LEVEL II SCOUR ANALYSIS FOR BRIDGE 38 (ANDOVT00110038) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

U.S. Geological Survey
Open-File Report 97-368

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

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By Lora K. Striker and Robert E. Hammond

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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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 38 (CHESVT00110038) ON STATE ROUTE 11, CROSSING the MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

_By_ Lora K. Striker 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 ANDOVT00110038 on State Route 11 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 south central Vermont. The 5.65-mi^2 drainage area is in a predominantly rural and forested basin. Upstream and downstream of the study site banks and overbanks are forested.

In the study area, the Middle Branch Williams River has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 44 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 54.0 mm (0.177 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 5, 1996, indicated that the reach was stable.

The State Route 11 crossing of the Middle Branch Williams River is a 33-ft-long, two-lane bridge consisting of one 31-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March 29, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 55 degrees to the opening while the measured opening-skew-to-roadway is 45 degrees.

There were no scour problems observed during the Level I assessment. Type-4 stone fill (less than 60 inches diameter) and type-3 stone fill (less than 48 inches diameter) was present on the left bank upstream and right bank upstream respectively. Type-2 stone fill (less than 36 inches diameter) was present in the upstream left wing wall area. 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 1.8 to 3.4 ft. The worst-case contraction scour occurred at the 500-year flow. Abutment scour ranged from 12.0 to 14.0 ft. The worst-case abutment scour occurred at the 500-year flow at the right abutment. 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 ANDOVT00110038 ***Stream*** Middle Branch Williams River

County Windsor ***Road*** VT11 ***District*** 2

Description of Bridge

Bridge length 33 ***ft*** ***Bridge width*** 32 ***ft*** ***Max span length*** 31 ***ft***

Alignment of bridge to road (on curve or straight) Curve; right/ Straight; left

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

Stone fill on abutment? No ***Date of inspection*** 09/05/96

Description of stone fill Type-2, around the upstream end of the upstream left wingwall in good condition.

Abutments and wingwalls are concrete.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 55

There is a mild channel bend in the upstream reach.

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	09/05/96	0	0
Level II	09/05/96	0	0

Potential for debris Moderate.

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

There is no note of any feature that may affect flow at the bridge as of 09/05/96.

Description of the Geomorphic Setting

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

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

Date of inspection 09/05/96

DS left: Moderately sloped overbank to a steep bank

DS right: Steep channel bank to a narrow terrace

US left: Steep channel bank to moderately sloped overbank

US right: Steep valley wall

Description of the Channel

Average top width 44 ***ft*** ***Average depth*** 4 ***ft***

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

Sinuous but stable with non-alluvial channel boundaries.

Vegetative co ... 09/05/96

Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right:

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

Describe any obstructions in channel and date of observation. There were no obstructions in the channel noted that would block flow as of 09/05/96.

Hydrology

Drainage area 5.65 ***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***: -

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 1930 ***ft³/s*** ***Q500*** 2840 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(5.65/14.8)exp 0.68] with the Chester FEMA study. The drainage area above this area is 14.8 square miles. (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 To obtain VTAOT datum subtract 51 feet from USGS survey datum.

Description of reference marks used to determine USGS datum. RM9 is a chiseled X on top of the downstream end of the left abutment (elev. 499.960 ft). RM10 is a chiseled X on top of the upstream right wing wall near upstream end (elev. 499.73ft). RM11 is a chiseled X on top of downstream right wing wall near downstream end at ANDOVT00110039 downstream of ANDOVT00110038 (elev. 476.020).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-38	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	18	1	Road Grade section
APPRO	56	2	Modelled Approach section (Templated from APTEM)
APTEM	85	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 0.050 to 0.060, and overbank "n" values ranged from 0.035 to 0.075.

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 0.0202 ft/ft which was estimated from slope points surveyed during the field investigation (September 5, 1996).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.011 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 471.0 ***ft***
Average low steel elevation 467.6 ***ft***

100-year discharge 1,930 ***ft^3/s***
Water-surface elevation in bridge opening 468.0 ***ft***
Road overtopping? Y ***Discharge over road*** 91 ***ft^3/s***
Area of flow in bridge opening 181 ***ft^2***
Average velocity in bridge opening 10.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.7 ***ft/s***

Water-surface elevation at Approach section with bridge 471.0 ***ft***
Water-surface elevation at Approach section without bridge 465.4 ***ft***
Amount of backwater caused by bridge 5.6 ***ft***

500-year discharge 2,840 ***ft^3/s***
Water-surface elevation in bridge opening 467.6 ***ft***
Road overtopping? Y ***Discharge over road*** 806 ***ft^3/s***
Area of flow in bridge opening 179 ***ft^2***
Average velocity in bridge opening 11.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.1 ***ft/s***

Water-surface elevation at Approach section with bridge 472.2 ***ft***
Water-surface elevation at Approach section without bridge 466.3 ***ft***
Amount of backwater caused by bridge 5.9 ***ft***

Incipient overtopping discharge 1,770 ***ft^3/s***
Water-surface elevation in bridge opening 468.0 ***ft***
Area of flow in bridge opening 181 ***ft^2***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.0 ***ft/s***

Water-surface elevation at Approach section with bridge 470.3 ***ft***
Water-surface elevation at Approach section without bridge 465.2 ***ft***
Amount of backwater caused by bridge 5.1 ***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.

At this site, the 100-yr, 500-yr, and incipient roadway overtopping discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour 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.

Additional estimates of contraction scour also were computed by use of Laursen's clear-water scour equation (Richardson and others, 1995, p. 32, equation 20) and the results are presented in Appendix F. Furthermore, because the discharges resulted in unsubmerged orifice flow, contraction scour was computed by substituting alternative estimates for the depth of flow in the bridge at the downstream face in the Chang equation and Laursen's clear-water equation. Contraction scour results with respect to these substitutions also are provided in Appendix F.

Abutment scour for the left abutment and right abutment 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.

