LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (ANDOTH00010007) on TOWN HIGHWAY 1 (FAS 132), crossing ANDOVER BRANCH, ANDOVER, VERMONT

U.S. Geological Survey
Open-File Report 97-186

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

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By ROBERT H. FLYNN

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Pembroke, New Hampshire

1997

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

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (ANDOTH00010007) ON TOWN HIGHWAY 1 (FAS 132), CROSSING ANDOVER BRANCH, ANDOVER, VERMONT

By **Robert H. Flynn**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ANDOTH00010007 on Town Highway 1 crossing Andover Branch, 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 southern Vermont. The 7.21-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream of the bridge while the immediate banks have dense woody vegetation. Downstream of the bridge, the banks and overbanks are forested.

In the study area, Andover Branch has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 45 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 58.0 mm (0.19 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 due to evidence of lateral movement of the channel 200 feet upstream along the left bank and near the bridge along the right bank.

The Town Highway 1 crossing of Andover Branch is a 32-ft-long, two-lane bridge consisting of one 29-foot concrete slab span (Vermont Agency of Transportation, written communication, March 28, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

The scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the entire base length of the upstream wingwalls and type-3 stone fill (less than 48 inches diameter) along the entire base length of the downstream wingwalls and the right abutment. Additional details describing conditions at the site are included in the Level II Summary and Appendices
D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 1.6 ft. The worst-case contraction scour occurred at the 100-year discharge. Abutment scour ranged from 7.1 to 10.7 ft at the right abutment with the worst-case abutment scour occurring at the 500-year discharge. Abutment scour ranged from 7.5 to 8.3 ft at the left abutment with the worst-case abutment scour occurring at the incipient road overtopping 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. 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.

Andover, VT. Quadrangle, 1:24,000, 1971

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

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

LEVEL II SUMMARY

Structure Number ANDOTH00010007 ***Stream*** Andover Branch

County Windsor ***Road*** TH 1 ***District*** 2

Description of Bridge

Bridge length 32 ***ft*** ***Bridge width*** 29.4 ***ft*** ***Max span length*** 29 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 8/28/96

Description of stone fill Type-2 stone fill at the upstream wingwalls and type-3 stone fill at the downstream wingwalls and along the right abutment in good condition.

Abutments and wingwalls are concrete.

Brief description of piers/abutments

Y

Is bridge skewed to flood flow according to There ***survey?*** ***Angle*** 10 N

are severe channel bends 200 ft upstream and 230 ft downstream of the bridge.

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. The channel is laterally unstable and sinuous with tree cover along the upstream channel banks.

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

There is a point bar along the left abutment. 8/28/96

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley setting with a narrow flood plain and steep valley walls on both sides.

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

Date of inspection 8/28/96

DS left: Moderately sloped overbank to steep valley wall

DS right: Moderately sloped overbank to steep valley wall

US left: Moderately sloped overbank

US right: Moderately sloped overbank

Description of the Channel

Average top width 45 ***ft*** ***Average depth*** 5 ***ft***

Predominant bed material Cobble / Gravel ***Bank material*** Cobble / Gravel

Sinuous and laterally unstable with semi-alluvial channel boundaries and a narrow flood plain.

8/28/96

Vegetative co

DS left: Forest

DS right: Forest

US left: Grass and forest

US right: Meadow and forest

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

There is evidence of lateral movement of the channel 200 feet upstream along the left bank and near the bridge along the right bank. 8/28/96

None. 8/28/96

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 7.21 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***:

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,800 ***ft³/s*** ***Q500*** 2,650 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database. These values were selected due to the central tendency of the discharge frequency curve with others which were developed from empirical relationships and extended to the 500-year discharge (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 Subtract 0.2 ft from arbitrary survey datum to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left abutment (elev. 499.71 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 499.69 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	-27	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	16	1	Road Grade section
APPRO	60	1	Modelled 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 0.050, and overbank "n" values ranged from 0.040 to 0.065.

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 0.0167 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1971).

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

For the 100-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. 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 assumptions of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.6 *ft*
Average low steel elevation 497.9 *ft*

100-year discharge 1,800 *ft³/s*
Water-surface elevation in bridge opening 494.2 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 142 *ft²*
Average velocity in bridge opening 12.7 *ft/s*
Maximum WSPRO tube velocity at bridge 15.4 *ft/s*

Water-surface elevation at Approach section with bridge 497.2
Water-surface elevation at Approach section without bridge 495.3
Amount of backwater caused by bridge 1.9 *ft*

500-year discharge 2,650 *ft³/s*
Water-surface elevation in bridge opening 498.0 *ft*
Road overtopping? Y *Discharge over road* 144.0 *ft³/s*
Area of flow in bridge opening 247 *ft²*
Average velocity in bridge opening 8.8 *ft/s*
Maximum WSPRO tube velocity at bridge 10.5 */s*

Water-surface elevation at Approach section with bridge 500.6
Water-surface elevation at Approach section without bridge 496.4
Amount of backwater caused by bridge 4.2

Incipient overtopping discharge 2,170 *ft³/s*
Water-surface elevation in bridge opening 499.6 *ft*
Area of flow in bridge opening 769 *ft²*
Average velocity in bridge opening 2.8 *ft/s*
Maximum WSPRO tube velocity at bridge 4.4 *ft/s*

Water-surface elevation at Approach section with bridge 499.6
Water-surface elevation at Approach section without bridge 495.8
Amount of backwater caused by bridge 3.8 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the 100-year discharge model was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) . The 500-year discharge and incipient road-overflow models 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, the Chang equation (Richardson and others, 1995, pp. 145-146) was applied to compute the contraction scour for the 500-year and incipient road-overflow discharge. The results of Laursen's clear-water contraction scour were also computed for these discharges and can be found in appendix F. The 100-year discharge model resulted in the worst case contraction scour with a scour depth of 1.6 ft. However, it was not the worst case total scour. The computed depths to streambed armoring suggest armoring will not limit the depth of contraction scour.

Abutment scour at the left 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 right abutment was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29). 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	1.6	1.4	0.0
Depth to armoring	29.7	5.3	2.4
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	7.5	7.8	8.3
Right abutment	7.1	10.7	8.7
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	2.1	2.0	1.5
Right abutment	2.1	2.0	1.5
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--
	--	--	--

