LEVEL II SCOUR ANALYSIS FOR BRIDGE 31 (HUNTTH00220031) on TOWN HIGHWAY 22, crossing BRUSH BROOK, HUNTINGTON, VERMONT

Open-File Report 97-673

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 31 (HUNTTH00220031) on TOWN HIGHWAY 22, crossing BRUSH BROOK, HUNTINGTON, VERMONT

By ROBERT H. FLYNN AND JAMES R. DEGNAN

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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 31 (HUNTTH00220031) ON TOWN HIGHWAY 22, CROSSING BRUSH BROOK, HUNTINGTON, VERMONT

By **Robert H. Flynn and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure HUNTTH00220031 on Town Highway 22 crossing Brush Brook, Huntington, 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, obtained 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 west-central Vermont. The 5.01-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of trees and brush.

In the study area, Brush Brook has an incised, straight channel with a slope of approximately 0.06 ft/ft, an average channel top width of 44 ft and an average bank height of 4 ft. The channel bed material ranges from boulder to gravel with a median grain size (D_{50}) of 107.0 mm (0.352 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 25, 1996, indicated that the reach was stable.

The Town Highway 22 crossing of Brush Brook is a 34-ft-long, one-lane bridge consisting of one 30-foot steel I-beam span (Vermont Agency of Transportation, written communication, November 30, 1995). The opening length of the structure parallel to the bridge face is 31.2 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening while the computed opening-skew-to-roadway is 10 degrees. The VTAOT computed opening-skew-to-roadway is 2 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed at the downstream end 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) along the upstream right bank. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) 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 was computed to be zero ft. Abutment scour ranged from 7.0 to 10.5 ft. The worst-case abutment scour occurred at the 500-year discharge for the left abutment and at the incipient-overtopping discharge for the right abutment. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Huntington, VT. Quadrangle, 1:24,000, 1948
Photorevised 1980

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 HUNTTH00220031 ***Stream*** Brush Brook

County Chittenden ***Road*** TH31 ***District*** 5

Description of Bridge

Bridge length 34 ***ft*** ***Bridge width*** 15.8 ***ft*** ***Max span length*** 30 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** None

Stone fill on abutment? No ***Date of inspection*** 06/25/96

Description of stone fill Type-2, along the upstream right bank.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a one foot deep scour hole in front of the downstream end of the left abutment.

Is bridge skewed to flood flow according to Level I survey? Yes ***Angle*** 15

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe) No

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	06/25/96	0	0
Level II	06/25/96	0	0

Potential for debris Moderate. There is debris (logs and branches) in the upstream and downstream channel.

Describe any features near or at the bridge that may affect flow (include observation date) None noted as of 06/25/96.

Description of the Geomorphic Setting

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

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

Date of inspection 06/25/96

DS left: Steep channel bank to a narrow overbank.

DS right: Moderately sloped channel bank to a road on the overbank.

US left: Moderately sloped channel bank to a narrow overbank.

US right: Steep channel bank to a road on the overbank.

Description of the Channel

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

Predominant bed material Boulder / Cobbles ***Bank material*** Boulder /Cobbles

Straight and stable with non-alluvial channel boundaries.

06/25/96

Vegetative co Trees and brush along immediate banks with grass on the overbanks.

DS left: Trees and brush.

DS right: Trees and brush along immediate banks with grass on the overbanks.

US left: Trees and brush.

US right:

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

Describe any obstructions in channel and date of observation. The assessment of 06/25/96 noted flow conditions are influenced by boulders on the banks and in the channel. In addition, some debris is caught on boulders in the channel upstream.

Hydrology

Drainage area 5.01 ***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***: Although there are not a significant number of homes, there are a few houses on the upstream and downstream overbank areas.

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 1,500 ***ft³/s*** ***Q500*** 1,970 ***ft³/s***

The 100-year discharge is based on flood frequency estimates available from the VTAOT database. The 500-year discharge is based on a drainage area relationship [(5.0 / 9.2)exp 0.55] with bridge number 12 in Huntington. Bridge number 12 crosses Brush Brook downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 12 is 9.2 square miles. The values selected are within a range defined by discharge frequency curves 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 None

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. 498.15 ft, arbitrary survey datum). RM2 is a nail, 6 ft above the ground, in a 1.5 ft diameter maple tree located 30 ft downstream on the right overbank and 10 ft streamward from the road (elev. 500.01 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	-28	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	50	2	Modelled Approach section (Templated from APTEM)
APTEM	53	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 0.060 to 0.070, and overbank "n" values ranged from 0.035 to 0.065.

Critical depth at the exit section (EXITX) was assumed as the starting water surface for all modelled discharges and was computed based on minimum specific energy. Normal depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0626 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1948, photorevised, 1980). This slope resulted in a normal depth up to 0.5 ft less than critical depth and WSPRO defaulted to critical depth. The assumption of critical depth in the downstream reach for all modelled discharges is considered to be a satisfactory solution.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.068 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 498.5 *ft*
Average low steel elevation 496.5 *ft*

100-year discharge 1,500 *ft³/s*
Water-surface elevation in bridge opening 496.6 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 187 *ft²*
Average velocity in bridge opening 8.0 *ft/s*
Maximum WSPRO tube velocity at bridge 11.6 *ft/s*

Water-surface elevation at Approach section with bridge 498.3
Water-surface elevation at Approach section without bridge 495.8
Amount of backwater caused by bridge 2.5 *ft*

500-year discharge 1,970 *ft³/s*
Water-surface elevation in bridge opening 496.5 *ft*
Road overtopping? Y *Discharge over road* 215 *ft³/s*
Area of flow in bridge opening 185 *ft²*
Average velocity in bridge opening 9.5 *ft/s*
Maximum WSPRO tube velocity at bridge 13.1 *ft/s*

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 496.7
Amount of backwater caused by bridge 2.6 *ft*

Incipient overtopping discharge 1,610 *ft³/s*
Water-surface elevation in bridge opening 496.8 *ft*
Area of flow in bridge opening 188 *ft²*
Average velocity in bridge opening 8.6 *ft/s*
Maximum WSPRO tube velocity at bridge 10.0 *ft/s*

Water-surface elevation at Approach section with bridge 498.6
Water-surface elevation at Approach section without bridge 496.1
Amount of backwater caused by bridge 2.5 *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.

At this site, the 100-year, 500-year, and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146).

For comparison, contraction scour for the discharges resulting in orifice flow was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in Appendix F.

