LEVEL II SCOUR ANALYSIS FOR BRIDGE 35 (ANDOVT00110035) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

Open-File Report 98-87

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

U.S. Department of the Interior
USGS
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LEVEL II SCOUR ANALYSIS FOR BRIDGE 35 (ANDOVT00110035) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

By RONDA L. BURNS and EMILY C. WILD

U.S. Geological Survey
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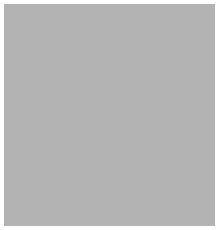

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 35 (ANDOVT00110035) ON STATE ROUTE 11, CROSSING THE 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 ANDOVT00110035 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 (Federal Highway Administration, 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 4.65-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest on the left bank and small trees and brush on the right bank upstream and downstream of the bridge.

In the study area, the Middle Branch Williams River has an incised, meandering channel with a slope of approximately 0.02 ft/ft, an average channel top width of 57 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 31.4 mm (0.103 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 28, 1996, indicated that the reach was laterally unstable. There are cut-banks upstream and downstream of the bridge and an island in the channel upstream.

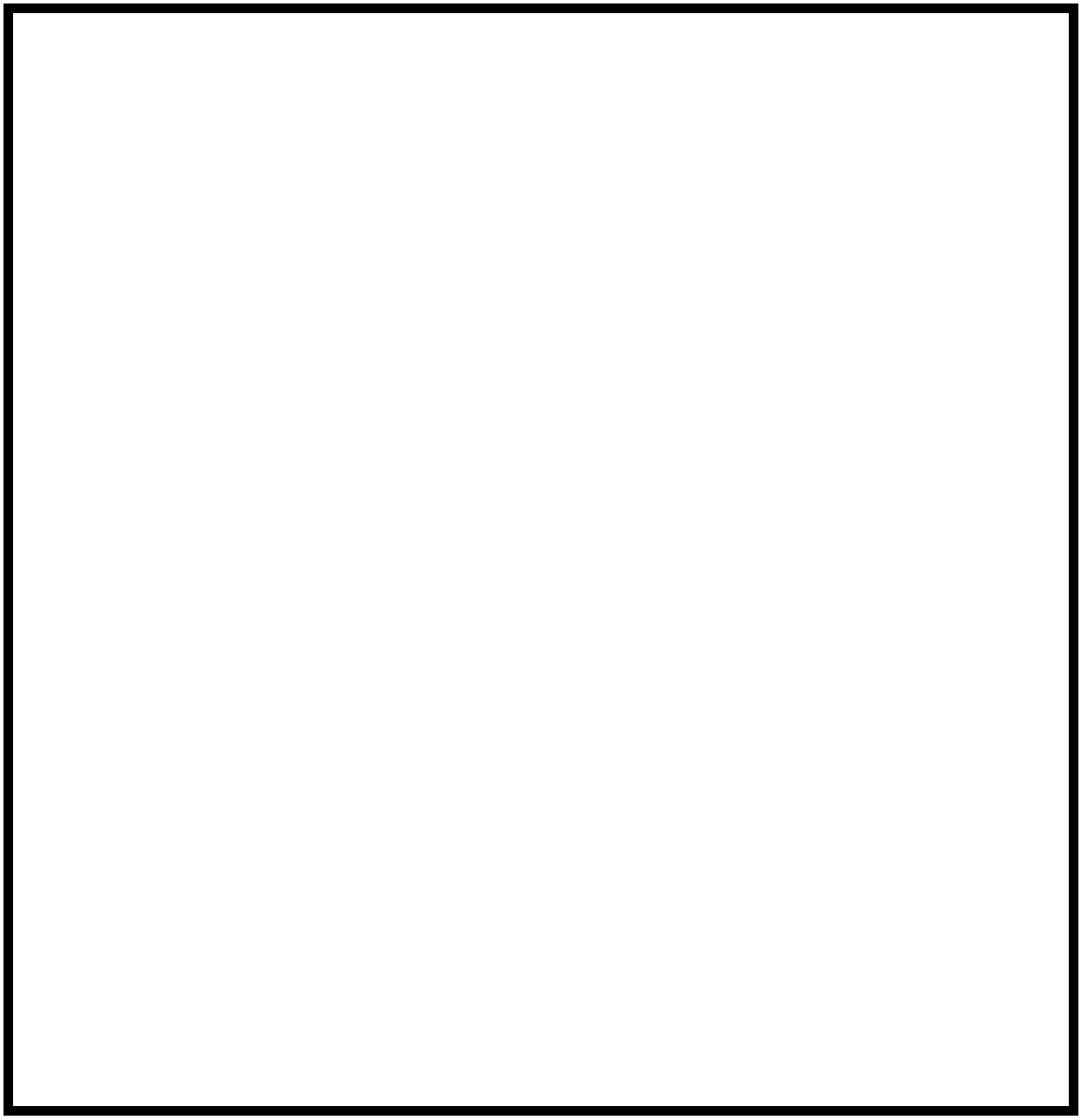
The State Route 11 crossing of the Middle Branch Williams River is a 28-ft-long, two-lane bridge consisting of one 24-ft concrete tee-beam span (Vermont Agency of Transportation, written communication, March 28, 1995). The opening length of the structure parallel to the bridge face is 23.6 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 45 degrees to the opening while the computed opening-skew-to-roadway is 25 degrees.

A scour hole ranging from 1.5 to 1.75 ft deeper than the mean thalweg depth was observed along the upstream left wingwall, the left abutment, and the downstream left wingwall during the Level I assessment. The scour countermeasures at the site included type-1 stone fill (less than 12 inches diameter) at the right road approach upstream and downstream of the bridge and type-2 stone fill (less than 36 inches diameter) at the left road approach upstream and downstream of the bridge. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 2.0 to 4.3 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 14.4 to 16.5 ft at the left abutment and from 6.3 to 8.8 ft at the right abutment. 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 Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