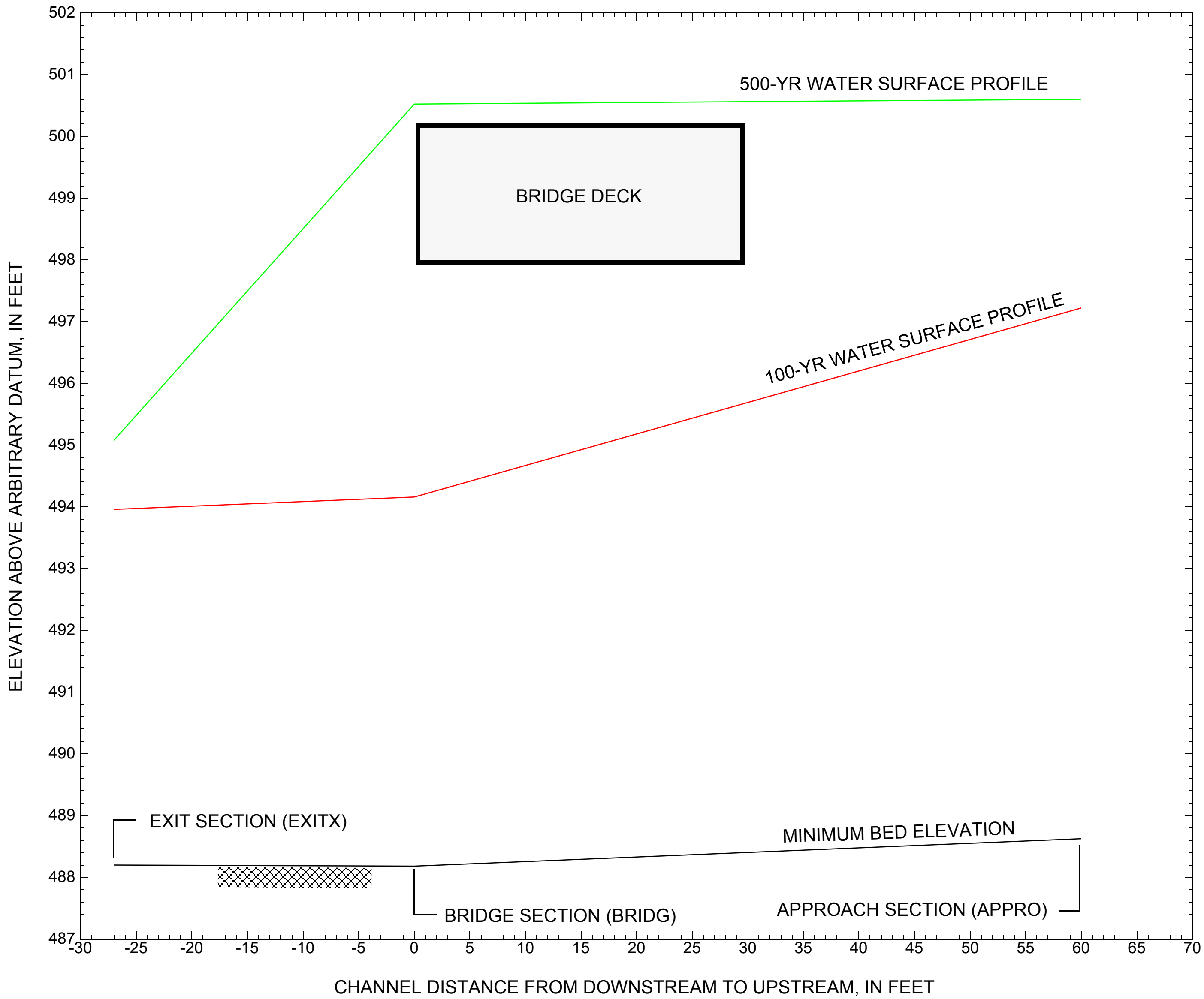

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ANDOTH00010007 on Town Highway 1, crossing Andover Branch, Andover, Vermont.

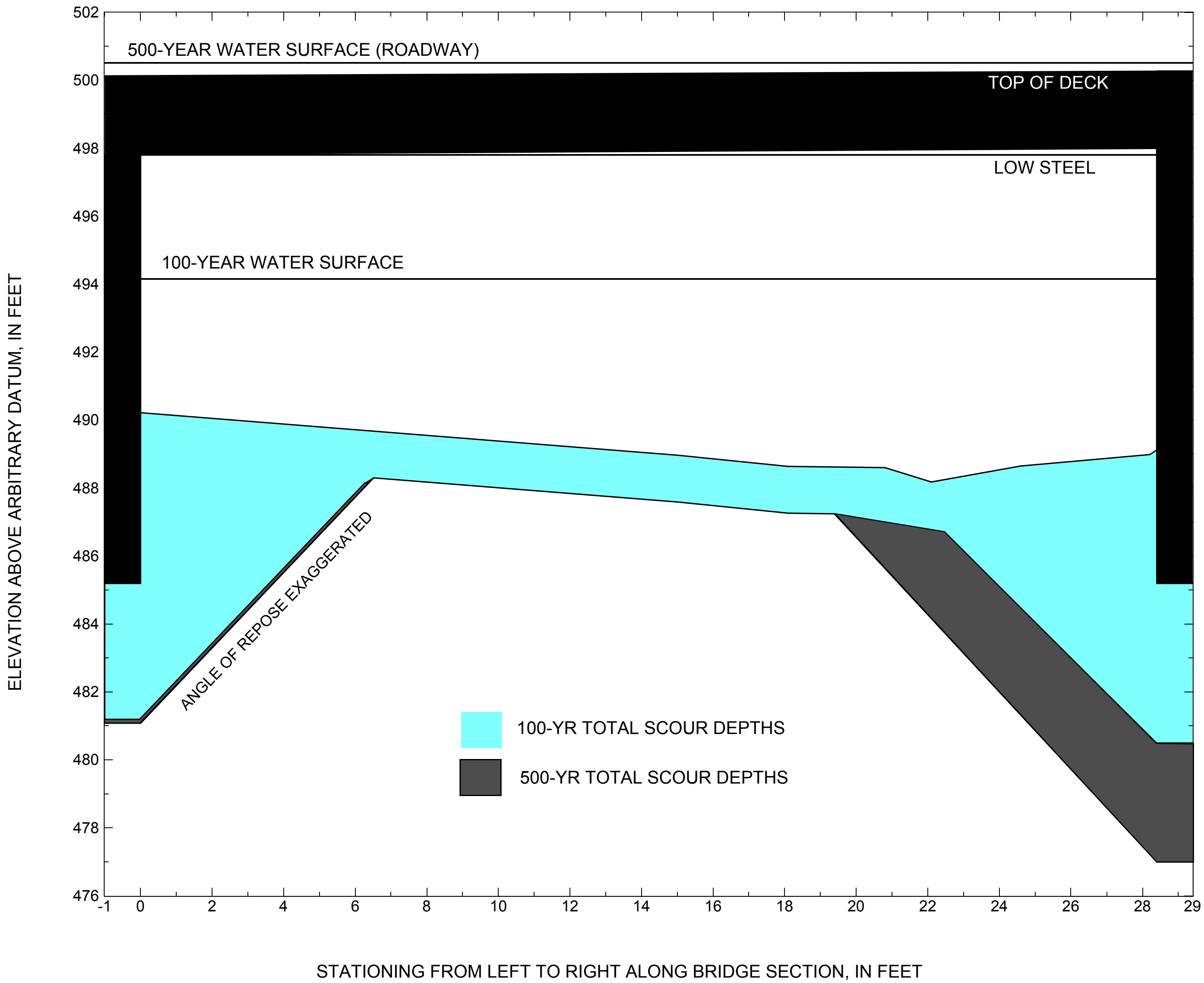

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ANDOTH00010007 on Town Highway 1, crossing Andover Branch, Andover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ANDOTH00010007 on TOWN HIGHWAY 1, crossing ANDOVER BRANCH, ANDOVER, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,800 cubic-feet per second											
Left abutment	0.0	498.0	497.8	485.2	490.2	1.6	7.5	--	9.1	481.1	-4.1
Right abutment	28.4	498.2	498.0	485.2	489.0	1.6	7.1	--	8.7	480.3	-4.9

