LEVEL II SCOUR ANALYSIS FOR BRIDGE 41 (ANDOVT00110041) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

Open-File Report 97-771

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 41 (ANDOVT00110041) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

By EMILY C. WILD and ROBERT E. HAMMOND

U.S. Geological Survey
Open-File Report 97-771

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

Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
Mark Schaefer, Acting Director

For additional information
write to:

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

Copies of this report may be
purchased from:

U.S. Geological Survey
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 41 (ANDOVT00110041) ON STATE ROUTE 11, CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

By **Emily C. Wild 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 ANDOVT00110041 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 southeastern Vermont. The 12.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is grass on the upstream right overbank while the immediate banks have dense woody vegetation. The upstream left overbank and downstream right overbank are brushland. The downstream left overbank is forested.

In the study area, the Middle Branch Williams River has an incised, sinuous channel with a slope of approximately 0.018 ft/ft, an average channel top width of 71 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 85.0 mm (0.279 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 10, 1996, indicated that the reach was laterally unstable due to a cut-bank present on the upstream right bank and a wide channel bar with vegetation in the upstream reach.

The State Route 11 crossing of the Middle Branch Williams River is a 46-ft-long, two-lane bridge consisting of a concrete 44-foot tee-beam span (Vermont Agency of Transportation, written communication, March 29, 1995). The opening length of the structure parallel to the bridge face is 42 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 35 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 0.8 ft deeper than the mean thalweg depth was observed along the downstream end of the left abutment and downstream left wingwall during the Level I assessment. Type-2 stone fill (less than 36 inches diameter) protects the upstream end of the upstream left wingwall, the downstream ends of the downstream left and right wingwalls and the downstream right road embankment. Type-3 stone fill protects the upstream end of the upstream right wingwall and the upstream right bank. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 2.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 11.1 to 18.7 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Essex Junction, VT. Quadrangle, 1:24,000, 1948, photoinspected 1987

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.

Figure 3. Structure ANDOVT00110041 viewed from upstream (November 8, 1994).

Figure 5. Upstream channel viewed from structure ANDOVT00110041 (November 8, 1994).

LEVEL II SUMMARY

Structure Number ANDOVT00110041 ***Stream*** Middle Branch Williams River

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

Description of Bridge

Bridge length 46 ***ft*** ***Bridge width*** 35 ***ft*** ***Max span length*** 44 ***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*** 9/10/96

Description of stone fill Type-2, along the upstream end of the upstream left wingwall, the downstream end of the downstream wingwalls, and the downstream right road embankment. Type-3, along the upstream end of the upstream right wingwall and the upstream right bank. Abutments and

Brief description of piers/abutments wingwalls are concrete. There is a scour hole along the downstream end of the left abutment and the downstream left wingwall.

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

Y 35

There is a moderate channel bend in the upstream reach and in the downstream 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	9/10/96	0	0
Level II	9/10/96	0	0

Potential for debris Moderate. There is some debris caught on boulders and trees in the upstream reach.

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

None. 9/10/96

Description of the Geomorphic Setting

General topography The channel is located within a narrow, irregular flood plain with steep valley walls on both sides.

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

Date of inspection 9/10/96

DS left: Narrow flood plain with a steep valley wall.

DS right: Narrow flood plain.

US left: Narrow flood plain.

US right: Steep channel bank.

Description of the Channel

Average top width 71 ***ft***   ***Average depth*** 4 ***ft***

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

Sinuous but stable with alluvial channel boundaries and a narrow flood plain.

9/10/96

Vegetative co Trees and brush.

DS left: Trees and brush.

DS right: Short grass and brush with trees on immediate banks.

US left: Brush, grass and trees.

US right: N

Do banks appear stable? During the 9/10/96 site visit, the banks appear to be laterally unstable. Light to moderate fluvial erosion was noted along the upstream right bank. Moderate to severe fluvial erosion was noted along the downstream left bank.

date of observation.

The assessment of 9/10/96 noted a vegetated point bar along the right abutment.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 12.1 ***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? Yes

USGS gage description Williams River at Brockways Mills, VT

USGS gage number 01153500

Gage drainage area 103 ***mi²***

Is there a lake/ No

Calculated Discharges

Q100 3,270 ***ft³/s*** ***Q500*** 4,810 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(12.1/14.8)exp 0.68] with discharge values above the Andover Branch confluence, published in the Flood Insurance Study for the Town of Chester, VT (Federal Emergency Management Agency, 1982). Andover Branch enters the Middle Branch Williams River downstream of this site. These values are within a range defined by several empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans To obtain VTAOT datum, add 569.7 ft to USGS survey.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the right end of the downstream curb (elev. 500.11 ft, arbitrary survey datum). RM2 is a chiseled X on top of the left end of the upstream curb (elev. 501.04 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	-42	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	19	1	Road Grade section
APPRO	82	1	Approach section as surveyed

[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 0.055, and overbank "n" values ranged from 0.048 to 0.110.

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 0.0180 ft/ft, which was calculated from thalweg points surveyed downstream of the bridge.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 499.9 *ft*
Average low steel elevation 496.1 *ft*

100-year discharge 3,270 *ft³/s*
Water-surface elevation in bridge opening 496.3 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 362 *ft²*
Average velocity in bridge opening 9.0 *ft/s*
Maximum WSPRO tube velocity at bridge 12.3 *ft/s*

Water-surface elevation at Approach section with bridge 498.1
Water-surface elevation at Approach section without bridge 494.6
Amount of backwater caused by bridge 3.5 *ft*

500-year discharge 4,810 *ft³/s*
Water-surface elevation in bridge opening 496.4 *ft*
Road overtopping? Y *Discharge over road* 421 *ft³/s*
Area of flow in bridge opening 362 *ft²*
Average velocity in bridge opening 12.1 *ft/s*
Maximum WSPRO tube velocity at bridge 14.3 *ft/s*

Water-surface elevation at Approach section with bridge 501.1
Water-surface elevation at Approach section without bridge 496.1
Amount of backwater caused by bridge 5.0

Incipient overtopping discharge 4,010 *ft³/s*
Water-surface elevation in bridge opening 496.4 *ft*
Area of flow in bridge opening 362 *ft²*
Average velocity in bridge opening 11.1 *ft/s*
Maximum WSPRO tube velocity at bridge 13.1 *ft/s*

Water-surface elevation at Approach section with bridge 499.7
Water-surface elevation at Approach section without bridge 495.3
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 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.

The 100-year, 500-year, and incipient roadway-overtopping discharges modelled 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.