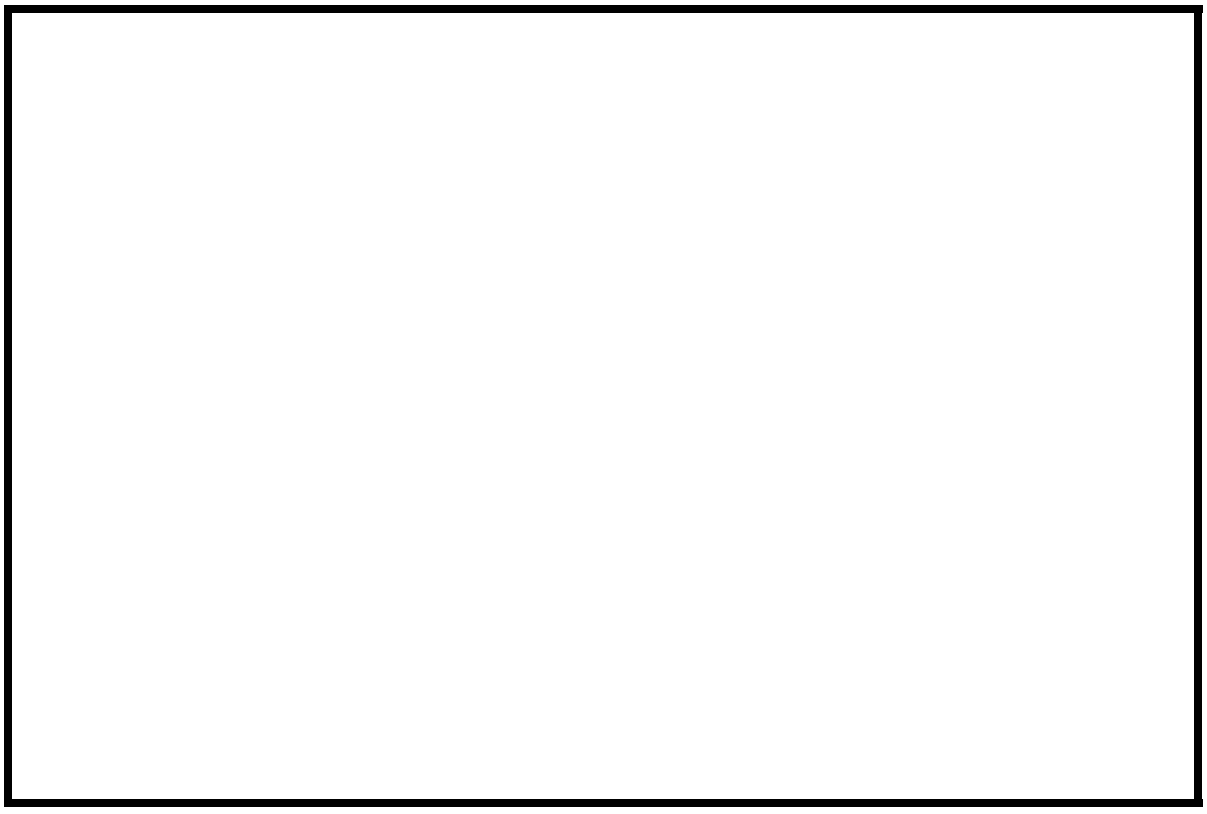


Saxtons River, VT. Quadrangle, 1:25,000, 1984

NORTH

Figure 1. Location of study area on USGS 1:25,000 scale map.

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



LEVEL II SUMMARY

Structure Number ANDOVT00110035 ***Stream*** Middle Branch Williams River

County Windsor ***Road*** VT 11 ***District*** 2

Description of Bridge

Bridge length 28 ***ft*** ***Bridge width*** 31.2 ***ft*** ***Max span length*** 24 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/28/96

Description of stone fill Type-1, at the right road approach upstream and downstream. Type-2, at the left road approach upstream and downstream.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a 1.5 ft deep scour hole in front of the upstream left wingwall and left abutment that deepens to 1.75 ft in front of the downstream left wingwall.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 45

There is a mild channel bend through the bridge. The scour hole has developed in the location where the flow impacts the left abutment and wingwalls.

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	8/28/96	0	0
Level II	8/28/96	0	0

Potential for debris Moderate. There is some debris caught on the island in the upstream channel.

Describe any features near or at the bridge that may affect flow (include observation date) A point bar along the right abutment affects low flow by directing the water towards the left abutment as noted on 8/28/96.

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 8/28/96

DS left: Low channel bank and flat overbank to a steep valley wall

DS right: Low channel bank to a moderately sloped overbank

US left: Steep valley wall

US right: Steep channel bank to a moderately sloped overbank

Description of the Channel

Average top width 57 ***ft*** ***Average depth*** 4 ***ft***

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

Channel type (straight, meandering with point bars, braided, etc.) Meandering with semi-alluvial channel boundaries and wide point bars.

8/28/96

Vegetative co Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right: Trees and brush

Do banks appear stable? No

If not, describe location and type of instability and date of observation. There are cut-banks on the upstream left bank and downstream right bank.

The assessment of 8/28/96 noted flow conditions up to bank-full level are influenced by an island in the upstream channel.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 4.65 ***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***: None.

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

USGS gage description --

USGS gage number --

Gage drainage area ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,670 ***ft³/s*** ***Q500*** 2,450 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(4.65/1.44)exp 0.83] with flood frequency estimates available from the VTAOT database (written communication, May 1995) for bridge number 10 in Windham. Bridge number 10 crosses the Middle Branch Williams River upstream of this site and has a drainage area of 1.44 square miles. The drainage area adjusted values were within a range defined by flood frequency curves derived from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans Add 21.3 to the VTAOT plans' datum to obtain the USGS arbitrary survey datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the left abutment (elev. 518.05 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the right abutment (elev. 518.28 ft, arbitrary survey datum). RM3 is a survey disk on top of the downstream end of the left abutment of bridge 36, 700 ft downstream, (499.25 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	-30	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APPRO	49	2	Modelled Approach section (Templated from APTEM)
APTEM	68	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.063, and overbank "n" values ranged from 0.060 to 0.070.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0161 ft/ft, which was estimated from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0317 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 518.3 *ft*
Average low steel elevation 515.3 *ft*

100-year discharge 1,670 *ft³/s*
Water-surface elevation in bridge opening 515.5 *ft*
Road overtopping? Yes *Discharge over road* 22 *ft³/s*
Area of flow in bridge opening 192 *ft²*
Average velocity in bridge opening 8.7 *ft/s*
Maximum WSPRO tube velocity at bridge 11.4 *ft/s*

Water-surface elevation at Approach section with bridge 517.1
Water-surface elevation at Approach section without bridge 511.1
Amount of backwater caused by bridge 6.0 *ft*

500-year discharge 2,450 *ft³/s*
Water-surface elevation in bridge opening 515.5 *ft*
Road overtopping? Yes *Discharge over road* 456 *ft³/s*
Area of flow in bridge opening 192 *ft²*
Average velocity in bridge opening 10.5 *ft/s*
Maximum WSPRO tube velocity at bridge 13.8 *ft/s*

Water-surface elevation at Approach section with bridge 518.4
Water-surface elevation at Approach section without bridge 511.6
Amount of backwater caused by bridge 6.8 *ft*

Incipient overtopping discharge 1,500 *ft³/s*
Water-surface elevation in bridge opening 511.7 *ft*
Area of flow in bridge opening 114 *ft²*
Average velocity in bridge opening 13.1 *ft/s*
Maximum WSPRO tube velocity at bridge 17.9 *ft/s*

Water-surface elevation at Approach section with bridge 515.4
Water-surface elevation at Approach section without bridge 511.0
Amount of backwater caused by bridge 4.4 *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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100- and 500-year 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 for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

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

Abutment scour was computed for all modeled flows by use of the Froehlich equation (Richardson and Davis, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.0	4.3	3.1
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank			

Local scour:			
Abutment scour	15.3	16.5	14.4
Left abutment	6.3	8.8	7.9
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
	(D_{50} in feet)		
Abutments:	2.4	2.7	2.3
Left abutment	2.4	2.7	2.3
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