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 ANDOTH00010007 on TOWN HIGHWAY 1, crossing ANDOVER BRANCH, ANDOVER, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,650 cubic-feet per second											
Left abutment	0.0	498.0	497.8	485.2	490.2	1.4	7.8	--	9.2	481.0	-4.2
Right abutment	28.4	498.2	498.0	485.2	489.0	1.4	10.7	--	12.1	476.9	-8.3

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

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 ando007.wsp
T2        Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
T3        Bridge 7 over Andover Branch in Andover, VT    RHF
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1800.0   2650.0   2170.0
SK          0.0167   0.0167   0.0167
*
XS   EXITX    -27           0.
GR         -221.6, 503.36   -184.3, 497.67   -106.2, 499.48    -42.0, 498.99
GR          -34.2, 496.60    -11.4, 492.73      0.0, 488.74      6.2, 488.84
GR           10.0, 488.55     13.0, 488.26     16.7, 488.32     21.6, 488.20
GR           23.6, 488.76     31.5, 493.10     67.3, 496.31    115.7, 498.51
GR          230.8, 504.29    328.8, 510.35    411.4, 516.38
*
N           0.065       0.050         0.065
SA                -42.0        31.5
*
*
XS   FULLV      0  * * *   0.0069
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.89       0.0
GR            0.0, 497.80      0.1, 497.33     0.1, 490.22     15.0, 488.97
GR           18.1, 488.64     20.8, 488.60    22.1, 488.18     24.6, 488.65
GR           28.2, 488.99     28.4, 489.12    28.4, 497.53     28.4, 497.98
GR            0.0, 497.80
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      32.8      2.7   499.64    44.8
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     16      29.4     1
GR         -157.3, 505.25    -83.3, 502.24    -34.4, 499.60      0.0, 500.13
GR           29.6, 500.27    294.2, 508.21    434.0, 518.07
*
*
AS   APPRO     60           0.
GR          -86.9, 504.02    -31.5, 500.85    -14.0, 498.42     -8.9, 496.61
GR            0.0, 491.35     17.4, 489.47     18.7, 489.11     21.3, 488.62
GR           23.0, 489.16     28.6, 489.13     30.5, 489.49     37.2, 495.22
GR          146.3, 498.32    215.6, 499.69    289.7, 503.16    319.6, 508.21
GR          430.9, 517.43
*
N           0.040      0.050       0.040
SA               -14.0        37.2
*
HP 1 BRIDG   494.16 1 494.16
HP 2 BRIDG   494.16 * * 1800
HP 1 APPRO   497.22 1 497.22
HP 2 APPRO   497.22 * * 1800
*
HP 1 BRIDG   497.98 1 497.98
HP 2 BRIDG   497.98 * * 2510
HP 1 APPRO   500.60 1 500.60
HP 2 APPRO   500.60 * * 2650
HP 2 RDWAY   500.52 * * 144
*
HP 1 BRIDG   497.98 1 497.98
HP 2 BRIDG   497.98 * * 2170
HP 1 APPRO   499.63 1 499.63
HP 2 APPRO   499.63 * * 2170
*
EX
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V090192            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando007.wsp
        Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
        Bridge 7 over Andover Branch in Andover, VT    RHF
           *** RUN DATE & TIME: 02-11-97  09:15
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     142.   12800.    28.    38.                        1799.
   494.16          142.   12800.    28.    38.  1.00     0.    28.   1799.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.16     0.1    28.4   141.7   12800.    1800.  12.70

X STA.         0.1        3.1        5.0        6.6        8.2        9.6
  A(I)            12.2        8.1        7.3        7.0        6.7
  V(I)            7.35      11.16      12.34      12.82      13.43

X STA.         9.6       11.0       12.2       13.5       14.7       15.8
  A(I)             6.4        6.3        6.2        6.0        6.1
  V(I)           14.08      14.18      14.60      15.00      14.70

X STA.        15.8       16.9       18.0       19.1       20.1       21.2
  A(I)             5.9        5.8        5.9        6.0        6.0
  V(I)           15.26      15.41      15.32      15.04      15.00

X STA.        21.2       22.3       23.4       24.6       26.0       28.4
  A(I)             6.2        6.4        6.7        7.8       12.7
  V(I)           14.51      14.13      13.38      11.56       7.11



    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      60.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     287.   26765.    48.    52.                        3988.
             3      70.    2621.    70.    70.                         399.
   497.22          357.   29387.   118.   122.  1.19   -11.   108.   3231.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      60.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.22   -10.6   107.6   357.3   29387.    1800.   5.04

X STA.       -10.6        0.0        3.1        5.8        8.1       10.4
  A(I)            29.3       18.5       17.2       15.7       15.3
  V(I)            3.07       4.88       5.23       5.73       5.87

X STA.        10.4       12.4       14.4       16.2       17.9       19.6
  A(I)            14.5       14.3       13.7       13.4       13.2
  V(I)            6.19       6.29       6.55       6.70       6.80

X STA.        19.6       21.1       22.6       24.3       25.9       27.5
  A(I)            12.9       12.9       13.0       13.1       13.3
  V(I)            6.96       6.96       6.92       6.85       6.76

X STA.        27.5       29.2       31.2       34.8       50.5      107.6
  A(I)            13.7       15.4       19.9       31.4       46.3
  V(I)            6.57       5.84       4.52       2.87       1.94
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        U.S. Geological Survey WSPRO Input File ando007.wsp
        Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
        Bridge 7 over Andover Branch in Andover, VT    RHF
           *** RUN DATE & TIME: 02-11-97  09:15
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     247.   20703.     0.    73.                           0.
   497.98          247.   20703.     0.    73.  1.00     0.    28.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.98     0.0    28.4   247.3   20703.    2510.  10.15

X STA.         0.0         2.8        4.6         6.2         7.6        9.0
  A(I)             20.9        13.9        12.8        11.7        11.5
  V(I)             6.02        9.05        9.79       10.74       10.90

X STA.         9.0        10.3       11.6        12.9        14.1       15.3
  A(I)             11.5        11.0        11.0        10.8        10.6
  V(I)            10.95       11.46       11.43       11.64       11.86

X STA.        15.3        16.5       17.6        18.8        19.9       21.0
  A(I)             10.5        10.7        10.6        10.3        10.9
  V(I)            11.90       11.73       11.86       12.14       11.49

X STA.        21.0        22.2       23.3        24.6        26.0       28.4
  A(I)             10.9        11.2        12.0        13.2        21.4
  V(I)            11.57       11.18       10.44        9.50        5.87