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 Umbrell's pressure-flow scour equation (Richardson and other, 1995, p. 144-146), and the results are presented in Appendix F. Furthermore, since 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 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 at the left abutment for all discharges was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	2.1	1.1
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	13.6	18.7	16.9
Right abutment	11.1	14.6	12.4
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	2.4	2.9	2.7
Right abutment	2.4	2.9	2.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

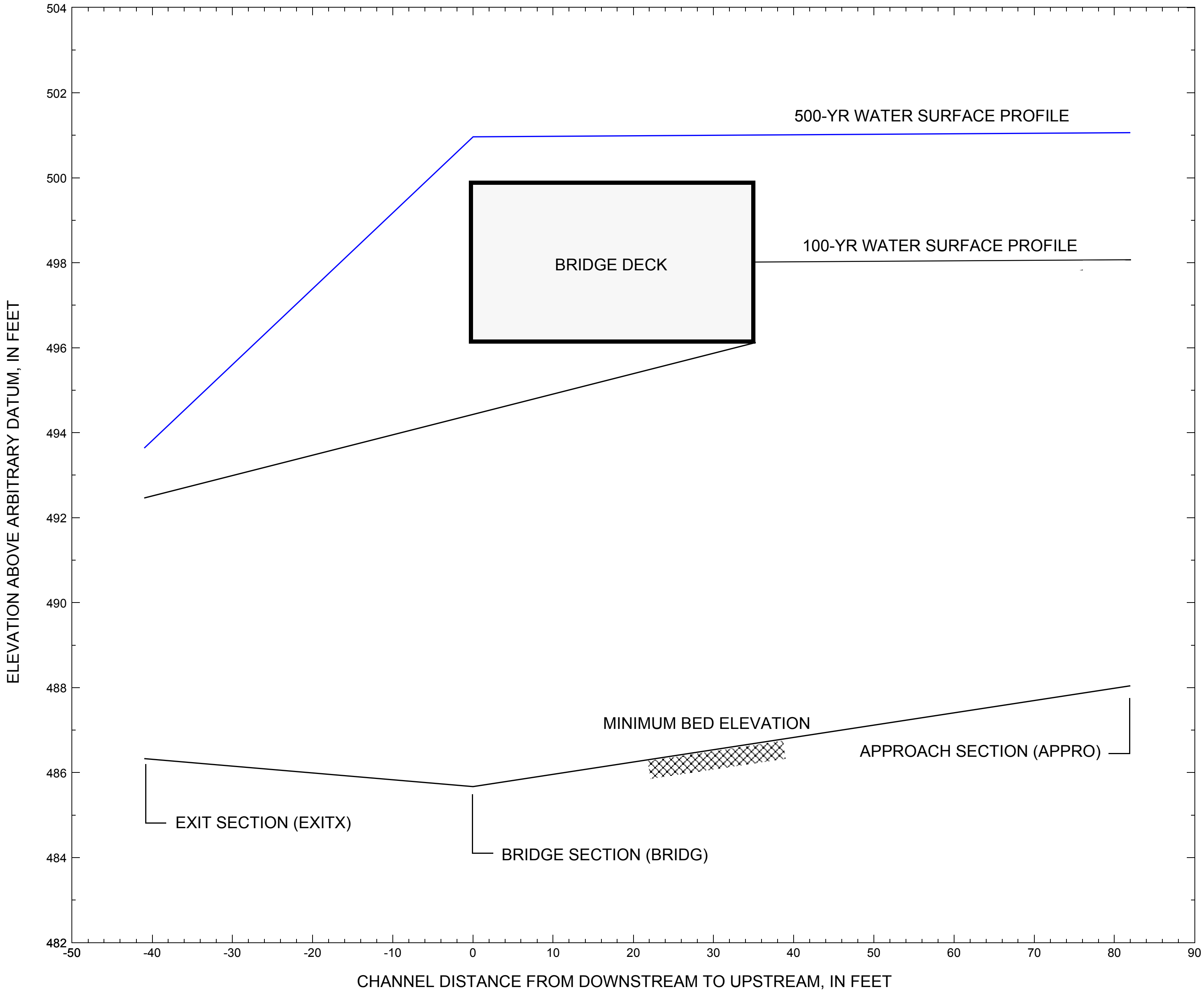


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ANDOVT00110041 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

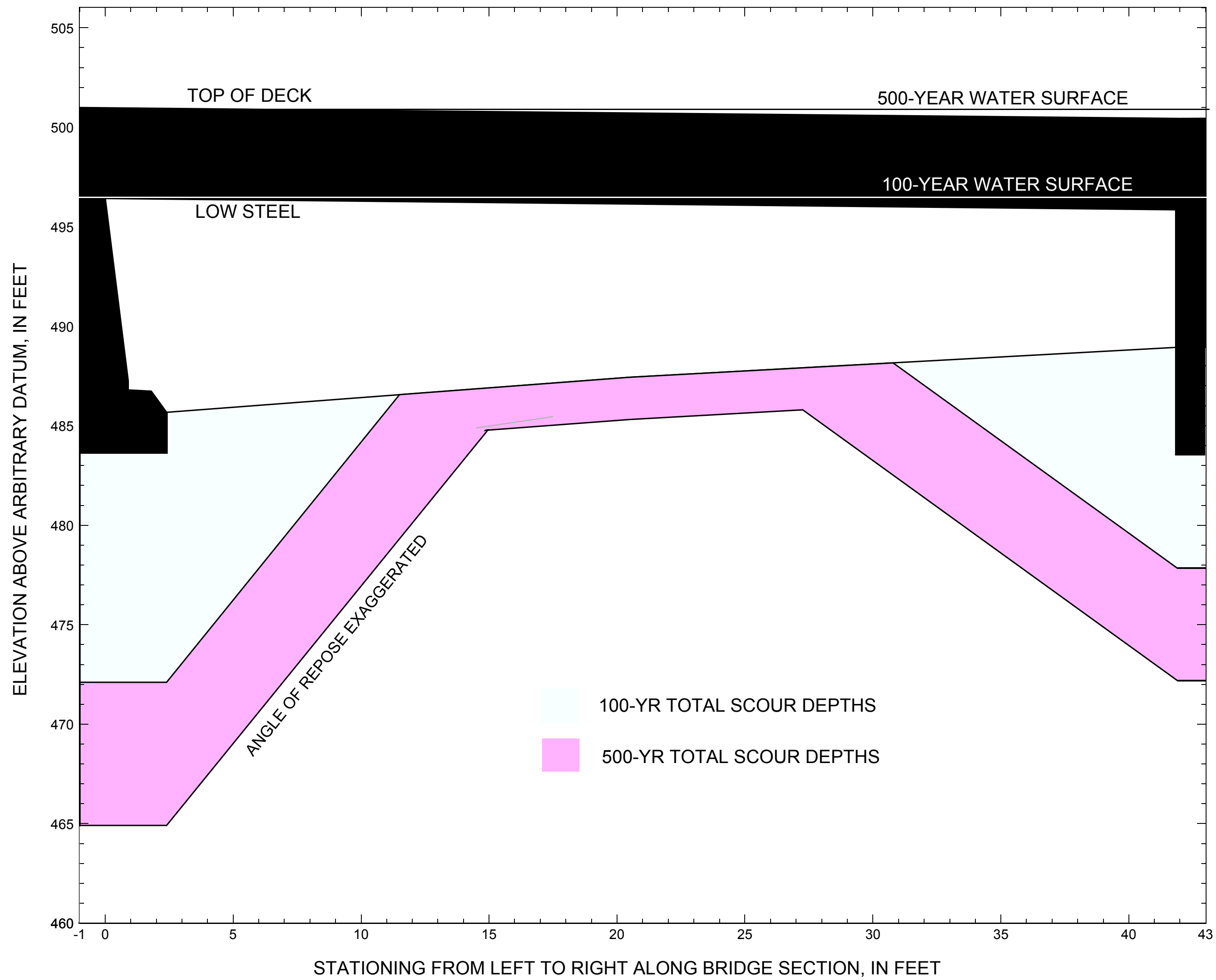


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ANDOVT00110041 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ANDOVT00110041 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 3,270 cubic-feet per second											
Left abutment	0.0	1065.8	496.4	483.5	485.7	0.0	13.6	--	13.6	472.1	-11.4
Right abutment	42.0	1065.3	495.9	483.5	488.9	0.0	11.1	--	11.1	477.8	-5.7

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 ANDOVT00110041 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 4,810 cubic-feet per second											
Left abutment	0.0	1065.8	496.4	483.5	485.7	2.1	18.7	--	20.8	464.9	-18.6
Right abutment	42.0	1065.3	495.9	483.5	488.9	2.1	14.6	--	16.7	472.2	-11.3

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158.