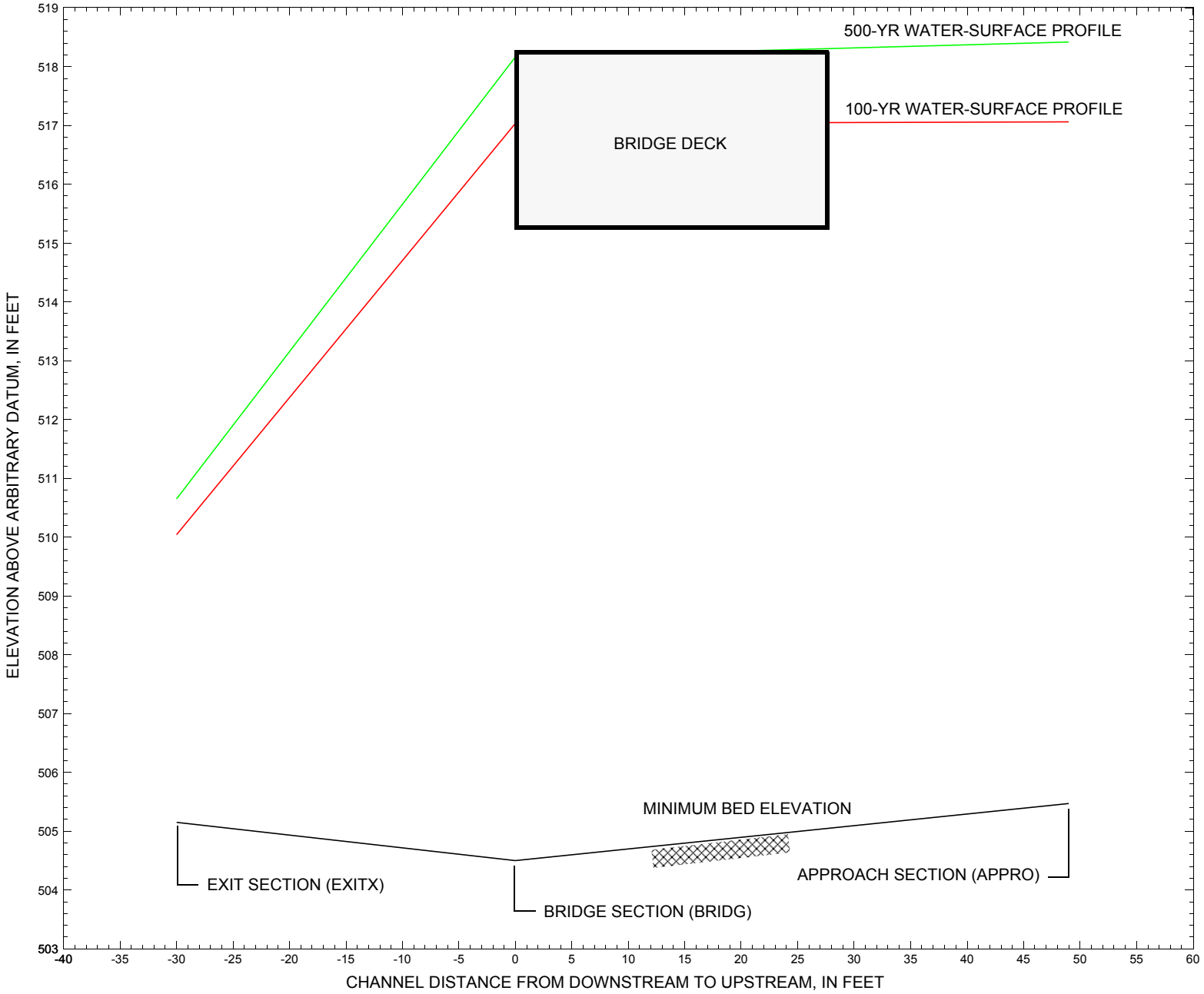


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ANDOVT00110035 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

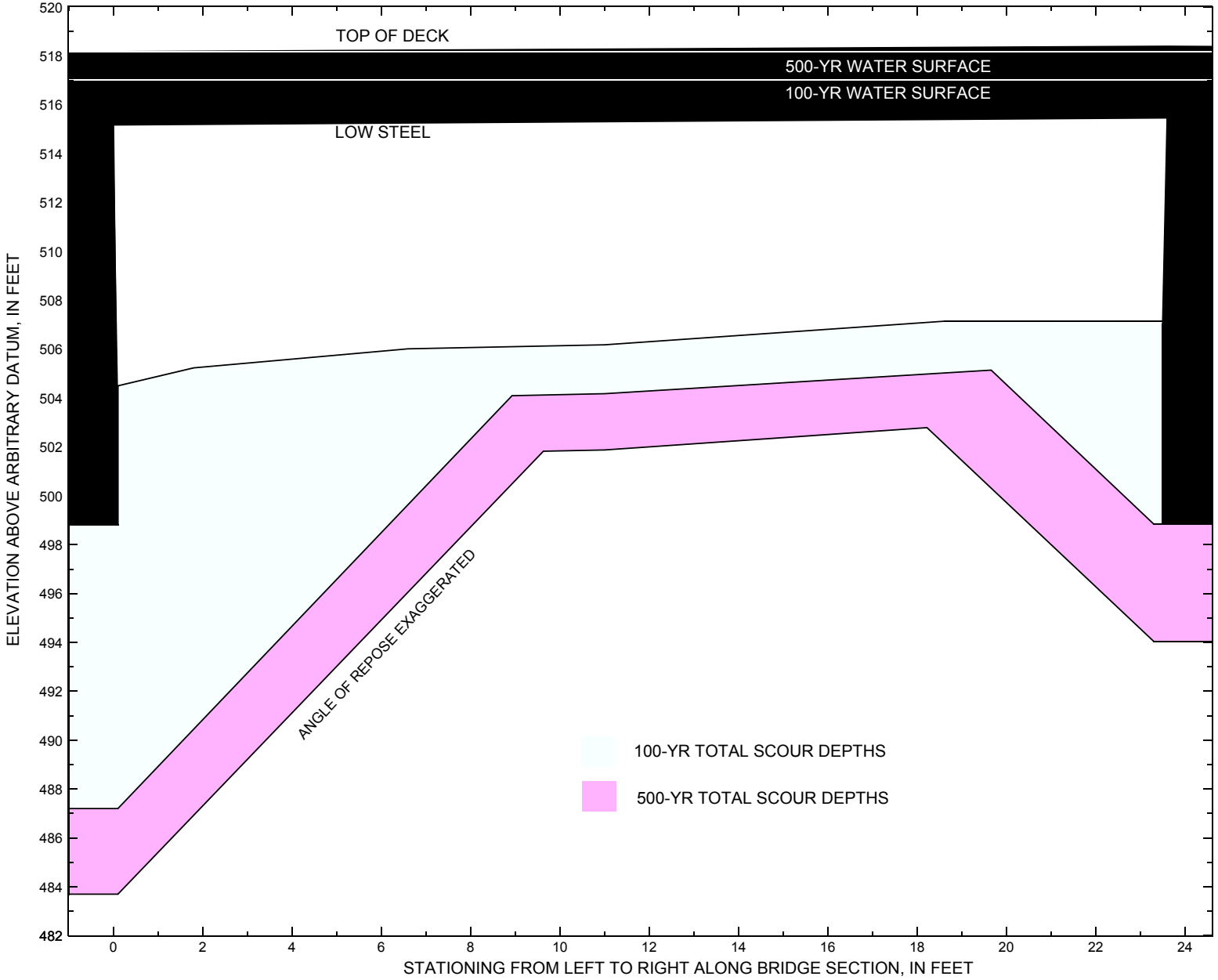


Figure 8. Scour elevations for the 100- and 500-yr discharges at structure ANDOVT00110035 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure ANDOVT00110035 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr discharge is 1,670 cubic-feet per second											
Left abutment	0.0	494.0	515.2	498.8	504.5	2.0	15.3	--	17.3	487.2	-11.6
Right abutment	23.6	494.0	515.5	498.8	507.0	2.0	6.3	--	8.3	498.7	-0.1

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

2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-yr discharge at structure ANDOVT00110035 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr discharge is 2,450 cubic-feet per second											
Left abutment	0.0	494.0	515.2	498.8	504.5	4.3	16.5	--	20.8	483.7	-15.1
Right abutment	23.6	494.0	515.5	498.8	507.0	4.3	8.8	--	13.1	493.9	-4.9

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

2.Arbitrary datum for this study.

