.81
HP 2 BRIDG   498.81 * * 2169
HP 2 RDWAY   501.94 * * 2764
HP 1 APPRO   501.94 1 501.94
HP 2 APPRO   501.94 * * 4970
```

APPENDIX B:

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ando027.wsp
        Hydraulic analysis for structure ANDOTH00290027   Date: 31-JAN-97
        TH029 crossing the middle branch of the williams river in Andover, VT
           *** RUN DATE & TIME: 02-20-97  12:30

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     234.   14855.     0.    75.                           0.
   498.81          234.   14855.     0.    75.  1.00     0.    30.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.81     0.0    29.6   234.0   14855.    2313.   9.89

 X STA.        0.0        2.1        3.3        4.4        5.6        6.7
   A(I)            20.2       11.9       10.9       10.7       10.3
   V(I)            5.73       9.74      10.62      10.85      11.28

 X STA.        6.7        8.0        9.2       10.4       11.6       12.9
   A(I)            10.3       10.1       10.2       10.1       10.2
   V(I)           11.25      11.47      11.37      11.49      11.31

 X STA.       12.9       14.3       15.6       17.0       18.4       19.9
   A(I)            10.3       10.5       10.7       10.6       10.9
   V(I)           11.25      11.05      10.85      10.88      10.63

 X STA.       19.9       21.4       23.0       24.7       26.6       29.6
   A(I)            11.1       11.3       12.0       13.1       18.7
   V(I)           10.39      10.23       9.62       8.80       6.17

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.24   -54.5   258.7   247.9    8421.    1141.   4.60

 X STA.      -54.5       70.4       93.1      108.3      120.5      131.0
   A(I)            27.3       16.7       14.0       13.0       12.5
   V(I)            2.09       3.41       4.07       4.40       4.58

 X STA.      131.0      140.0      148.2      155.9      163.4      170.7
   A(I)            11.4       11.0       10.7       10.6       10.4
   V(I)            4.99       5.18       5.32       5.39       5.47

 X STA.      170.7      177.6      184.6      191.2      197.7      204.3
   A(I)            10.2       10.3        9.9       10.0       10.1
   V(I)            5.62       5.53       5.78       5.71       5.62

 X STA.      204.3      210.5      217.1      223.7      231.5      258.7
   A(I)             9.7       10.3       10.6       11.5       17.4
   V(I)            5.85       5.52       5.36       4.96       3.27

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     476.   44569.    61.    65.                        7570.
             3     459.    9410.   216.   216.                        3793.
   501.24          935.   53979.   276.   281.  2.19   -15.   261.   6590.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.24   -15.0   261.5   934.8   53979.    3390.   3.63

 X STA.      -15.0       -3.4        0.2        3.3        6.2        9.0
   A(I)            49.7       31.9       28.9       27.0       26.5
   V(I)            3.41       5.32       5.86       6.27       6.39

 X STA.        9.0       11.7       14.4       17.1       19.6       22.2
   A(I)            25.8       25.6       25.4       24.5       25.0
   V(I)            6.56       6.63       6.67       6.91       6.78

 X STA.       22.2       24.7       27.3       29.9       32.8       36.1
   A(I)            24.5       24.9       25.3       26.6       27.7
   V(I)            6.91       6.80       6.70       6.37       6.12


X STA.       36.1       40.5       63.3       99.7      149.3      261.5
   A(I)            32.9       77.3      110.4      126.2      168.6
   V(I)            5.16       2.19       1.53       1.34       1.01
```

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      U.S. Geological Survey WSPRO Input File ando027.wsp
      Hydraulic analysis for structure ANDOTH00290027   Date: 31-JAN-97
      TH029 crossing the middle branch of the williams river in Andover, VT
         *** RUN DATE & TIME: 02-20-97  12:30

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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     234.   14855.     0.    75.                          0.
 498.81          234.   14855.     0.    75.  1.00     0.    30.      0.