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	2.5	3.4	1.8
Depth to armoring	N/A	33.4	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	12.4	12.3	12.0
Right abutment	13.9	14.0	13.4
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.9	3.5	2.5
Right abutment	2.9	3.5	2.5
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

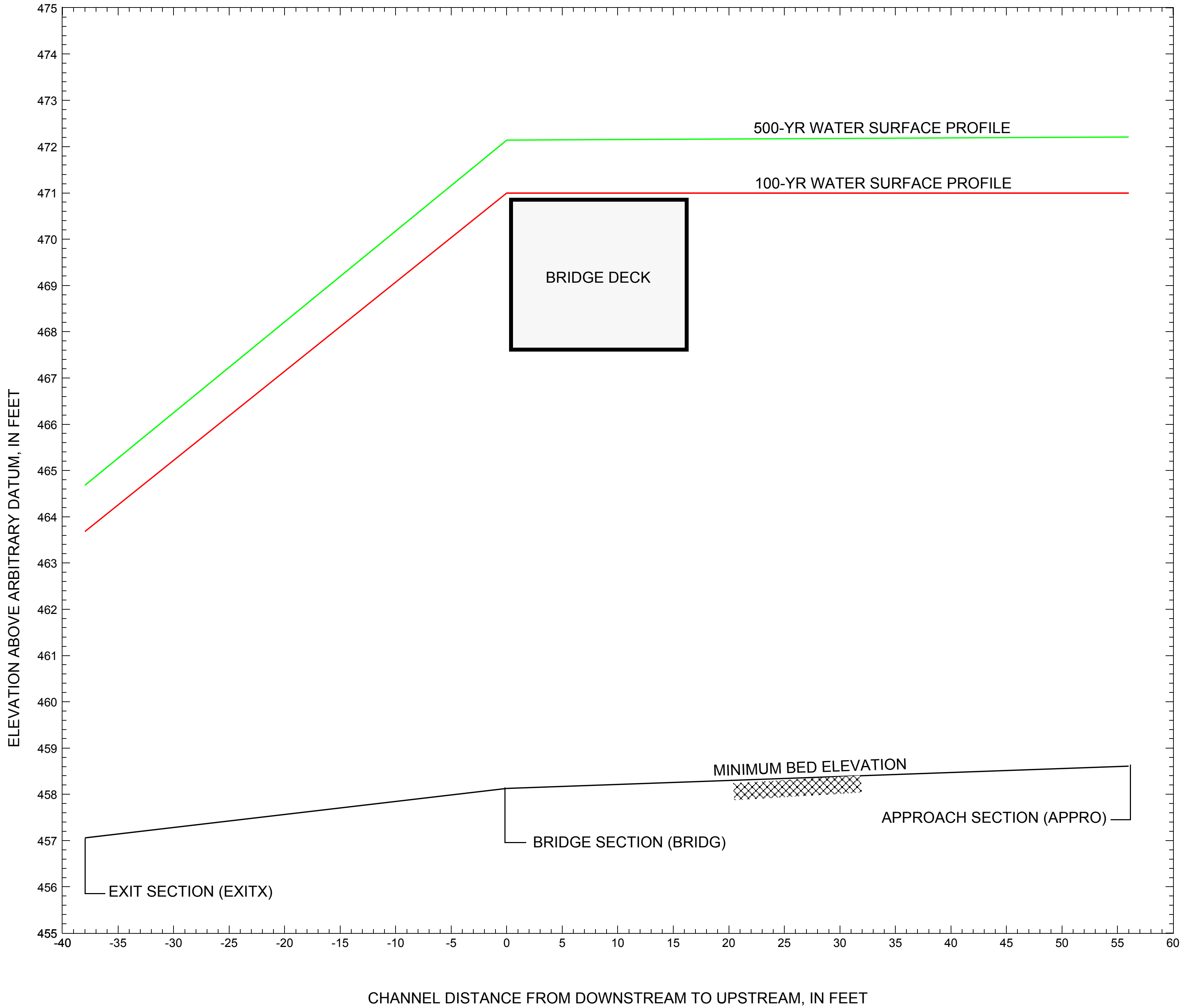

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ANDOVT00110038 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