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ando035.wsp
T2        Hydraulic analysis for structure ANDOVT00110035   Date: 15-DEC-97
T3        VT 11 CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VT      RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1670.0   2450.0   1500.0
SK          0.0161   0.0161   0.0161
*
XS   EXITX    -30           0.
* GR          -306.1, 516.51   -299.6, 511.64   -264.4, 512.54   -244.1, 507.65
GR          -143.2, 528.32   -115.5, 514.32   -115.5, 508.37
GR             0.0, 509.02      2.4, 507.24      6.7, 505.96      7.9, 505.31
GR            10.9, 505.15     13.4, 505.91     16.4, 505.70     20.0, 505.42
GR            25.2, 505.91     36.1, 506.98     38.0, 509.63     54.7, 510.38
GR           103.0, 511.64    285.9, 519.10    520.5, 523.27    556.0, 525.14
*
N           0.070        0.055        0.060
SA                  0.0         38.0
*
XS   FULLV      0  * * *   0.0030
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    515.32      25.0
GR            0.0, 515.17      0.0, 504.50
GR            1.8, 505.23      6.6, 506.01     11.0, 506.17     15.3, 506.67
GR           18.6, 507.14     23.3, 507.03     23.6, 515.46      0.0, 515.17
*
*          BRTYPE  BRWDTH       WWANGL    WWWID
CD            1      46.1 * *     66.0      8.1
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     14      31.2     1
* GR          -210.8, 532.65   -193.6, 518.10   -172.4, 515.89   -142.2, 516.25
GR          -143.2, 528.32   -121.1, 516.54      0.0, 518.17     24.6, 518.39
GR           140.4, 519.24    356.9, 522.51    700.8, 529.84
*
XT   APTEM     68           0.
GR          -143.2, 528.32   -115.5, 514.32    -56.7, 515.63    -39.8, 514.90
GR           -33.0, 512.33    -28.7, 509.08    -22.9, 508.32    -16.3, 506.76
GR           -13.8, 508.02      0.0, 511.33      5.3, 508.92     12.1, 507.23
GR            13.6, 506.83     20.0, 506.10     22.5, 506.16     24.1, 506.07
GR            24.4, 507.07     25.6, 509.76     35.8, 516.12    367.0, 521.42
GR           519.0, 525.21    559.3, 526.84
*
AS   APPRO     49  * * *  0.0317
GT
N           0.070        0.063        0.070
SA                 -39.8        35.8
*
HP 1 BRIDG  515.46 1 515.46
HP 2 BRIDG  515.46 * * 1670
HP 1 BRIDG  512.09 1 512.09
HP 2 RDWAY  517.03 * * 22
HP 1 APPRO  517.06 1 517.06
HP 2 APPRO  517.06 * * 1670
*
HP 1 BRIDG  515.46 1 515.46
HP 2 BRIDG  515.46 * * 2015
HP 1 BRIDG  512.84 1 512.84
HP 2 RDWAY  518.16 * * 456
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ando035.wsp
        Hydraulic analysis for structure ANDOVT00110035   Date: 15-DEC-97
        VT 11 CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VT      RLB
           *** RUN DATE & TIME: 01-12-98  11:05

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     192.   15208.     0.    62.                          0.
   515.46          192.   15208.     0.    62.  1.00     0.    24.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      515.46     0.0    23.6   192.0   15208.    1670.   8.70

X STA.          0.0        3.0        3.8        4.6        5.5        6.4
  A(I)             27.1        7.3        7.5        7.6        7.8
  V(I)             3.08      11.43      11.17      11.00      10.77

X STA.          6.4        7.4        8.3        9.2       10.2       11.1
  A(I)              7.6        7.7        7.7        7.9        7.9
  V(I)            10.94      10.82      10.79      10.56      10.59

X STA.         11.1       12.1       13.0       14.0       15.0       16.0
  A(I)              7.9        7.8        7.8        8.0        8.0
  V(I)            10.55      10.67      10.66      10.43      10.43

X STA.         16.0       17.1       18.1       19.2       20.2       23.6
  A(I)              7.9        7.9        8.0        8.0       24.4
  V(I)            10.57      10.59      10.40      10.38       3.42

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     123.   10812.    21.    34.                       1682.
   512.09          123.   10812.    21.    34.  1.00     0.    23.   1682.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      14.

        WSEL     LEW     REW    AREA        K        Q    VEL
      517.03  -122.0   -84.7     9.1      76.      22.   2.41

X STA.       -122.0     -120.7     -120.0     -119.2     -118.5     -117.6
  A(I)             0.4        0.4        0.3        0.4        0.4
  V(I)            2.68       3.10       3.18       3.07       2.99

X STA.       -117.6     -116.8     -115.9     -115.0     -114.0     -113.7
  A(I)             0.4        0.4        0.4        0.4        0.1
  V(I)            3.02       2.95       2.87       2.84       8.04

X STA.       -113.7     -113.5     -112.6     -111.7     -110.7     -109.6
  A(I)             0.1        0.3        0.3        0.4        0.4
  V(I)           16.92       3.19       3.16       3.14       2.96

X STA.       -109.6     -108.4     -107.1     -105.7     -104.0      -84.7
  A(I)             0.4        0.4        0.4        0.5        2.5
  V(I)            2.81       2.77       2.55       2.44       0.44

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     210.    8263.    82.    83.                       1898.
             2     615.   55153.    76.    83.                       9948.
             3      74.    1330.    96.    96.                        370.
   517.06          899.   64746.   254.   263.  1.36  -122.   132.   8220.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      517.06  -122.1   132.2   898.7   64746.    1670.   1.86

X STA.       -122.1      -93.2      -60.6      -31.2      -26.6      -23.1
  A(I)            80.1       80.8       87.1       37.0       32.3
  V(I)            1.04       1.03       0.96       2.26       2.58

X STA.        -23.1      -19.9      -16.9      -14.0      -10.5       -6.4
  A(I)            30.9       30.7       30.9       32.3       34.1
  V(I)            2.70       2.72       2.70       2.58       2.45

X STA.         -6.4       -1.2        4.3        8.0       11.2       14.1
  A(I)            37.5       39.3       33.2       31.0       30.4
  V(I)            2.22       2.12       2.52       2.70       2.75

X STA.         14.1       16.7       19.3       21.7       24.5      132.2
  A(I)            28.8       29.5       27.8       31.8      132.9
  V(I)            2.90       2.83       3.00       2.63       0.63
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ando035.wsp
        Hydraulic analysis for structure ANDOVT00110035   Date: 15-DEC-97
        VT 11 CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VT      RLB
           *** RUN DATE & TIME: 01-12-98  11:05

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     192.   15208.     0.    62.                          0.
   515.46          192.   15208.     0.    62.  1.00     0.    24.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      515.46     0.0    23.6   192.0   15208.    2015.  10.50

X STA.          0.0        3.0        3.8        4.6        5.5        6.4
  A(I)             27.1        7.3        7.5        7.6        7.8
  V(I)             3.71      13.79      13.48      13.27      13.00

X STA.          6.4        7.4        8.3        9.2       10.2       11.1
  A(I)              7.6        7.7        7.7        7.9        7.9
  V(I)            13.20      13.05      13.01      12.74      12.78

X STA.         11.1       12.1       13.0       14.0       15.0       16.0
  A(I)              7.9        7.8        7.8        8.0        8.0
  V(I)            12.73      12.87      12.86      12.59      12.59

X STA.         16.0       17.1       18.1       19.2       20.2       23.6
  A(I)              7.9        7.9        8.0        8.0       24.4
  V(I)            12.75      12.78      12.55      12.53       4.13

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     139.   12872.    21.    36.                       2018.
   512.84          139.   12872.    21.    36.  1.00     0.    24.   2018.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      14.

        WSEL     LEW     REW    AREA        K        Q    VEL
      518.16  -124.1    -0.7   100.0    1845.     456.   4.56

X STA.       -124.1     -119.8     -117.4     -115.0     -112.4     -109.7
  A(I)              4.5        3.9        3.8        3.9        3.9
  V(I)             5.08       5.87       6.03       5.82       5.80

X STA.       -109.7     -107.0     -104.0     -101.0      -97.7      -96.6
  A(I)              4.0        4.2        4.1        4.3        1.4
  V(I)             5.69       5.41       5.57       5.25      16.10

X STA.        -96.6      -96.1      -93.1      -90.0      -86.7      -83.2
  A(I)              0.7        3.8        3.8        3.8        4.1
  V(I)            32.10       6.06       5.99       5.95       5.62

X STA.        -83.2      -79.2      -75.0      -70.1      -64.6       -0.7
  A(I)              4.3        4.3        4.7        4.9       27.4
  V(I)             5.33       5.25       4.84       4.62       0.83

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     323.   16623.    85.    86.                       3579.
             2     718.   71368.    76.    83.                      12546.
             3     263.    7180.   181.   181.                       1799.
   518.42          1304.   95170.   342.   351.  1.49  -125.   217.  11839.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      518.42  -124.8   217.2  1304.1   95170.    2450.   1.88

X STA.       -124.8      -99.0      -77.4      -51.4      -31.9      -26.4
  A(I)             96.5       88.5       93.3       89.7       51.2
  V(I)             1.27       1.38       1.31       1.37       2.39