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      60.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      17.     671.    16.    16.                         101.
             2     458.   55800.    51.    55.                        7771.
             3     537.   38941.   198.   198.                        5024.
   500.60         1012.   95412.   265.   269.  1.22   -30.   235.  10169.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      60.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.60   -29.7   235.0  1012.3   95412.    2650.   2.62

X STA.       -29.7        -2.5        2.6         6.6        10.3       13.7
  A(I)             70.8        45.4        39.3        37.2        35.8
  V(I)             1.87        2.92        3.37        3.56        3.70

X STA.        13.7        16.8       19.8        22.6        25.5       28.4
  A(I)             33.8        34.0        33.4        32.6        33.7
  V(I)             3.92        3.89        3.97        4.06        3.93

X STA.        28.4        31.7       38.6        47.8        58.0       69.1
  A(I)             36.0        50.3        48.2        50.2        51.6
  V(I)             3.68        2.64        2.75        2.64        2.57

X STA.        69.1        82.7       98.6       119.2       149.5      235.0
  A(I)             58.1        61.4        68.8        79.3       112.2
  V(I)             2.28        2.16        1.93        1.67        1.18


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      16.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.52   -51.4    37.9    40.9     750.     144.   3.52

X STA.       -51.4       -40.6      -38.0       -36.0       -34.4      -32.9
  A(I)              3.2         1.7         1.6         1.4         1.4
  V(I)             2.27        4.30        4.62        5.04        5.12

X STA.       -32.9       -31.2      -29.4       -27.6       -25.5      -23.4
  A(I)              1.5         1.5         1.5         1.6         1.7
  V(I)             4.90        4.75        4.72        4.43        4.34

X STA.       -23.4       -21.0      -18.4       -15.5       -12.0       -8.1
  A(I)              1.7         1.8         1.9         2.1         2.1
  V(I)             4.16        4.00        3.72        3.51        3.35

X STA.        -8.1        -3.1        3.4        11.2        20.4       37.9
  A(I)              2.4         2.6         2.8         2.9         3.5
  V(I)             3.03        2.80        2.58        2.47        2.04
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        U.S. Geological Survey WSPRO Input File ando007.wsp
        Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
        Bridge 7 over Andover Branch in Andover, VT    RHF
           *** RUN DATE & TIME: 02-11-97  09:15
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     247.   20703.     0.    73.                          0.
   497.98          247.   20703.     0.    73.  1.00     0.    28.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.98     0.0    28.4   247.3   20703.    2170.   8.78

X STA.         0.0        2.8        4.6        6.2        7.6        9.0
  A(I)            20.9       13.9       12.8       11.7       11.5
  V(I)            5.20       7.82       8.46       9.29       9.42

X STA.         9.0       10.3       11.6       12.9       14.1       15.3
  A(I)            11.5       11.0       11.0       10.8       10.6
  V(I)            9.47       9.91       9.88      10.06      10.25

X STA.        15.3       16.5       17.6       18.8       19.9       21.0
  A(I)            10.5       10.7       10.6       10.3       10.9
  V(I)           10.29      10.14      10.26      10.49       9.94

X STA.        21.0       22.2       23.3       24.6       26.0       28.4
  A(I)            10.9       11.2       12.0       13.2       21.4
  V(I)           10.00       9.67       9.03       8.21       5.07


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      60.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       5.     140.     9.     9.                         23.
             2     408.   46083.    51.    55.                       6542.
             3     355.   21199.   175.   175.                       2871.
   499.63          769.   67422.   235.   240.  1.28   -23.   213.   6977.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      60.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.63   -22.7   212.6   769.0   67422.    2170.   2.82

X STA.       -22.7       -1.6        2.7        6.1        9.3       12.3
  A(I)            53.6       35.3       30.0       29.0       28.3
  V(I)            2.02       3.08       3.61       3.74       3.84

X STA.        12.3       15.0       17.5       20.0       22.3       24.6
  A(I)            26.3       25.7       25.6       24.9       24.8
  V(I)            4.12       4.22       4.24       4.36       4.38

X STA.        24.6       27.0       29.5       32.5       39.7       49.4
  A(I)            25.4       25.4       29.4       41.0       40.7
  V(I)            4.27       4.28       3.70       2.65       2.67

X STA.        49.4       60.7       74.2       91.5      115.7      212.6
  A(I)            44.0       48.2       53.7       61.0       96.9
  V(I)            2.47       2.25       2.02       1.78       1.12
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 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ando007.wsp
         Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
         Bridge 7 over Andover Branch in Andover, VT    RHF
            *** RUN DATE & TIME: 02-11-97  09:15

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

 EXITX:XS   ******   -19.     198.  1.32 *****  495.29  493.46   1800.  493.96
       -27. ******    41.   13921.  1.03 ***** *******    0.89    9.09

 FULLV:FV      27.   -22.     229.  1.02  0.38  495.65 *******   1800.  494.63
         0.    27.    47.   16539.  1.06  0.00   -0.02    0.78    7.86
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS      60.    -7.     198.  1.28  0.77  496.56 *******   1800.  495.28
        60.    60.    39.   15353.  1.00  0.13    0.01    0.77    9.08
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =     1800.     494.16

             <<<<<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      27.     0.     142.  2.51 *****  496.67  494.16   1800.  494.16
         0.    27.    28.   12815.  1.00 ***** *******    1.00   12.69

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        4. ****   1.  1.000 ******  497.89 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      16.        <<<<<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      27.   -11.     357.  0.47  0.24  497.69  494.41   1800.  497.22
        60.    28.   107.   29338.  1.19  0.78    0.01    0.56    5.05

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.383  0.182   23965.     3.    31.  497.10

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ando007.wsp
         Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
         Bridge 7 over Andover Branch in Andover, VT    RHF
            *** RUN DATE & TIME: 02-11-97  09:15
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
    EXITX:XS     -27.   -19.    41.   1800.   13921.     198.    9.09  493.96
    FULLV:FV       0.   -22.    47.   1800.   16539.     229.    7.86  494.63
    BRIDG:BR       0.     0.    28.   1800.   12815.     142.   12.69  494.16
    RDWAY:RG      16.**************      0.*****************    1.00********
    APPRO:AS      60.   -11.   107.   1800.   29338.     357.    5.05  497.22

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS       3.    31.   23965.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    493.46    0.89  488.20  516.38************  1.32  495.29  493.96
    FULLV:FV  ********    0.78  488.39  516.57  0.38  0.00  1.02  495.65  494.63
    BRIDG:BR    494.16    1.00  488.18  497.98************  2.51  496.67  494.16
    RDWAY:RG  ****************  499.60  518.07**********************************
    APPRO:AS    494.41    0.56  488.62  517.43  0.24  0.78  0.47  497.69  497.22
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WSPRO OUTPUT FILE (continued)

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 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ando007.wsp
         Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
         Bridge 7 over Andover Branch in Andover, VT    RHF
            *** RUN DATE & TIME: 02-11-97  09:15