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    498.81     0.0    29.6   234.0   14855.    2169.   9.27

X STA.        0.0        2.1        3.3        4.4        5.6        6.7
  A(I)           20.2       11.9       10.9       10.7       10.3
  V(I)           5.37       9.13       9.96      10.18      10.58

X STA.        6.7        8.0        9.2       10.4       11.6       12.9
  A(I)           10.3       10.1       10.2       10.1       10.2
  V(I)          10.55      10.75      10.66      10.77      10.61

X STA.       12.9       14.3       15.6       17.0       18.4       19.9
  A(I)           10.3       10.5       10.7       10.6       10.9
  V(I)          10.55      10.36      10.17      10.20       9.97

X STA.       19.9       21.4       23.0       24.7       26.6       29.6
  A(I)           11.1       11.3       12.0       13.1       18.7
  V(I)           9.74       9.60       9.02       8.25       5.79

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

      WSEL     LEW     REW    AREA        K        Q    VEL
    501.94  -127.7   273.5   483.6   20562.    2764.   5.72

X STA.     -127.7      -37.4       -6.0       64.7       83.6       99.0
  A(I)           41.1       30.1       47.6       25.7       23.7
  V(I)           3.36       4.60       2.91       5.38       5.84

X STA.       99.0      112.4      124.1      134.9      144.9      154.2
  A(I)           22.4       21.2       20.7       20.0       19.4
  V(I)           6.17       6.52       6.69       6.90       7.14

X STA.      154.2      163.3      172.3      181.2      189.8      198.2
  A(I)           19.1       19.4       19.2       18.9       18.7
  V(I)           7.24       7.14       7.21       7.31       7.39

X STA.      198.2      206.8      215.5      224.2      235.3      273.5
  A(I)           19.4       19.6       20.2       22.9       34.5
  V(I)           7.11       7.05       6.85       6.03       4.01

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1       5.      55.    30.    30.                         11.
           2     519.   51108.    61.    66.                       8576.
           3     615.   14651.   231.   231.                       5690.
 501.94         1139.   65815.   323.   327.  2.29   -46.   277.   8020.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

      WSEL     LEW     REW    AREA        K        Q    VEL
    501.94   -45.5   277.1  1139.0   65815.    4970.   4.36

X STA.      -45.5       -3.7        0.2        3.5        6.7        9.6
  A(I)           60.4       36.8       33.4       32.0       29.8
  V(I)           4.12       6.75       7.44       7.76       8.34

X STA.        9.6       12.6       15.5       18.4       21.1       23.8
  A(I)           30.4       29.4       29.2       28.4       28.8
  V(I)           8.18       8.45       8.50       8.75       8.64

X STA.       23.8       26.6       29.4       32.5       35.9       40.4
  A(I)           28.9       29.3       30.3       31.4       37.1
  V(I)           8.61       8.47       8.21       7.90       6.70

X STA.       40.4       59.5       91.0      123.9      178.1      277.1
  A(I)           79.8      117.8      120.9      143.8      181.1
  V(I)           3.11       2.11       2.06       1.73       1.37
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WSPRO OUTPUT FILE (continued)

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       U.S. Geological Survey WSPRO Input File ando027.wsp
       Hydraulic analysis for structure ANDOTH00290027   Date: 31-JAN-97
       TH029 crossing the middle branch of the williams river in Andover, VT
          *** RUN DATE & TIME: 02-20-97  12:30

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

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     169.  12902.    30.    41.                        2293.
  496.56          169.  12902.    30.    41.  1.00     0.    30.   2293.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.56     0.0    29.6   169.0   12902.    1980.  11.71

X STA.         0.0        2.1        3.3        4.4        5.5        6.6
  A(I)            16.2        9.1        8.0        7.7        7.5
  V(I)            6.09      10.83      12.43      12.86      13.25

X STA.         6.6        7.7        8.9       10.0       11.2       12.4
  A(I)             7.1        7.1        6.9        7.2        7.0
  V(I)           13.99      13.99      14.28      13.79      14.10

X STA.        12.4       13.7       15.0       16.3       17.7       19.2
  A(I)             7.1        7.2        7.3        7.6        7.6
  V(I)           13.86      13.72      13.54      13.11      12.98

X STA.        19.2       20.7       22.3       24.1       26.1       29.6
  A(I)             7.8        8.2        8.5        9.5       14.4
  V(I)           12.67      12.13      11.70      10.38       6.88

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            2     349.  27565.    58.    61.                        4865.
            3      70.    737.    91.    91.                         352.
  499.09          419.  28303.   148.   152.  1.33   -12.   136.   3461.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.09   -12.1   136.3   419.2   28303.    1980.   4.72

X STA.       -12.1       -3.0        0.0        2.5        4.8        7.0
  A(I)            30.4       19.7       18.1       16.9       16.2
  V(I)            3.26       5.02       5.47       5.86       6.10

X STA.         7.0        9.3       11.4       13.6       15.7       17.8
  A(I)            16.2       15.6       15.8       15.6       15.7
  V(I)            6.10       6.35       6.28       6.33       6.30