X STA.        -26.4      -22.4      -18.7      -15.2      -11.3       -6.8
  A(I)             41.9       42.0       41.3       42.7       45.0
  V(I)             2.92       2.92       2.97       2.87       2.72

X STA.         -6.8       -1.2        4.8        9.0       12.6       15.8
  A(I)             48.3       51.2       43.8       41.6       38.7
  V(I)             2.54       2.39       2.80       2.95       3.16

X STA.         15.8       18.9       21.9       26.9       58.0      217.2
  A(I)             39.1       38.9       56.3      111.1      202.8
  V(I)             3.13       3.15       2.17       1.10       0.60
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ando035.wsp
        Hydraulic analysis for structure ANDOVT00110035   Date: 15-DEC-97
        VT 11 CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VT      RLB
           *** RUN DATE & TIME: 01-12-98  11:05

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     114.    9723.    21.    33.                       1507.
   511.68          114.    9723.    21.    33.  1.00     0.    23.   1507.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      511.68     0.0    23.5   114.5    9723.    1500.  13.10

X STA.          0.0         3.1         3.8         4.6         5.4         6.2
  A(I)             18.5         4.2         4.2         4.3         4.4
  V(I)             4.05       17.88       17.82       17.51       17.12

X STA.          6.2         7.1         7.9         8.8         9.7        10.6
  A(I)              4.4         4.4         4.4         4.5         4.5
  V(I)            17.07       17.23       16.88       16.58       16.68

X STA.         10.6        11.5        12.4        13.4        14.4        15.4
  A(I)              4.6         4.5         4.6         4.6         4.6
  V(I)            16.32       16.62       16.20       16.38       16.16

X STA.         15.4        16.5        17.6        18.7        19.9        23.5
  A(I)              4.7         4.8         4.8         4.8        14.7
  V(I)            15.99       15.56       15.75       15.68        5.11

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      49.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      72.    1427.    79.    79.                        388.
             2     486.   37310.    75.    83.                       6995.
   515.35          557.   38737.   154.   162.  1.18  -119.    36.   5533.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      515.35  -118.7    35.5   557.2   38737.    1500.   2.69

X STA.       -118.7      -29.8       -26.3       -23.3       -20.6       -18.1
  A(I)            103.1        23.8        22.5        20.9        21.0
  V(I)             0.73        3.15        3.34        3.58        3.58

X STA.        -18.1       -15.9       -13.3       -10.2        -6.6        -2.0
  A(I)             20.4        21.7        22.6        24.0        26.2
  V(I)             3.67        3.46        3.31        3.13        2.86

X STA.         -2.0         3.5         7.0         9.8        12.3        14.5
  A(I)             28.8        23.7        22.3        20.7        20.4
  V(I)             2.60        3.17        3.37        3.63        3.68

X STA.         14.5        16.7        18.7        20.7        22.6        35.5
  A(I)             20.5        19.4        19.6        18.9        57.0
  V(I)             3.66        3.87        3.84        3.97        1.32
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File ando035.wsp
       Hydraulic analysis for structure ANDOVT00110035   Date: 15-DEC-97
       VT 11 CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VT      RLB
          *** RUN DATE & TIME: 01-12-98  11:05

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

EXITX:XS   ******  -116.     302.  0.75 *****  510.79  509.96   1670.  510.04
      -30. ******    47.   13158.  1.57 ***** *******    0.90    5.53

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.43

FULLV:FV      30.  -116.     399.  0.41  0.34  511.11 *******   1670.  510.70
        0.    30.    64.   18878.  1.49  0.00   -0.02    0.60    4.19
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.86     511.10     510.78
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   510.20     527.72    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   510.20     527.72     510.78
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.49

APPRO:AS      49.   -32.     193.  1.16  0.78  512.26  510.78   1670.  511.10
       49.    49.    29.    9303.  1.00  0.38    0.00    0.86    8.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   512.07     515.94     515.97     515.32
 ===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      30.     0.     192.  1.19 *****  516.65  512.09   1676.  515.46
        0. ******    24.   15208.  1.00 ***** *******    0.54    8.73

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.449  0.000  515.32 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.    18.  0.01  0.07  517.12    0.02     22.  517.03

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     22.    37.  -122.   -85.   0.5   0.2   2.6   2.4   0.3   3.0
   RT:      0.   227.    10.   237.   2.4   1.4   7.0   7.4   2.3   3.1

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

APPRO:AS       3.  -122.     900.  0.07  0.02  517.14  510.78   1670.  517.06
       49.     6.   132.   64812.  1.36  1.11    0.02    0.20    1.86

      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     -30.  -116.    47.   1670.   13158.      302.    5.53  510.04
   FULLV:FV       0.  -116.    64.   1670.   18878.      399.    4.19  510.70
   BRIDG:BR       0.     0.    24.   1676.   15208.      192.    8.73  515.46
   RDWAY:RG      14.*******    22.     22.*********       0.    1.00  517.03
   APPRO:AS      49.  -122.   132.   1670.   64812.      900.    1.86  517.06

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    509.96    0.90  505.15  528.32************  0.75  510.79  510.04
   FULLV:FV  ********    0.60  505.24  528.41  0.34  0.00  0.41  511.11  510.70
   BRIDG:BR    512.09    0.54  504.50  515.46************  1.19  516.65  515.46
   RDWAY:RG  ***************  516.54  529.84  0.01******  0.07  517.12  517.03
   APPRO:AS    510.78    0.20  505.47  527.72  0.02  1.11  0.07  517.14  517.06
```

WSPRO OUTPUT FILE (continued)

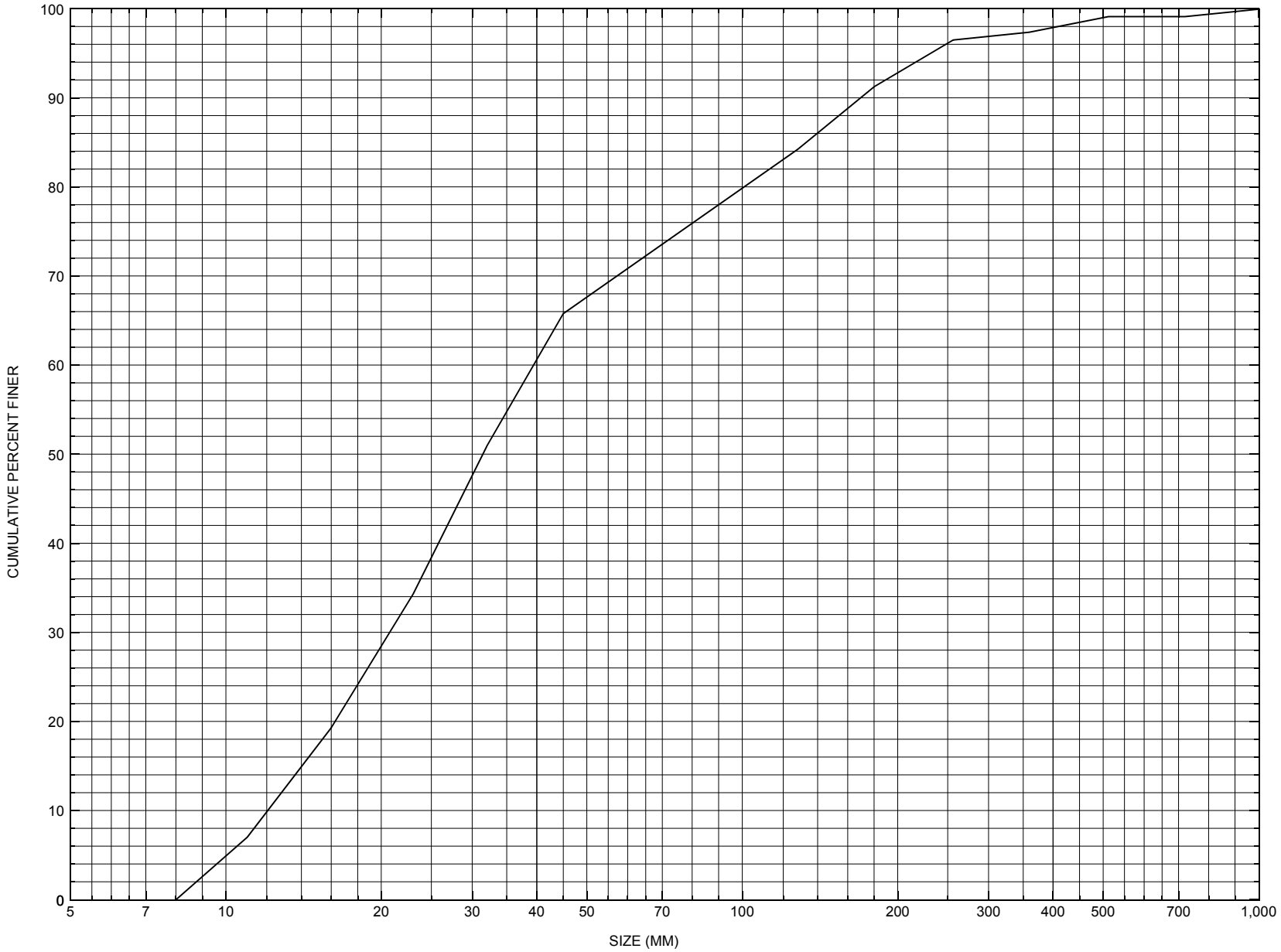
```
       U.S. Geological Survey WSPRO Input File ando035.wsp
       Hydraulic analysis for structure ANDOVT00110035   Date: 15-DEC-97
       VT 11 CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VT      RLB
          *** RUN DATE & TIME: 01-12-98  11:05