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

 EXITX:XS   ******   -25.     275.  1.58 *****  496.66  494.74   2650.  495.08
       -27. ******    54.   20501.  1.10 ***** *******    0.95    9.62

 FULLV:FV      27.   -29.     326.  1.16  0.37  497.03 *******   2650.  495.87
         0.    27.    60.   24879.  1.13  0.00    0.00    0.80    8.14
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
               FNTEST,FR#,WSEL,CRWS =  0.80    1.02     496.39     495.92
  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                    WSLIM1,WSLIM2,DELTAY =   495.37     517.43    0.50
  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                    WSLIM1,WSLIM2,CRWS =   495.37     517.43     495.92

 APPRO:AS      60.    -9.     272.  1.63  0.76  498.02  495.92   2650.  496.39
        60.    60.    78.   22282.  1.11  0.23    0.00    1.02    9.73
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
            WS1,WSSD,WS3,RGMIN =   499.68       0.00     495.64     499.60
  ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
            WS3,WSIU,WS1,LSEL =   495.64     499.53     499.68     497.89
  ===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      27.     0.     247.  1.60 *****  499.58  495.41   2510.  497.98
         0. ******    28.   20703.  1.00 ***** *******    0.61   10.15

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        4. ****   5.  0.475 ******  497.89 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      16.    31.  0.02  0.13  500.71    0.00    144.  500.52

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:   126.    67.   -51.    15.   0.9   0.5   3.9   3.5   0.7   3.1
    RT:    18.    23.    15.    38.   0.3   0.2   2.9   3.5   0.4   3.0

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

 APPRO:AS      27.   -30.    1012.  0.13  0.10  500.73  495.92   2650.  500.60
        60.    28.   235.   95401.  1.22  0.65    0.00    0.26    2.62

                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ando007.wsp
         Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
         Bridge 7 over Andover Branch in Andover, VT    RHF
            *** RUN DATE & TIME: 02-11-97  09:15
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -27.   -25.    54.   2650.   20501.     275.    9.62  495.08
    FULLV:FV       0.   -29.    60.   2650.   24879.     326.    8.14  495.87
    BRIDG:BR       0.     0.    28.   2510.   20703.     247.   10.15  497.98
    RDWAY:RG      16.*******   126.    144.       0.       0.    1.00  500.52
    APPRO:AS      60.   -30.   235.   2650.   95401.    1012.    2.62  500.60

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    494.74    0.95  488.20  516.38************  1.58  496.66  495.08
    FULLV:FV  ********    0.80  488.39  516.57  0.37  0.00  1.16  497.03  495.87
    BRIDG:BR    495.41    0.61  488.18  497.98************  1.60  499.58  497.98
    RDWAY:RG ****************  499.60  518.07  0.02******  0.13  500.71  500.52
    APPRO:AS    495.92    0.26  488.62  517.43  0.10  0.65  0.13  500.73  500.60
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WSPRO OUTPUT FILE (continued)

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 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ando007.wsp
         Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
         Bridge 7 over Andover Branch in Andover, VT    RHF
            *** RUN DATE & TIME: 02-11-97  09:15

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

 EXITX:XS   ******   -22.     232.  1.45 *****  495.94  494.05   2170.  494.49
       -27. ******    47.   16783.  1.06 ***** *******    0.93    9.36

 FULLV:FV      27.   -25.     272.  1.08  0.37  496.31 *******   2170.  495.23
         0.    27.    53.   20236.  1.10  0.00    0.00    0.79    7.97
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.92    495.80     494.96
  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   494.73     517.43    0.50
  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   494.73     517.43     494.96

 APPRO:AS      60.    -8.     227.  1.47  0.76  497.27  494.96   2170.  495.79
        60.    60.    57.   18257.  1.04  0.20    0.00    0.92    9.56
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
            WS3,WSIU,WS1,LSEL =   494.84     498.03     498.23     497.89
  ===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      27.     0.     247.  1.19 *****  499.17  494.82   2167.  497.98
         0. ******    28.   20703.  1.00 ***** *******    0.52    8.76

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        4. ****   2.  0.440 ******  497.89 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      16.        <<<<<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      27.   -23.     768.  0.16  0.09  499.79  494.96   2170.  499.63
        60.    28.   212.   67339.  1.28  0.72    0.00    0.31    2.83

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      ****** ****** ******** ****** ******   499.59

                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ando007.wsp
         Hydraulic analysis for structure ANDOTH00010007   Date: 10-JAN-97
         Bridge 7 over Andover Branch in Andover, VT    RHF
            *** RUN DATE & TIME: 02-11-97  09:15
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -27.   -22.    47.   2170.   16783.     232.    9.36  494.49
    FULLV:FV       0.   -25.    53.   2170.   20236.     272.    7.97  495.23
    BRIDG:BR       0.     0.    28.   2167.   20703.     247.    8.76  497.98
    RDWAY:RG      16.**************       0.       0.       0.    1.00********
    APPRO:AS      60.   -23.   212.   2170.   67339.     768.    2.83  499.63