Abutment scour was computed 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	0.0	0.0	0.0
Depth to armoring	19.7	21.2	19.9
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	7.8	10.5	8.6
Right abutment	7.9	7.0	8.1
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	1.7	2.0	1.8
Right abutment	1.7	2.0	1.8
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

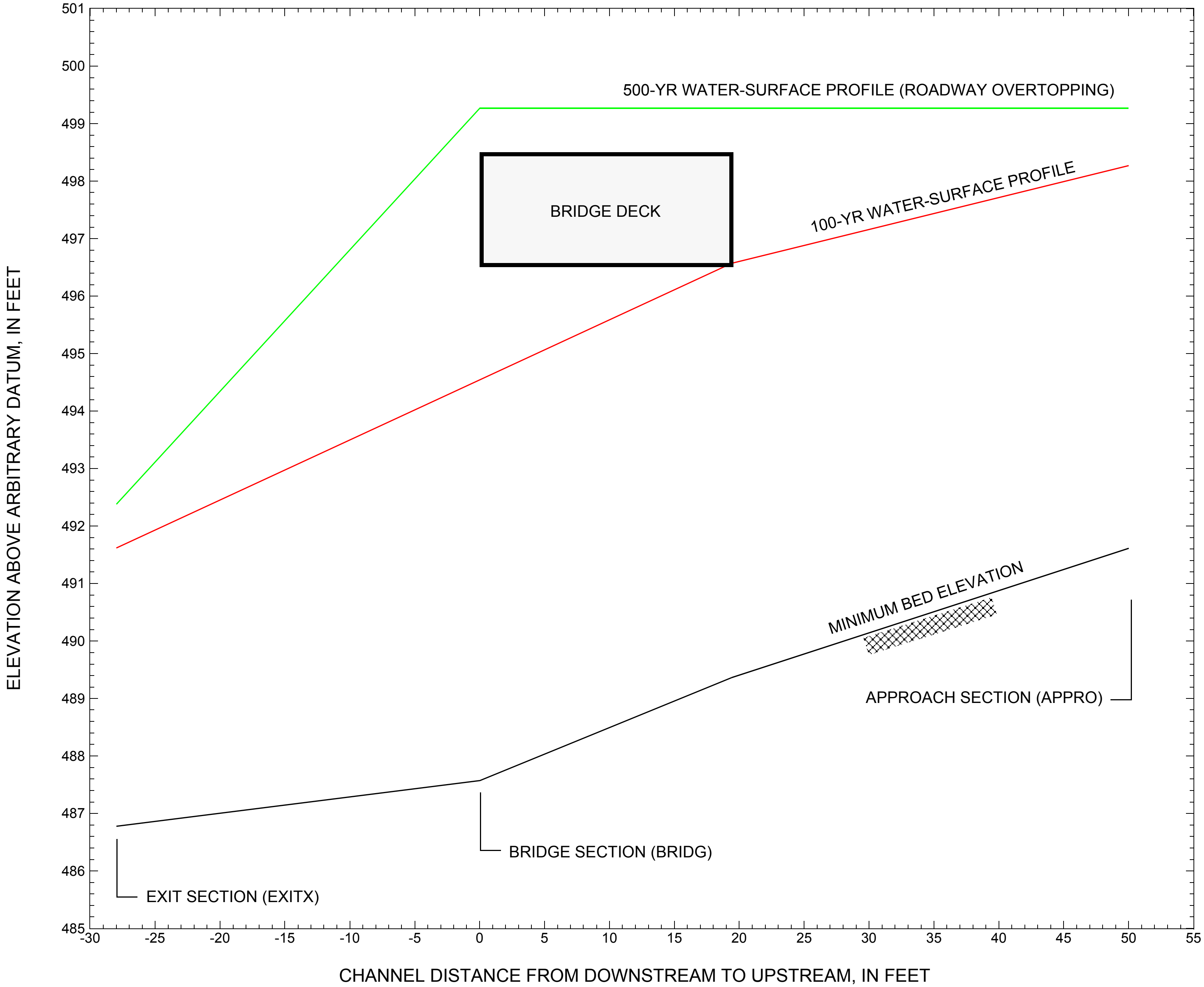

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure HUNTTH00220031 on Town Highway 22, crossing Brush Brook, Huntington, Vermont.

