LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (DANVTH00610025) on TOWN HIGHWAY 61, crossing WATER ANDRIC BROOK, DANVILLE, VERMONT

Open-File Report 97-796

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

U.S. Department of the Interior
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By ROBERT H. FLYNN AND TIMOTHY SEVERANCE

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Pembroke, New Hampshire

1997

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

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Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (DANVTH00610025) ON TOWN HIGHWAY 61, CROSSING WATER ANDRIC BROOK, DANVILLE, VERMONT

By **Robert H. Flynn and Timothy Severance**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure DANVTH00610025 on Town Highway 61 crossing Water Andric Brook, Danville, 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 New England Upland section of the New England physiographic province in northeastern Vermont. The 9.69-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the downstream left bank while the upstream right bank is grass with trees along the immediate banks. The downstream right bank and upstream left bank are forested.

In the study area, Water Andric Brook has a straight channel with a slope of approximately 0.007 ft/ft, an average channel top width of 45 ft and an average bank height of 4 ft. The predominant channel bed material is gravel with a median grain size (D_{50}) of 53.4 mm (0.175 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 22, 1995, indicated that the reach was stable.

The Town Highway 61 crossing of Water Andric Brook is a 24-ft-long, two-lane bridge consisting of one 22-foot concrete slab span (Vermont Agency of Transportation, written communication, March 24, 1995). The opening length of the structure parallel to the bridge face is 22.9 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 5 degrees to the opening and the computed opening-skew-to-roadway is 5 degrees. The VTAOT computed opening-skew-to-roadway is zero degrees.

A scour hole 0.5 ft deeper than the mean thalweg depth was observed along the upstream half of the left abutment during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream left wingwall. 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) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is 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 0.7 to 1.3 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 9.1 to 12.5 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.

St. Johnsbury, VT. Quadrangle, 1:25,000, 1983

NORTH

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

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

LEVEL II SUMMARY

Structure Number DANVTH00610025 ***Stream*** Water Andric Brook

County Caledonia ***Road*** TH61 ***District*** 7

Description of Bridge

Bridge length 24 ***ft*** ***Bridge width*** 22.1 ***ft*** ***Max span length*** 22 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/22/95

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

Abutments and upstream wingwalls are concrete. The downstream wingwalls are "laid-up" stone. There is a 0.5 foot deep scour hole in front of the upstream half of the left abutment.

Yes 5

Is bridge skewed to flood flow according to No ***survey?*** ***Angle***

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	8/22/95	0	0
Level II	8/22/95	0	0

Potential for debris Moderate. There is some debris in the channel upstream. Cutbanks are evident upstream and there are trees with exposed roots along the banks.

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

A point bar along the upstream right bank and right abutment, noted on 8/22/95, directs flow along the left side of the channel during low flows.

Description of the Geomorphic Setting

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

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

Date of inspection 8/22/95

DS left: Steep channel bank to flood plain (including TH61).

DS right: Steep channel bank to a moderately sloped overbank.

US left: Steep channel bank to a flood plain.

US right: Moderately sloped channel bank and overbank.

Description of the Channel

Average top width 45 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material Gravel ***Bank material*** Silt / Clay /Gravel

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

Vegetative co 8/22/95

Tall grass and brush.

DS left: Trees and brush.

DS right: Trees and brush.

US left: Short grass with a few trees along the bank.

US right:

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

Describe any obstructions in channel and date of observation. The assessment of 8/22/95 noted low flow conditions are influenced by gravel point bars on the downstream left bank and upstream right bank. In addition, some debris is caught in the upstream channel.

Hydrology

Drainage area 9.69 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/New England Upland	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 1,890 ***ft³/s*** ***Q500*** 2,600 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates computed by use of the FHWA empirical method (FHWA, 1983). 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; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the concrete curb on the downstream left corner of the bridge deck (elev. 500.49 ft, arbitrary survey datum). RM2 is a chiseled X on top of the concrete curb on the upstream right corner of the bridge deck (elev. 500.97 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	-31	1	Exit section
FULLV	0	4	Downstream Full-valley section (Based on EXITX overbank and BRIDG channel coordinate values.)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APPRO	45	2	Modelled Approach section (Templated from APTEM)
APTEM	50	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.050, and overbank "n" values ranged from 0.045 to 0.090.

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 0.007 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1983).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0057 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.9 ***ft***
Average low steel elevation 499.0 ***ft***

100-year discharge 1,890 ***ft³/s***
Water-surface elevation in bridge opening 499.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 400 ***ft³/s***
Area of flow in bridge opening 164 ***ft²***
Average velocity in bridge opening 9.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.8 ***ft/s***

Water-surface elevation at Approach section with bridge 501.2
Water-surface elevation at Approach section without bridge 498.2
Amount of backwater caused by bridge 3.0 ***ft***

500-year discharge 2,600 ***ft³/s***
Water-surface elevation in bridge opening 499.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 985 ***ft³/s***
Area of flow in bridge opening 164 ***ft²***
Average velocity in bridge opening 9.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.8 ***ft/s***

Water-surface elevation at Approach section with bridge 501.8
Water-surface elevation at Approach section without bridge 498.7
Amount of backwater caused by bridge 3.1 ***ft***

Incipient overtopping discharge 1,260 ***ft³/s***
Water-surface elevation in bridge opening 496.7 ***ft***
Area of flow in bridge opening 112 ***ft²***
Average velocity in bridge opening 11.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.1 ***ft/s***

Water-surface elevation at Approach section with bridge 499.2
Water-surface elevation at Approach section without bridge 497.7
Amount of backwater caused by bridge 1.5 ***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, 500-year, and incipient roadway-overtopping discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100- and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 100- and 500-year discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146) and presented in tables 1 and 2 and in figure 8. The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

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

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.7	1.3	1.0
Depth to armoring	10.0	8.9	18.3
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	10.4	10.9	9.9
Right abutment	11.4	12.5	9.1
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	2.0
Right abutment	2.1	2.0	2.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