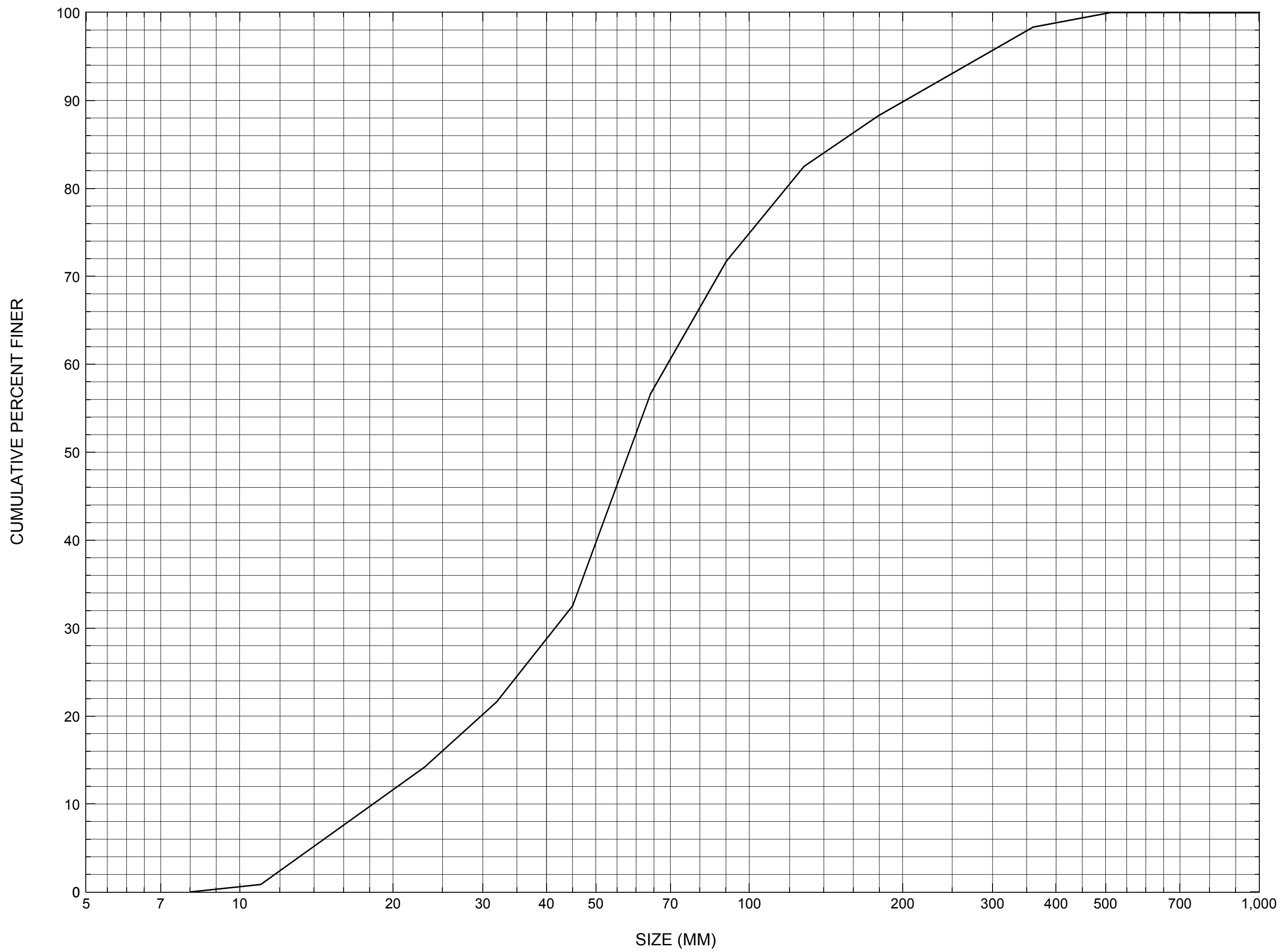
  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    494.05    0.93  488.20  516.38************  1.45  495.94  494.49
    FULLV:FV  ********    0.79  488.39  516.57  0.37  0.00  1.08  496.31  495.23
    BRIDG:BR    494.82    0.52  488.18  497.98************  1.19  499.17  497.98
    RDWAY:RG  ****************  499.60  518.07************  0.16  499.75********
    APPRO:AS    494.96    0.31  488.62  517.43  0.09  0.72  0.16  499.79  499.63
   ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ANDOTH00010007, in Andover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ANDOTH00010007

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)* 004520

Waterway *(I - 6)* ANDOVER BRANCH

Road Name *(I - 7):* -

Route Number TH01

Vicinity *(I - 9)* 1.9 MI N JCT. VT.11

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43164

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

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20013200071401

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

Maximum span length *(I - 48; nnnn)* 0029

Year built *(I - 27; YYYY)* 1979

Structure length *(I - 49; nnnnnn)* 000032

Average daily traffic, ADT *(I - 29; nnnnnn)* 000770

Deck Width *(I - 52; nn.n)* 294

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

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

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

Waterway adequacy *(I - 71; n)* 8

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

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

Structure type *(I - 43; nnn)* 101

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*) 8.5

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

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

Comments:

The structural inspection report of 8/3/94 indicates the structure is a concrete slab type bridge with an asphalt road surface. The structure is part of the Federal Aid System and is listed under the route number FAS 132. Both concrete abutment walls are clean with the exception of some hairline vertical cracks. The most severe vertical crack is at the end of the upstream right abutment. The concrete wingwalls are reportedly "like-new". The footings are not in view. A shallow gravel point bar is noted on the left abutment side of the channel with flow along the right abutment. The banks are well protected with stone fill. Some granite block riprap is exposed along the front of the right abutment. The **(Continued, page 33)**

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area (*mi²*): 7.06

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data (*cfs*): $Q_{2.33}$ - Q_{10} 900 Q_{25} 1200

Q_{50} 1500 Q_{100} 1800 Q_{500} -

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

Estimated Discharge (*cfs*): 1200 Velocity at Q 25 (*ft/s*): 11.8

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*)	-	4.8	5.8	6.7	7.6
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): 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 (*ft²*): -

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

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

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

Comments:

channel makes a slight turn into bridge. There is stone fill reported on the bed under the bridge.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **7.21** mi^2 Lake and pond area **0.01** mi^2

Watershed storage *(ST)* **0.1** %

Bridge site elevation **1060** ft Headwater elevation **2860** ft

Main channel length **4.89** mi

10% channel length elevation **1120** ft 85% channel length elevation **2020** ft

Main channel slope *(S)* **245.45** 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)*: **06** / **1979**

Project Number **BRS 0132(4)S** Minimum channel bed elevation: **487.0**

Low superstructure elevation: USLAB **497.14** DSLAB **497.14** USRAB **497.32** DSRAB **497.32**

Benchmark location description:

Spike in root or trunk of an 18 inch white birch tree, BM#2, elevation 499.45, located about 40 feet left-bankward from the left abutment and about 20 feet perpendicular from roadway center line in the down-stream direction just behind the seventh guard rail post from the left bank end.

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: **485.0**

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

If 3: Footing bottom elevation: ______

Is boring information available? **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 stamped built as designed. Bridge will handle a Q100 without overtopping. Other elevation points: 1. the point on the top streamward edge of the upstream left wingwall where the concrete slope changes to a decline, elevation 499.49; 2. the point at the same location described above except on the upstream right wingwall, elevation 499.67.

Cross-sectional Data

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

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

Comments: **Upstream brige face cross section from left to right bank. At this section the channel was graded to an elevation of 489.0. The channel baseline runs along the left bank perpindicular to and 1 foot from the left abutment streamward face.**

Station	1	17	29	-	-	-	-	-	-	-	-
Feature	LCL	-	LCR	-	-	-	-	-	-	-	-
Low cord elevation	497.8	-	498.0	-	-	-	-	-	-	-	-
Bed elevation	489.0	489.0	489.0	-	-	-	-	-	-	-	-
Low cord to bed length	8.8	-	9.0	-	-	-	-	-	-	-	-

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

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

Comments: **Downstream bridge face cross section from left to right bank. Also, this section was graded to an elevation of 489.0.**

Station	2	11	17	29	31.5	-	-	-	-	-	-
Feature	LCL	-	-	-	LCR	-	-	-	-	-	-
Low cord elevation	497.8	-	-	-	498.0	-	-	-	-	-	-
Bed elevation	489.0	489.0	489.0	489.0	489.0	-	-	-	-	-	-
Low cord to bed length	8.8	-	-	-	9.0	-	-	-	-	-	-

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 09/24/96
Computerized by: RB Date: 09/25/96
Reviewd by: RF Date: 01/24/97

Structure Number ANDOTH00010007

A. General Location Descriptive

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

2. Highway District Number 02
Mile marker 004520
County 027 WINDSOR
Town 01300 ANDOVER
Waterway *(I - 6)* ANDOVER BRANCH
Road Name -
Route Number TH01
Hydrologic Unit Code: 01080107

3. Descriptive comments:
Located 1.9 miles north of the junction with VT 11 and about 0.4 miles west of the town line at the junction with the dirt road.