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

EXITX:XS   ******  -116.     406.  0.85 *****  511.50  510.49   2450.  510.65
      -30. ******    65.   19304.  1.49 ***** *******    0.87    6.04

FULLV:FV      30.  -116.     518.  0.50  0.35  511.83 *******   2450.  511.33
        0.    30.    88.   26546.  1.45  0.00   -0.02    0.63    4.73
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.03     511.58     511.64
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   510.83     527.72    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   510.83     527.72     511.64
 ===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 =   511.64     527.72     511.64

APPRO:AS      49.   -33.     226.  1.82 *****  513.46  511.64   2450.  511.64
       49.    49.    30.   11892.  1.00 ***** *******    1.00   10.82
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   518.57       0.00     513.74     516.54
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   513.33     517.86     517.89     515.32
 ===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      30.     0.     192.  1.71 *****  517.17  512.84   2015.  515.46
        0. ******    24.   15208.  1.00 ***** *******    0.65   10.50

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.487  0.000  515.32 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.    18.  0.01  0.08  518.49    0.01    456.  518.16

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     456.   124.  -124.     0.   1.6   0.8   4.9   4.5   1.1   3.0
   RT:       0.   227.    10.   237.   2.4   1.4   7.0   7.4   2.3   3.1

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

APPRO:AS       3.  -125.    1304.  0.08  0.02  518.50  511.64   2450.  518.42
       49.     6.   217.   95156.  1.49  1.14    0.01    0.21    1.88

       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     -30.  -116.    65.   2450.   19304.     406.    6.04  510.65
   FULLV:FV       0.  -116.    88.   2450.   26546.     518.    4.73  511.33
   BRIDG:BR       0.     0.    24.   2015.   15208.     192.   10.50  515.46
   RDWAY:RG      14.*******   456.    456.*********       0.    1.00  518.16
   APPRO:AS      49.  -125.   217.   2450.   95156.    1304.    1.88  518.42

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    510.49    0.87  505.15  528.32************  0.85  511.50  510.65
   FULLV:FV  ********    0.63  505.24  528.41  0.35  0.00  0.50  511.83  511.33
   BRIDG:BR    512.84    0.65  504.50  515.46************  1.71  517.17  515.46
   RDWAY:RG  ***************  516.54  529.84  0.01******  0.08  518.49  518.16
   APPRO:AS    511.64    0.21  505.47  527.72  0.02  1.14  0.08  518.50  518.42
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File ando035.wsp
       Hydraulic analysis for structure ANDOVT00110035   Date: 15-DEC-97
       VT 11 CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VT      RLB
          *** RUN DATE & TIME: 01-12-98  11:05

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

EXITX:XS   ******  -116.     277.  0.72 *****  510.61  509.83   1500.  509.89
      -30. ******    44.   11819.  1.59 ***** *******    0.91    5.41

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.46

FULLV:FV      30.  -116.     371.  0.38  0.33  510.93 *******   1500.  510.55
        0.    30.    58.   17207.  1.51  0.00   -0.02    0.60    4.04
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.82     510.96     510.54
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   510.05     527.72    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   510.05     527.72     510.54
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.50

APPRO:AS      49.   -32.     185.  1.02  0.74  511.99  510.54   1500.  510.96
       49.    49.    28.    8675.  1.00  0.32    0.00    0.82    8.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1500.     511.68

           <<<<<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      30.     0.     114.  2.67 *****  514.35  511.68   1500.  511.68
        0.    30.    23.    9711.  1.00 ***** *******    1.00   13.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  515.32 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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       3.  -119.     558.  0.13  0.04  515.49  510.54   1500.  515.35
       49.     6.    36.   38772.  1.18  1.10    0.00    0.27    2.69

      M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
     0.613  0.546   17625.    -1.    23.   515.33

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -30.  -116.    44.   1500.   11819.     277.    5.41  509.89
   FULLV:FV       0.  -116.    58.   1500.   17207.     371.    4.04  510.55
   BRIDG:BR       0.     0.    23.   1500.    9711.     114.   13.11  511.68
   RDWAY:RG      14.**************      0.******************    1.00********
   APPRO:AS      49.  -119.    36.   1500.   38772.     558.    2.69  515.35

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    23.   17625.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    509.83    0.91  505.15  528.32************  0.72  510.61  509.89
   FULLV:FV  ********    0.60  505.24  528.41  0.33  0.00  0.38  510.93  510.55
   BRIDG:BR    511.68    1.00  504.50  515.46************  2.67  514.35  511.68
   RDWAY:RG  ****************  516.54  529.84************************************
   APPRO:AS    510.54    0.27  505.47  527.72  0.04  1.10  0.13  515.49  515.35
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ANDOVT00110035, in Andover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ANDOVT00110035

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 28 / 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)* 000810

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

Road Name *(I - 7)*: -

Route Number VT 11

Vicinity *(I - 9)* 2.0 MI E JCT VT 121

Topographic Map Saxtons River

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43146

Longitude *(i - 17; nnnnn.n)* 72423

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001600351401

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

Maximum span length *(I - 48; nnnn)* 0024

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

Structure length *(I - 49; nnnnnn)* 000028

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

Deck Width *(I - 52; nn.n)* 312

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 1970

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*) 9.5

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 bridge with an asphalt surface. Some slight settlement of the road embankments is reported behind the abutment walls. The structure was widened along each side in 1970 using steel stringers. The upstream right wingwall end has some minor spalling noted. The waterway makes a sharp turn into the structure and there is some very minor localized scour at the upstream end of the left abutment. The streambed consists of stone and gravel with a few random boulders. Very minor bank erosion is reported. The stone fill is normal stone and boulder.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (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)* **4.65** mi^2 Lake/pond/swamp area **0** mi^2

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

Bridge site elevation **1280** ft Headwater elevation **2894** ft

Main channel length **4.13** mi

10% channel length elevation **1332** ft 85% channel length elevation **2165** ft

Main channel slope *(S)* **269.07** 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):* - / 1929

Project Number BMA 6733 Minimum channel bed elevation: 483.0

Low superstructure elevation: USLAB 494.0 DSLAB 494.0 USRAB 494.0 DSRAB 494.0

Benchmark location description:

BM#1, mark on a boulder about 272 feet right bankward on the roadway from the right abutment and 33 feet from the centerline of the roadway perpendicular in a downstream direction near the bottom of a grass slope on the roadway embankment, elevation 500.00.