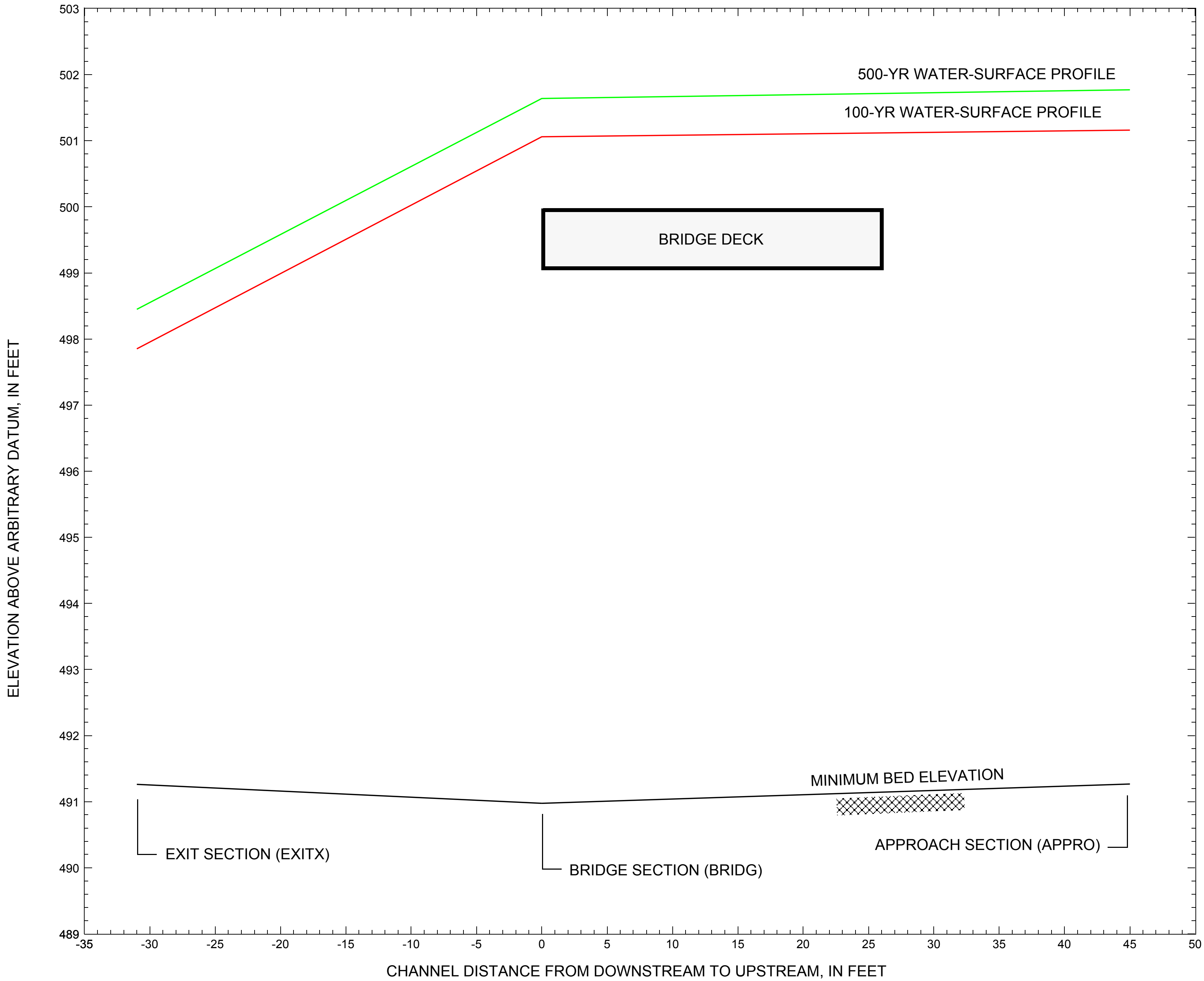

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure DANVTH00610025 on Town Highway 61, crossing Water Andric Brook, Danville, Vermont.

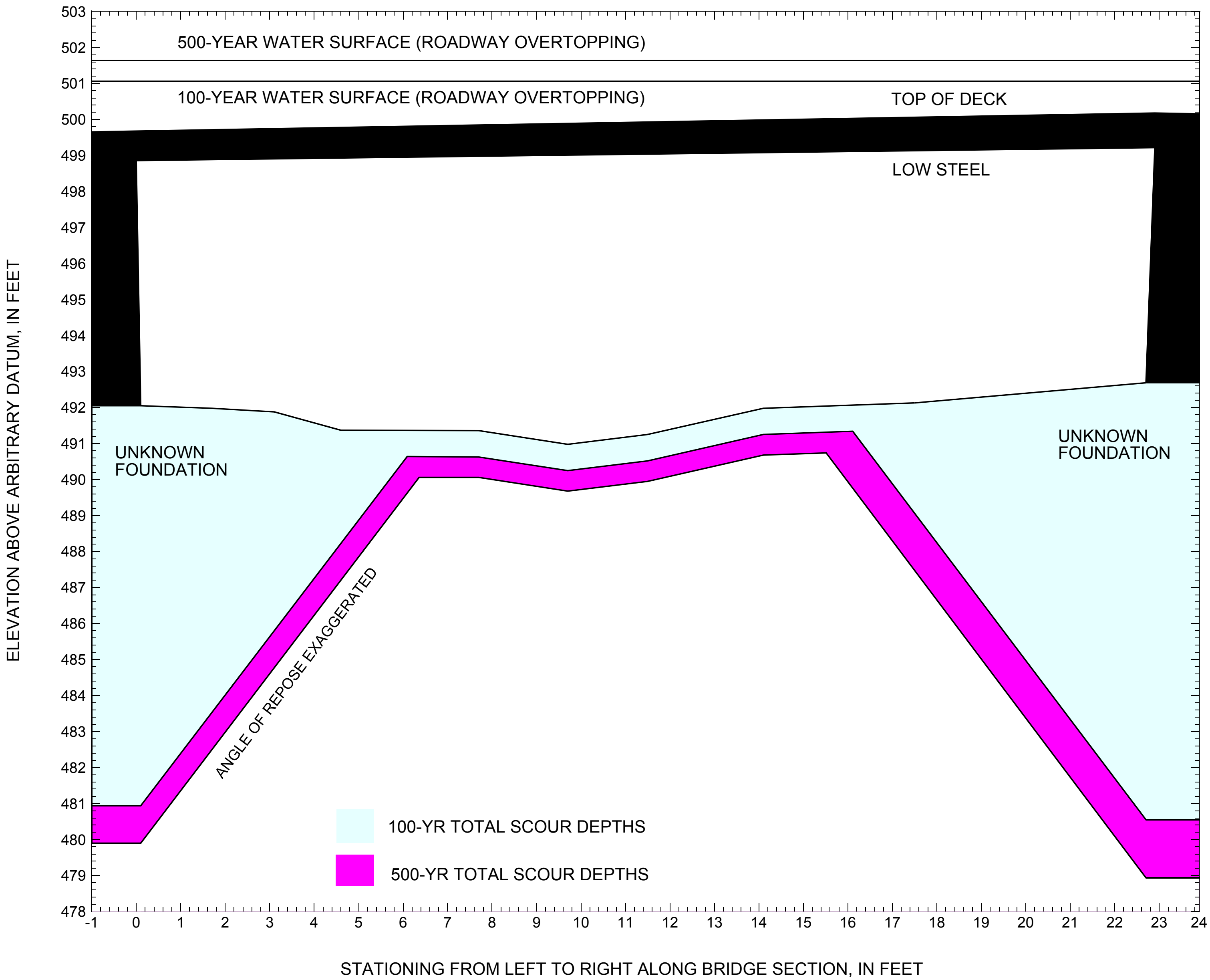

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure DANVTH00610025 on Town Highway 61, crossing Water Andric Brook, Danville, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure DANVTH00610025 on Town Highway 61, crossing Water Andric Brook, Danville, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,890 cubic-feet per second											
Left abutment	0.0	-	498.9	-	492.1	0.7	10.4	--	11.1	481.0	-
Right abutment	22.9	-	499.2	-	492.7	0.7	11.4	--	12.1	480.6	-

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 DANVTH00610025 on Town Highway 61, crossing Water Andric Brook, Danville, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,600 cubic-feet per second											
Left abutment	0.0	-	498.9	-	492.1	1.3	10.9	--	12.2	479.9	-
Right abutment	22.9	-	499.2	-	492.7	1.3	12.5	--	13.8	478.9	-

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.