B. Bridge Deck Observations

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

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

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

7. Bridge length 32 *(feet)* Span length 29 *(feet)* Bridge width 29.4 *(feet)*

Road approach to bridge:

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

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

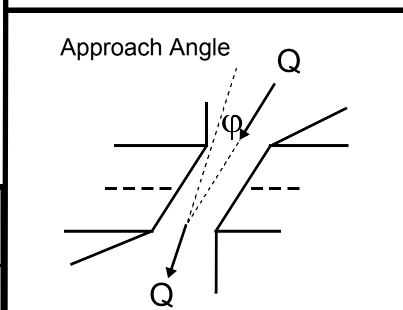
10. Embankment slope (*run / rise in feet / foot*):
US left 3.3:1 US right 2.0:1

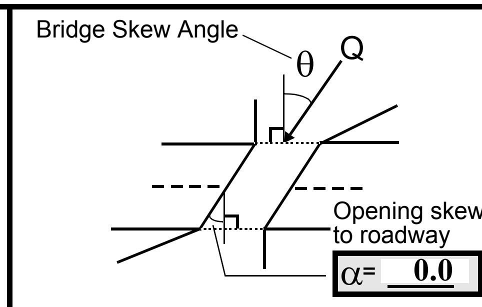
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	1	2	1
RBUS	1	1	2	1
RBDS	1	1	2	1
LBDS	1	1	2	1

*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: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 35 feet US *(US, UB, DS)* to 5 feet DS

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 40 feet DS *(US, UB, DS)* to +230 feet DS

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

18. Bridge Type: **4**

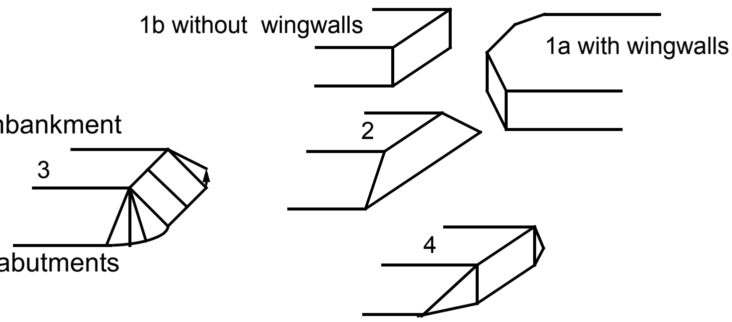
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. The left bank US surface cover is pasture within 1 bridge length and then it is forest beyond.
7. Values are from the VTAOT files. Measured bridge length between the backs of the abutments is 31.8 ft. US and 31.7 ft. DS. Span length between the abutment faces is 28.9 ft. US and 29.1 ft. DS, and bridge width is 27.8 ft. between the insides of the bridge rails and 29.2 ft. between the outsides of the deck.
17. The second impact zone is caused by a gradual channel bend to the left.
18. The wingwalls are vertical to about 2 ft. below low chord.

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
27.5	5.5			5.5	2	1	435	435	0	2

23. Bank width **30.0** 24. Channel width **40.0** 25. Thalweg depth **46.0** 29. Bed Material **435**

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

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

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

26. On the left bank there is no vegetation cover to 43 ft. US then it is 100% cover. On the right bank there is minor vegetation to 70 ft. US and then 75% cover.
27. Bank materials listed are found US of the protection.
28. Erosion on the right bank is from 13 ft. US to 200 ft. US. There is a cut bank and some slumping of the bank. On the left bank there is no evident erosion up to 110 ft. US.
30. Protection on both banks extends from 2 ft. US to 50 ft. US.
31. From 13 ft. US to 50 ft. US, the protection has been under cut on the right bank and has slumped into the channel.
The channel bends 90 degrees at 200 ft. US and is split about 250 ft. US and rejoins at 100 ft. US. The outside channel has cut into the left bank from 240 ft. US to 170 ft. US. Large stone fill (type 3) has been dumped along the impact zone.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 28 35. Mid-bar width: 20

36. Point bar extent: 60 feet US (US, UB) to 35 feet DS (US, UB, DS) positioned 0 %LB to 60 %RB

37. Material: 435

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

-

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

41. Mid-bank distance: 30 42. Cut bank extent: 13 feet US (US, UB) to 200+ feet US (US, UB, DS)

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

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

See comments under 32.

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

Local scour at stone fill US on the left bank.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
30.5		1.0		2	7	7	0

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

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

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

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

342

63. The type 3 placed protection in the channel along the right abutment is not included in the bed material.

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

The debris accumulation is small.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	0	-	-	90.0
RABUT	1	10	90			2	0	28.0

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.):

-

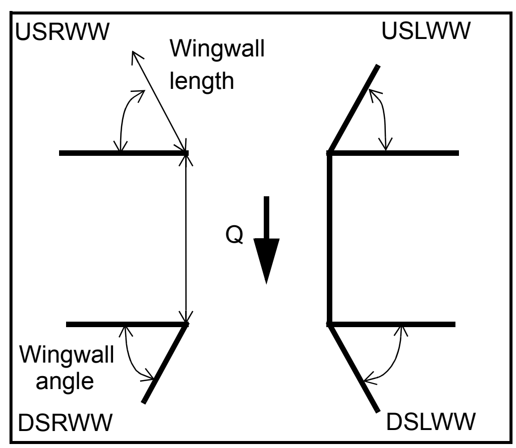
-

1

74. The channel runs along the right abutment, thus the ambient water is deeper along this abutment. However, the type 3 protection of flat slabs of rocks placed in the channel along the abutment have prevented scour from occurring.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						28.0	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	33.0	
DSRWW:	1		0		-	32.5	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	1	1	-	1
Condition	Y	-	1	-	1	1	-	1
Extent	1	-	0	2	2	0	3	-

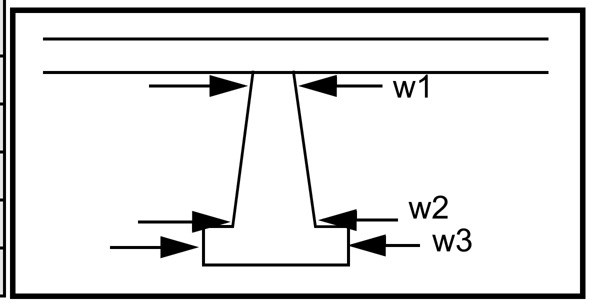
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				45.0	10.0	45.0
Pier 2	9.5			45.0	10.0	45.0
Pier 3		-	-	10.0	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	RB	Bank angle (BF) LB	RB	% Veg. cover (BF) LB	RB	Bank material (BF) LB	RB	Bank erosion (BF) LB	RB
-	-			-	-	NO	PIE	RS		

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

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

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

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

3
2
435
435
0
2
435
3
3
1
1
On both banks, the bank protection is from 2 ft. DS to 20 ft. DS.
The right bank erosion is on the outside of the bend in the channel from 40 ft. DS to 200 ft. DS.