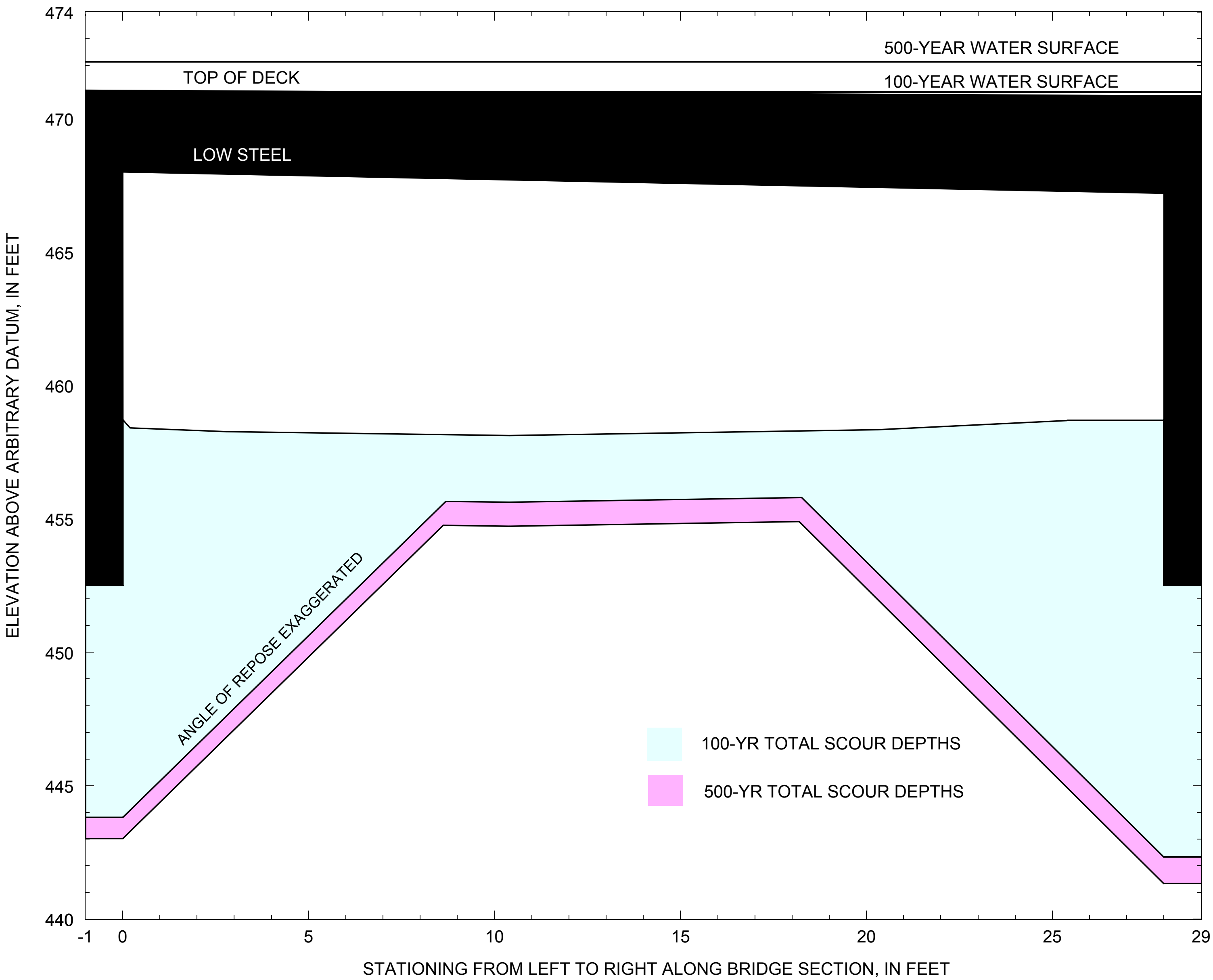

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ANDOVT00110038 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ANDOVT00110038 on State Route 11, crossing the 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 1930 cubic-feet per second											
Left abutment	0.0	417.0	468.0	452.5	458.4	2.5	12.4	--	14.9	443.5	-9.0
Right abutment	28.0	417.0	467.2	452.5	458.7	2.5	13.9	--	16.4	442.3	-10.2

1.Measured along the face of the most constricting side of the bridge.
2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure ANDOVT00110038 on State Route 11, crossing the 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 2840 cubic-feet per second											
Left abutment	0.0	417.0	468.0	452.5	458.4	3.4	12.3	--	15.7	442.7	-9.8
Right abutment	28.0	417.0	467.2	452.5	458.7	3.4	14.0	--	17.4	441.3	-11.2

1.Measured along the face of the most constricting side of the bridge.
2.Arbitrary datum for this study.