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, 1983, St. Johnsbury, Vermont 7.5 X 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File
T2        Hydraulic analysis for structure DANVTH00610025   Date: 08-JUL-97
T3        Bridge #25 over Water Andric Brook in Danville, 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           1890.0   2600.0   1260.0
SK          0.0070   0.0070   0.0070
*
XS   EXITX    -31
GR         -229.4, 514.20   -209.9, 509.35   -186.3, 504.69   -135.7, 502.04
GR         -102.7, 496.21    -79.7, 495.84     -7.9, 496.78     -2.6, 495.17
GR            0.0, 492.43      2.4, 492.00      3.7, 491.62      7.9, 491.99
GR           15.1, 491.91     18.3, 491.33     21.6, 491.26     23.2, 491.86
GR           25.3, 493.68     30.8, 496.17     42.7, 496.13     52.1, 497.32
GR           67.7, 500.85     77.8, 505.08     88.6, 506.01     99.2, 511.15
*
N           0.050        0.050        0.065
SA                   -7.9         30.8
*
XS   FULLV      0
GR         -229.4, 514.22   -209.9, 509.37   -186.3, 504.71   -135.7, 502.06
GR         -102.7, 496.23    -79.7, 495.86     -7.9, 496.80     -2.6, 495.19
GR            0.1, 492.05      1.7, 491.98      3.1, 491.88
GR            4.6, 491.37      7.7, 491.36      9.7, 490.98     11.5, 491.25
GR           14.1, 491.98     17.5, 492.13     22.7, 492.69     25.3, 493.70
GR           30.8, 496.19     42.7, 496.15     52.1, 497.34     67.7, 500.87
GR           77.8, 505.10     88.6, 506.03     99.2, 511.17
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    499.04       5.0
GR            0.0, 498.86      0.1, 492.05      1.7, 491.98      3.1, 491.88
GR            4.6, 491.37      7.7, 491.36      9.7, 490.98     11.5, 491.25
GR           14.1, 491.98     17.5, 492.13     22.7, 492.69     22.9, 499.22
GR            0.0, 498.86
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      26.2 * *     46.3      4.4
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      22.1     2
GR         -163.8, 506.67   -114.2, 501.06    -56.8, 500.34      0.0, 499.68
GR            0.4, 500.10      0.6, 500.64     24.7, 501.01     24.8, 500.03
GR           54.4, 501.39     98.1, 502.49    110.7, 502.93    131.9, 505.08
GR          155.5, 507.70
*
XT   APTEM     50
GR         -110.0, 508.50    -47.3, 497.44    -15.6, 497.22     -5.4, 494.74
GR           -3.1, 493.98     -1.9, 492.02     -1.0, 491.36      0.0, 491.27
GR            3.5, 492.01      7.5, 492.49     11.5, 492.50     15.9, 492.01
GR           19.3, 492.45     26.9, 494.96     35.2, 496.92     48.6, 497.92
GR           61.8, 499.90     81.7, 502.32
*
AS   APPRO     45 * * * 0.0057
GT
N           0.090        0.050        0.045
SA                 -15.6         35.2
*
HP 1 BRIDG  499.22 1 499.22
HP 2 BRIDG  499.22 * * 1490
HP 1 BRIDG  498.16 1 498.16
HP 2 RDWAY  501.06 * * 400
HP 1 APPRO  501.16 1 501.16
HP 2 APPRO  501.16 * * 1890
*
HP 1 BRIDG  499.22 1 499.22
HP 2 BRIDG  499.22 * * 1620
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. Geological Survey WSPRO Input File
        Hydraulic analysis for structure DANVTH00610025   Date: 08-JUL-97
        Bridge #25 over Water Andric Brook in Danville, Vt.   RHF
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      164     10740      0     59                      8628784
   499.22           164     10740      0     59  1.00      0     23  8628784

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.22     0.0    22.9   164.0   10740.    1490.   9.09

X STA.         0.0         2.1         3.4         4.5         5.5         6.5
  A(I)            14.1         9.2         8.0         7.6         7.4
  V(I)            5.29        8.08        9.31        9.76       10.03

X STA.         6.5         7.5         8.4         9.3        10.1        11.0
  A(I)             7.2         7.0         6.9         6.9         6.9
  V(I)           10.39       10.68       10.79       10.72       10.83

X STA.        11.0        11.9        12.8        13.8        14.8        15.9
  A(I)             6.9         7.1         7.2         7.2         7.6
  V(I)           10.84       10.48       10.32       10.31        9.84

X STA.        15.9        17.0        18.1        19.3        20.7        22.9
  A(I)             7.6         7.7         8.2         9.2        14.0
  V(I)            9.87        9.63        9.04        8.12        5.31


    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      144     12381     23     34                         2054
   498.16           144     12381     23     34  1.00      0     23     2054


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.06  -114.2    47.2    98.2    2090.     400.   4.07

X STA.      -114.2       -74.5       -63.0       -54.6       -48.0       -42.2
  A(I)             9.9         6.6         5.8         5.2         4.9
  V(I)            2.02        3.04        3.44        3.83        4.09

X STA.       -42.2       -37.3       -32.8       -28.9       -25.2       -21.8
  A(I)             4.5         4.4         4.0         3.9         3.8
  V(I)            4.41        4.60        4.95        5.17        5.29

X STA.       -21.8       -18.7       -15.8       -13.0       -10.4        -8.0
  A(I)             3.6         3.5         3.3         3.2         3.1
  V(I)            5.58        5.76        5.97        6.21        6.45

X STA.        -8.0        -5.2        -2.3         4.5        29.3        47.2
  A(I)             3.6         3.9         5.2         8.3         7.4
  V(I)            5.48        5.15        3.82        2.40        2.71

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      162      5637     53     53                         1610
             2      371     40331     51     53                         5695
             3       87      5091     37     37                          760
   501.16           621     51059    141    144  1.45    -68     72     6144

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.16   -68.6    72.4   620.8   51059.    1890.   3.04

X STA.       -68.6       -35.5       -18.9       -10.1        -5.5        -1.7
  A(I)            84.4        64.6        38.7        27.2        28.0
  V(I)            1.12        1.46        2.44        3.47        3.37