X STA.        17.8       19.9       21.8       23.9       25.9       28.0
  A(I)            15.3       15.2       15.7       15.3       16.2
  V(I)            6.45       6.53       6.32       6.46       6.13

X STA.        28.0       30.3       32.7       35.7       39.6      136.3
  A(I)            16.4       17.1       18.8       21.7       87.2
  V(I)            6.02       5.80       5.27       4.55       1.14
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File ando027.wsp
        Hydraulic analysis for structure ANDOTH00290027   Date: 31-JAN-97
        TH029 crossing the middle branch of the williams river in Andover, VT
           *** RUN DATE & TIME: 02-20-97  12:30

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

 EXITX:XS   ******    -58.     503.  0.76 *****  499.36  496.92   3390.  498.60
       -33. ******    180.   36318.  1.07 ***** *******    0.66    6.74

 FULLV:FV      33.    -64.     591.  0.61  0.25  499.62 *******   3390.  499.01
         0.    33.    258.   41960.  1.19  0.00    0.01    0.77    5.73
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
               FNTEST,FR#,WSEL,CRWS =  0.80    1.00     499.04     497.71

  ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                    WSLIM1,WSLIM2,DELTAY =   498.51     514.06    0.50

  ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                    WSLIM1,WSLIM2,CRWS =   498.51     514.06     497.71

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              “APPRO”     KRATIO =  0.67

 APPRO:AS      45.    -12.     415.  1.38  0.44  500.44  497.71   3390.  499.06
        45.    45.    136.   28051.  1.32  0.38    0.00    0.99    8.17
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

  ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                         WS3N,LSEL =   499.01     498.76

             <<<<<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      33.      0.     234.  1.52 *****  500.33  496.59   2313.  498.81
         0. ******     30.   14855.  1.00 ***** *******    0.62    9.88

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        4. ****   6.  0.800  0.000  498.76 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG       8.    31.  0.12  0.45  501.57    0.02   1141.  501.24

             Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:    55.    53.   -55.    -2.   0.4   0.2   2.9   5.1   0.5   2.7
    RT:  1086.   227.    32.   259.   1.6   1.0   5.2   4.6   1.4   3.0

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

 APPRO:AS      29.    -15.     935.  0.45  0.31  501.69  497.71   3390.  501.24
        45.    31.    262.   54010.  2.19  0.00    0.02    0.51    3.62

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

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
    EXITX:XS     -33.   -58.   180.   3390.   36318.     503.    6.74  498.60
    FULLV:FV       0.   -64.   258.   3390.   41960.     591.    5.73  499.01
    BRIDG:BR       0.     0.    30.   2313.   14855.     234.    9.88  498.81
    RDWAY:RG       8.*******    55.   1141.       0.*********    2.00  501.24
    APPRO:AS      45.   -15.   262.   3390.   54010.     935.    3.62  501.24

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

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
    EXITX:XS    496.92    0.66  489.74  510.59************  0.76  499.36  498.60
    FULLV:FV  ********    0.77  489.74  510.59  0.25  0.00  0.61  499.62  499.01
    BRIDG:BR    496.59    0.62  488.63  498.81************  1.52  500.33  498.81
    RDWAY:RG  ****************  499.62  511.04  0.12******  0.45  501.57  501.24
    APPRO:AS    497.71    0.51  491.34  514.06  0.31  0.00  0.45  501.69  501.24
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        U.S. Geological Survey WSPRO Input File ando027.wsp
        Hydraulic analysis for structure ANDOTH00290027   Date: 31-JAN-97
        TH029 crossing the middle branch of the williams river in Andover, VT
           *** RUN DATE & TIME: 02-20-97  12:30

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******   -73.     784.  0.84 *****  500.38  498.28   4970.  499.54
      -33. ******   321.   53283.  1.34 ***** *******    0.92    6.34

FULLV:FV      33.  -113.    1006.  0.51  0.23  500.60 *******   4970.  500.09
        0.    33.   323.   67439.  1.34  0.00   -0.01    0.67    4.94
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.41     499.71     500.10

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   499.59     514.06    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   499.59     514.06     500.10

 ===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 =   500.10     514.06     500.10

APPRO:AS      45.   -13.     634.  1.79 *****  501.89  500.10   4970.  500.10
       45.    45.   236.   38268.  1.87 ***** *******    1.19    7.83
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   500.09     498.76

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =    2764.      2489.    1.11

            <<<<<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      33.     0.     234.  1.34 *****  500.15  496.35   2169.  498.81
        0. ******    30.   14855.  1.00 ***** *******    0.58    9.27