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U.S. Geological Survey, 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 ando038.wsp
T2        Hydraulic analysis for structure ANDOVT00110038   Date: 11-FEB-97
T3        VT 11 over the Middle Branch of the Williams River
*
*J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1930.0   2840.0  1770.0
SK          0.0202   0.0202  0.0202
*
XS   EXITX    -38           0.
GR          -65.4, 479.26    -48.5, 463.57    -37.3, 462.88    -12.5, 460.90
GR           -9.6, 459.42      0.0, 457.74      1.7, 457.14      5.2, 457.06
GR            8.0, 457.58     10.8, 457.78     14.1, 458.88     27.4, 462.20
GR           37.6, 469.58     51.6, 471.18     87.8, 469.95     95.3, 472.24
GR          106.0, 481.20
*
N           0.075  0.060      0.035
SA             -12.5     37.6
*
XS   FULLV      0  * * *   0.01567
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    467.61      45.0
GR            0.0, 468.01      0.1, 458.72      0.2, 458.41      2.8, 458.27
GR           10.4, 458.13     20.3, 458.35     25.4, 458.69     27.3, 458.73
GR           28.0, 467.21      0.0, 468.01
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      46.2 * *     64.0     11.5
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     18      32.0     1
GR         -134.5, 478.69   -126.4, 473.79   -114.4, 473.15    -24.9, 471.30
GR            0.0, 471.06     30.3, 470.84     68.9, 470.21     77.0, 470.55
GR           84.6, 479.27
*
XT   APTEM     85           0.
GR         -143.3, 483.44   -133.3, 478.79   -127.1, 474.41   -115.5, 473.99
GR          -84.8, 473.50    -26.3, 471.19     -6.7, 465.54      0.0, 461.25
GR            3.7, 460.36     10.3, 459.64     12.3, 459.27     17.1, 459.08
GR           18.5, 458.93     20.5, 459.24     22.5, 459.72     24.6, 460.26
GR           30.1, 463.50     33.3, 465.18     50.2, 483.41
*
AS   APPRO     56 * * * 0.011
GT
N           0.035        0.060
SA                 -26.3
*
HP 1 BRIDG   468.01 1 468.01
HP 2 BRIDG   468.01 * * 1875
HP 2 RDWAY   471.00 * *   91
* full valley Laursen's
HP 1 BRIDG   464.55 1 464.55
HP 1 APPRO   471.00 1 471.00
HP 2 APPRO   471.00 * * 1930
*
HP 1 BRIDG   467.61 1 467.61
HP 2 BRIDG   467.61 * * 2043
HP 2 RDWAY   472.14 * *  806
* full valley Laursen's
HP 1 BRIDG   465.58 1 465.58
HP 1 APPRO   472.21 1 472.21
HP 2 APPRO   472.21 * * 2840
*
HP 1 BRIDG   468.01 1 468.01
HP 2 BRIDG   468.01 * * 1770
* full valley Laursen's
```

APPENDIX B:

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File ando038.wsp
     Hydraulic analysis for structure ANDOVT00110038   Date: 11-FEB-97
     VT 11 over the Middle Branch of the Williams River
        *** RUN DATE & TIME: 02-28-97  09:40

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      181     11657      0     57                            0
468.01           181     11657      0     57  1.00      0     28        0

 VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL     LEW     REW    AREA        K        Q    VEL
    468.01     0.0    28.0   181.2   11657.    1875.  10.35

X STA.         0.0         2.6         4.1         5.4         6.6         7.8
  A(I)            17.4        10.0         8.9         8.5         7.9
  V(I)            5.39        9.34       10.53       11.04       11.91

X STA.         7.8         8.9        10.0        11.2        12.3        13.4
  A(I)             7.7         7.5         7.6         7.4         7.4
  V(I)           12.19       12.44       12.37       12.59       12.66

X STA.        13.4        14.5        15.6        16.8        18.0        19.2
  A(I)             7.5         7.5         7.5         7.7         7.8
  V(I)           12.46       12.54       12.47       12.13       12.06

X STA.        19.2        20.4        21.8        23.2        24.9        28.0
  A(I)             8.2         8.6         8.9        10.2        16.9
  V(I)           11.48       10.94       10.52        9.15        5.55

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      18.
      WSEL     LEW     REW    AREA        K        Q    VEL
    471.00     8.3    77.4    25.2     641.      91.   3.61

X STA.         8.3        39.8        44.3        47.6        50.5        52.9
  A(I)             4.0         1.6         1.4         1.3         1.2
  V(I)            1.13        2.86        3.29        3.40        3.67

X STA.        52.9        55.1        57.0        58.8        60.5        62.0
  A(I)             1.2         1.1         1.1         1.1         1.0
  V(I)            3.83        4.02        4.15        4.32        4.42

X STA.        62.0        63.5        64.9        66.2        67.4        68.6
  A(I)             1.0         1.0         1.0         0.9         0.9
  V(I)            4.49        4.63        4.78        4.85        4.85

X STA.        68.6        69.8        71.2        72.7        74.5        77.4
  A(I)             0.9         1.0         1.0         1.1         1.3
  V(I)            4.96        4.64        4.45        4.26        3.40

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      121      8888     20     31                         1702
464.55           121      8888     20     31  1.00      0     28     1702


  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1        0         1      3      3                            0
          2      488     43466     65     72                         7559
471.00           488     43467     69     75  1.00    -29     39     7379

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
      WSEL     LEW     REW    AREA        K        Q    VEL
    471.00   -29.6    39.0   487.7   43467.    1930.   3.96

X STA.       -29.6        -8.1        -3.0         0.1         2.5         4.6
  A(I)            50.1        34.2        27.9        24.6        23.0
  V(I)            1.93        2.82        3.46        3.92        4.19

X STA.         4.6         6.5         8.3        10.0        11.7        13.3
  A(I)            21.3        20.5        20.3        19.7        18.9
  V(I)            4.54        4.70        4.75        4.90        5.11

X STA.        13.3        14.8        16.4        17.9        19.4        21.1
  A(I)            18.8        18.9        18.6        19.0        19.5
  V(I)            5.13        5.10        5.19        5.08        4.95

X STA.        21.1        22.8        24.7        26.9        30.1        39.0
  A(I)            20.0        21.6        23.2        27.6        40.2
  V(I)            4.83        4.47        4.17        3.50        2.40
```

```
      U.S. Geological Survey WSPRO Input File ando038.wsp
      Hydraulic analysis for structure ANDOVT00110038   Date: 11-FEB-97
      VT 11 over the Middle Branch of the Williams River
         *** RUN DATE & TIME: 02-28-97  09:40
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
 WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
           1      179     13070    10    47                          4327
 467.61           179     13070    10    47  1.00      0     28     4327

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL     LEW     REW    AREA        K        Q    VEL
    467.61     0.0    28.0   179.2   13070.    2043.  11.40

X STA.        0.0        2.7        4.1        5.3        6.4        7.4
 A(I)            17.2        9.4        8.0        7.2        7.0