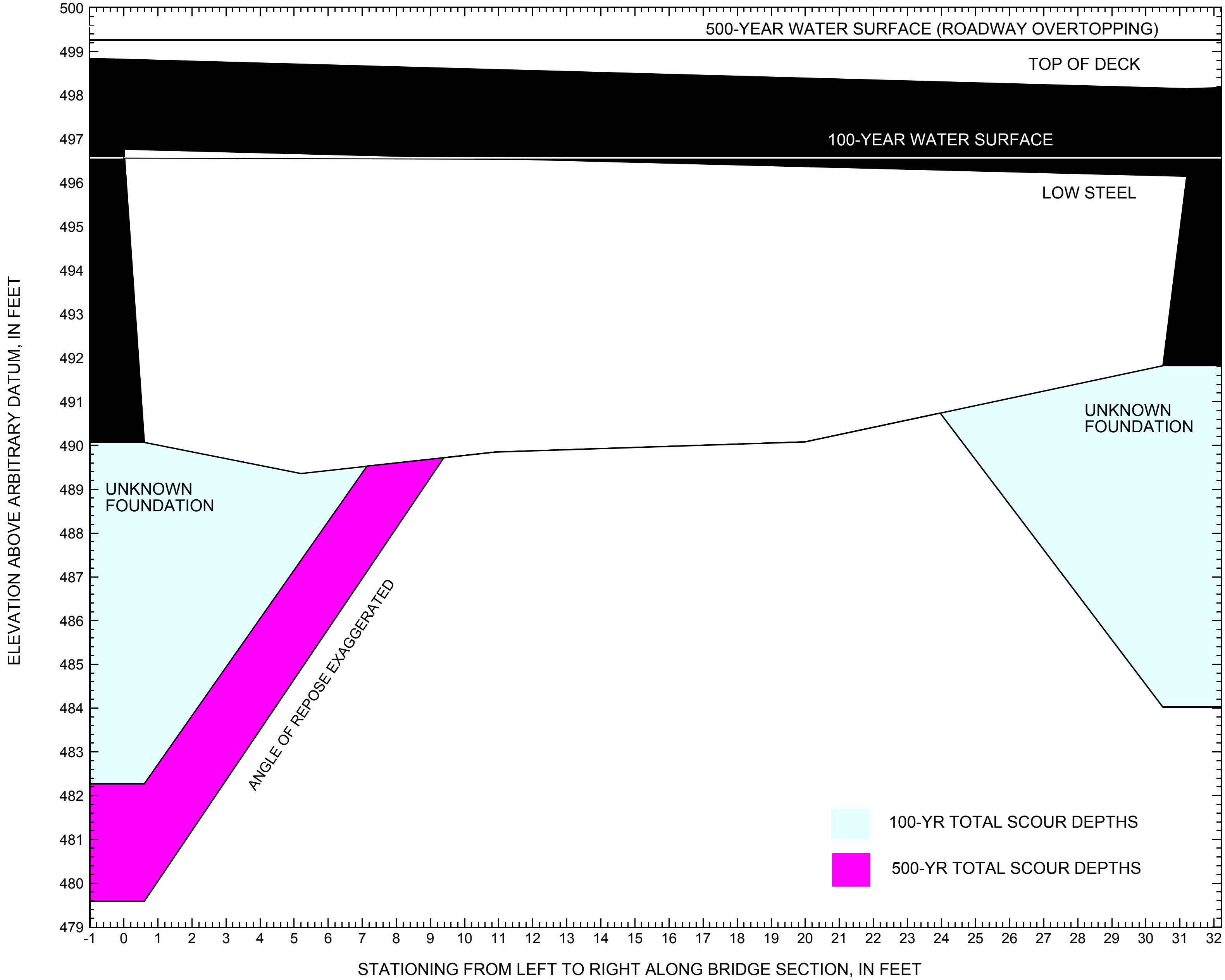

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure HUNTTH00220031 on Town Highway 22, crossing Brush Brook, Huntington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure HUNTTH00220031 on Town Highway 22, crossing Brush Brook, Huntington, 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 1,500 cubic-feet per second											
Left abutment	0.0	--	496.8	--	490.1	0.0	7.8	--	7.8	482.3	--
Right abutment	31.2	--	496.2	--	491.8	0.0	7.9	--	7.9	483.9	--

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 HUNTTH00220031 on Town Highway 22, crossing Brush Brook, Huntington, 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 1,970 cubic-feet per second											
Left abutment	0.0	--	496.8	--	490.1	0.0	10.5	--	10.5	479.6	--
Right abutment	31.2	--	496.2	--	491.8	0.0	7.0	--	7.0	484.8	--

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 Housing and Urban Development, Federal Insurance Administration, 1978, Flood Insurance Study, Town of Huntington, Chittenden County, Vermont: Washington, D.C., January 1978.

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, 1980, Huntington, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1980, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File hunt031.wsp
T2        Hydraulic analysis for structure HUNTTH00220031   Date: 03-JUL-97
T3        Bridge #31 crossing Brush Brook in Huntington, 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           1500.0   1970.0   1610.0
SK          0.0626   0.0626   0.0626
*
XS   EXITX    -28           0.
GR          -90.0, 507.42    -79.3, 500.38    -69.5, 498.82    -11.8, 496.24
GR           -7.7, 493.81     -5.4, 488.99      0.0, 488.18      2.9, 487.01
GR            7.2, 486.78     14.3, 487.53     22.1, 487.49     25.6, 488.23
GR           33.7, 490.76     51.2, 493.21     68.9, 494.08     89.6, 494.45
GR           92.9, 498.06    103.4, 502.40
*
N           0.065        0.070        0.060
SA                 -11.8        33.7
*
XS   FULLV      0  * * *   0.0561
*
*             SRD    LSEL      XSSKEW
BR   BRIDG     0    496.46      10.0
GR            0.0, 496.77      0.6, 490.07      5.2, 489.36     10.9, 489.85
GR           20.0, 490.08     30.5, 491.82     31.2, 496.15      0.0, 496.77
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      19.4 * *     3.6      6.0
N          0.060
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      15.8     2
GR        -109.5, 515.62    -99.0, 508.39    -86.8, 506.15    -61.3, 501.66
GR            0.0, 498.82     30.4, 498.15     46.2, 498.53     66.8, 498.67
GR           78.1, 504.94
*
XT   APTEM     53
GR        -117.7, 520.52    -97.8, 506.68    -83.5, 506.14    -74.5, 507.30
GR         -53.4, 505.30    -40.7, 498.82    -35.4, 498.42    -30.0, 497.01
GR         -25.2, 496.78    -18.8, 497.76     -2.8, 496.60      0.0, 492.43
GR           3.0, 491.71     10.3, 491.61     17.1, 491.77     26.6, 491.99
GR          28.7, 492.73     31.1, 493.30     36.5, 499.51     40.3, 501.95
GR          62.5, 502.12     76.1, 508.65
*
AS   APPRO     50 * * * 0.0680
GT
N          0.065        0.070        0.035
SA                  -2.8        40.3
*
HP 1 BRIDG   496.57 1 496.57
HP 2 BRIDG   496.57 * * 1500
HP 1 BRIDG   494.51 1 494.51
HP 1 APPRO   498.27 1 498.27
HP 2 APPRO   498.27 * * 1500
*
HP 1 BRIDG   496.46 1 496.46
HP 2 BRIDG   496.46 * * 1758
HP 1 BRIDG   495.00 1 495.00
HP 2 RDWAY   499.27 * * 215
HP 1 APPRO   499.27 1 499.27
HP 2 APPRO   499.27 * * 1970
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V042094             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File hunt031.wsp
        Hydraulic analysis for structure HUNTTH00220031   Date: 03-JUL-97
        Bridge #31 crossing Brush Brook in Huntington, VT. RHF

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1     187      9734     10     61                          4603
   496.57           187      9734     10     61  1.00      0     31      4603

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.57     0.0    31.2   186.7    9734.    1500.   8.03

X STA.        0.0        2.5        3.7        4.8        5.7        6.6
  A(I)           14.1        8.4        7.3        6.7        6.6
  V(I)           5.33       8.93      10.31      11.23      11.28

X STA.        6.6        7.6        8.5        9.5       10.7       12.1
  A(I)            6.5        6.5        6.6        7.8        9.3
  V(I)          11.58      11.52      11.40       9.60       8.08

X STA.       12.1       13.5       14.9       16.4       17.9       19.5
  A(I)            9.3        9.2        9.6        9.6        9.8
  V(I)           8.05       8.13       7.84       7.84       7.64

X STA.       19.5       21.1       22.9       24.9       27.3       31.2
  A(I)           10.0       10.4       11.0       12.1       16.0
  V(I)           7.51       7.23       6.81       6.20       4.67


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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1     128      7314     30     37                          1498
   494.51           128      7314     30     37  1.00      0     31      1498


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      40      1034     33     34                           250
              2     226     14525     38     43                          3119
   498.27           267     15559     72     77  1.14    -35     36      2730

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.27   -36.1    35.6   266.5   15559.    1500.   5.63