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

Federal Emergency Management Agency, 1982, Flood Insurance Study, Town of Chester, Windsor County, Vermont: Washington, D.C., February 1982.

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

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 ando041.wsp
T2        Hydraulic analysis for structure ANDOVT00110041   Date: 03-FEB-97
T3        VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT  ECW
*
J1         * * 0.0005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3270.0   4810.0   4010.0
SK          0.0180   0.0180   0.0180
*
XS   EXITX    -42           0.
GR         -203.9, 522.62   -128.0, 495.98    -79.5, 495.55    -36.6, 494.56
GR          -16.3, 491.00    -13.3, 488.03     -9.0, 487.61      0.0, 486.95
GR            0.9, 486.38      6.4, 486.33     12.6, 486.58     13.8, 486.95
GR           26.3, 487.99     44.7, 489.08     51.7, 490.62     54.6, 493.85
GR           78.7, 495.69    176.7, 496.22    241.5, 497.62    272.3, 496.82
GR          315.0, 502.45
*
N           0.080        0.051        0.110
SA                 -16.3         54.6
*
*
XS   FULLV      0  * * *   0.0139
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.14       0.0
GR            0.0, 496.42      0.9, 487.25      0.9, 486.79      1.8, 486.73
GR            2.4, 485.67      6.4, 486.05     12.3, 486.64     20.5, 487.43
GR           41.9, 488.94     42.0, 495.85      0.0, 496.42
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      45.0 * *     42.7      8.1
N           0.040
*
*             SRD   EMBWID  IPAVE
XR   RDWAY     19     35.0     1
GR         -592.6, 515.31   -180.0, 502.86     -1.0, 500.20     -1.0, 500.95
GR            0.0, 500.98     42.8, 500.44     44.2, 500.42     44.3, 499.61
GR          286.4, 502.73
*
*
AS   APPRO     82
GR         -504.5, 513.00   -443.5, 508.45   -141.4, 500.81    -95.8, 496.67
GR          -19.4, 493.21    -11.4, 491.77      0.0, 490.28      4.1, 489.29
GR            6.2, 489.00      8.1, 488.66     20.1, 489.22     26.4, 488.82
GR           31.1, 488.22     34.1, 488.04     37.2, 489.05     39.8, 490.06
GR           47.9, 491.45     52.2, 500.85    252.3, 501.79
*
N           0.048        0.055       0.080
SA                   0.0        52.2
*
HP 1 BRIDG 496.33 1 496.33
HP 2 BRIDG 496.33 * * 3270
HP 1 BRIDG 493.35 1 493.35
HP 1 APPRO 498.07 1 498.07
HP 2 APPRO 498.07 * * 3270
*
HP 1 BRIDG 496.42 1 496.42
HP 2 BRIDG 496.42 * * 4389
HP 1 BRIDG 494.60 1 494.60
HP 2 RDWAY 500.96 * * 421
HP 1 APPRO 501.06 1 501.06
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ando041.wsp
        Hydraulic analysis for structure ANDOVT00110041   Date: 03-FEB-97
        VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT  ECW
           *** RUN DATE & TIME: 07-01-97  08:59

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      362     33212      7     94                        15182
   496.33           362     33212      7     94  1.00      0     42    15182


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.33     0.0    42.0   362.0   33212.    3270.   9.03

X STA.        0.0        3.2        4.7        6.0        7.3        8.9
  A(I)            27.1       15.7       13.3       14.1       15.7
  V(I)            6.04      10.44      12.27      11.60      10.39

X STA.        8.9       10.5       12.1       13.8       15.5       17.3
  A(I)            15.6       15.6       16.4       16.2       16.4
  V(I)           10.45      10.48       9.97      10.09       9.99

X STA.       17.3       19.2       21.2       23.2       25.3       27.6
  A(I)            17.0       17.2       17.3       17.9       18.4
  V(I)            9.60       9.53       9.43       9.15       8.87

X STA.       27.6       29.8       32.3       34.9       37.8       42.0
  A(I)            18.0       19.2       19.8       21.2       29.7
  V(I)            9.07       8.51       8.24       7.71       5.50


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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      246     25539     42     53                         3388
   493.35           246     25539     42     53  1.00      0     42     3388


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      375     26103    111    112                         3905
             2      432     45841     51     56                         7152
   498.07           807     71944    162    167  1.12   -110     51     9647


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.07  -111.2    50.9   807.4   71944.    3270.   4.05

X STA.     -111.2      -62.0      -43.5      -30.6      -20.2      -12.0
  A(I)            83.9       62.1       52.5       47.8       44.8
  V(I)            1.95       2.63       3.12       3.42       3.65

X STA.      -12.0       -6.1       -1.1        3.1        6.6        9.8
  A(I)            38.8       36.4       33.7       30.9       30.5
  V(I)            4.21       4.49       4.85       5.29       5.36

X STA.        9.8       13.2       16.6       20.1       23.7       27.0
  A(I)            31.1       30.6       31.5       31.9       30.8
  V(I)            5.25       5.34       5.19       5.12       5.31

X STA.       27.0       30.4       33.5       37.0       41.8       50.9
  A(I)            32.2       31.1       33.8       39.1       53.8
  V(I)            5.08       5.25       4.84       4.18       3.04
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ando041.wsp
        Hydraulic analysis for structure ANDOVT00110041   Date: 03-FEB-97
        VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT  ECW
           *** RUN DATE & TIME: 07-01-97  08:59

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      362     31755      0    100                            0
   496.42           362     31755      0    100  1.00      0     42        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.42     0.0    42.0   362.3   31755.    4389.  12.12

X STA.         0.0        3.4        5.1        6.8        8.3        9.9
  A(I)             29.1       18.4       17.0       16.0       15.9
  V(I)             7.53      11.92      12.89      13.70      13.80

X STA.         9.9       11.5       13.1       14.8       16.5       18.3
  A(I)             15.4       15.8       15.6       15.9       16.1
  V(I)            14.29      13.87      14.11      13.78      13.64

X STA.        18.3       20.1       22.0       24.0       26.0       28.1
  A(I)             16.0       16.7       16.6       17.1       16.9
  V(I)            13.72      13.17      13.22      12.82      13.01