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

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

105. Drop structure comments (eg. downstream scour depth):
vegetation cover on the right bank is 0% to 30 ft. DS then 100%. On the left bank it is also 0% next to the bridge to 20 ft. DS and then 75%.
The channel bends towards the left bank to about 230 ft. DS then it makes a 90 degree bend to the left.

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 **N** %LB to **-** %RB

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **150** feet **15** *(US, UB, DS)* to **105** feet **DS** *(US, UB, DS)*

Bank damage: **250** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

+
DS
0
50

Is channel scour present? **345** *(Y or if N type ctrl-n cs)* Mid-scour distance: **The**

Scour dimensions: Length **bar** Width **con-** Depth: **tinu** Positioned **es** %LB to **bey** %RB

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

ond the 90 degree bend.

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

Confluence 1: Distance **100** Enters on **40** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **115** Enters on **DS** *(LB or RB)* Type **1** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

-

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N
-
-
-
-
-
-
NO CHANNEL SCOUR

Y

109. **G. Plan View Sketch**

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: ANDOTH00010007   Town: Andover
Road Number: TH 1   County: Windsor
Stream: Andover Branch

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

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1800	2650	2170
Main Channel Area, ft2	287	458	408
Left overbank area, ft2	0	17	5
Right overbank area, ft2	70	537	355
Top width main channel, ft	48	51	51
Top width L overbank, ft	0	16	9
Top width R overbank, ft	70	198	175
D50 of channel, ft	0.1905	0.1905	0.1905
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.0	9.0	8.0
y1, average depth, LOB, ft	ERR	1.1	0.6
y1, average depth, ROB, ft	1.0	2.7	2.0
Total conveyance, approach	29387	95412	67422
Conveyance, main channel	26765	55800	46083
Conveyance, LOB	0	671	140
Conveyance, ROB	2621	38941	21199
Percent discrepancy, conveyance	0.0034	0.0000	0.0000
Qm, discharge, MC, cfs	1639.4	1549.8	1483.2
Ql, discharge, LOB, cfs	0.0	18.6	4.5
Qr, discharge, ROB, cfs	160.5	1081.6	682.3
Vm, mean velocity MC, ft/s	5.7	3.4	3.6
Vl, mean velocity, LOB, ft/s	ERR	1.1	0.9
Vr, mean velocity, ROB, ft/s	2.3	2.0	1.9
Vc-m, crit. velocity, MC, ft/s	8.7	9.3	9.1
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

ARMORING

D90	0.664	0.664	0.664

D95	0.941	0.941	0.941
Critical grain size,Dc, ft	0.7956	0.4033	0.3015
Decimal-percent coarser than Dc	0.07436	0.18744	0.27692
Depth to armoring,ft	29.71	5.25	2.36

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	287	458	408
Main channel width, ft	48	51	51
y1, main channel depth, ft	5.98	8.98	8.00

Bridge Section			
(Q) total discharge, cfs	1800	2650	2170
(Q) discharge thru bridge, cfs	1800	2510	2170
Main channel conveyance	12800	20703	20703
Total conveyance	12800	20703	20703
Q2, bridge MC discharge,cfs	1800	2510	2170
Main channel area, ft2	142	247	247
Main channel width (skewed), ft	28.3	28.4	28.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	28.3	28.4	28.4
y_bridge (avg. depth at br.), ft	5.01	8.71	8.71
Dm, median (1.25*D50), ft	0.238125	0.238125	0.238125
y2, depth in contraction,ft	6.55	8.69	7.67
ys, scour depth (y2-ybridge), ft	1.55	-0.02	-1.04

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	1800	2650	2170
Q, thru bridge, cfs	1800	2510	2170
Total Conveyance, bridge	12800	20703	20703
Main channel(MC) conveyance, bridge	12800	20703	20703
Q, thru bridge MC, cfs	1800	2510	2170
Vc, critical velocity, ft/s	8.69	9.30	9.12
Vc, critical velocity, m/s	2.65	2.83	2.78
Main channel width (skewed), ft	28.3	28.4	28.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	28.3	28.4	28.4
qbr, unit discharge, ft2/s	63.6	88.4	76.4
qbr, unit discharge, m2/s	5.9	8.2	7.1
Area of full opening, ft2	141.7	247.3	247.3

Hb, depth of full opening, ft	5.01	8.71	8.71
Hb, depth of full opening, m	1.53	2.65	2.65
Fr, Froude number, bridge MC	0	0.61	0.52
Cf, Fr correction factor (<=1.0)	0.00	1.00	1.00
Elevation of Low Steel, ft	0	497.89	497.89
Elevation of Bed, ft	-5.01	489.18	489.18
Elevation of Approach, ft	0	500.6	499.63
Friction loss, approach, ft	0	0.1	0.09
Elevation of WS immediately US, ft	0.00	500.50	499.54
ya, depth immediately US, ft	5.01	11.32	10.36
ya, depth immediately US, m	1.53	3.45	3.16
Mean elevation of deck, ft	0	500.203	500.203
w, depth of overflow, ft (>=0)	0.00	0.30	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.94	0.96
Ys, depth of scour, ft	N/A	1.38	0.04

Comparison of Chang and Laursen results (for unsubmerged orifice flow)

y2, from Laursen's equation, ft	6.553887	8.688771	7.669639
Full valley WSEL, ft		495.87	495.23
Full valley depth, ft	ERR	6.687746	6.047746
Ys, depth of scour (y2-yfullv), ft	N/A	2.001024	1.621893

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	1800	2650	2170	1800	2650	2170
a', abut.length blocking flow, ft	10.7	29.7	22.7	79.2	206.6	184.2
Ae, area of blocked flow ft2	29.9	74.75	66.73	119.45	614.1	426.08
Qe, discharge blocked abut.,cfs	92.9		148.87	402.35		915.74
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.11	2.12	2.23	3.37	2.15	2.15
ya, depth of f/p flow, ft	2.79	2.52	2.94	1.51	2.97	2.31
--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	0.328	0.211	0.229	0.483	0.219	0.249
ys, scour depth, ft	7.48	7.76	8.31	11.40	16.55	14.43

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)	10.7	29.7	22.7	79.2	206.6	184.2
y1 (depth f/p flow, ft)	2.79	2.52	2.94	1.51	2.97	2.31

a'/y1	3.83	11.80	7.72	52.51	69.51	79.63
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.33	0.21	0.23	0.48	0.22	0.25
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	8.63	13.10	10.63
vertical w/ ww's	ERR	ERR	ERR	7.08	10.74	8.72
spill-through	ERR	ERR	ERR	4.75	7.20	5.85

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother	Q100	Q500	Qother
Fr, Froude Number	1	0.61	0.52	1	0.61	0.52
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.01	8.71	8.71	5.01	8.71	8.71
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.00	1.46	ERR	2.00	1.46
Fr>0.8 (vertical abut.)	2.09	ERR	ERR	2.09	ERR	ERR
Fr<=0.8 (spillthrough abut.)	ERR	1.75	1.27	ERR	1.75	1.27
Fr>0.8 (spillthrough abut.)	1.85	ERR	ERR	1.85	ERR	ERR