X STA.      -36.1       -7.4        0.4        2.5        4.2        5.8
  A(I)           32.2       21.7       13.1       11.4       10.9
  V(I)           2.33       3.46       5.73       6.60       6.86

X STA.        5.8        7.4        8.9       10.4       12.0       13.5
  A(I)           10.7       10.7       10.4       10.6       10.5
  V(I)           6.99       6.99       7.23       7.08       7.12

X STA.       13.5       15.1       16.7       18.3       19.9       21.6
  A(I)           10.5       10.7       10.6       10.9       11.0
  V(I)           7.17       6.99       7.05       6.86       6.81

X STA.       21.6       23.3       25.1       27.0       29.4       35.6
  A(I)           11.3       11.8       12.3       14.3       20.8
  V(I)           6.65       6.35       6.12       5.23       3.60
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WSPRO OUTPUT FILE (continued)

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      U.S. Geological Survey WSPRO Input File hunt031.wsp
      Hydraulic analysis for structure HUNTTH00220031   Date: 03-JUL-97
      Bridge #31 crossing Brush Brook in Huntington, VT. RHF

  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      185    10242     15     56                         3656
 496.46           185    10242     15     56  1.00      0     31     3656

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     496.46     0.0    31.2   185.3   10242.    1758.   9.49

X STA.         0.0         2.6         3.9         5.0         6.0         7.0
  A(I)             14.5         8.7         7.5         7.0         6.9
  V(I)             6.05       10.07       11.69       12.58       12.69

X STA.         7.0         8.0         9.0        10.0        11.0        12.1
  A(I)              6.8         6.7         6.8         6.8         6.9
  V(I)            12.91       13.10       12.92       12.99       12.69

X STA.        12.1        13.2        14.4        15.5        17.2        18.9
  A(I)              7.1         7.3         7.5        10.6        10.7
  V(I)            12.31       11.99       11.67        8.28        8.25

X STA.        18.9        20.6        22.5        24.6        27.2        31.2
  A(I)             10.7        11.3        11.7        12.9        16.7
  V(I)             8.21        7.77        7.54        6.79        5.25

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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      143     8626     30     38                         1762
 495.00           143     8626     30     38  1.00      0     31     1762

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

       WSEL     LEW     REW    AREA        K        Q    VEL
     499.27    -9.7    67.9    54.9     999.     215.   3.92

X STA.        -9.7         5.7        11.5        15.8        19.4        22.5
  A(I)              5.1         3.7         3.3         3.0         2.8
  V(I)             2.10        2.91        3.30        3.59        3.79

X STA.        22.5        25.2        27.6        29.9        32.0        34.1
  A(I)              2.6         2.5         2.4         2.4         2.3
  V(I)             4.11        4.26        4.44        4.56        4.77

X STA.        34.1        36.2        38.5        40.9        43.7        46.9
  A(I)              2.1         2.2         2.2         2.4         2.4
  V(I)             5.18        4.97        4.93        4.52        4.40

X STA.        46.9        50.4        54.2        58.2        62.3        67.9
  A(I)              2.5         2.6         2.6         2.7         3.1
  V(I)             4.24        4.09        4.06        3.98        3.51

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
           1       78     2785     39     40                          620
           2      265    18534     39     45                         3911
 499.27           343    21319     78     84  1.14    -41     36     3807

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

       WSEL     LEW     REW    AREA        K        Q    VEL
     499.27   -42.0    36.5   342.9   21319.    1970.   5.75

X STA.       -42.0       -22.9        -8.6        -0.3         2.0         3.9
  A(I)             32.6        29.6        27.1        16.8        14.3
  V(I)             3.02        3.33        3.64        5.87        6.89

X STA.         3.9         5.6         7.3         9.0        10.7        12.3
  A(I)             13.4        13.6        13.2        13.1        13.0
  V(I)             7.34        7.24        7.46        7.53        7.55

X STA.        12.3        14.0        15.7        17.5        19.3        21.1
  A(I)             13.3        13.2        13.3        13.7        13.8
  V(I)             7.40        7.44        7.40        7.19        7.14

X STA.        21.1        22.9        24.9        26.9        29.5        36.5
  A(I)             14.1        14.8        15.4        17.6        26.8
  V(I)             6.97        6.65        6.40        5.58        3.68
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        U.S. Geological Survey WSPRO Input File hunt031.wsp
        Hydraulic analysis for structure HUNTTH00220031   Date: 03-JUL-97
        Bridge #31 crossing Brush Brook in Huntington, VT. RHF

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      188      8871      0     72                            0
   496.77           188      8871      0     72  1.00      0     31        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.77     0.0    31.2   187.7    8871.    1610.   8.58

X STA.         0.0         2.6         4.0         5.2         6.4         7.5
  A(I)             15.2         9.6         8.6         8.5         8.0
  V(I)             5.30        8.35        9.31        9.43       10.04

X STA.         7.5         8.7         9.9        11.2        12.4        13.7
  A(I)              8.3         8.1         8.2         8.2         8.4
  V(I)             9.69        9.89        9.82        9.86        9.64

X STA.        13.7        15.0        16.3        17.6        19.0        20.4
  A(I)              8.3         8.3         8.6         8.6         8.8
  V(I)             9.67        9.76        9.40        9.39        9.16

X STA.        20.4        21.9        23.6        25.4        27.6        31.2
  A(I)              9.0         9.5         9.8        10.9        14.8
  V(I)             8.90        8.51        8.17        7.40        5.44


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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      135      7895     30     37                         1615
   494.73           135      7895     30     37  1.00      0     31     1615


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       53      1508     38     38                          355
             2      240     15923     39     44                         3397
   498.63           293     17431     77     82  1.16    -40     36     3028

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.63   -40.7    35.9   293.2   17431.    1610.   5.49

X STA.       -40.7       -12.9        -0.7         1.7         3.5         5.2
  A(I)             34.0        26.9        15.6        12.5        12.1
  V(I)             2.37        3.00        5.16        6.42        6.65

X STA.         5.2         6.8         8.4        10.0        11.6        13.2
  A(I)             11.6        11.6        11.4        11.3        11.3
  V(I)             6.96        6.96        7.03        7.11        7.15

X STA.        13.2        14.8        16.4        18.0        19.7        21.4
  A(I)             11.5        11.5        11.6        11.9        12.0
  V(I)             6.97        7.01        6.97        6.77        6.73

X STA.        21.4        23.2        25.1        27.0        29.4        35.9
  A(I)             12.3        12.8        13.3        15.2        22.9
  V(I)             6.57        6.27        6.04        5.30        3.51
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        U.S. Geological Survey WSPRO Input File hunt031.wsp
        Hydraulic analysis for structure HUNTTH00220031   Date: 03-JUL-97
        Bridge #31 crossing Brush Brook in Huntington, VT. RHF
           *** RUN DATE & TIME: 07-18-97  13:55