X STA.        28.1       30.4       32.7       35.2       37.9       42.0
  A(I)             18.0       17.9       19.0       20.3       28.5
  V(I)            12.16      12.25      11.56      10.80       7.71

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      298     34126     42     55                         4514
   494.60           298     34126     42     55  1.00      0     42     4514

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      19.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.96   -52.1   149.1   101.7    1266.     421.   4.14

X STA.       -52.1      -18.2      -11.6       -7.1       25.5       38.4
  A(I)              8.6        3.7        2.9        8.0        4.9
  V(I)             2.46       5.73       7.34       2.65       4.26

X STA.        38.4       45.2       47.1       49.0       50.8       52.6
  A(I)              4.2        2.5        2.4        2.3        2.2
  V(I)             4.99       8.38       8.63       9.07       9.53

X STA.        52.6       54.3       57.8       62.0       66.5       71.8
  A(I)              2.2        4.2        4.7        5.0        5.4
  V(I)             9.73       4.98       4.46       4.20       3.89

X STA.        71.8       77.7       84.7       93.7      106.1      149.1
  A(I)              5.6        6.2        6.9        7.8       11.9
  V(I)             3.73       3.42       3.03       2.69       1.77

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      758     68679    151    152                         9619
             2      587     73568     52     59                        11164
             3        5        19     45     45                            9
   501.06          1349    142267    248    255  1.09   -150     97    17113

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.06  -151.3    96.9  1349.0  142267.    4810.   3.57

X STA.      -151.3      -87.9      -69.7      -55.2      -43.2      -33.0
  A(I)            143.0       93.9       85.6       78.0       71.3
  V(I)             1.68       2.56       2.81       3.08       3.37

X STA.       -33.0      -23.7      -15.5       -8.9       -3.3        1.7
  A(I)             69.7       64.7       60.2       56.5       53.4
  V(I)             3.45       3.71       4.00       4.26       4.50

X STA.         1.7        6.1       10.3       14.4       18.7       23.1
  A(I)             51.5       50.9       50.9       50.9       52.8
  V(I)             4.67       4.73       4.72       4.72       4.56

X STA.        23.1       27.3       31.5       35.9       41.1       96.9
  A(I)             51.1       52.8       56.6       60.3       94.8
  V(I)             4.71       4.55       4.25       3.99       2.54
```

```
      U.S. Geological Survey WSPRO Input File ando041.wsp
      Hydraulic analysis for structure ANDOVT00110041   Date: 03-FEB-97
      VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT  ECW
         *** RUN DATE & TIME: 07-01-97  08:59

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

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1       362     31755      0    100                            0
 496.42           362     31755      0    100  1.00      0     42        0


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

       WSEL     LEW     REW    AREA        K        Q    VEL
     496.42     0.0    42.0   362.3   31755.    4010.  11.07

X STA.         0.0        3.4        5.1        6.8        8.3        9.9
  A(I)            29.1       18.4       17.0       16.0       15.9
  V(I)            6.88      10.89      11.77      12.52      12.60

X STA.         9.9       11.5       13.1       14.8       16.5       18.3
  A(I)            15.4       15.8       15.6       15.9       16.1
  V(I)           13.05      12.67      12.89      12.59      12.46

X STA.        18.3       20.1       22.0       24.0       26.0       28.1
  A(I)            16.0       16.7       16.6       17.1       16.9
  V(I)           12.54      12.04      12.08      11.71      11.88

X STA.        28.1       30.4       32.7       35.2       37.9       42.0
  A(I)            18.0       17.9       19.0       20.3       28.5
  V(I)           11.11      11.19      10.56       9.86       7.04


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

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1       272     29776     42     54                         3942
 493.98           272     29776     42     54  1.00      0     42     3942


  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1       576     48216    130    130                         6890
          2       518     60636     52     58                         9310
 499.74          1094    108852    181    188  1.08   -129     52    14647


  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

       WSEL     LEW     REW    AREA        K        Q    VEL
     499.74  -129.6    51.7  1094.2  108852.    4010.   3.66

X STA.      -129.6      -79.2      -60.8      -46.9      -35.1      -25.1
  A(I)           109.3       78.0       68.9       65.2       60.6
  V(I)            1.83       2.57       2.91       3.08       3.31

X STA.       -25.1      -16.5       -9.8       -4.2        0.7        4.9
  A(I)            56.0       51.3       48.3       44.8       43.3
  V(I)            3.58       3.91       4.15       4.48       4.63

X STA.         4.9        8.8       12.7       16.6       20.6       24.6
  A(I)            41.8       42.2       42.0       42.7       42.6
  V(I)            4.79       4.75       4.77       4.69       4.71

X STA.        24.6       28.4       32.3       36.3       41.3       51.7
  A(I)            42.2       43.9       46.4       50.2       74.3
  V(I)            4.75       4.57       4.32       3.99       2.70
```

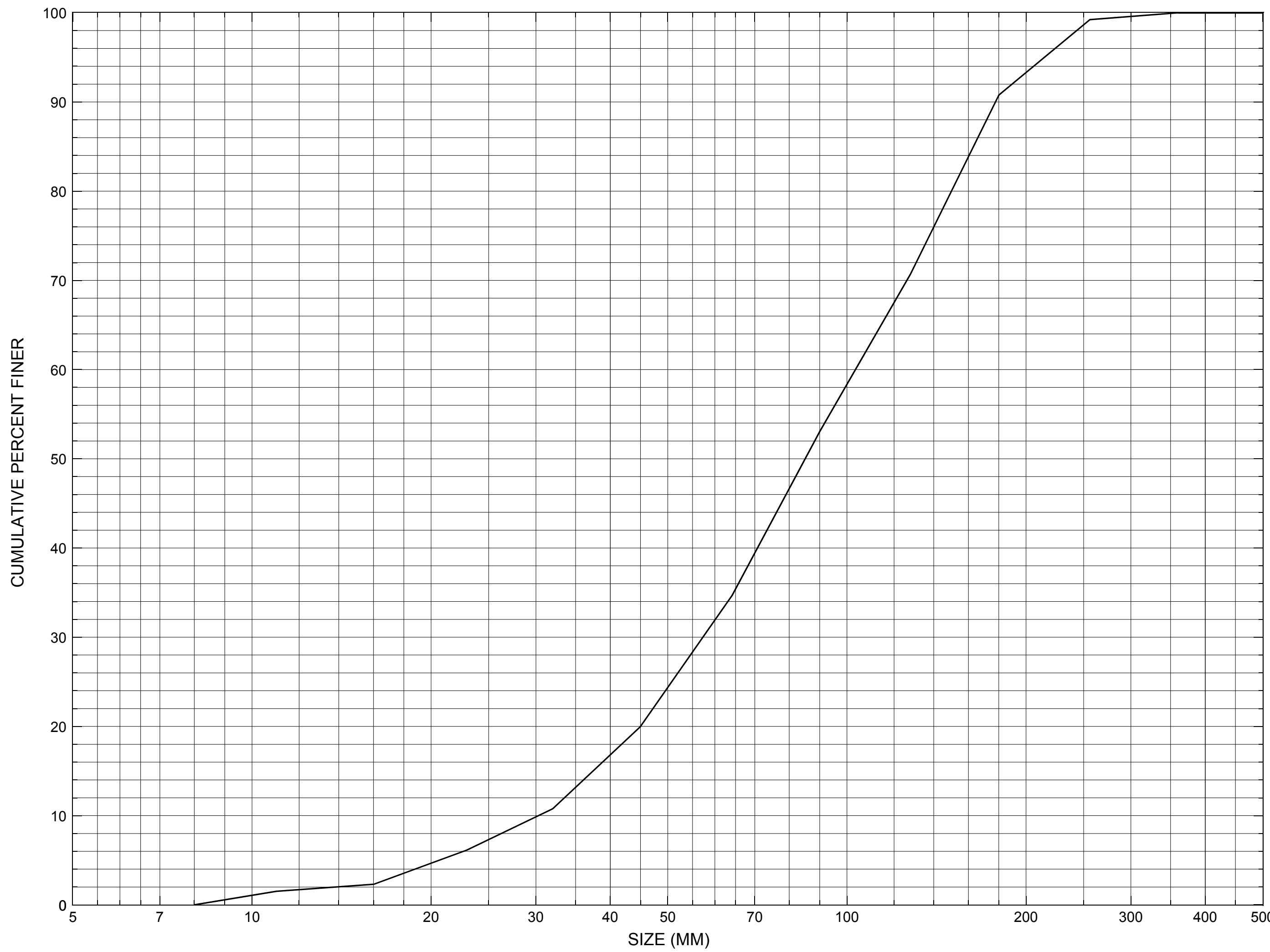
```
 U.S. Geological Survey WSPRO Input File ando041.wsp
 Hydraulic analysis for structure ANDOVT00110041   Date: 03-FEB-97
 VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT  ECW
    *** RUN DATE & TIME: 07-01-97  08:59