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   6.  0.800  0.000  498.76 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    31.  0.17  0.68  502.45   -0.01   2764.  501.94

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    458.   141.  -128.    13.   1.1   0.6   4.5   5.7   1.1   2.9
   RT:   2306.   242.    32.   274.   2.3   1.7   6.6   5.7   2.2   3.0

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

APPRO:AS      29.   -46.    1140.  0.68  0.45  502.62  500.10   4970.  501.94
       45.    34.   277.   65861.  2.29  0.00   -0.01    0.62    4.36
       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -33.    -73.   321.   4970.   53283.     784.    6.34  499.54
   FULLV:FV       0.  -113.   323.   4970.   67439.    1006.    4.94  500.09
   BRIDG:BR       0.      0.    30.   2169.   14855.     234.    9.27  498.81
   RDWAY:RG       8.*******   458.   2764.******************    2.00  501.94
   APPRO:AS      45.    -46.   277.   4970.   65861.    1140.    4.36  501.94

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    498.28    0.92  489.74  510.59************  0.84  500.38  499.54
   FULLV:FV  ********    0.67  489.74  510.59  0.23  0.00  0.51  500.60  500.09
   BRIDG:BR    496.35    0.58  488.63  498.81************  1.34  500.15  498.81
   RDWAY:RG  ****************  499.62  511.04  0.17******  0.68  502.45  501.94
   APPRO:AS    500.10    0.62  491.34  514.06  0.45  0.00  0.68  502.62  501.94
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        U.S. Geological Survey WSPRO Input File ando027.wsp
        Hydraulic analysis for structure ANDOTH00290027   Date: 31-JAN-97
        TH029 crossing the middle branch of the williams river in Andover, VT
           *** RUN DATE & TIME: 02-20-97  12:30

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

EXITX:XS   ******   -35.     336.  0.56 *****  497.69  495.21   1980.  497.13
      -33. ******    61.   21215.  1.04 ***** *******    0.56    5.89
FULLV:FV      33.   -41.     372.  0.46  0.25  497.95 *******   1980.  497.49
        0.    33.    64.   24338.  1.05  0.00    0.01    0.51    5.32
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      45.   -10.     269.  0.84  0.39  498.52 *******   1980.  497.68
       45.    45.    45.   18582.  1.00  0.19   -0.01    0.59    7.36
         <<<<<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      33.     0.     169.  2.14  0.47  498.69  496.04   1980.  496.56
        0.    33.    30.   12886.  1.00  0.52    0.00    0.86   11.72

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  498.76 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD      EGL      ERR        Q    WSEL
   RDWAY:RG        8.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      29.   -12.     419.  0.46  0.33  499.55  496.04   1980.  499.09
       45.    30.   136.   28262.  1.33  0.53    0.01    0.57    4.73

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.462  0.278   20325.     4.    34.   498.93

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -33.   -35.    61.   1980.   21215.     336.    5.89  497.13
   FULLV:FV       0.   -41.    64.   1980.   24338.     372.    5.32  497.49
   BRIDG:BR       0.     0.    30.   1980.   12886.     169.   11.72  496.56
   RDWAY:RG       8.**************      0.******************     2.00********
   APPRO:AS      45.   -12.   136.   1980.   28262.     419.    4.73  499.09

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       4.    34.   20325.