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                          WSI,CRWS =   491.32     491.62

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

EXITX:XS   ******     -6      147  1.66 *****  493.28  491.62    1500  491.62
       -27 ******     40     6930  1.02 ***** *******    1.02   10.22

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.12     492.96     493.19
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.12     508.99    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.12     508.99     493.19
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "FULLV"
                  WSBEG,WSEND,CRWS =   493.19     508.99     493.19

FULLV:FV       28     -6      147  1.66 *****  494.85  493.19    1500  493.19
         0     28     40     6930  1.02 ***** *******    1.02   10.22
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.08     495.64     495.84
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.69     520.32    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.69     520.32     495.84
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   495.84     520.32     495.84

APPRO:AS       50     -1      136  1.90 *****  497.74  495.84    1500  495.84
        50     50     33     6589  1.00 ***** *******    1.00   11.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.51     496.57     497.41     496.46
 ===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       28      0      187  1.00 *****  497.58  494.51    1501  496.57
         0 ******     31     9722  1.00 ***** *******    0.58    8.04

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.453  0.000  496.46 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<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       31    -35      266  0.56  0.47  498.83  495.84    1500  498.27
        50     32     36    15537  1.14  0.82    0.00    0.55    5.64

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   497.95

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -28.    -7.    40.   1500.    6930.     147.   10.22  491.62
   FULLV:FV       0.    -7.    40.   1500.    6930.     147.   10.22  493.19
   BRIDG:BR       0.     0.    31.   1501.    9722.     187.    8.04  496.57
   RDWAY:RG      10.**************      0.       0.       0.    2.00********
   APPRO:AS      50.   -36.    36.   1500.   15537.     266.    5.64  498.27

    XSID:CODE   XLKQ   XRKQ        KQ
   APPRO:AS  ***********************
 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    491.62    1.02  486.78  507.42************  1.66  493.28  491.62
   FULLV:FV    493.19    1.02  488.35  508.99************  1.66  494.85  493.19
   BRIDG:BR    494.51    0.58  489.36  496.77************  1.00  497.58  496.57
   RDWAY:RG  ****************  498.15  515.62************  0.56  498.51********
   APPRO:AS    495.84    0.55  491.41  520.32  0.47  0.82  0.56  498.83  498.27
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        U.S. Geological Survey WSPRO Input File hunt031.wsp
        Hydraulic analysis for structure HUNTTH00220031   Date: 03-JUL-97
        Bridge #31 crossing Brush Brook in Huntington, VT. RHF

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                          WSI,CRWS =   491.90     492.38
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******     -6      184  1.86 *****  494.24  492.38    1970  492.38
       -27 ******     45     9584  1.05 ***** *******    1.03   10.70
 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.19     493.53     493.95
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.88     508.99    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.88     508.99     493.95
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "FULLV"
                  WSBEG,WSEND,CRWS =   493.95     508.99     493.95

FULLV:FV       28     -6      184  1.86 *****  495.81  493.95    1970  493.95
         0     28     45     9584  1.05 ***** *******    1.03   10.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.16     496.20     496.68
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.45     520.32    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.45     520.32     496.68
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   496.68     520.32     496.68

APPRO:AS       50    -26      167  2.18 *****  498.86  496.68    1970  496.68
        50     50     34     8994  1.01 ***** *******    1.07   11.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   498.62       0.00     495.38     498.15
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   502.05         0.      1970.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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       28      0      185  1.40 *****  497.86  495.00    1758  496.46
         0 ******     31    10242  1.00 ***** *******    0.69    9.48

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.488  0.000  496.46 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       10.    34.  0.29  0.59  499.56    0.00    215.  499.27

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     31.    13.     0.    13.   0.7   0.6   4.0   3.9   0.9   2.8
   RT:    184.    55.    13.    68.   1.1   0.8   4.5   4.1   1.1   2.9

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS       31    -41      343  0.59  0.50  499.85  496.68    1970  499.27
        50     32     36    21302  1.14  0.00    0.00    0.52    5.75

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

  FIRST USER DEFINED TABLE.
  XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -28.    -7.    45.   1970.    9584.     184.   10.70  492.38
   FULLV:FV       0.    -7.    45.   1970.    9584.     184.   10.70  493.95
   BRIDG:BR       0.     0.    31.   1758.   10242.     185.    9.48  496.46
   RDWAY:RG      10.*******    31.    215.       0.       0.    2.00  499.27
   APPRO:AS      50.   -42.    36.   1970.   21302.     343.    5.75  499.27

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     492.38    1.03  486.78  507.42************  1.86  494.24  492.38
   FULLV:FV     493.95    1.03  488.35  508.99************  1.86  495.81  493.95
   BRIDG:BR     495.00    0.69  489.36  496.77************  1.40  497.86  496.46
   RDWAY:RG   ****************  498.15  515.62  0.29******  0.59  499.56  499.27
   APPRO:AS     496.68    0.52  491.41  520.32  0.50  0.00  0.59  499.85  499.27
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        U.S. Geological Survey WSPRO Input File hunt031.wsp
        Hydraulic analysis for structure HUNTTH00220031   Date: 03-JUL-97
        Bridge #31 crossing Brush Brook in Huntington, VT. RHF
           *** RUN DATE & TIME: 07-18-97  13:55

 ===015 WSI IN WRONG FLOW REGIME AT SECID “EXITX”:  USED WSI = CRWS.
                          WSI,CRWS =   491.46     491.80
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******     -6      155  1.71 *****  493.52  491.80    1610  491.80
       -27 ******     41     7535  1.03 ***** *******    1.03   10.35
 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.14     493.10     493.37
 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.30     508.99    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.30     508.99     493.37
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “FULLV”
                  WSBEG,WSEND,CRWS =   493.37     508.99     493.37

FULLV:FV       28     -6      155  1.71 *****  495.09  493.37    1610  493.37
         0     28     41     7535  1.03 ***** *******    1.03   10.35
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.10     495.78     496.05
 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.87     520.32    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.87     520.32     496.05
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “APPRO”
                  WSBEG,WSEND,CRWS =   496.05     520.32     496.05

APPRO:AS       50     -2      143  1.96 *****  498.01  496.05    1610  496.05
        50     50     34     7149  1.00 ***** *******    1.00   11.24
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.73     496.88     497.69     496.46
 ===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       28      0      188  1.14 *****  497.91  494.73    1607  496.77
         0 ******     31     8871  1.00 ***** *******    0.62    8.56