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

EXITX:XS   ******    -24      319  1.68 *****  494.14  492.08    3270  492.46
       -41 ******     53    24366  1.03 ***** *******    0.91   10.26

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.83     493.34     492.66

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   491.96     523.20    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   491.96     523.20     492.66

FULLV:FV       42    -25      343  1.47  0.68  494.82  492.66    3270  493.35
         0     42     54    27112  1.04  0.00   -0.01    0.83    9.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.98     494.62     494.45

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   492.85     513.00    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   492.85     513.00     494.45

APPRO:AS       82    -50      341  1.63  1.35  496.26  494.45    3270  494.63
        82     82     49    23986  1.14  0.08    0.02    0.98    9.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   493.22     496.33     496.68     496.14

 ===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       42      0      362  1.27 *****  497.60  493.22    3270  496.33
         0 ******     42    33200  1.00 ***** *******    0.54    9.03

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.447  0.000  496.14 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      19.        <<<<<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       37   -110      808  0.29  0.17  498.36  494.45    3270  498.07
        82     38     51    72034  1.12  0.79    0.00    0.34    4.05

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   497.98

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -42.   -25.    53.   3270.   24366.     319.   10.26  492.46
   FULLV:FV       0.   -26.    54.   3270.   27112.     343.    9.54  493.35
   BRIDG:BR       0.     0.    42.   3270.   33200.     362.    9.03  496.33
   RDWAY:RG      19.**************      0.*****************     1.00********
   APPRO:AS      82.  -111.    51.   3270.   72034.     808.    4.05  498.07

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    492.08    0.91  486.33  522.62************  1.68  494.14  492.46
   FULLV:FV    492.66    0.83  486.91  523.20  0.68  0.00  1.47  494.82  493.35
   BRIDG:BR    493.22    0.54  485.67  496.42************  1.27  497.60  496.33
   RDWAY:RG  ****************  499.61  515.31************  0.12  500.45********
   APPRO:AS    494.45    0.34  488.04  513.00  0.17  0.79  0.29  498.36  498.07
```

```
        U.S. Geological Survey WSPRO Input File ando041.wsp
        Hydraulic analysis for structure ANDOVT00110041   Date: 03-FEB-97
        VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT  ECW
           *** RUN DATE & TIME: 07-01-97  08:59

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

EXITX:XS   ******    -30      415  2.22 *****  495.86  493.34    4810  493.64
       -41 ******     54    35841  1.06 ***** *******    0.96   11.58

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.88     494.59     493.93

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.14     523.20    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.14     523.20     493.93

FULLV:FV       42    -33      449  1.92  0.68  496.53  493.93    4810  494.60
         0     42     57    40027  1.08  0.00   -0.01    0.88   10.72
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.91     496.10     495.77

 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   494.10     513.00    0.50

 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   494.10     513.00     495.77

APPRO:AS       82    -83      514  1.60  1.19  497.71  495.77    4810  496.11
        82     82     50    39850  1.17  0.00   -0.01    0.91    9.36
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.92     499.03     499.29     496.14

 ===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       42      0      362  2.28 *****  498.70  494.46    4389  496.42
         0 ******     42    31755  1.00 ***** *******    0.73   12.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.496  0.000  496.14 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      19.    47.  0.05  0.21  501.22    0.00    421.  500.96

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     91.    67.   -52.    18.   0.8   0.3   3.5   4.4   0.6   3.1
   RT:    330.   130.    18.   149.   1.3   0.6   4.3   4.1   0.9   3.1

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

APPRO:AS       37   -150     1350  0.21  0.18  501.28  495.77    4810  501.06
        82     39     98   142333  1.09  0.78    0.00    0.28    3.56

       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     -42.   -31.    54.   4810.   35841.     415.   11.58  493.64
   FULLV:FV       0.   -34.    57.   4810.   40027.     449.   10.72  494.60
   BRIDG:BR       0.     0.    42.   4389.   31755.     362.   12.11  496.42
   RDWAY:RG      19.*******    91.    421.******************    1.00  500.96
   APPRO:AS      82.  -151.    98.   4810.  142333.    1350.    3.56  501.06

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    493.34    0.96  486.33  522.62************  2.22  495.86  493.64
   FULLV:FV    493.93    0.88  486.91  523.20  0.68  0.00  1.92  496.53  494.60
   BRIDG:BR    494.46    0.73  485.67  496.42************  2.28  498.70  496.42
   RDWAY:RG  ***************  499.61  515.31  0.05******  0.21  501.22  500.96
   APPRO:AS    495.77    0.28  488.04  513.00  0.18  0.78  0.21  501.28  501.06
```

```
       U.S. Geological Survey WSPRO Input File ando041.wsp
       Hydraulic analysis for structure ANDOVT00110041   Date: 03-FEB-97
       VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT  ECW
          *** RUN DATE & TIME: 07-01-97  08:59

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

EXITX:XS   ******    -27      366  1.95 *****  495.00  492.71    4010  493.05
      -41 ******     54    29880  1.05 ***** *******    0.93   10.95

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.85     493.97     493.29

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   492.55     523.20    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   492.55     523.20     493.29

FULLV:FV       42    -29      394  1.70  0.68  495.68  493.29    4010  493.98
         0     42     54    33270  1.06  0.00   -0.01    0.85   10.17
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.98     495.29     495.14

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   493.48     513.00    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   493.48     513.00     495.14