 V(I)            5.95      10.90      12.77      14.21      14.62

X STA.        7.4        8.4        9.4       10.3       11.3       12.2
 A(I)             6.5        6.4        6.4        6.4        6.4
 V(I)           15.73      16.01      15.86      16.04      16.08

X STA.       12.2       13.2       14.2       15.5       16.8       18.2
 A(I)             6.5        6.9        8.6        8.5        8.8
 V(I)           15.68      14.76      11.94      12.00      11.61

X STA.       18.2       19.6       21.1       22.7       24.5       28.0
 A(I)             9.4        9.3       10.4       11.3       18.8
 V(I)           10.92      10.97       9.87       9.01       5.44

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      18.

      WSEL     LEW     REW    AREA        K        Q    VEL
    472.14   -65.5    78.4   154.7    5989.     806.   5.21

X STA.      -65.5      -17.0       -3.3        7.0       16.6       25.1
 A(I)            24.0       13.5       11.2       11.2       10.4
 V(I)            1.68       2.98       3.58       3.60       3.87

X STA.       25.1       33.1       39.0       42.7       46.2       49.4
 A(I)            10.3        8.2        5.5        5.3        5.2
 V(I)            3.89       4.92       7.27       7.60       7.82

X STA.       49.4       52.5       55.5       58.3       61.0       63.6
 A(I)             5.1        4.9        4.9        4.8        4.7
 V(I)            7.92       8.18       8.18       8.34       8.49

X STA.       63.6       66.1       68.6       71.1       73.9       78.4
 A(I)             4.6        4.7        4.8        4.9        6.3
 V(I)            8.74       8.58       8.40       8.18       6.40
 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
 WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
           1      141     11024    20    33                          2143
 465.58           141     11024    20    33  1.00      0     28     2143


 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
           1       23       739    34    34                           105
           2      567     55097    66    73                          9406
 472.21           590     55837   100   107  1.04    -59     40     7956

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
      WSEL     LEW     REW    AREA        K        Q    VEL
    472.21   -60.2    40.1   589.9   55837.    2840.   4.81

X STA.      -60.2      -13.2       -6.7       -2.5        0.4        2.7
 A(I)            64.8       39.7       35.2       30.5       26.9
 V(I)            2.19       3.57       4.04       4.66       5.27
```

```
X STA.        2.7        4.8        6.8        8.7       10.5       12.2
  A(I)            25.3       24.5       23.7       23.3       23.1
  V(I)            5.62       5.80       6.00       6.09       6.15

X STA.       12.2       13.9       15.6       17.3       18.9       20.7
  A(I)            22.2       22.3       22.7       22.7       23.5
  V(I)            6.40       6.37       6.26       6.25       6.05

X STA.       20.7       22.6       24.6       27.1       30.3       40.1
  A(I)            24.1       25.4       28.8       32.0       49.3
  V(I)            5.89       5.60       4.94       4.43       2.88
```

```
        U.S. Geological Survey WSPRO Input File ando038.wsp
        Hydraulic analysis for structure ANDOVT00110038   Date: 11-FEB-97
        VT 11 over the Middle Branch of the Williams River
           *** RUN DATE & TIME: 02-28-97  09:40
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      181     11657      0     57                            0
   468.01           181     11657      0     57  1.00      0     28        0

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       468.01     0.0    28.0   181.2   11657.    1770.   9.77

X STA.        0.0        2.6        4.1        5.4        6.6        7.8
  A(I)            17.4       10.0        8.9        8.5        7.9
  V(I)            5.08       8.81       9.94      10.42      11.24

X STA.        7.8        8.9       10.0       11.2       12.3       13.4
  A(I)             7.7        7.5        7.6        7.4        7.4
  V(I)           11.50      11.74      11.68      11.88      11.95

X STA.       13.4       14.5       15.6       16.8       18.0       19.2
  A(I)             7.5        7.5        7.5        7.7        7.8
  V(I)           11.76      11.83      11.77      11.46      11.39

X STA.       19.2       20.4       21.8       23.2       24.9       28.0
  A(I)             8.2        8.6        8.9       10.2       16.9
  V(I)           10.84      10.33       9.93       8.64       5.24

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      117      8465     20     31                         1616
   464.34           117      8465     20     31  1.00      0     28     1616


     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      441     37932     63     69                         6651
   470.28           441     37932     63     69  1.00    -23     38     6651

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
         WSEL     LEW     REW    AREA        K        Q    VEL
       470.28   -24.2    38.3   441.3   37932.    1770.   4.01

X STA.      -24.2       -6.5       -1.8        0.9        3.2        5.2
  A(I)            45.2       31.4       24.9       22.3       20.4
  V(I)            1.96       2.82       3.56       3.97       4.35

X STA.        5.2        7.0        8.8       10.4       12.0       13.5
  A(I)            19.2       19.1       17.8       17.9       17.1
  V(I)            4.61       4.63       4.98       4.95       5.17

X STA.       13.5       15.0       16.5       18.0       19.5       21.0
  A(I)            17.1       17.2       16.9       17.2       17.7
  V(I)            5.18       5.16       5.24       5.13       5.01
```

```
X STA.        21.0       22.7       24.5       26.7       29.7       38.3
  A(I)             18.1       19.5       21.0       24.9       36.5
  V(I)             4.89       4.53       4.21       3.55       2.43
```

```
        U.S. Geological Survey WSPRO Input File ando038.wsp
        Hydraulic analysis for structure ANDOVT00110038   Date: 11-FEB-97
        VT 11 over the Middle Branch of the Williams River
           *** RUN DATE & TIME: 02-28-97  09:40

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

EXITX:XS   ******    -48      237  1.26 *****  464.93  463.29    1930  463.68
       -37 ******     29    13574  1.22 ***** *******    0.91    8.13

FULLV:FV       38    -48      259  1.05  0.69  465.60 *******    1930  464.55
         0     38     30    15206  1.22  0.00   -0.02    0.80    7.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     0.85     465.37     464.86

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   464.05     483.12    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   464.05     483.12     464.86

APPRO:AS       56     -6      187  1.66  1.13  467.02  464.86    1930  465.36
        56     56     34    12127  1.00  0.31   -0.02    0.85   10.34
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   465.09     469.84     469.96     467.61

 ===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       38      0      181  1.67 *****  469.68  464.98    1875  468.01
         0 ******     28    11657  1.00 ***** *******    0.72   10.35
```