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.468  0.000  496.46 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<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       31    -40      293  0.54  0.53  499.17  496.05    1610  498.63
        50     32     36    17428  1.16  0.81    0.00    0.53    5.49

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.34
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -28.    -7.    41.   1610.    7535.     155.   10.35  491.80
   FULLV:FV       0.    -7.    41.   1610.    7535.     155.   10.35  493.37
   BRIDG:BR       0.     0.    31.   1607.    8871.     188.    8.56  496.77
   RDWAY:RG      10.**************      0.       0.       0.    2.00********
   APPRO:AS      50.   -41.    36.   1610.   17428.     293.    5.49  498.63

 SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    491.80    1.03  486.78  507.42************  1.71  493.52  491.80
   FULLV:FV    493.37    1.03  488.35  508.99************  1.71  495.09  493.37
   BRIDG:BR    494.73    0.62  489.36  496.77************  1.14  497.91  496.77
   RDWAY:RG  ****************  498.15  515.62************  0.54  498.88********
   APPRO:AS    496.05    0.53  491.41  520.32  0.53  0.81  0.54  499.17  498.63

  ER
  NORMAL  END  OF  WSPRO  EXECUTION.
```
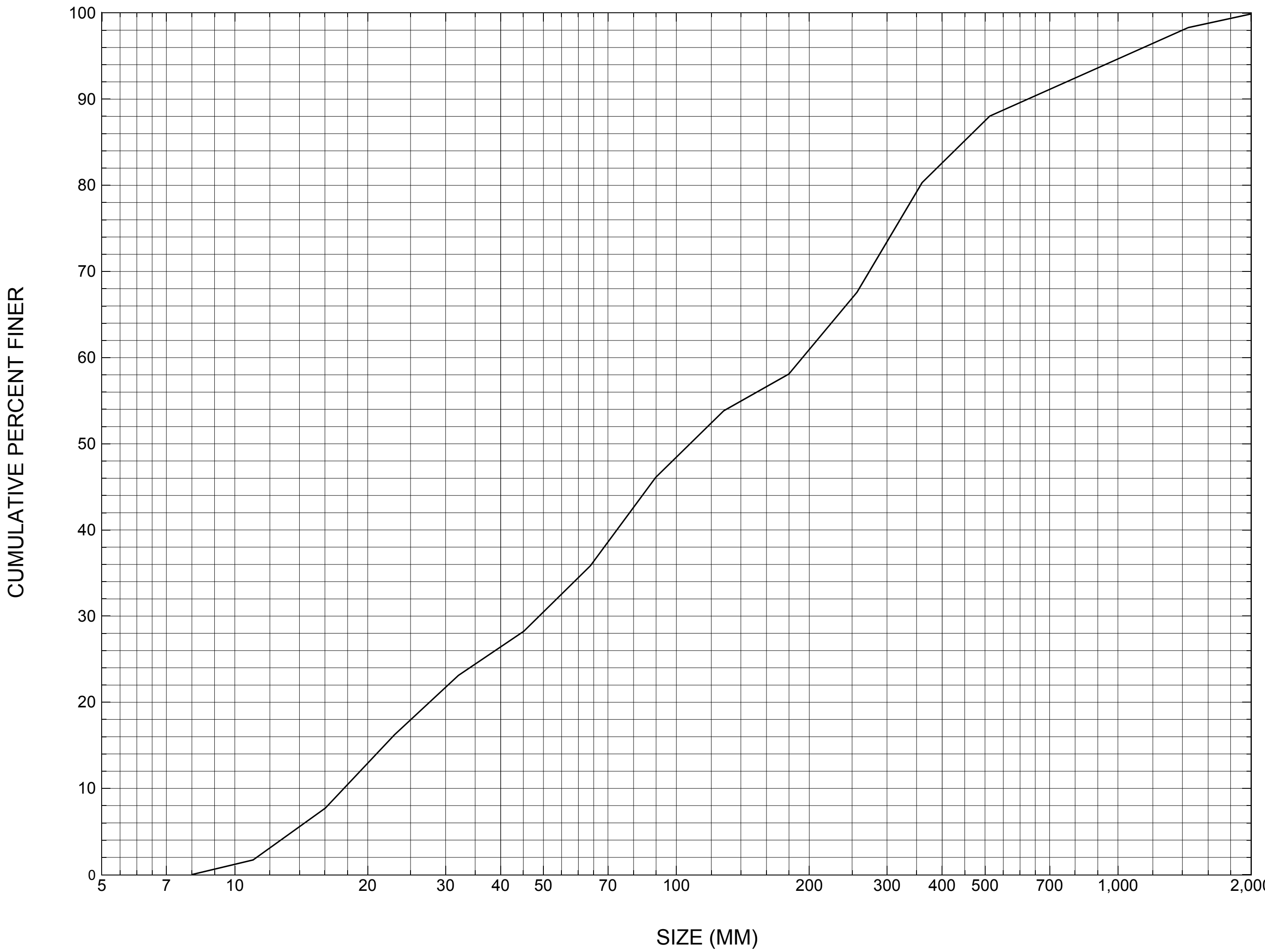

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure HUNTTH00220031, in Huntington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **HUNTTH00220031**

General Location Descriptive

Data collected by *(First Initial, Full last name)* **L**. **Medalie**

Date *(MM/DD/YY)* **11** / **30** / **95**

Highway District Number *(I - 2; nn)* **05**

County *(FIPS county code; I - 3; nnn)* **007**

Town *(FIPS place code; I - 4; nnnnn)* **34600**

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

Waterway *(I - 6)* **Brush Brook**

Road Name *(I - 7):* **-**

Route Number **C3022**

Vicinity *(I - 9)* **1.0 MI TO JCT W CL3 TH21**

Topographic Map **Huntington**

Hydrologic Unit Code: **02010003**

Latitude *(I - 16; nnnn.n)* **44178**

Longitude *(i - 17; nnnnn.n)* **72560**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10040800310408**

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

Maximum span length *(I - 48; nnnn)* **0030**

Year built *(I - 27; YYYY)* **1925**

Structure length *(I - 49; nnnnnn)* **000034**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000020**

Deck Width *(I - 52; nn.n)* **158**

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

Channel & Protection *(I - 61; n)* **4**

Opening skew to Roadway *(I - 34; nn)* **02**

Waterway adequacy *(I - 71; n)* **6**

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

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

Structure type *(I - 43; nnn)* **302**

Year Reconstructed *(I - 106)* **0000**

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

Clear span (*nnn.n ft*) **28**

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

Vertical clearance from streambed (*nnn.n ft*) **7.5**

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

Waterway of full opening (*nnn.n ft*^{2}) **210**

Comments:

According to the structural inspection report dated 7/17/95, the structure is a steel I-beam type bridge with a wooden deck. The abutments, backwalls, and wingwalls are concrete with a few fine cracks and small leaks overall, including a diagonal spall under the right fascia beam on the RABUT. The LABUT is undermined most of its length. The undermining is up to 15” by 2-3” deep. A diagonal settlement crack under the left fascia beam is 1/4” at the top and fine at the bottom, with some deep spalling along the crack line. The left end and left wingwall have cracks and leaks, with areas of delamination overall. The backwall has several cracks with small leaks and some chipping along the crack lines. A diagonal settlement crack at **(Continued, page 33)**

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **5**

Terrain character: **Hilly to mountainous, mostly forested and sparsely populated**

Stream character & type: -

Streambed material: **Gravel and boulders**

Discharge Data *(cfs)*: $Q_{2.33}$ **400** Q_{10} **775** Q_{25} **1000**

Q_{50} **1250** Q_{100} **1500** 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*))	**946.11**	**947.09**			
Velocity (*ft / sec*)	**947.64**	**948.21**	**949.28**	-	-

Long term stream bed changes: -
-

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

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

Are there other structures nearby? (*Yes, No, Unknown*): - *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): - Town: - Year Built: **Y**

Highway No. : **.04** Structure No. : **Hun-** Structure Type: **tington**

Clear span (*ft*): **1925** Clear Height (*ft*): **TH22** Full Waterway (*ft²*): **30**

Downstream distance (*miles*): I- Town: beam Year Built: 26

Highway No. : 10 Structure No. : 260 Structure Type: .45

Clear span (*ft*): Hun- Clear Height (*ft*): ting- Full Waterway (ft^2): ton

Comments:

1925
TH22
32
I-beam
35

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 5.01 mi^2 Lake/pond/swamp area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 1050 ft Headwater elevation 4290 ft

Main channel length 2.956 mi

10% channel length elevation 1140 ft 85% channel length elevation 2900 ft

Main channel slope *(S)* 793.86 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? 10 *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 35 / 0

Project Number the right end of the abut- Minimum channel bed elevation: ment

Low superstructure elevation: USLAB starts DSLAB under USRAB beam DSRAB 2, is 3/

Benchmark location description:

8" at the top, and 1/8" at the bottom. The
abutments could possibly be concrete faced laid up stone. There are numerous large boulders in the US and DS channel and along embankments, with areas of erosion from past flooding.

Reference Point (*MSL, Arbitrary, Other*): ________ Datum (*NAD27, NAD83, Other*): N

Foundation Type: - (*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? - *If no, type ctrl-n bi* Number of borings taken: -

Foundation Material Type: No (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:

benchmark information.

-
-

Comments:

4

-
-
-
-
-

Cross-sectional Data

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

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

Comments: 3
No foundation material information is available.

Station		plan		VTA	tion	The	vatio	vey	repo	The	lengt
Feature		s		OT	is the	low	n is	log	rt on	low	h
Low cord elevation		avail		This	upst	chor	from	done	06/	chor	data
Bed elevation		able.		cross	ream	d	the	for	26/	d to	is
Low cord bed length	No		Y	-sec-	face.	ele-	sur-	this	96.	bed	from

Station	the	to a	repo	95.	done	0	4	10	16	28	-
Feature	sketc	brid	rt	The	on	LAB	-	-	-	RAB	-
Low cord elevation	h	ge	date	sketc	11/	496.7	-	-	-	496.2	-
Bed elevation	attac	inspe	d 07/	h	03/	490.1	-	-	-	491.2	-
Low cord to bed length	hed	ction	17/	was	93.	6.6	7.4	6.7	7.1	5.0	-

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RLB Date: 7/12/97
Computerized by: RLB Date: 7/12/97