APPRO:AS       82    -64      411  1.71  1.31  497.00  495.14    4010  495.29
        82     82     50    30288  1.16  0.01    0.01    0.98    9.75
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.06     497.69     497.99     496.14

 ===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       42      0      362  1.91 *****  498.33  494.06    4011  496.42
         0 ******     42    31755  1.00 ***** *******    0.66   11.07

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.489  0.000  496.14 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      19.        <<<<<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       37   -129     1094  0.23  0.18  499.96  495.14    4010  499.74
        82     39     52   108792  1.08  0.79    0.00    0.27    3.67

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.67

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

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -42.   -28.    54.   4010.   29880.     366.   10.95  493.05
   FULLV:FV       0.   -30.    54.   4010.   33270.     394.   10.17  493.98
   BRIDG:BR       0.     0.    42.   4011.   31755.     362.   11.07  496.42
   RDWAY:RG      19.**************      0.       0.       0.    1.00********
   APPRO:AS      82.  -130.    52.   4010.  108792.    1094.    3.67  499.74

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  **********************
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    492.71    0.93  486.33  522.62************  1.95  495.00  493.05
   FULLV:FV    493.29    0.85  486.91  523.20  0.68  0.00  1.70  495.68  493.98
   BRIDG:BR    494.06    0.66  485.67  496.42************  1.91  498.33  496.42
   RDWAY:RG  ****************  499.61  515.31************  0.23  499.90********
   APPRO:AS    495.14    0.27  488.04  513.00  0.18  0.79  0.23  499.96  499.74
  ER

  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ANDOVT00110041, in Andover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ANDOVT00110041

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)* 002670

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

Road Name *(I - 7):* -

Route Number VT 11

Vicinity *(I - 9)* 4.0 MI E JCT VT 121

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43156

Longitude *(i - 17; nnnnn.n)* 72421

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001600411401

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

Maximum span length *(I - 48; nnnn)* 0044

Year built *(I - 27; YYYY)* 1927

Structure length *(I - 49; nnnnnn)* 000046

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

Deck Width *(I - 52; nn.n)* 350

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

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

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

Waterway adequacy *(I - 71; n)* 3

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) ______

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

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

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

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

Comments:

The structural inspection report of 11/10/93 indicates the structure is a concrete T-beam type bridge with an asphault roadway surface. The deck was extensively rehabilitated in the summer of 1992. Both abutment walls are older sections of concrete walls with newer ends. Along the bottom of the original concrete wall of the left abutment there is some deep erosion of the concrete. Erosion extends up to 9 inches behind the front face of the abutment wall. The footing is in view along the older portion, and for the most part appears to be quite sound. It does have some deep erosion. The newer section of the footing is exposed along the downstream end of the left abutment, but there is no apparent **(Continued, page 33)**

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:
undermining. There is a very small area where the top of the footing is exposed on the newer portion at the upstream end of the right abutment. All four wingwalls are in new condition. The waterway has a slight turn through the structure. The streambed consists of stone and boulders. There is a cobble bar roughly 100 feet upstream.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **12.07** mi^2 Lake and pond area **0** mi^2
Watershed storage *(ST)* **0** %
Bridge site elevation **1088** ft Headwater elevation **2894** ft
Main channel length **6.05** mi
10% channel length elevation **1140** ft 85% channel length elevation **1988** ft
Main channel slope *(S)* **186.93** 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)*: **03** / **1962**

Project Number **MA259/25.03M/1960** Minimum channel bed elevation: **1057.2**

Low superstructure elevation: USLAB **1066.10** DSLAB **1065.83** USRAB **1065.54** DSRAB **1065.27**

Benchmark location description:

BM#38: spot on the upstream right wingwall, elevation 1068.69 transferred, now probably closer to 1068.88.

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: **1053.2**

If 2: Pile Type: ____ (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: _______

If 3: Footing bottom elevation: ______

Is boring information available? **N** *If no, type ctrl-n bi* Number of borings taken: **-**

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION.

Comments:

Plans are for bridge widening. The abutments were lengthened and footings set 2.3 feet lower than the bottom of the original footing set at 1055.5, which still remains for the middle 19 feet of the abutment walls. Other elevation points: 1. on the streamward edge of the upstream right wingwall on top of the concrete where the concrete slope declines, elevation 1068.88; 2. point at the same location as described above except on the upstream left wingwall, elevation 1069.44.

Cross-sectional Data

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

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

Comments: **Several cross sections are available on the plans and may be retrieved when needed.**

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:

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **10/01/96**
Computerized by: **RB** Date: **10/01/96**
Reviewd by: **EW** Date: **7/01/97**

Structure Number **ANDOVT00110041**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. HAMMOND** Date *(MM/DD/YY)* **09** / **10** / 19**96**
2. Highway District Number **02** Mile marker **002670**
   County **WINDSOR (027)** Town **ANDOVER (01300)**
   Waterway *(I - 6)* **MIDDLE BR. WILLIAMS RIVER** Road Name **-**
   Route Number **VT11** Hydrologic Unit Code: **01080107**
3. Descriptive comments:
Located 4.0 miles east of junction with VT 121 and about 1.1 miles west of the Andover/Chester town line.

B. Bridge Deck Observations

4. Surface cover... LBUS **5** RBUS **2** LBDS **6** RBDS **5** Overall **5**
*(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 **46** *(feet)* Span length **44** *(feet)* Bridge width **35** *(feet)*

Road approach to bridge:

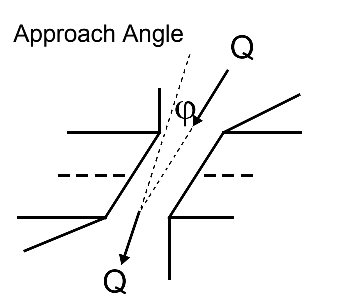
8. LB **2** RB **0** *(**0** even, **1**- lower, **2**- higher)*
9. LB **1** RB **1** *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

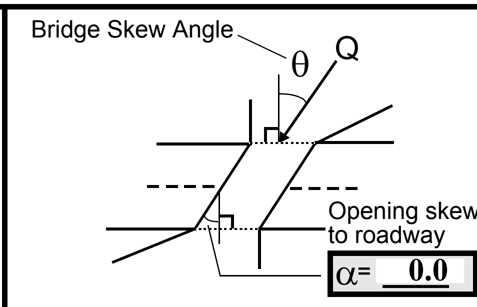
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	2	1	0	-
LBDS	0	-	2	1

*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: **35** 16. Bridge skew: **35**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **3**
Range? **180** feet **US** *(US, UB, DS)* to **0** feet **US**
Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **0** feet **US** *(US, UB, DS)* to **85** feet **DS**

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

18. Bridge Type: 1a

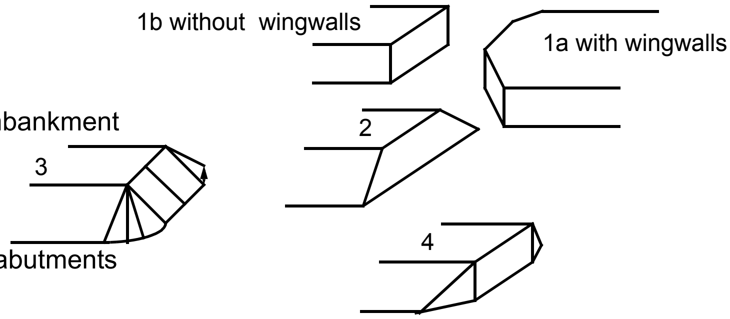
1a- Vertical abutments with wingwalls

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 immediate banks are all tree covered. On the upstream left and right banks there are houses and lawns. On the right bank downstream there is a house and lawn and a fence with pine trees along Vermont 11. The right bank downstream is forest.