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    495.21    0.56  489.74  510.59************  0.56  497.69  497.13
   FULLV:FV  ********    0.51  489.74  510.59  0.25  0.00  0.46  497.95  497.49
   BRIDG:BR    496.04    0.86  488.63  498.81  0.47  0.52  2.14  498.69  496.56
   RDWAY:RG  ****************  499.62  511.04**********************************
   APPRO:AS    496.04    0.57  491.34  514.06  0.33  0.53  0.46  499.55  499.09
  ER
```
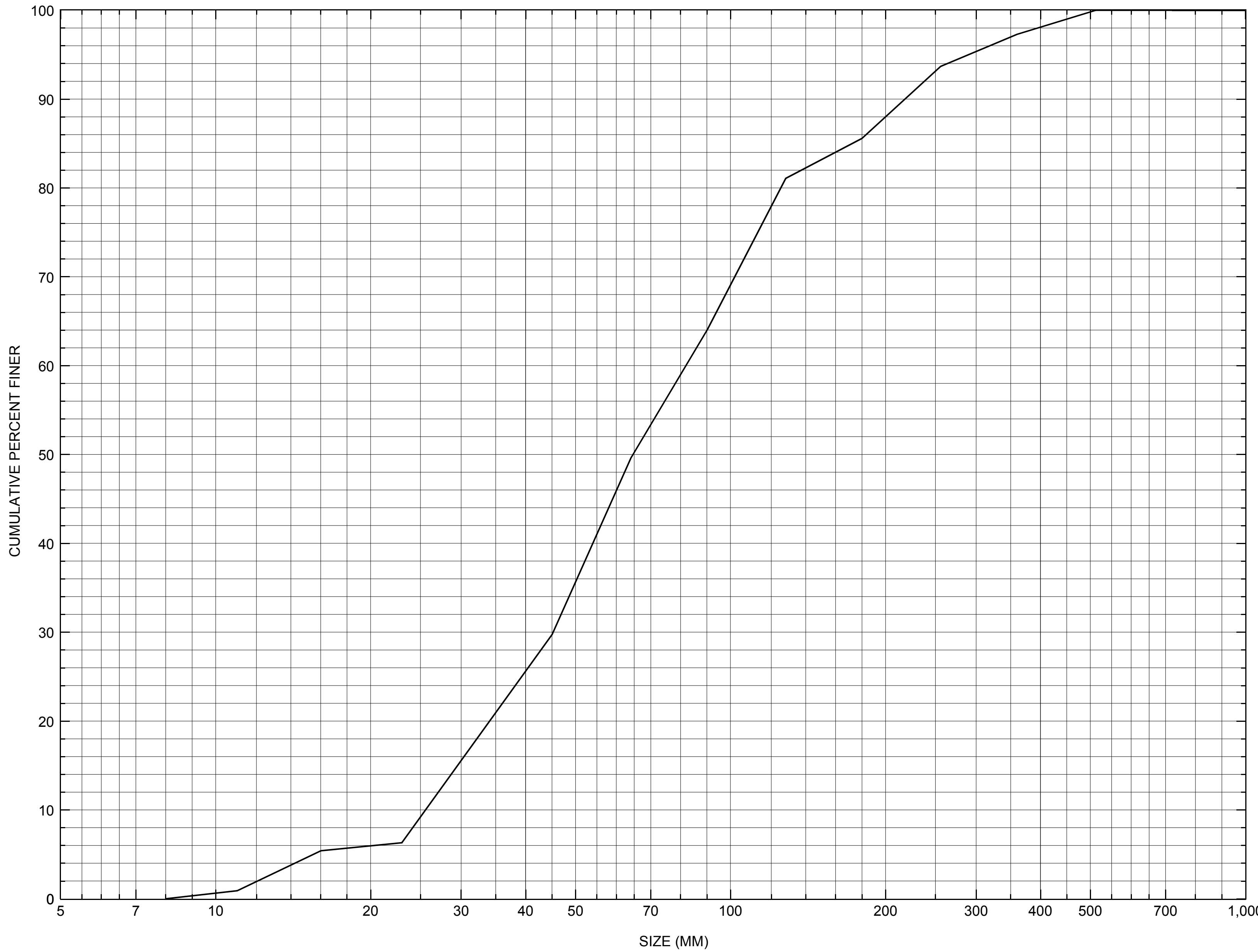

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ANDOTH00290027, in Andover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ANDOTH00290027

General Location Descriptive

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

Date *(MM/DD/YY)* 04 / 05 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 01300

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

Waterway *(I - 6)* MIDDLE BRANCH WILLIAMS R.

Road Name *(I - 7):* -

Route Number TH029

Vicinity *(I - 9)* 0.08 MI TO JCT W VT11

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43157

Longitude *(i - 17; nnnnn.n)* 72415

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10140100271401

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

Maximum span length *(I - 48; nnnn)* 0032

Year built *(I - 27; YYYY)* 1974

Structure length *(I - 49; nnnnnn)* 000034

Average daily traffic, ADT *(I - 29; nnnnnn)* 000010

Deck Width *(I - 52; nn.n)* 144

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) _______

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

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

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

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

Comments:

The structural inspection report of 09/22/93 indicates the structure is a single span, steel stringer type bridge with a concrete deck. Both abutment walls and wingwalls are concrete, which reportedly is in like-new condition. No footings are exposed. Presently all the flow is along the left abutment side of the channel. There is some localized scour along the left abutment wall. In the scour holes, some fairly large boulders are on the streambed. There is a shallow stone bar in front of the right abutment. The banks are well protected with stone fill at all four corners of the structure.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **12.69** mi^2

Lake and pond area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **980** ft

Headwater elevation **2894** ft

Main channel length **6.78** mi

10% channel length elevation **1088** ft

85% channel length elevation **1870** ft

Main channel slope *(S)* **153.89** 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? ______ *If no, type ctrl-n xs*

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

Comments: -

NO CROSS SECTION INFORMATION

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

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

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

Comments: -

NO CROSS SECTION INFORMATION

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **10/01/96**

Computerized by: **RB** Date: **10/01/96**

Reviewd by: **SAO** Date: **03/24/97**

Structure Number **ANDOTH00290027**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E**. **WILD** Date *(MM/DD/YY)* **09** / **10** / 19**96**

2. Highway District Number **02**

County **027**

Waterway *(I - 6)* **MIDDLE BR. WILLIAMS RIVER**

Route Number **TH29**

Mile marker **0000**

Town **ANDOVER 01300**

Road Name **TROMBLEY ROAD**

Hydrologic Unit Code: **01080107**

3. Descriptive comments:

Located 0.08 miles from the junction with VT 11.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **6** LBDS **4** RBDS **5** Overall **4**
*(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 **1** *(**1**- pool; **2**- riffle)*

6. Bridge structure type **1** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length **34** *(feet)* Span length **32** *(feet)* Bridge width **14.4** *(feet)*

Road approach to bridge:

8. LB **0** RB **0** *(**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 **2.3:1** US right **2.7:1**

	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	-
RBUS	2	2	0	-
RBDS	0	-	2	1
LBDS	3	2	2	1

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

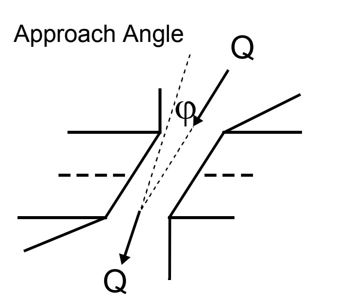
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

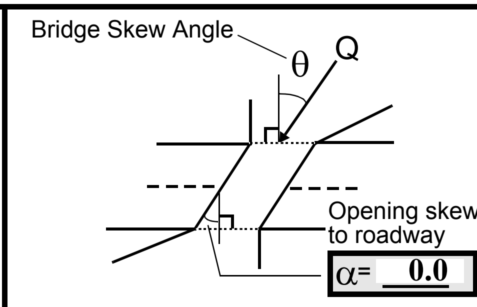
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: **15** 16. Bridge skew: **25**





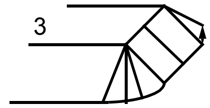
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **250** feet **US** *(US, UB, DS)* to **0** feet **US**

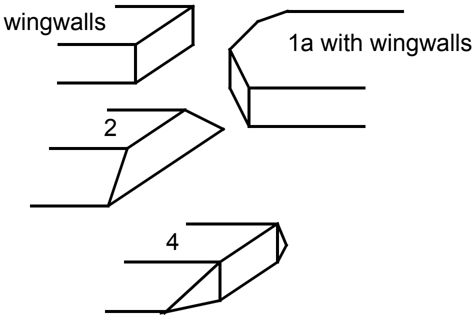
Channel impact zone 2: Exist? **N** *(Y or N)*
Where? **-** *(LB, RB)* Severity **-**
Range? **-** feet **-** *(US, UB, DS)* to **-** feet **-**

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

18. Bridge Type: 4

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. The left bank US has trees along the bank and then the overbank is a field and a dirt road. The right bank US is forest. On the left bank DS there is a grassy field with some trees and a house, barn and silo about 0.1 miles from the channel. The right bank DS is brush land with some large pine trees and VT 11, 0.08 miles away.
7. Values are from the VT AOT files. Measured bridge length is 34.4 ft., span length is 29.9 ft., and the bridge width is 14.6 ft. from the outside of the curbs.
11. The right bank US protection and the left bank DS protection is slumped into the channel.

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
31.5	8.5			4.5	2	3	435	435	1	1

23. Bank width 35.0   24. Channel width 30.0   25. Thalweg depth 61.5   29. Bed Material 43

30 .Bank protection type: LB 3 RB 2   31. Bank protection condition: LB 1 RB 2

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 left bank protection extends from 250 ft. US to 5 ft. US. The right bank protection extends from 48 ft. US to the middle of the wingwall at 7 ft. US.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 91 35. Mid-bar width: 14

36. Point bar extent: 165 feet US (US, UB) to 11 feet US (US, UB, DS) positioned 60 %LB to 100 %RB

37. Material: 430

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

The side bar is vegetated with grass. Additional clumps of grass protrude into the channel along the left bank.

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

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

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

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

NO CUT BANKS

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
42.0		0.5		2	7	7	-

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

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

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

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

43

The channel bed elevation grades from high to low from the right abutment to the left abutment, as a result, the main flow attacks the left abutment moderately. Large boulders have been placed in the scour hole in front of the left abutment.

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 **1**____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