X STA.        -1.7         0.6         2.7         5.0         7.3         9.7
  A(I)            21.7        20.5        21.0        20.5        20.8
  V(I)            4.35        4.60        4.50        4.61        4.55

X STA.         9.7        12.1        14.4        16.7        19.0        21.7
  A(I)            20.6        21.1        20.4        20.8        22.4
  V(I)            4.58        4.49        4.64        4.55        4.22

X STA.        21.7        24.9        29.1        35.1        44.2        72.4
  A(I)            23.8        26.6        29.7        36.1        51.9
  V(I)            3.98        3.56        3.18        2.62        1.82
```

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      U.S. Geological Survey WSPRO Input File
      Hydraulic analysis for structure DANVTH00610025   Date: 08-JUL-97
      Bridge #25 over Water Andric Brook in Danville, Vt.   RHF

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

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      164     10740      0     59                      8628784
 499.22           164     10740      0     59  1.00      0     23  8628784

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL     LEW     REW    AREA        K        Q    VEL
   499.22     0.0    22.9   164.0   10740.    1620.   9.88

X STA.         0.0         2.1         3.4         4.5         5.5         6.5
  A(I)             14.1         9.2         8.0         7.6         7.4
  V(I)             5.76        8.78       10.12       10.61       10.90

X STA.         6.5         7.5         8.4         9.3        10.1        11.0
  A(I)              7.2         7.0         6.9         6.9         6.9
  V(I)            11.30       11.61       11.74       11.66       11.78

X STA.        11.0        11.9        12.8        13.8        14.8        15.9
  A(I)              6.9         7.1         7.2         7.2         7.6
  V(I)            11.78       11.39       11.22       11.21       10.70

X STA.        15.9        17.0        18.1        19.3        20.7        22.9
  A(I)              7.6         7.7         8.2         9.2        14.0
  V(I)            10.73       10.47        9.82        8.83        5.77


  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      158     14076     23     36                         2352
 498.76           158     14076     23     36  1.00      0     23     2352


  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.
     WSEL     LEW     REW    AREA        K        Q    VEL
   501.64  -119.3    64.3   197.5    6205.     985.   4.99

X STA.      -119.3       -95.3       -81.8       -71.4       -62.6       -54.9
  A(I)             14.7        12.2        11.0        10.3         9.8
  V(I)             3.36        4.05        4.49        4.76        5.04

X STA.       -54.9       -48.2       -42.0       -36.4       -31.1       -26.2
  A(I)              9.1         8.9         8.5         8.2         8.0
  V(I)             5.38        5.55        5.77        6.03        6.18

X STA.       -26.2       -21.6       -17.2       -13.2        -9.2        -5.3
  A(I)              7.8         7.6         7.3         7.2         7.4
  V(I)             6.31        6.52        6.75        6.87        6.69

X STA.        -5.3        -1.3         7.7        25.5        31.1        64.3
  A(I)              7.7        10.2        14.1         8.1        19.6
  V(I)             6.42        4.81        3.49        6.07        2.52


  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.
   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      195      7379     56     57                         2065
           2      402     46096     51     53                         6422
           3      112      7034     42     43                         1030
 501.77           709     60509    149    153  1.46    -71     77     7252

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.
     WSEL     LEW     REW    AREA        K        Q    VEL
   501.77   -72.0    77.4   709.3   60509.    2600.   3.67

X STA.       -72.0       -38.1       -22.4       -11.5        -6.5        -2.4
  A(I)             94.2        70.5        51.4        31.0        30.5
  V(I)             1.38        1.85        2.53        4.20        4.26

X STA.        -2.4         0.2         2.4         4.9         7.3         9.9
  A(I)             26.2        23.3        23.9        23.3        23.6
  V(I)             4.96        5.58        5.45        5.59        5.51

X STA.         9.9        12.3        14.8        17.2        19.7        22.6
  A(I)             23.3        23.1        23.3        24.0        25.2
  V(I)             5.59        5.64        5.57        5.41        5.15

X STA.        22.6        26.3        30.9        37.6        46.8        77.4
  A(I)             28.0        29.6        34.8        40.2        60.1
  V(I)             4.65        4.39        3.74        3.23        2.16
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        U.S. Geological Survey WSPRO Input File
        Hydraulic analysis for structure DANVTH00610025   Date: 08-JUL-97
        Bridge #25 over Water Andric Brook in Danville, Vt.   RHF
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      112      8587     23     32                         1405
    496.74           112      8587     23     32  1.00      0     23     1405

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        496.74     0.0    22.8   111.7    8587.    1260.  11.29

 X STA.        0.0        2.3        3.6        4.6        5.6        6.5
   A(I)            10.4        6.4        5.5        5.2        4.9
   V(I)            6.04       9.89      11.56      12.19      12.93

 X STA.        6.5        7.4        8.3        9.1        9.9       10.7
   A(I)             4.7        4.7        4.6        4.5        4.5
   V(I)           13.42      13.41      13.73      14.01      14.11

 X STA.       10.7       11.5       12.3       13.3       14.3       15.4
   A(I)             4.5        4.6        4.8        4.9        5.0
   V(I)           14.03      13.63      13.14      12.74      12.55

 X STA.       15.4       16.5       17.6       18.9       20.4       22.8
   A(I)             5.2        5.3        5.6        6.4       10.0
   V(I)           12.14      11.97      11.17       9.78       6.30


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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       68      1571     42     42                          497