WSPRO OUTPUT FILE (continued)

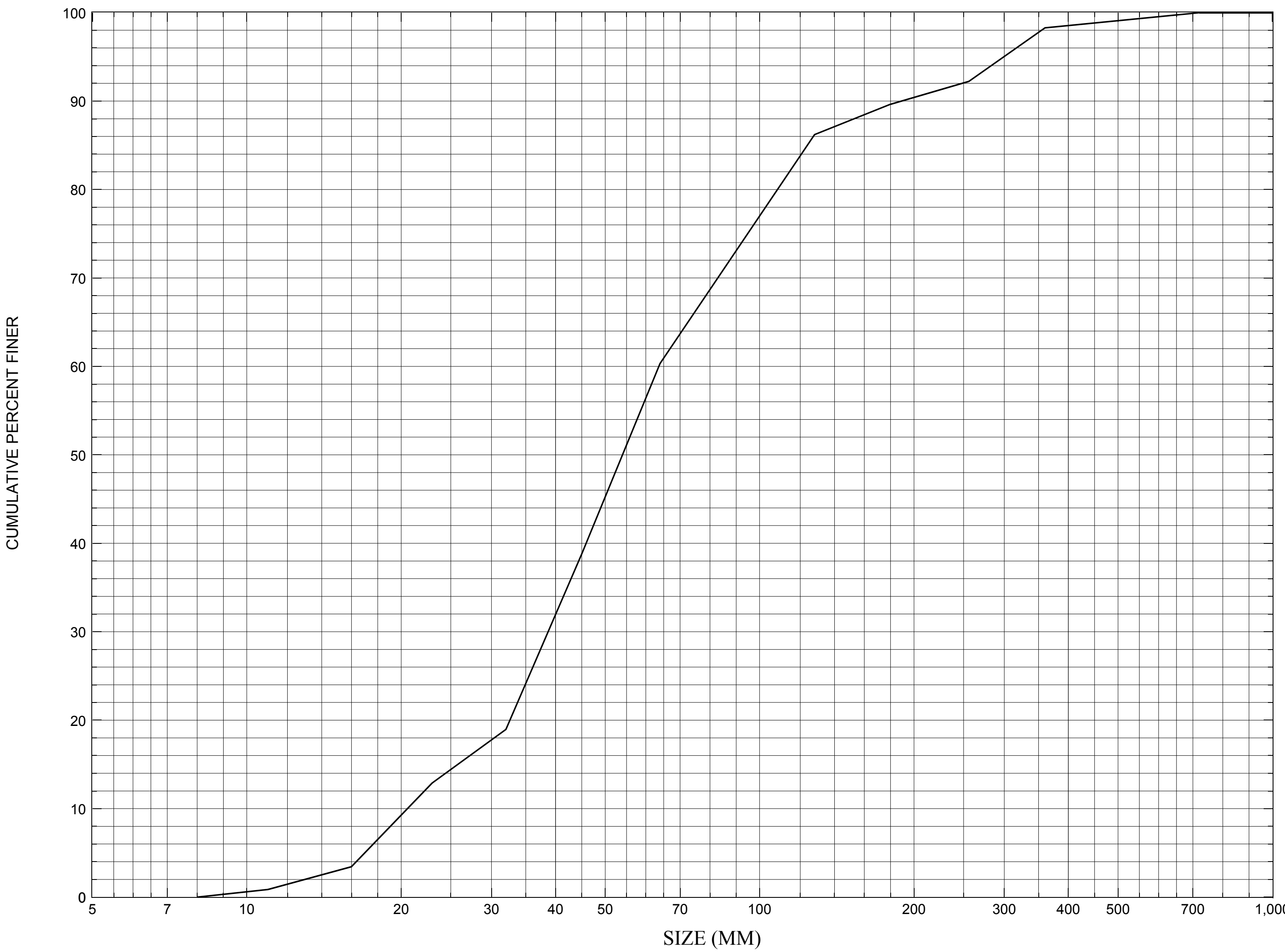
```
     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.495  0.000  467.61 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       18.    24.  0.05  0.24  471.20    0.02     91.  471.00

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.    44.   -31.    14.   0.5   0.3   3.3   4.2   0.5   3.1
   RT:    91.    64.    14.    77.   0.8   0.4   3.6   3.6   0.6   3.1

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

APPRO:AS       10    -29      488  0.24  0.08  471.25  464.86    1930  471.00
        56     12     39    43495  1.00  1.72    0.02    0.26    3.96


  FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -38.   -49.    29.   1930.   13574.     237.    8.13  463.68
   FULLV:FV       0.   -49.    30.   1930.   15206.     259.    7.45  464.55
   BRIDG:BR       0.     0.    28.   1875.   11657.     181.   10.35  468.01
   RDWAY:RG      18.*******     0.     91.       0.*********    1.00  471.00
   APPRO:AS      56.   -30.    39.   1930.   43495.     488.    3.96  471.00

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    463.29    0.91  457.06  481.20************  1.26  464.93  463.68
   FULLV:FV  ********    0.80  457.66  481.80  0.69  0.00  1.05  465.60  464.55
   BRIDG:BR    464.98    0.72  458.13  468.01************  1.67  469.68  468.01
   RDWAY:RG  ****************  470.21  479.27  0.05******  0.24  471.20  471.00
   APPRO:AS    464.86    0.26  458.61  483.12  0.08  1.72  0.24  471.25  471.00
```

```
        U.S. Geological Survey WSPRO Input File ando038.wsp
        Hydraulic analysis for structure ANDOVT00110038   Date: 11-FEB-97
        VT 11 over the Middle Branch of the Williams River
           *** RUN DATE & TIME: 02-28-97  09:40

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

EXITX:XS   ******    -49      317  1.50 *****  466.19  464.39    2840  464.68
       -37 ******     31    19968  1.21 ***** *******    0.87    8.95

FULLV:FV       38    -49      342  1.29  0.69  466.87 *******    2840  465.58
         0     38     31    22099  1.20  0.00   -0.01    0.78    8.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.98    466.30     466.22

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   465.08     483.12    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   465.08     483.12     466.22

APPRO:AS       56     -9      227  2.43  1.30  468.73  466.22    2840  466.30
        56     56     35    15754  1.00  0.57    0.00    0.98   12.49
```

```
        U.S. Geological Survey WSPRO Input File ando038.wsp
        Hydraulic analysis for structure ANDOVT00110038   Date: 11-FEB-97
        VT 11 over the Middle Branch of the Williams River
           *** RUN DATE & TIME: 02-28-97  09:40

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

EXITX:XS   ******    -46      221  1.21 *****  464.67  463.05    1770  463.47
       -37 ******     29    12442  1.21 ***** *******    0.91    8.00

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81     464.34     463.64

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   462.97     481.80    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                        WSLIM1,WSLIM2,CRWS =   462.97     481.80     463.64

FULLV:FV       38    -48      242  1.01  0.69  465.35  463.64    1770  464.34
         0     38     30    13946  1.22  0.00   -0.01    0.81    7.30
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.82     465.18     464.57

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   463.84     483.12    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   463.84     483.12     464.57

APPRO:AS       56     -6      179  1.51  1.09  466.69  464.57    1770  465.18
        56     56     34    11499  1.00  0.25    0.00    0.82    9.87
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   464.73     469.25     469.37     467.61

 ===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       38      0      181  1.46 *****  469.47  464.69    1753  468.01
         0 ******     28    11657  1.00 ***** *******    0.67    9.68

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.490  0.000  467.61 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      18.        <<<<<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       10    -23      441  0.25  0.08  470.53  464.57    1770  470.28
        56     12     38    37903  1.00  1.69   -0.01    0.27    4.01


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -38.   -47.    29.   1770.   12442.     221.    8.00  463.47
   FULLV:FV       0.   -49.    30.   1770.   13946.     242.    7.30  464.34
   BRIDG:BR       0.     0.    28.   1753.   11657.     181.    9.68  468.01
   RDWAY:RG      18.**************      0.       0.       0.    1.00********
   APPRO:AS      56.   -24.    38.   1770.   37903.     441.    4.01  470.28

  SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    463.05    0.91  457.06  481.20************  1.21  464.67  463.47
   FULLV:FV    463.64    0.81  457.66  481.80  0.69  0.00  1.01  465.35  464.34
   BRIDG:BR    464.69    0.67  458.13  468.01************  1.46  469.47  468.01
   RDWAY:RG   ****************  470.21  479.27************  0.25  470.47********
   APPRO:AS    464.57    0.27  458.61  483.12  0.08  1.69  0.25  470.53  470.28
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ANDOVT00110038, in Andover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ANDOVT00110038

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 29 / 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)* 001510

Waterway *(I - 6)* The Middle Branch Williams River

Road Name *(I - 7):* -

Route Number VT 11

Vicinity *(I - 9)* 2.8 MI E JCT VT 121

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43152

Longitude *(i - 17; nnnnn.n)* 72432

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001600381401

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

Maximum span length *(I - 48; nnnn)* 0031

Year built *(I - 27; YYYY)* 1929

Structure length *(I - 49; nnnnnn)* 000033

Average daily traffic, ADT *(I - 29; nnnnnn)* 002736

Deck Width *(I - 52; nn.n)* 320

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

Channel & Protection *(I - 61; n)* 8

Opening skew to Roadway *(I - 34; nn)* 40

Waterway adequacy *(I - 71; n)* 4

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

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

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 1972

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*) 9.0

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

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

Comments:

The structural inspection report of 11/10/93 indicates the structure is a concrete T-beam type bridge with an asphalt roadway surface. The concrete abutment walls have a couple of hairline vertical shrinkage cracks noted. There is minor scaling along the flow lines. All four wingwalls are in generally good condition. The footings are not in view. The streambed consists of stone and gravel. The banks are well protected with stone fill.