2

68. 69. Capture efficiency and ice blockage potential are moderate because the vertical clearance of the bridge is only 7.0 ft. along the US bridge face.

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		25	90	2	1	1.5	0	90.0
RABUT	1	0	90			2	0	29.5

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

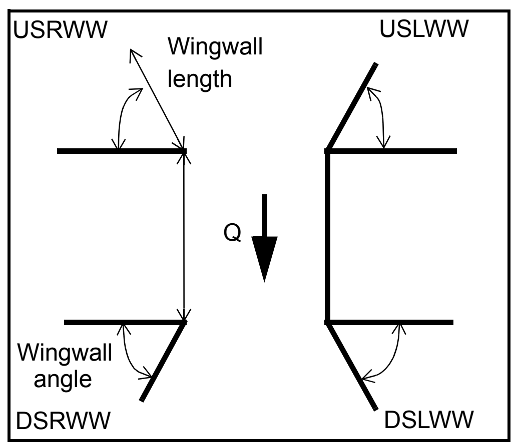
71. At low flow the attack angle is 45 degrees from the drop in the stream bed.

75. Three very large boulders have been placed in the scour hole. Between the left abutment and these placed boulders a scour hole still exists and is about 3.5 ft. wide. The scour depth assumes a thalweg of 0.5 ft.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						29.5	
USRWW:	Y		1		1	1.0	
DSLWW:	0.5		0		Y	16.0	
DSRWW:	1		0		-	16.0	

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	Y	-	1	2	1	-
Condition	Y	0.7	1	-	1	2	1	-
Extent	1	0	0	2	2	3	0	-

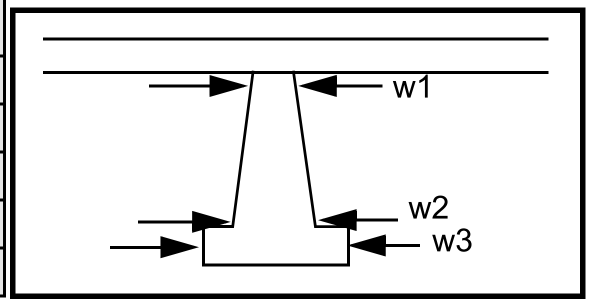
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
3
2
3
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				60.0	10.0	60.0
Pier 2				11.5	60.0	12.0
Pier 3			-	60.0	12.0	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	In	have	DS	the	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	front	been	left	DS	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	of	place	wing	end	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	the	d	wall	of	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	US	alon	only	the	*Y- yes; N- no*
91. Attack ∠ (BF)	left	g its	has	DS	
92. Pushed	wing	entir	scou	left	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	wall	e	r at	wing	
95. Cross-members	very	base	the	wall	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	large	lengt	US	are	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	boul-	h.	end.	mas-	
98. Exposure depth	ders	The	At	sive	

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

boulders, about 4 ft. in diameter. Both the US and DS left wingwall scour depths assume a thalweg of 0.5 ft.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -

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

-
-
-
-

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

Cut bank extent: RS 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.):

Is channel scour present? ____ (Y or if N type ctrl-n cs) Mid-scour distance: 1

Scour dimensions: Length 1 Width 342 Depth: 342 Positioned 1 %LB to 1 %RB

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

342
2
0
2

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

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

Confluence 2: Distance k, the Enters on per- (LB or RB) Type cent (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

vegetation cover increases to 51% to 75% from 105 ft. DS. The left bank protection extends from 9 ft. DS to 36 ft. DS.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: ANDOTH00290027 Town: ANDOVER
Road Number: TH029 County: WINDSOR
Stream: Middle Branch of the Williams River

Initials RLB Date: 2/11/97 Checked: SAO

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

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

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3390	4970	1980
Main Channel Area, ft2	476	519	349
Left overbank area, ft2	--	5	--
Right overbank area, ft2	459	615	70
Top width main channel, ft	61	61	58
Top width L overbank, ft	--	30	--
Top width R overbank, ft	216	231	91
D50 of channel, ft	0.212	0.212	0.212
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.8	8.5	6.0
y1, average depth, LOB, ft	ERR	0.2	ERR
y1, average depth, ROB, ft	2.1	2.7	0.8