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: 477.5

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:

Statement on plans: foundations are set in heavy gravel.

Comments:

The plans that exist are for the original T-beam bridge. The structure was rehabilitated in 1970, according to structure records, by widening the upstream and downstream sides (plans not found). Benchmark information is based on the original structure. Other points on the plans with an elevation: 1) The point on the streamward edge, top of concrete at the upstream end of the upstream left wingwall, elevation 494.5. 2) The point at the above described location on the downstream right wingwall, elevation 487.5.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 09/24/96
Computerized by: RB Date: 09/25/96
Reviewd by: RB Date: 01/13/98

Structure Number ANDOVT00110035

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. WILD Date *(MM/DD/YY)* 08 / 28 / 1996

2. Highway District Number 02
County WINDSOR (027)
Waterway *(I - 6)* MIDDLE BR. WILLIAMS RIVER
Route Number VT11
Mile marker 000810
Town ANDOVER (01300)
Road Name -
Hydrologic Unit Code: 01080107

3. Descriptive comments:
This bridge is located 2.0 miles east of the junction with VT 121, also, 0.2 miles west of TH35, Gates Road, and 600 ft southwest of ANDO036.

B. Bridge Deck Observations

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

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

7. Bridge length 28 *(feet)* Span length 24 *(feet)* Bridge width 31.2 *(feet)*

Road approach to bridge:

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

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

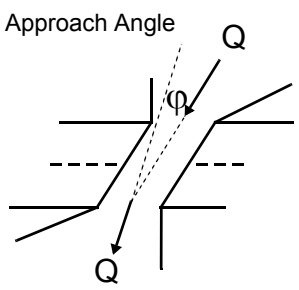
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

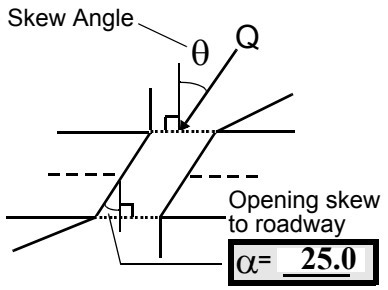
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	2	3	2
RBUS	1	2	2	2
RBDS	1	1	2	1
LBDS	2	1	2	1

*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: 10 16. Bridge skew: 45





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 140 feet US *(US, UB, DS)* to 3 feet UB

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 42 feet DS *(US, UB, DS)* to 104 feet DS

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

18. Bridge Type: **1a**

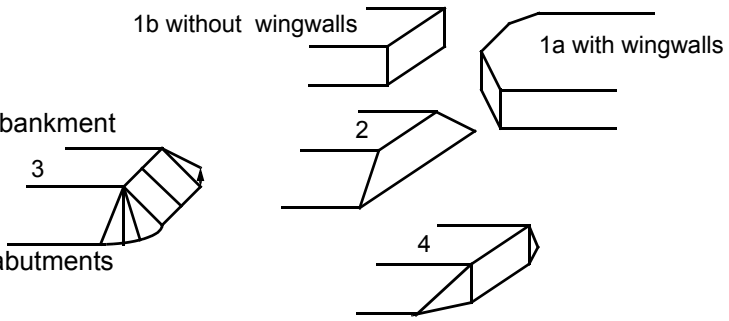
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. The right bank surface cover is trees and brush. The left bank surface cover is trees. State Route 11 crosses the US right bank and the DS left bank.

7. The values are from the VTAOT files. The measured bridge dimensions are the same.

18. The US wingwalls are type 1a and the DS wingwalls are type 4.

C. Upstream Channel Assessment

	21. Bank height (BF)		22. Bank angle (BF)		26. % Veg. cover (BF)		27. Bank material (BF)		28. Bank erosion (BF)	
20. SRD	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
34.0	**6.0**			**6.5**	**3**	**3**	**234**	**234**	**2**	**1**

23. Bank width **25.0** 24. Channel width **30.0** 25. Thalweg depth **75.5** 29. Bed Material **435**

30 .Bank protection type: LB **0** RB **0** 31. 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*

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

At about 135 ft US the US end of a dry channel is close to the left bank. At high flows, the water goes towards the left bank, into this channel, and exits adjacent to the end of the US left wingwall, forming an island.

33. Point/Side bar present? Y *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: 0 US 35. Mid-bar width: 15.5

36. Point bar extent: 29 feet US *(US, UB)* to 42 feet DS *(US, UB, DS)* positioned 25 %LB to 100 %RB

37. Material: 345

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

The DS end of the point bar is gravel, sand and grass with some small trees. An additional point bar extends from 117 ft US to 58 ft US with the mid-bar distance at 105 ft US where it is 11 ft wide. It is positioned from 50% LB to 100% RB and is comprised of cobbles, gravel, and boulders.

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

There is a cut bank in the dry channel on the left bank from 60 ft US to 30 ft US. Mid-bank distance is 35 ft US where it is 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.):

NO CHANNEL SCOUR

49. Are there major confluences? Y *(Y or if N type ctrl-n mc)* 50. How many? 1

51. Confluence 1: Distance 6 52. Enters on LB *(LB or RB)* 53. Type 2 *(**1**- perennial; **2**- ephemeral)*

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

54. Confluence comments (eg. confluence name):

The confluence is 6 ft wide and enters perpendicular to the bridge face.

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
47.0		1.0		2	7	7	-

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

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

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

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

435

-

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

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

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

70. Debris and Ice Comments:

1

66. There is debris caught on the island where the stream bends sharply to go under the bridge.

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	-	90.0
RABUT	1	0	90			2	0	21.5

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.):

-

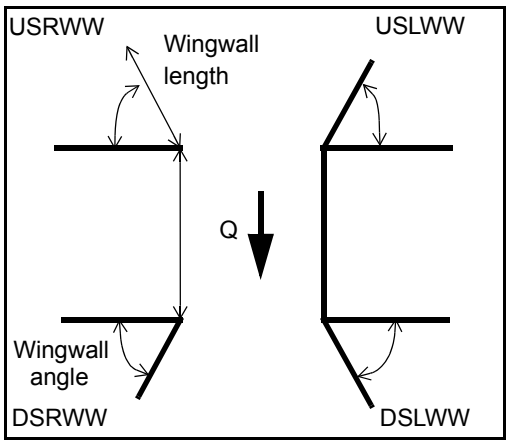
-

1

74. There is scour along the US left wingwall and the left abutment. It is 2.75 ft wide and 42 ft in length. Scour depth assumes a thalweg of 0.3 ft. The left abutment footing at the middle of the bridge is beneath about 0.1 ft of sand and gravel.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						21.5	1.0
USRWW:	Y		1		1	28.0	
DSLWW:	1.5		-		Y	27.5	
DSRWW:	1		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	-	-	-	-	-
Condition	Y	1.75	1	-	-	-	-	-
Extent	1	-	0	0	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*

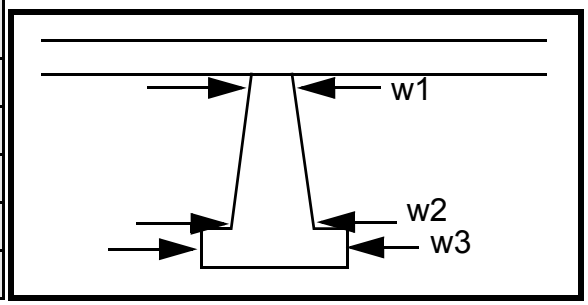
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
0
-
-

Piers:

84. Are there piers? **Th** *(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	**100.0**			**20.0**	**40.0**	**20.0**
Pier 2				**50.0**	**15.5**	**110.0**
Pier 3		-	-	**14.0**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e**	**ment**	**bridge**	**deck.**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**brid**	**joint**	**deck**		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**ge**	**s**	**and**		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**deck**	**with**	**the**		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**was**	**the**	**abut**		*Y- yes; N- no*
91. Attack ∠ (BF)	**wid-**	**wing**	**ment**		
92. Pushed	**ened**	**walls**	**s are**		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**so**	**are**	**nar-**		
95. Cross-members	**that**	**unde**	**rowe**		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**all of**	**rnea**	**r**		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**the**	**th**	**than**	**N**	
98. Exposure depth	**abut**	**the**	**the**	**-**	