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)* 5.65 mi^2

Lake and pond area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 1220 ft

Headwater elevation 2894 ft

Main channel length 4.85 mi

10% channel length elevation 1260 ft

85% channel length elevation 2047 ft

Main channel slope *(S)* 216.64 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)*: 01 / 1971

Project Number BMA 6229 Minimum channel bed elevation: 407.0

Low superstructure elevation: USLAB 417.0 DSLAB 417.0 USRAB 417.0 DSRAB 417.0

Benchmark location description:

BM#8 is a spike in a stump of a 20 inch yellow birch tree, elevation 418.21, located about 68 feet right bankward from right abutment and 23 feet perpendicular from center line of the roadway in the downstream direction. This benchmark is taken from the bridge plans of the original bridge.

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: 401.5

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:

-

Comments:

This bridge is the same as the original but widened in 1972 on the upstream side. Other elevation points: 1) point on top of the downstream left wingwall at the downstream end on the streamward edge, elevation 412.08 and 2) the point at the same location described above on the downstream right wingwall, elevation 414.25.

Cross-sectional Data

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

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

Comments: **-There is no cross-section information available.**

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: **There is no cross-section information available.**

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: **09/24/96**
Computerized by: **RB** Date: **09/25/96**
Reviewd by: **LKS** Date: **03/27/97**

Structure Number **ANDOVT00110038**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. HAMMOND** Date *(MM/DD/YY)* **09** / **05** / 19**96**

2. Highway District Number **02**
Mile marker **001510**
County **027 WINDSOR**
Town **01300 ANDOVER**
Waterway *(I - 6)* **The Middle Branch Williams River**
Road Name **Vermont Route 11**
Route Number **VT 11**
Hydrologic Unit Code: **01080107**

3. Descriptive comments:
The bridge is located 2.8 miles east of the junction with VT 121. It is also 1.5 miles north of the Windsor/ Windham county line and 0.1 miles south of Casthaldo Road, TH 48.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **6** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **2** UB **2** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **33** *(feet)* Span length **31** *(feet)* Bridge width **32** *(feet)*

Road approach to bridge:

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

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

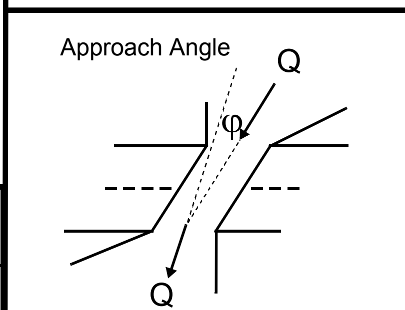
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

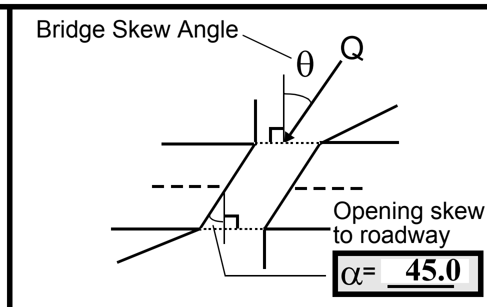
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	5	1	2	1
RBUS	2	1	2	1
RBDS	2	1	2	1
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **55**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **105** feet **US** *(US, UB, DS)* to **5** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **95** feet **DS** *(US, UB, DS)* to **+200** feet **DS**

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

18. Bridge Type: **1a**

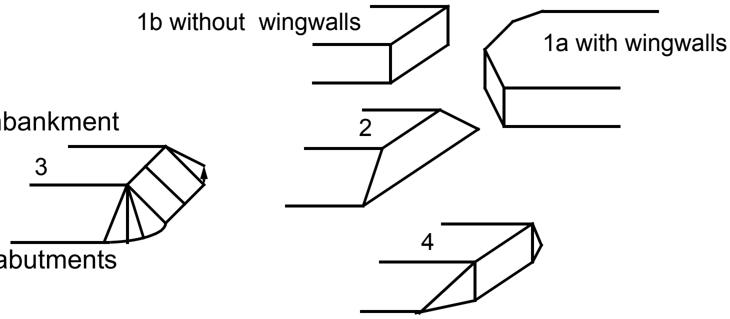
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

7. Values are from the VT AOT files. The measured bridge length between the back of the abutments DS is 32 ft. and 46.2 ft. US, span length between the abutment faces DS is 29.1 ft. and 42.9 ft. US, and the deck width between the insides of the bridge rail is 29.3 ft. and 32.3 ft. between the outsides of the deck.

11. The left bank US protection is a 4 ft. wide strip of asphalt. On the right bank US and DS there is type 2 protection at the end of the wingwalls and gravel fill, no protection, for the rest of the road embankment.

16. The bridge has been widened on the US side. The bridge skew is 55 degrees US based on the new deck face and 40 degrees DS based on the old deck face.

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
50.5	4.5			3.0	4	4	342	342	1	3

23. Bank width **35.0** 24. Channel width **30.0** 25. Thalweg depth **37.0** 29. Bed Material **435**

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.):

28. The right bank is high and steep and is being undercut from 85 ft. US to 50 ft. US, in the impact zone. This area is experiencing slumping.

30. The left bank protection is from 45 ft. US to 13 ft. US. On the right bank the protection extends from 1 ft. US to 8 ft. under the bridge.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 51 35. Mid-bar width: 12

36. Point bar extent: 70 feet US (US, UB) to 0 feet US (US, UB, DS) positioned 0 %LB to 60 %RB

37. Material: 435

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

-

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

41. Mid-bank distance: 70 42. Cut bank extent: +200 feet US (US, UB) to 50 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.):

Between 55 ft. US to 83 ft. US on the right bank there is block failure. There is also a cut bank on the left bank from +200 ft. US to 80 ft. US with mid-bank distance at 105 ft. US. Recent high flows have cut both banks US of the bridge. These banks are eroded.

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

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

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

There is no channel scour present at this site as of 09/05/96. There is some local scour beside and downstream of the large boulders in the stream.

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

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

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

54. Confluence comments (eg. confluence name):

There are no major confluences present upstream at the site.

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
24.5		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.):

342

Perpendicular measurement from abutment face to abutment face under the bridge is 20 ft.

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

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

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

70. Debris and Ice Comments:

1

-

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	2	0	-	-	90.0
RABUT	1	0	90			2	0	20.0

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

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

-

-

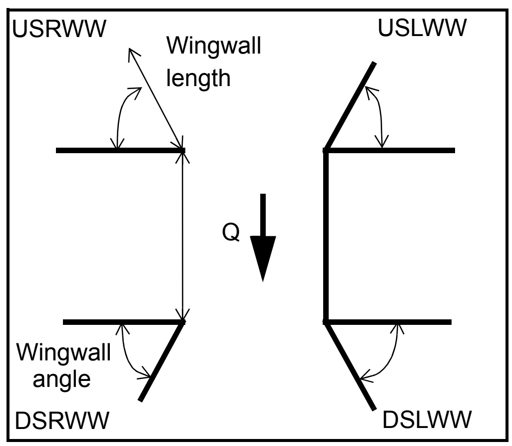
1

-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						20.0	
USRWW:	Y		1		0	0.5	
DSLWW:	-		-		Y	36.5	
DSRWW:	1		0		-	35.5	

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