Reviewd by: RHF Date: 7/23/97

Structure Number HUNTTH00220031

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 06 / 25 / 1996

2. Highway District Number 05 Mile marker 0000

County Chittenden (007) Town Huntington (34600)

Waterway *(I - 6)* Brush Brook Road Name -

Route Number C3022 Hydrologic Unit Code: 02010003

3. Descriptive comments:

This is a steel I-beam type bridge with a wooden deck located 1 mile from the junction with TH 21. There are houses on the overbanks. The bridge is located near an intersection and a sign indicates that this is the road to Camel's Hump Hiking Trails.

B. Bridge Deck Observations

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

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

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

7. Bridge length 34 *(feet)* Span length 30 *(feet)* Bridge width 15.8 *(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)*

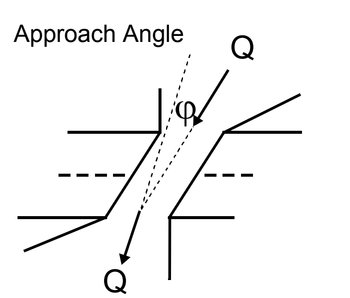
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

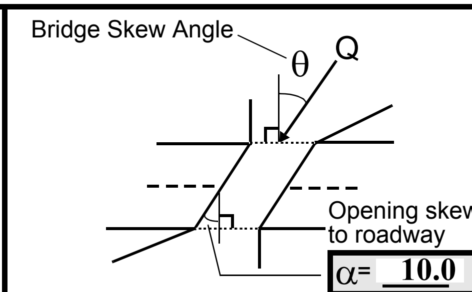
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	3	1	1
RBUS	2	1	2	2
RBDS	0	-	1	2
LBDS	0	-	1	2

*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: 20 16. Bridge skew: 15





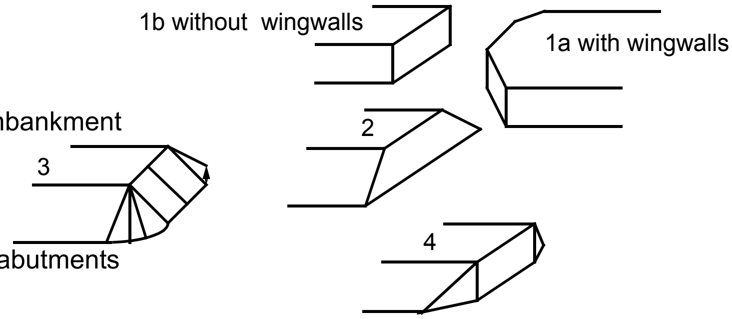
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 40 feet US *(US, UB, DS)* to 0 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 0 feet DS *(US, UB, DS)* to 30 feet DS

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

18. Bridge Type: 1a

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

7. Values are from the VT AOT database.
18. There are wingwalls on the left side and they are almost parallel to the road. There are no wingwalls on the right side of the bridge.

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
33.0	4.0			6.0	3	2	543	543	2	2

23. Bank width 55.0 24. Channel width 50.0 25. Thalweg depth 43.0 29. Bed Material 543

30 .Bank protection type: LB 0 RB 2 31. Bank protection condition: LB - RB 3

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

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

30. The right bank protection extends from 0 ft US to 24 ft US where it is eroded by road wash.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **85** 35. Mid-bar width: **14**

36. Point bar extent: **105** feet **US** (US, UB) to **70** feet **US** (US, UB, DS) positioned **80** %LB to **100** %RB

37. Material: **543**

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: **45** 42. Cut bank extent: **50** feet **US** (US, UB) to **36** 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.):

Both banks have exposed tree roots.

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES. On the left bank a dry channel rejoins the stream at the US left wingwall. There is a culvert on the right bank 65 ft US.

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
31.0		**1.0**		**2**	**7**	**7**	**-**

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

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

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

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

543

-

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

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

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

70. Debris and Ice Comments:

2

66. There are logs and branches in the channel US and DS.

69. There is scarring on the trees due to ice.

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	90	2	0	-	-	90.0
RABUT	1	-	90			2	0	30.5

Pushed: LB or RB *Toe Location (Loc.): **0**- even, **1**- set back, **2**- protrudes*

*Scour cond.: **0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**-undermined footing; **4**- piling exposed; **5**- settled; **6**- failed*

Materials: **1**- Concrete; **2**- Stone masonry or drywall; **3**- steel or metal; **4**- wood

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

-

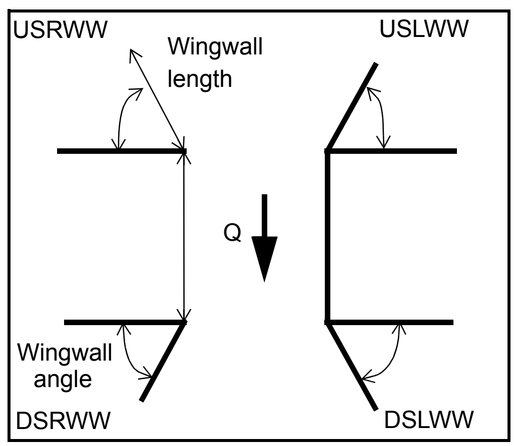
-

1

74. There is some undermining of the left abutment.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						30.5	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		N	21.5	
DSRWW:	-		-		-	16.5	



*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	N	-	-	-	-	-
Condition	Y	-	-	-	-	-	-	-
Extent	1	-	-	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*

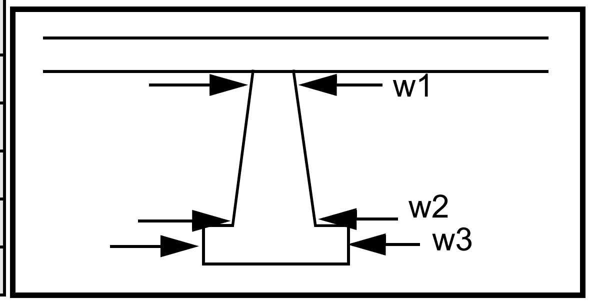
*Protection extent: **1**- entire base length; **2**- US end; **3**- DS end; **4**- other*

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	5.0	-	5.0	6.0	-	4.5
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
-
-
-
-
-
NO PIERS

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):

3
3
543
543
2

106. Point/Side bar present? 1 (Y or N. if N type ctrl-n pb) Mid-bar distance: 543 Mid-bar width: 0

Point bar extent: 0 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.):

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

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

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

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

-

NO DROP STRUCTURE

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

Scour dimensions: Length ____ Width Y Depth: 0 DS Positioned 15 %LB to 0 %RB

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

US

17

DS

40

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

Confluence 1: Distance 453 Enters on The (LB or RB) Type re is (**1**- perennial; **2**- ephemeral)

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

Confluence comments (eg. confluence name):

t bar on the right bank extending from 48 ft DS to 90 ft DS. The mid-bar is at 60 ft DS with a width of 7 ft. It consists of mostly gravel and some cobbles and boulders.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

Y
LB
10
0
DS
40
DS
2
-

109. G. Plan View Sketch

Y

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: HUNTTH00220031 Town: Huntington
Road Number: TH022 County: Chittenden
Stream: Brush Brook

Initials RHF Date: 7/17/97 Checked: RLB

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	1500	1970	1610
Main Channel Area, ft2	226	265	240
Left overbank area, ft2	40	78	53
Right overbank area, ft2	0	0	0
Top width main channel, ft	38	39	39
Top width L overbank, ft	33	39	38
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.3521	0.3521	0.3521
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.9	6.8	6.2
y1, average depth, LOB, ft	1.2	2.0	1.4
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	15559	21319	17431
Conveyance, main channel	14525	18534	15923
Conveyance, LOB	1034	2785	1508
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1400.3	1712.6	1470.7
Ql, discharge, LOB, cfs	99.7	257.4	139.3
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	6.2	6.5	6.1
Vl, mean velocity, LOB, ft/s	2.5	3.3	2.6
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	10.7	10.9	10.7
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

Main Channel	0	0	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

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	1500	1758	1610
Main channel area (DS), ft2	128	143	135