              2      271     23818     51     53                         3545
              3       29      1183     22     22                          194
    499.18           369     26572    115    117  1.36    -56     57     3223

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        499.18   -57.3    57.2   368.6   26572.    1260.   3.42

 X STA.      -57.3      -20.7       -8.7       -4.3       -1.3        0.5
   A(I)            58.3       29.4       18.7       17.9       13.8
   V(I)            1.08       2.14       3.36       3.52       4.57

 X STA.        0.5        2.2        3.9        5.8        7.7        9.6
   A(I)            13.2       12.8       13.2       13.1       12.9
   V(I)            4.78       4.94       4.78       4.82       4.89

 X STA.        9.6       11.6       13.5       15.3       17.1       19.0
   A(I)            12.9       13.1       12.8       12.9       13.2
   V(I)            4.88       4.80       4.94       4.88       4.78

 X STA.       19.0       21.2       23.9       27.6       34.2       57.2
   A(I)            14.4       15.2       17.2       21.5       32.0
   V(I)            4.38       4.14       3.65       2.93       1.97
1
   *
   EX
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File
        Hydraulic analysis for structure DANVTH00610025   Date: 08-JUL-97
        Bridge #25 over Water Andric Brook in Danville, Vt.   RHF

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

EXITX:XS   ******   -111      380  0.54 *****  498.40  497.41    1890  497.85
       -30 ******     54    22572  1.41 ***** *******    0.69    4.97

FULLV:FV       31   -113      427  0.42  0.19  498.58 *******    1890  498.16
         0     31     56    26321  1.37  0.00    0.00    0.58    4.43
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.89     498.19     497.55
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   497.66     508.47    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   497.66     508.47     497.55
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.68

APPRO:AS       45    -51      263  1.00  0.34  499.21  497.55    1890  498.21
        45     45     51    17774  1.25  0.29    0.00    0.88    7.19
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   501.46       0.00     497.83     499.68
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   497.39     500.64     500.78     499.04
 ===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       31      0      164  1.28 *****  500.50  496.95    1490  499.22
         0 ******     23    10740  1.00 ***** *******    0.60    9.09

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.470  0.000  499.04 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      11.    23.  0.03  0.21  501.34    0.00    400.  501.06

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    346.   125.  -114.    11.   1.4   0.7   4.4   4.1   1.0   3.0
   RT:     54.    36.    11.    47.   1.0   0.4   3.4   3.9   0.7   2.8

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

APPRO:AS       19    -68      621  0.21  0.11  501.37  497.55    1890  501.16
        45     20     72    51035  1.45  0.71    0.00    0.31    3.05

       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     -31.  -112.    54.   1890.   22572.     380.    4.97  497.85
   FULLV:FV       0.  -114.    56.   1890.   26321.     427.    4.43  498.16
   BRIDG:BR       0.     0.    23.   1490.   10740.     164.    9.09  499.22
   RDWAY:RG      11.*******   346.    400.******************    2.00  501.06
   APPRO:AS      45.   -69.    72.   1890.   51035.     621.    3.05  501.16

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    497.41    0.69  491.26  514.20************  0.54  498.40  497.85
   FULLV:FV  ********    0.58  490.98  514.22  0.19  0.00  0.42  498.58  498.16
   BRIDG:BR    496.95    0.60  490.98  499.22************  1.28  500.50  499.22
   RDWAY:RG  ****************  499.68  507.70  0.03******  0.21  501.34  501.06
   APPRO:AS    497.55    0.31  491.24  508.47  0.11  0.71  0.21  501.37  501.16
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```
        U.S. Geological Survey WSPRO Input File
        Hydraulic analysis for structure DANVTH00610025   Date: 08-JUL-97
        Bridge #25 over Water Andric Brook in Danville, Vt.   RHF

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

EXITX:XS   ******   -114      482  0.60 *****  499.06  497.87    2600  498.45
       -30 ******     57    31069  1.33 ***** *******    0.66    5.39

FULLV:FV       31   -116      531  0.49  0.19  499.25 *******    2600  498.76
         0     31     58    35488  1.30  0.00    0.00    0.57    4.90
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.98     498.70     498.47
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   498.26     508.47    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   498.26     508.47     498.47
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.62

APPRO:AS       45    -54      314  1.40  0.39  500.09  498.47    2600  498.69
        45     45     54    21877  1.31  0.46   -0.01    0.98    8.28
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   503.85       0.00     498.90     499.68
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   498.50     501.23     501.37     499.04
 ===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       31      0      164  1.52 *****  500.74  497.23    1620  499.22
         0 ******     23    10740  1.00 ***** *******    0.65    9.88

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.484  0.000  499.04 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    23.  0.04  0.31  502.03    0.00    985.  501.64

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    798.   130.  -119.    11.   2.0   1.2   5.7   5.0   1.6   3.0
   RT:    187.    53.    11.    64.   1.6   0.7   4.7   4.8   1.1   3.0

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

APPRO:AS       19    -71      709  0.31  0.14  502.07  498.47    2600  501.77
        45     21     77    60449  1.46  0.55    0.00    0.36    3.67

      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     -31.  -115.    57.   2600.   31069.     482.    5.39  498.45
   FULLV:FV       0.  -117.    58.   2600.   35488.     531.    4.90  498.76
   BRIDG:BR       0.     0.    23.   1620.   10740.     164.    9.88  499.22