7. Values are from the Vermont AOT files. Measured bridge length is 45.8 ft downstream and 45.9 ft upstream, span length is 42.8 ft downstream and 42.9 ft upstream, and the bridge width is 30.1 ft from curb to curb and 34.9 ft between the outsides of bridge deck.

13. On the left bank upstream there is a very small tributary at the base of the road embankment that has type 2 protection.

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
44.0	1.5			9.5	4	2	342	342	0	1

23. Bank width 10.0 24. Channel width 60.0 25. Thalweg depth 71.5 29. Bed Material 345

30 .Bank protection type: LB 0 RB 3 31. Bank protection condition: LB - RB 1

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

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

30. The right bank protection is from 10 ft upstream to 50 ft upstream.
At 300 ft upstream the channel starts to widen and the gradient becomes flatter as it goes through a 120 degree bend to the left. At this location in the channel, the bed material is smaller. High banks on both sides have trees of at least 1 ft in diameter.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **130** 35. Mid-bar width: **25**

36. Point bar extent: **250** feet **US** *(US, UB)* to **13** feet **UB** *(US, UB, DS)* positioned **0** %LB to **40** %RB

37. Material: **342**

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

There is also a channel bar from 190 ft upstream to 25 ft upstream with a width of 16 ft and a mid-bar distance of 80 ft upstream. It is positioned from 50% left bank to 70% right bank, at its widest point. The channel bar has grass and woody vegetation growing on it.

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: **65** 42. Cut bank extent: **175** feet **US** *(US, UB)* to **35** feet **US** *(US, UB, DS)*

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

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

At the downstream end of the cut-bank, large chunks of concrete have been placed to establish some stability along the cut-bank.

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES
A minor ephemeral tributary is on the left bank at 20 ft upstream.

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
59.5		0.5		2	7	7	0

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

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

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

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

345

The bridge deck was widened and steel I beams were added at the upstream and downstream bridge faces. Upstream, the concrete low chord is 0.6 ft lower than the steel and downstream it is only 0.4 ft lower. The difference between the steel low chord and its bridge seat is 0.2 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? **1**___ *(Y or N)* Ice Blockage Potential **N**____ *(**1**- Low; **2**- Moderate; **3**- High)*

70. Debris and Ice Comments:

1

There is some debris caught on boulders and trees in the upstream reach.

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		**35**	**90**	**2**	**2**	**0.8**	**0.85**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**0**	**42.0**

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*

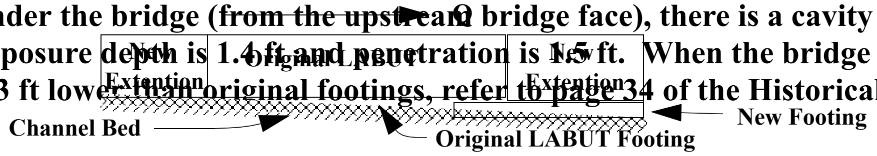
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

-

-

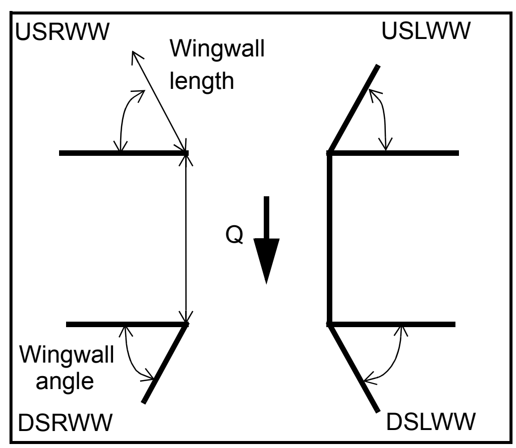
1

Average thalweg is 0.5 ft. The left abutment footing is above the new footing extending from 26 ft under the bridge (from the upstream bridge face) to 36 ft under the bridge (from the upstream bridge face). The old footing is from 9 ft. under the bridge to 26 ft. under the bridge. At the junction of the two footings at 26 ft under the bridge (from the upstream bridge face), there is a cavity and the old footing is undermined. The exposure depth is 1.4 ft and penetration is 1.5 ft. When the bridge was widened, the footings were extended 2.3 ft lower than original footings, refer to page 34 of the Historical Form.



80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**42.0**	
USRWW:	**Y**		**1**		**0**	**1.5**	
DSLWW:	**-**		**-**		**Y**	**38.0**	
DSRWW:	**1**		**2**		**0**	**37.0**	



*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	**0**	**2**	**Y**	**-**	**1**	**1**	**-**	**-**
Condition	**Y**	**0.8**	**1**	**-**	**2**	**2**	**-**	**-**
Extent	**1**	**0.85**	**0**	**2**	**3**	**0**	**0**	**-**

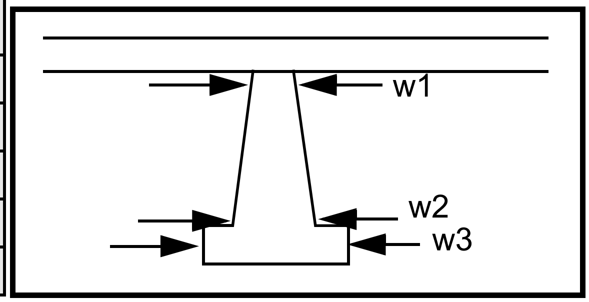
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
3
2
1
3

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**40.0**	**11.0**	**45.0**
Pier 2				**11.0**	**45.0**	**11.5**
Pier 3			-	**45.0**	**11.5**	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**wall**	**w**		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**top**	**is**	**the**		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**of**	**expo**	**imm**		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**the**	**sed**	**edi-**		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**foot-**	**but**	**ate**		*Y- yes; N- no*
91. Attack ∠ (BF)	**ing**	**the**	**grad**		
92. Pushed	**of**	**strea**	**e of**	**N**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**the**	**mwa**	**the**	-	
95. Cross-members	**upst**	**rd**	**bed.**	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**ream**	**edge**		-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**right**	**is**		-	
98. Exposure depth	**wing**	**belo**		-	

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 (Amb) - Bed Material -

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

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

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

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

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

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

NO PIERS

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

Point bar extent: ______ feet ____ *(US, UB, DS)* to ______ feet ____ *(US, UB, DS)* positioned ____ %LB to _____ %RB

Material: **4**

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

4
34
34
2

Is a cut-bank present? **0** *(Y or if N type ctrl-n cb)* Where? **345** *(LB or RB)* Mid-bank distance: **2**

Cut bank extent: **0** feet **3** *(US, UB, DS)* to **-** feet **Th** *(US, UB, DS)*

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

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

is evidence of bank protection from 10 ft downstream to 100 ft downstream on the left bank. Between 20 ft downstream and 60 ft downstream the protection is eroded.