82. **Bank / Bridge Protection**:

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

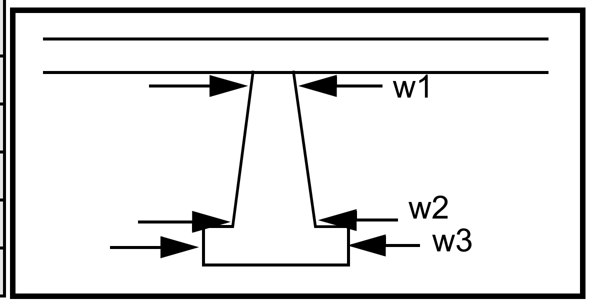
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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				25.0	22.0	105.0
Pier 2				12.0	105.0	11.5
Pier 3			-	15.0	17.5	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	The	re	are	no	pier

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

Bank protection type (Qmax): LB this RB bri Bank protection condition: LB dge. RB

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

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

4
4
342
342
1
1
453

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: **0** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
-
-
There is natural bank protection on the right bank, however, some of the large boulders may have been dumped to protect the road embankment.
There is minor cutting of both banks at the gradual bend to the right in the channel. The bending is gradual, however the total bend is near 90 degrees. Past slumps of material had sufficient large material, cobbles,

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

Point bar extent: **and** feet **gra** (US, UB, DS) to **vel,** feet **to** (US, UB, DS) positioned **pre** %LB to **ven** %RB

Material: **t a**

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

cut bank from occurring. Light fluvial washing is observed in the impact or slump area. There is good soil cover above the wash.

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

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

-

There are no drop structures at this bridge site.

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

Scour dimensions: Length ______ Width **Y** Depth: **120** Positioned **25** %LB to **80** %RB

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

DS
+200
DS
30

Are there major confluences? **10** (Y or if N type ctrl-n mc) How many? **0**

Confluence 1: Distance **435** Enters on **This** (LB or RB) Type **poin** (**1**- perennial; **2**- ephemeral)

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

Confluence comments (eg. confluence name):

gradual bend in the stream that extends at least another 200 ft. downstream.

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
-
-
-
-
-
-
-
There are no cut-banks present.

109. G. Plan View Sketch

\- N

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: ANDOVT00110038 Town: ANDOVER
Road Number: VT 11 County: WINDSOR
Stream: MIDDLE BR WILLIAMS R

Initials LKS Date: 02/28/97 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	1930	2840	1770
Main Channel Area, ft2	488	567	441
Left overbank area, ft2	0	23	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	65	66	63
Top width L overbank, ft	3	34	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.1773	0.1773	0.1773
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.5	8.6	7.0
y1, average depth, LOB, ft	0.0	0.7	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	43467	55837	37932
Conveyance, main channel	43466	55097	37932
Conveyance, LOB	1	739	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0018	0.0000
Qm, discharge, MC, cfs	1930.0	2802.4	1770.0
Ql, discharge, LOB, cfs	0.0	37.6	0.0
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	4.0	4.9	4.0
Vl, mean velocity, LOB, ft/s	ERR	1.6	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	8.8	9.0	8.7
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	488	567	441
Main channel width, ft	65	66	63
y1, main channel depth, ft	7.51	8.59	7.00

Bridge Section			
(Q) total discharge, cfs	1930	2840	1770
(Q) discharge thru bridge, cfs	1875	2043	1770
Main channel conveyance	11657	13070	11657
Total conveyance	11657	13070	11657
Q2, bridge MC discharge,cfs	1875	2043	1770
Main channel area, ft2	181	179	181
Main channel width (skewed), ft	19.8	19.8	19.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.8	19.8	19.8
y_bridge (avg. depth at br.), ft	9.14	9.04	9.14
Dm, median (1.25*D50), ft	0.221625	0.221625	0.221625
y2, depth in contraction,ft	9.41	10.13	8.96
ys, scour depth (y2-ybridge), ft	0.27	1.09	-0.19
Ys, depth of scour (y2-yfullv), ft	3.328084	3.117269	3.084581

ARMORING			
D90	0.6189	0.6189	0.6189
D95	0.9815	0.9815	0.9815
Critical grain size,Dc, ft	1.0546	0.8660	1.0194
Decimal-percent coarser than Dc	0.0373	0.0722	0.0433
Depth to armoring,ft	81.66	33.38	67.57

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	1930	2840	1770
Q, thru bridge, cfs	1875	2043	1770
Total Conveyance, bridge	11657	13070	11657
Main channel(MC) conveyance, bridge	11657	13070	11657
Q, thru bridge MC, cfs	1875	2043	1770
Vc, critical velocity, ft/s	8.81	9.01	8.71
Vc, critical velocity, m/s	2.69	2.75	2.65
Main channel width (skewed), ft	19.8	19.8	19.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.8	19.8	19.8
qbr, unit discharge, ft2/s	94.7	103.2	89.4
qbr, unit discharge, m2/s	8.8	9.6	8.3
Area of full opening, ft2	181.0	179.0	181.0
Hb, depth of full opening, ft	9.14	9.04	9.14

Hb, depth of full opening, m	2.79	2.76	2.79
Fr, Froude number, bridge MC	0.72	0.79	0.67
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	467.61	467.61	467.61
Elevation of Bed, ft	458.47	458.57	458.47
Elevation of Approach, ft	471	472.21	470.28
Friction loss, approach, ft	0.08	0.1	0.08
Elevation of WS immediately US, ft	470.92	472.11	470.20
ya, depth immediately US, ft	12.45	13.54	11.73
ya, depth immediately US, m	3.80	4.13	3.58
Mean elevation of deck, ft	470.95	470.95	470.95
w, depth of overflow, ft (>=0)	0.00	1.16	0.00
Cc, vert contrac correction (<=1.0)	0.92	0.92	0.94
Ys, depth of scour, ft	2.51	3.40	1.80

Results of Chang using estimated downstream bridge face properties for unsubmerged orifice flow

Ys, depth of scour, ft	6.16	5.60	5.42

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	1930	2840	1770	1930	2840	1770
a', abut.length blocking flow, ft	33.7	64.3	28.3	15.1	16.2	14.4
Ae, area of blocked flow ft2	154.32	171.04	132.98	98.17	97.38	88.9
Qe, discharge blocked abut.,cfs	459.52	--	393.82	---	---	295
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.98	3.76	2.96	3.30	4.00	3.32
ya, depth of f/p flow, ft	4.58	2.66	4.70	6.50	6.01	6.17
--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	45	45	45	135	135	135
K2	0.91	0.91	0.91	1.05	1.05	1.05
Fr, froude number f/p flow	0.245	0.363	0.241	0.226	0.260	0.235
ys, scour depth, ft	12.38	12.25	11.96	13.90	13.95	13.39

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)	33.7	64.3	28.3	15.1	16.2	14.4
y1 (depth f/p flow, ft)	4.58	2.66	4.70	6.50	6.01	6.17
a'/y1	7.36	24.17	6.02	2.32	2.70	2.33
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.25	0.36	0.24	0.23	0.26	0.24
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.72	0.79	0.67	0.72	0.79	0.67
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	9.14	9.04	9.14	9.14	9.04	9.14
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	2.93	3.49	2.54	2.93	3.49	2.54