   RDWAY:RG      11.*******   798.    985.******************    2.00  501.64
   APPRO:AS      45.   -72.    77.   2600.   60449.     709.    3.67  501.77

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    497.87    0.66  491.26  514.20************  0.60  499.06  498.45
   FULLV:FV  ********    0.57  490.98  514.22  0.19  0.00  0.49  499.25  498.76
   BRIDG:BR    497.23    0.65  490.98  499.22************  1.52  500.74  499.22
   RDWAY:RG ****************  499.68  507.70  0.04******  0.31  502.03  501.64
   APPRO:AS    498.47    0.36  491.24  508.47  0.14  0.55  0.31  502.07  501.77
```

```
        U.S. Geological Survey WSPRO Input File
        Hydraulic analysis for structure DANVTH00610025   Date: 08-JUL-97
        Bridge #25 over Water Andric Brook in Danville, Vt.   RHF
           *** RUN DATE & TIME: 07-24-97  15:33

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

EXITX:XS   ******   -107      273  0.50 *****  497.69  496.85    1260  497.20
       -30 ******     51    15046  1.50 ***** *******    0.76    4.61

FULLV:FV       31   -109      319  0.36  0.18  497.87 *******    1260  497.51
         0     31     53    18061  1.47  0.00   -0.01    0.60    3.95
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       45    -48      208  0.64  0.29  498.29 *******    1260  497.65
        45     45     45    13706  1.12  0.14   -0.01    0.76    6.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

BRIDG:BR       31      0      112  1.98  0.38  498.72  496.41    1260  496.74
         0     31     23     8578  1.00  0.65    0.00    0.90   11.29

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  499.04 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<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       19    -56      368  0.25  0.14  499.42  496.39    1260  499.18
        45     20     57    26539  1.36  0.56    0.01    0.39    3.42

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.757  0.353   17110.    -1.    22.   499.12

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

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -31.  -108.    51.   1260.   15046.     273.    4.61  497.20
   FULLV:FV       0.  -110.    53.   1260.   18061.     319.    3.95  497.51
   BRIDG:BR       0.     0.    23.   1260.    8578.     112.   11.29  496.74
   RDWAY:RG      11.**************      0.******************    2.00********
   APPRO:AS      45.   -57.    57.   1260.   26539.     368.    3.42  499.18

    XSID:CODE   XLKQ   XRKQ      KQ
   APPRO:AS      -1.    22.   17110.

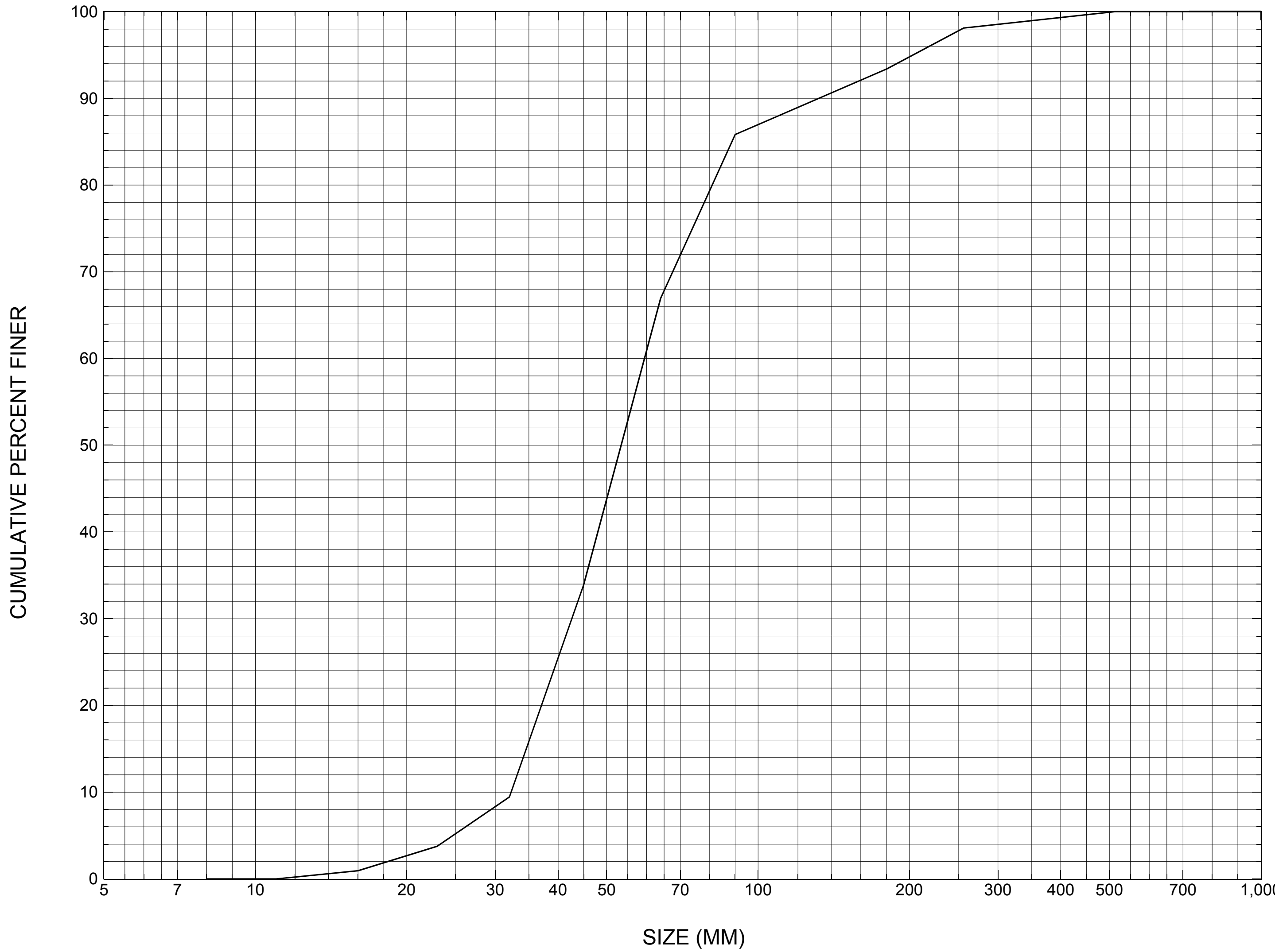
  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    496.85    0.76  491.26  514.20************  0.50  497.69  497.20
   FULLV:FV  ********    0.60  490.98  514.22  0.18  0.00  0.36  497.87  497.51
   BRIDG:BR    496.41    0.90  490.98  499.22  0.38  0.65  1.98  498.72  496.74
   RDWAY:RG  ****************  499.68  507.70**********************************
   APPRO:AS    496.39    0.39  491.24  508.47  0.14  0.56  0.25  499.42  499.18
  ER

1  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 DANVTH00610025, in Danville, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number DANVTH00610025

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 03 / 24 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 17125

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

Waterway *(I - 6)* Water Andric Brook

Road Name *(I - 7):* -

Route Number TH061

Vicinity *(I - 9)* 0.1 MI JCT TH 61 + TH 73

Topographic Map St. Johnsbury

Hydrologic Unit Code: 01080101

Latitude *(I - 16; nnnn.n)* 44233

Longitude *(i - 17; nnnnn.n)* 72037

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030300250303

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

Maximum span length *(I - 48; nnnn)* 0022

Year built *(I - 27; YYYY)* 1947

Structure length *(I - 49; nnnnnn)* 000024

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 221

Year of ADT *(I - 30; YY)* 93

Channel & Protection *(I - 61; n)* 6

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

Waterway adequacy *(I - 71; n)* 7

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*) 006.6

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

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

Comments:

The structural inspection report of 9/20/93 indicates that the structure is a concrete slab type bridge. The abutment walls and wingwalls are concrete and have a few minor fine cracks and spalls overall. Otherwise, the report indicates that the footings are not exposed and that no settlement is apparent. A low gravel point bar has developed in front of the right abutment wall and blocks half the channel. Boulder stone fill has been piled on the roadway embankments at the downstream ends of both abutments. Most of the flow proceeds along the left abutment wall and some local channel scour is reported here. There is some boulder stone fill reported on the banks upstream. Debris accumulation at this site is noted as minor.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **9.685** mi^2 Lake/pond/swamp area **.01** mi^2

Watershed storage *(ST)* **.1** %

Bridge site elevation **650** ft   Headwater elevation **1772** ft

Main channel length **6.366** mi

10% channel length elevation **709** ft   85% channel length elevation **1467** ft

Main channel slope *(S)* **158.8** ft / mi

Watershed Precipitation Data

Average site precipitation - in   Average headwater precipitation - in

Maximum 2yr-24hr precipitation event *(I24,2)* - in

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: - / -

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:
NO BENCHMARK INFORMATION

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

Foundation Type: 4 (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 02/27/96
Computerized by: EW Date: 02/27/96
Reviewd by: RF Date: 07/28/97

Structure Number DANVTH00610025

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. SEVERANCE Date *(MM/DD/YY)* 08 / 22 / 1995

2. Highway District Number 07 Mile marker -

County 005 Town Danville 17125

Waterway *(I - 6)* Water Andric Brook Road Name -

Route Number TH061 Hydrologic Unit Code: 01080101

3. Descriptive comments:

The bridge is located 0.1 miles from the junction between TH61 and TH73.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 4 LBDS 4 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 1 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 24 *(feet)* Span length 22 *(feet)* Bridge width 22.1 *(feet)*