Total conveyance, approach	53979	65815	28303
Conveyance, main channel	44569	51108	27565
Conveyance, LOB	0	55	0
Conveyance, ROB	9410	14651	737
Percent discrepancy, conveyance	0.0000	0.0015	0.0035
Qm, discharge, MC, cfs	2799.0	3859.4	1928.4
Ql, discharge, LOB, cfs	0.0	4.2	0.0
Qr, discharge, ROB, cfs	591.0	1106.4	51.6
Vm, mean velocity MC, ft/s	5.9	7.4	5.5
Vl, mean velocity, LOB, ft/s	ERR	0.8	ERR
Vr, mean velocity, ROB, ft/s	1.3	1.8	0.7
Vc-m, crit. velocity, MC, ft/s	9.4	9.6	9.0
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)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	476	519	349
Main channel width, ft	61	61	58
y1, main channel depth, ft	7.80	8.51	6.02

Bridge Section			
(Q) total discharge, cfs	3390	4970	1980
(Q) discharge thru bridge, cfs	2313	2169	1980
Main channel conveyance	14855	14855	12902
Total conveyance	14855	14855	12902
Q2, bridge MC discharge,cfs	2313	2169	1980
Main channel area, ft2	234	234	169
Main channel width (skewed), ft	29.6	29.6	29.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.6	29.6	29.6
y_bridge (avg. depth at br.), ft	7.91	7.91	5.71
Dm, median (1.25*D50), ft	0.265	0.265	0.265
y2, depth in contraction,ft	7.58	7.18	6.64
ys, scour depth (y2-ybridge), ft	-0.32	-0.73	0.93

ARMORING			
D90	0.715	0.715	0.715
D95	0.95	0.95	0.95
Critical grain size,Dc, ft	0.4096	0.3602	0.6600
Decimal-percent coarser than Dc	0.201	0.264	0.119
Depth to armoring,ft	4.88	3.01	14.66

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	3390	4970	0
Q, thru bridge, cfs	2313	2169	0
Total Conveyance, bridge	14855	14855	0
Main channel(MC) conveyance, bridge	14855	14855	0
Q, thru bridge MC, cfs	2313	2169	0
Vc, critical velocity, ft/s	9.41	9.55	0.00
Vc, critical velocity, m/s	2.87	2.91	0.00
Main channel width (skewed), ft	29.6	29.6	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0

W, adjusted width, ft	29.6	29.6	0.0
qbr, unit discharge, ft2/s	78.1	73.3	ERR
qbr, unit discharge, m2/s	7.3	6.8	N/A
Area of full opening, ft2	234.0	234.0	0.0
Hb, depth of full opening, ft	7.91	7.91	ERR
Hb, depth of full opening, m	2.41	2.41	N/A
Fr, Froude number, bridge MC	0.62	0.58	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
Elevation of Low Steel, ft	498.76	498.76	0
Elevation of Bed, ft	490.85	490.85	N/A
Elevation of Approach, ft	501.24	501.94	0
Friction loss, approach, ft	0.31	0.45	0
Elevation of WS immediately US, ft	500.93	501.49	0.00
ya, depth immediately US, ft	10.08	10.64	N/A
ya, depth immediately US, m	3.07	3.24	N/A
Mean elevation of deck, ft	501.74	501.74	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.93	ERR
Ys, depth of scour, ft	0.93	0.39	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	3390	4970	1980	3390	4970	1980
a', abut.length blocking flow, ft	15	15.5	12.1	231.9	247.5	106.7
Ae, area of blocked flow ft2	75.7	77.2	50.1	340.4	351.62	149.79
Qe, discharge blocked abut.,cfs	--	--	198	--	--	426.13
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.13	5.14	3.95	2.11	2.66	2.84
ya, depth of f/p flow, ft	5.05	4.98	4.14	1.47	1.42	1.40
--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	115	115	115	65	65	65
K2	1.03	1.03	1.03	0.96	0.96	0.96
Fr, froude number f/p flow	0.315	0.375	0.342	0.236	0.271	0.423
ys, scour depth, ft	12.70	13.55	10.70	11.04	11.93	10.95

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.62	0.58	0.86	0.62	0.58	0.86
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	7.91	7.91	5.71	7.91	7.91	5.71

Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.88	1.64	ERR	1.88	1.64	0.00
Fr>0.8 (vertical abut.)	ERR	ERR	2.29	ERR	ERR	2.29
Fr<=0.8 (spillthrough abut.)	1.64	1.43	ERR	1.64	1.43	0.00
Fr>0.8 (spillthrough abut.)	ERR	ERR	2.02	ERR	ERR	2.02