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
-	-			-	-	-	-	-	-	-

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

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

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

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

-

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

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

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

-

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

Point bar extent: NO feet PI *(US, UB, DS)* to ERS 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? ____ *(Y or if N type ctrl-n cb)* Where? 3 *(LB or RB)* Mid-bank distance: 2

Cut bank extent: 342 feet 342 *(US, UB, DS)* to 1 feet 2 *(US, UB, DS)*

Bank damage: 435 *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

0
0
-
-

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

Scour dimensions: Length _____ Width _____ Depth: _____ Positioned ____ %LB to ____ %RB

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

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

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

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

Confluence comments (eg. confluence name):

OP STRUCTURE

F. Geomorphic Channel Assessment

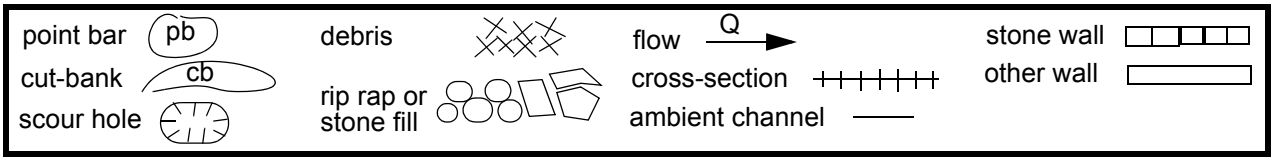
107. Stage of reach evolution ____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

Y
107
9
76
DS
125
DS
0
30
234

109. G. Plan View Sketch - Re



APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: ANDOVT00110035 Town: ANDOVER
Road Number: VT 11 County: WINDSOR
Stream: MIDDLE BRANCH WILLIAMS RIVER

Initials RLB Date: 1/2/98 Checked: MAI

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 Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1670	2450	1500
Main Channel Area, ft2	615	718	486
Left overbank area, ft2	210	323	72
Right overbank area, ft2	74	263	0
Top width main channel, ft	76	76	75
Top width L overbank, ft	82	85	79
Top width R overbank, ft	96	181	0
D50 of channel, ft	0.1032	0.1032	0.1032
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.1	9.4	6.5
y1, average depth, LOB, ft	2.6	3.8	0.9
y1, average depth, ROB, ft	0.8	1.5	ERR
Total conveyance, approach	64746	95170	38737
Conveyance, main channel	55153	71368	37310
Conveyance, LOB	8263	16623	1427
Conveyance, ROB	1330	7180	0
Percent discrepancy, conveyance	0.0000	-0.0011	0.0000
Qm, discharge, MC, cfs	1422.6	1837.3	1444.7
Ql, discharge, LOB, cfs	213.1	427.9	55.3
Qr, discharge, ROB, cfs	34.3	184.8	0.0
Vm, mean velocity MC, ft/s	2.3	2.6	3.0
Vl, mean velocity, LOB, ft/s	1.0	1.3	0.8
Vr, mean velocity, ROB, ft/s	0.5	0.7	ERR
Vc-m, crit. velocity, MC, ft/s	7.5	7.6	7.2
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1670	2450	1500
(Q) discharge thru bridge, cfs	1670	2015	1500
Main channel conveyance	15208	15208	9723
Total conveyance	15208	15208	9723
Q2, bridge MC discharge,cfs	1670	2015	1500
Main channel area, ft2	192	192	115
Main channel width (normal), ft	21.4	21.4	21.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.4	21.4	21.3
y_bridge (avg. depth at br.), ft	8.97	8.97	5.38
Dm, median (1.25*D50), ft	0.129	0.129	0.129
y2, depth in contraction,ft	9.30	10.93	8.52
ys, scour depth (y2-ybridge), ft	0.33	1.96	**3.14**

Armoring

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

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1670	2015	1500
Main channel area (DS), ft2	123	139	114.5
Main channel width (normal), ft	21.4	21.4	21.3
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	21.4	21.4	21.3
D90, ft	0.5563	0.5563	0.5563
D95, ft	0.7601	0.7601	0.7601
Dc, critical grain size, ft	0.7946	0.8617	0.7606
Pc, Decimal percent coarser than Dc	0.043	0.034	0.050
Depth to armoring, ft	**N/A**	**N/A**	**N/A**

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	1670	2450	1500
Q, thru bridge MC, cfs	1670	2015	1500
Vc, critical velocity, ft/s	7.45	7.65	7.18
Va, velocity MC approach, ft/s	2.31	2.56	2.97
Main channel width (normal), ft	21.4	21.4	21.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.4	21.4	21.3
qbr, unit discharge, ft2/s	78.0	94.2	70.4
Area of full opening, ft2	192.0	192.0	114.5
Hb, depth of full opening, ft	8.97	8.97	5.38
Fr, Froude number, bridge MC	0.54	0.65	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	123	139	0
**Hb, depth at downstream face, ft	5.75	6.50	0.00
**Fr, Froude number at DS face	1.00	1.00	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	515.32	515.32	0
Elevation of Bed, ft	506.35	506.35	-5.38
Elevation of Approach, ft	517.06	518.42	0
Friction loss, approach, ft	0.02	0.02	0
Elevation of WS immediately US, ft	517.04	518.40	0.00
ya, depth immediately US, ft	10.69	12.05	5.38
Mean elevation of deck, ft	518.28	518.28	0
w, depth of overflow, ft (>=0)	0.00	0.12	0.00
Cc, vert contrac correction (<=1.0)	0.96	0.93	1.00
**Cc, for downstream face (<=1.0)	0.79	0.79	0
Ys, scour w/Chang equation, ft	**1.97**	**4.29**	N/A
Ys, scour w/Umbrell equation, ft	-3.15	-2.15	N/A

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

**Ys, scour w/Chang equation, ft	7.51	9.09	N/A

**Ys, scour w/Umbrell equation, ft	0.07	0.33	ERR

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

y2, from Laursen's equation, ft	9.30	10.93	8.52
WSEL at downstream face, ft	512.09	512.84	0.00
Depth at downstream face, ft	5.75	6.50	0.00
Ys, depth of scour (Laursen), ft	3.56	4.43	N/A

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 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	1670	2450	1500	1670	2450	1500
a', abut.length blocking flow, ft	123.2	125.9	119.8	109.7	194.7	13.1
Ae, area of blocked flow ft2	520.83	600.23	322.43	155.61	363.44	58.99
Qe, discharge blocked abut.,cfs	--	--	792.27	143.14	352.8	82.89
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.80	1.99	2.46	0.92	0.97	1.41
ya, depth of f/p flow, ft	4.23	4.77	2.69	1.42	1.87	4.50
--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	0.153	0.149	0.264	0.136	0.125	0.117
ys, scour depth, ft	**15.25**	**16.49**	**14.43**	**6.28**	**8.78**	**7.93**

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	123.2	125.9	119.8	109.7	194.7	13.1
y1 (depth f/p flow, ft)	4.23	4.77	2.69	1.42	1.87	4.50
a'/y1	29.14	26.41	44.51	77.33	104.30	2.91
Skew correction (p. 49, fig. 16)	1.06	1.06	1.06	0.92	0.92	0.92
Froude no. f/p flow	0.15	0.15	0.26	0.14	0.13	0.12
Ys w/ corr. factor K1/0.55:						
vertical	17.47	19.53	13.32	4.90	6.27	ERR
vertical w/ ww's	14.33	16.02	10.92	4.02	5.14	ERR
spill-through	9.61	10.74	7.32	2.69	3.45	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 Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	1	1	1	1
y, depth of flow in bridge, ft	5.75	6.50	5.38	5.75	6.50	5.38
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.40	2.72	2.25	2.40	2.72	2.25