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? **N** *(Y or if N type ctrl-n mc)* How many? **-**

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

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

Confluence comments (eg. confluence name):

RE

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
100
30
5
UB
160
DS
30
100
345

109. G. Plan View Sketch

- A

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: ANDOVT00110041 Town: ANDOVER
Road Number: VERMONT 11 County: WINDSOR
Stream: MIDDLE BRANCH WILLIAMS RIVER

Initials ECW Date: 5/9/97 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	3270	4810	4010
Main Channel Area, ft2	432	587	518
Left overbank area, ft2	375	758	576
Right overbank area, ft2	0	5	0
Top width main channel, ft	51	52	52
Top width L overbank, ft	111	151	130
Top width R overbank, ft	0	45	0
D50 of channel, ft	0.279	0.279	0.279
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.5	11.3	10.0
y1, average depth, LOB, ft	3.4	5.0	4.4
y1, average depth, ROB, ft	ERR	0.1	ERR
Total conveyance, approach	71944	142267	108606
Conveyance, main channel	45841	73568	60543
Conveyance, LOB	26103	68679	48063
Conveyance, ROB	0	19	0
Percent discrepancy, conveyance	0.0000	0.0007	0.0000
Qm, discharge, MC, cfs	2083.6	2487.3	2235.4
Ql, discharge, LOB, cfs	1186.4	2322.0	1774.6
Qr, discharge, ROB, cfs	0.0	0.6	0.0
Vm, mean velocity MC, ft/s	4.8	4.2	4.3
Vl, mean velocity, LOB, ft/s	3.2	3.1	3.1
Vr, mean velocity, ROB, ft/s	ERR	0.1	ERR
Vc-m, crit. velocity, MC, ft/s	10.5	11.0	10.7
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)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	3270	4810	4010
(Q) discharge thru bridge, cfs	3270	4389	4010
Main channel conveyance	33212	31755	31755
Total conveyance	33212	31755	31755
Q2, bridge MC discharge,cfs	3270	4389	4010
Main channel area, ft2	362	362	362
Main channel width (normal), ft	42.0	42.0	42.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	42	42	42
y_bridge (avg. depth at br.), ft	8.62	8.62	8.62
Dm, median (1.25*D50), ft	0.34875	0.34875	0.34875
y2, depth in contraction,ft	6.99	8.99	8.32
ys, scour depth (y2-ybridge), ft	-1.63	0.38	-0.29

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	3270	4810	4010
Q, thru bridge MC, cfs	3270	4389	4010
Vc, critical velocity, ft/s	10.46	10.97	10.74
Va, velocity MC approach, ft/s	4.82	4.24	4.32
Main channel width (normal), ft	42.0	42.0	42.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	42.0	42.0	42.0
qbr, unit discharge, ft2/s	77.9	104.5	95.5
Area of full opening, ft2	362.0	362.0	362.0
Hb, depth of full opening, ft	8.62	8.62	8.62
Fr, Froude number, bridge MC	0.54	0.73	0.66
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	246	298	272
**Hb, depth at downstream face, ft	5.86	7.10	6.48
**Fr, Froude number at DS face	0.97	0.97	1.02
**Cf, for downstream face (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	496.14	496.14	496.14
Elevation of Bed, ft	487.52	487.52	487.52
Elevation of Approach, ft	498.07	501.06	499.74
Friction loss, approach, ft	0.17	0.18	0.18
Elevation of WS immediately US, ft	497.90	500.88	499.56
ya, depth immediately US, ft	10.38	13.36	12.04
Mean elevation of deck, ft	500.71	500.71	500.71
w, depth of overflow, ft (>=0)	0.00	0.17	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.89	0.91
**Cc, for downstream face (<=1.0)	0.810794	0.79	0.79
Ys, scour w/Chang equation, ft	-0.82	2.12	1.09
Ys, scour w/Umbrell equation, ft	-1.45	-0.39	-0.97

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

**Ys, scour w/Chang equation, ft	3.32	4.96	4.77

```
 **Ys, scour w/Umbrell equation, ft  1.32     1.14     1.18

 In UNsubmerged orifice flow, an adjusted scour depth using the Laursen
 equation results and the estimated downstream bridge face properties
 can also be computed (ys=y2-ybridgeDS)
    y2, from Laursen's equation, ft  6.99     8.99     8.32
    WSEL at downstream face, ft      493.35   494.60   493.99
    Depth at downstream face, ft     5.86     7.10     6.48
 Ys, depth of scour (Laursen), ft    1.13     1.90     1.85

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  3270     4389     4010
   Main channel area (DS), ft2       246      298      272
   Main channel width (normal), ft   42.0     42       42.0
   Cum. width of piers, ft           0.0      0.0      0.0
   Adj. main channel width, ft       42.0     42.0     42.0
 D90, ft                             0.5829   0.5829   0.5829
 D95, ft                             0.7043   0.7043   0.7043
 Dc, critical grain size, ft         0.7704   0.8748   0.9093
 Pc, Decimal percent coarser than Dc 0.028    0.007    0.006

 Depth to armoring, ft                    N/A      N/A      N/A
Abutment Scour

 Froehlich's Abutment Scour
 Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
 (Richardson and others, 1995, p. 48, eq. 28)

                                     Left Abutment             Right Abutment
 Characteristic                    100 yr Q 500 yr Q Other Q  100 yr Q 500 yr Q Other Q

   (Qt), total discharge, cfs        3270     4810     4010     3270     4810     4010
 a', abut.length blocking flow, ft   111.1    150.9    129.6    8.9      10.2     9.7
 Ae, area of blocked flow ft2        373.8    756.6    576      52.5     69.6     69.3
 Qe, discharge blocked abut.,cfs     1187.3     --     1775.9   159.9      --     187
   (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)
 Ve, (Qe/Ae), ft/s                   3.18     3.07     3.08     3.04     2.55     2.70
 ya, depth of f/p flow, ft           3.36     5.01     4.44     5.90     6.82     7.14

 --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                               90       90       90       90       90       90
 K2                                  1.00     1.00     1.00     1.00     1.00     1.00

 Fr, froude number f/p flow          0.305    0.242    0.258    0.221    0.340    0.178

 ys, scour depth, ft                 17.02    21.98    19.87    11.11    14.64    12.44

 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)	111.1	150.9	129.6	8.9	10.2	9.7
y1 (depth f/p flow, ft)	3.36	5.01	4.44	5.90	6.82	7.14
a'/y1	33.02	30.10	29.16	1.51	1.49	1.36
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.31	0.24	0.26	0.22	0.34	0.18
Ys w/ corr. factor K1/0.55:						
vertical	16.54	22.82	20.66	ERR	ERR	ERR
vertical w/ ww's	13.56	18.71	16.94	ERR	ERR	ERR
spill-through	9.10	12.55	11.36	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)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.97	0.97	1.02	0.97	0.97	1.02
y, depth of flow in bridge, ft	5.86	7.10	6.48	5.86	7.10	6.48
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.)	2.43	2.94	2.72	2.43	2.94	2.72