Road approach to bridge:

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

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

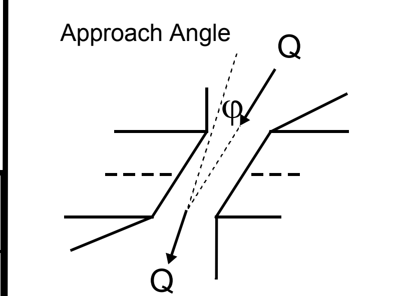
10. Embankment slope (*run / rise in feet / foot*):
US left - US right -

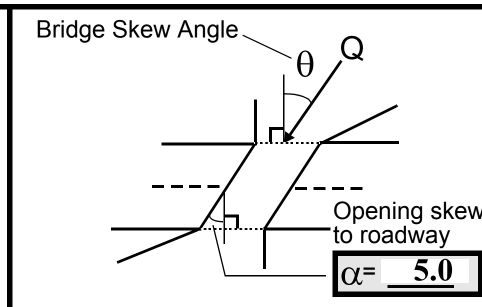
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	3	1
RBDS	0	-	2	2
LBDS	0	-	2	1

*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: 5 16. Bridge skew: 5





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 0 feet US *(US, UB, DS)* to 35 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 0 feet US *(US, UB, DS)* to 6 feet US

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

18. Bridge Type: **1a**

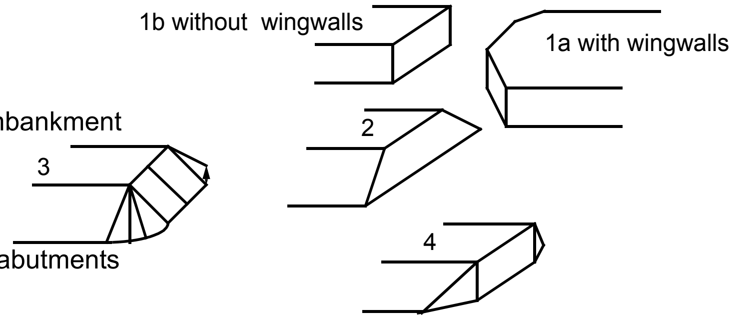
1a- Vertical abutments with wingwalls

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.)

#7: The values are from the VTAOT form. The measured values for bridge length, span length and bridge width were 24.35 ft, 22.4 ft, and 22.05 ft respectively.

#13: Along the US right bank, there are signs of both channel erosion and road wash at the end of the wingwall.

The DS left bank and DS right bank show signs of road wash, which is more severe on the right bank. The roadbed along the right bank is washing down through the placed stone (granite) wingwall on the downstream right bank and the wingwall is slumped.

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
45.0	5.0			4.5	4	1	034	04	1	2

23. Bank width **55.0** 24. Channel width **20.0** 25. Thalweg depth **51.0** 29. Bed Material **3**

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

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

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

#26: The US right overbank is a lawn. The left bank is populated with cedar trees and many roots are exposed. Along the right bank, there also exists a few trees with exposed roots.

#27: Both the left and right bank material is primarily organics, with few cobbles on both banks and some gravel along the left bank.

Fourteen feet upstream, along the left bank, a tree has fallen into the channel and debris has accumulated. The debris extends 6 feet into channel.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **29** 35. Mid-bar width: **20**

36. Point bar extent: **22** feet **UB** (US, UB) to **55** feet **US** (US, UB, DS) positioned **18** %LB to **100** %RB

37. Material: **3/1**

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

#37: The point bar consists of gravel with intermittent sand deposits on the surface. There is a very small amount of flow down the middle of the bar.

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

41. Mid-bank distance: **28** 42. Cut bank extent: **15** feet **US** (US, UB) to **77** 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.):

The cut-bank begins just US of a boulder, approximately 25 upstream of the US bridge face, on the US left bank and continues US to a rock dam. The bank is protected by cobbles, boulders and trees (with exposed roots) but, it is undercut by as much as 2 feet under one tree. The right bank is cut 45 feet US to 80 feet US (to dam) and has bank damage due to block failure. The mid-bank distance is 74 feet.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **23**

47. Scour dimensions: Length **12** Width **2** Depth : **0.75** Position **5** %LB to **15** %RB

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

The channel scour is along 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
21.5		0.5		2	7	7	1

58. Bank width (BF) **-** 59. Channel width **-** 60. Thalweg depth **90.0** 63. Bed Material **1**

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.):

3

The side bar extends under the bridge and is positioned 55% LB to 100% RB.

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

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

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

70. Debris and Ice Comments:

1

Both DS wingwalls have slumped into the channel. There is also a slight debris accumulation at the DS wingwalls.

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		5	0	2	2	0.5	1.3	90.0
RABUT	1	0	0			2	2	23.0

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.):

0

0.25

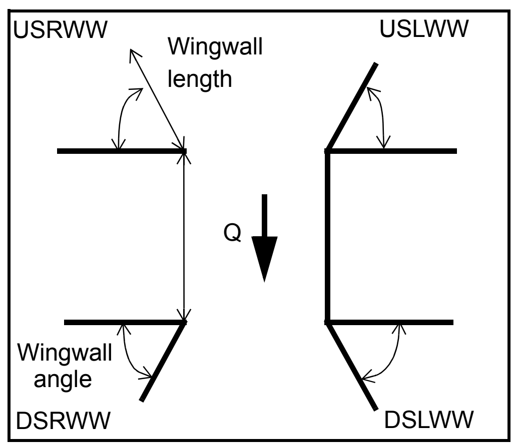
1

#75: Scour depth was measured at the US half of the left abutment. The scour depth is only a few inches at the DS end of the left abutment.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						23.0	
USRWW:	Y		1		2	1.0	
DSLWW:	0		1		Y	21.5	
DSRWW:	1		0		-	22.0	

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



82. Bank / Bridge Protection:

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

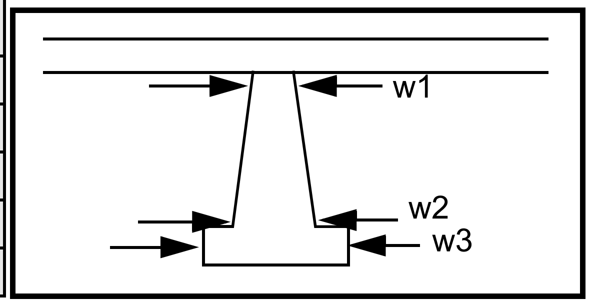
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**7.0**	**5.5**	**40.0**	**55.0**	**60.0**
Pier 2			**7.0**	**10.5**	**55.0**	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e DS**	**slumpe**	**debris**		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**wing**	**d**	**has**	**The**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**walls**	**into**	**accu**	**mate**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**are**	**the**	**mula**	**rial**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**“laid**	**chan**	**ted**	**behi**	*Y- yes; N- no*
91. Attack ∠ (BF)	**-up”**	**nel**	**wher**	**nd**	
92. Pushed	**stone**	**at**	**e the**	**the**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**.**	**the**	**stone**	**DS**	
95. Cross-members	**Both**	**base**	**s**	**right**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**wing**	**s.**	**pro-**	**wing**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**walls**	**Som**	**trud**	**wall**	
98. Exposure depth	**have**	**e**	**e.**	**is**	

99. Pier comments (eg. undermined penetration, protection and protection extent, unusual scour processes, etc.):
being washed out by road wash as well as by flow at bank full.

N
-

E. Downstream Channel Assessment

100.

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

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

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

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

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

101. Is a drop structure present? - *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet
103. Drop: - feet 104. Structure material: - *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*
105. Drop structure comments (eg. downstream scour depth):
-
-
-
-
-
-

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

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

Material: - ____

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

-
-
-
NO PIERS

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

Cut bank extent: ____ feet ____ *(US, UB, DS)* to ____ feet ____ *(US, UB, DS)*

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

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

1
4
1

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

Scour dimensions: Length **1** ____ Width **3** ____ Depth: **0** ____ Positioned **0** ____ %LB to - ____ %RB

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

-

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

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

Confluence 2: Distance ____ Enters on ____ *(LB or RB)* Type ____ *(**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 DROP STRUCTURE

Y
41
14
22

109. G. Plan View Sketch

- D

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: DANVTH00610025 Town: Danville
Road Number: TH061 County: Caledonia
Stream: Water Andric Brook
Initials RHF Date: 7/14/97 Checked: EMB

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	1890	2600	1260
Main Channel Area, ft2	371	402	271
Left overbank area, ft2	162	195	68
Right overbank area, ft2	87	112	29
Top width main channel, ft	51	51	51
Top width L overbank, ft	53	56	42
Top width R overbank, ft	37	42	22
D50 of channel, ft	0.1752	0.1752	0.1752
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.3	7.9	5.3
y1, average depth, LOB, ft	3.1	3.5	1.6
y1, average depth, ROB, ft	2.4	2.7	1.3
Total conveyance, approach	51059	60509	26572
Conveyance, main channel	40331	46096	23818
Conveyance, LOB	5637	7379	1571
Conveyance, ROB	5091	7034	1183
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1492.9	1980.7	1129.4
Ql, discharge, LOB, cfs	208.7	317.1	74.5
Qr, discharge, ROB, cfs	188.4	302.2	56.1
Vm, mean velocity MC, ft/s	4.0	4.9	4.2
Vl, mean velocity, LOB, ft/s	1.3	1.6	1.1
Vr, mean velocity, ROB, ft/s	2.2	2.7	1.9
Vc-m, crit. velocity, MC, ft/s	8.7	8.8	8.3
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
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	1490	1620	1260
Main channel area (DS), ft2	144	158	112
Main channel width (normal), ft	22.8	22.8	22.7
Cum. width of piers, ft	0.0	0.0	0.0

Adj. main channel width, ft	22.8	22.8	22.7
D90, ft	0.4345	0.4345	0.4345
D95, ft	0.6657	0.6657	0.6657
Dc, critical grain size, ft	0.4027	0.3816	0.5248
Pc, Decimal percent coarser than Dc	0.108	0.114	0.079
Depth to armoring, ft	9.95	8.90	18.33

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	1890	2600	1260
(Q) discharge thru bridge, cfs	1490	1620	1260
Main channel conveyance	10740	10740	8587
Total conveyance	10740	10740	8587
Q2, bridge MC discharge,cfs	1490	1620	1260
Main channel area, ft2	164	164	112
Main channel width (normal), ft	22.8	22.8	22.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	22.8	22.8	22.7
y_bridge (avg. depth at br.), ft	7.19	7.19	4.93
Dm, median (1.25*D50), ft	0.219	0.219	0.219
y2, depth in contraction,ft	6.87	7.38	5.97
ys, scour depth (y2-ybridge), ft	-0.32	0.19	1.04

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	1890	2600	1260
Q, thru bridge MC, cfs	1490	1620	1260
Vc, critical velocity, ft/s	8.73	8.85	8.29
Va, velocity MC approach, ft/s	4.02	4.93	4.17
Main channel width (normal), ft	22.8	22.8	22.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	22.8	22.8	22.7
qbr, unit discharge, ft2/s	65.4	71.1	55.5
Area of full opening, ft2	164.0	164.0	112.0
Hb, depth of full opening, ft	7.19	7.19	4.93
Fr, Froude number, bridge MC	0.6	0.65	0.9
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	144	158	N/A
**Hb, depth at downstream face, ft	6.32	6.93	N/A
**Fr, Froude number at DS face	0.73	0.69	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	499.04	499.04	0
Elevation of Bed, ft	491.85	491.85	-4.93
Elevation of Approach, ft	501.16	501.77	0
Friction loss, approach, ft	0.11	0.14	0
Elevation of WS immediately US, ft	501.05	501.63	0.00
ya, depth immediately US, ft	9.20	9.78	4.93

Mean elevation of deck, ft	500.83	500.83	0
w, depth of overflow, ft (>=0)	0.22	0.80	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.95	1.00
**Cc, for downstream face (<=1.0)	0.909618	0.935409	ERR
Ys, scour w/Chang equation, ft	0.73	1.30	N/A
Ys, scour w/Umbrell equation, ft	-0.93	0.00	N/A

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

**Ys, scour w/Chang equation, ft	1.91	1.65	N/A
**Ys, scour w/Umbrell equation, ft	-0.05	0.26	ERR

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

y2, from Laursen's equation, ft	6.87	7.38	5.97
WSEL at downstream face, ft	498.16	498.76	--
Depth at downstream face, ft	6.32	6.93	N/A
Ys, depth of scour (Laursen), ft	0.55	0.45	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	1890	2600	1260	1890	2600	1260
a', abut.length blocking flow, ft	68.6	72	57.3	49.6	54.6	34.5
Ae, area of blocked flow ft2	193.27	191.88	134.27	150.38	161.43	77.46
Qe, discharge blocked abut.,cfs	__	__	297.5	__	__	217
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.09	2.55	2.22	2.75	3.36	2.80
ya, depth of f/p flow, ft	2.82	2.67	2.34	3.03	2.96	2.25
--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	95	95	95	85	85	85
K2	1.01	1.01	1.01	0.99	0.99	0.99
Fr, froude number f/p flow	0.190	0.220	0.255	0.270	0.317	0.329
ys, scour depth, ft	10.38	10.85	9.89	11.41	12.45	9.07

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)	68.6	72	57.3	49.6	54.6	34.5
y1 (depth f/p flow, ft)	2.82	2.67	2.34	3.03	2.96	2.25
a'/y1	24.35	27.02	24.45	16.36	18.47	15.37
Skew correction (p. 49, fig. 16)	1.01	1.01	1.01	0.98	0.98	0.98
Froude no. f/p flow	0.19	0.22	0.26	0.27	0.32	0.33
Ys w/ corr. factor K1/0.55:						
vertical	ERR	11.89	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	9.75	ERR	ERR	ERR	ERR
spill-through	ERR	6.54	ERR	ERR	ERR	ERR

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.73	0.69	0.9	0.73	0.69	0.9
y, depth of flow in bridge, ft	6.31	6.93	4.92	6.31	6.93	4.92
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	2.08	2.04	ERR	2.08	2.04	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	2.00	ERR	ERR	2.00
Fr<=0.8 (spillthrough abut.)	1.81	1.78	ERR	1.81	1.78	ERR
Fr>0.8 (spillthrough abut.)	ERR	ERR	1.77	ERR	ERR	1.77