```
  Main channel width (normal), ft   30.7     30.73    30.7
  Cum. width of piers, ft           0.0      0.0      0.0
  Adj. main channel width, ft       30.7     30.7     30.7
D90, ft                             2.0436   2.0436   2.0436
D95, ft                             3.3900   3.3900   3.3900
Dc, critical grain size, ft         1.3393   1.3775   1.3423
Pc, Decimal percent coarser than Dc 0.169    0.163    0.169

Depth to armoring, ft               19.74    21.22    19.85
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          1500     1970     1610
  (Q) discharge thru bridge, cfs    1500     1758     1610
  Main channel conveyance           9734     10242    8871
  Total conveyance                  9734     10242    8871
Q2, bridge MC discharge,cfs         1500     1758     1610
  Main channel area, ft2            187      185      188
  Main channel width (normal), ft   30.7     30.7     30.7
  Cum. width of piers in MC, ft     0.0      0.0      0.0
W, adjusted width, ft               30.73    30.73    30.73
y_bridge (avg. depth at br.), ft    6.09     6.02     6.12
Dm, median (1.25*D50), ft           0.440125 0.440125 0.440125
y2, depth in contraction,ft           4.38     5.02     4.66

ys, scour depth (y2-ybridge), ft    -1.70    -1.00    -1.46


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                       1500     1970     1610
Q, thru bridge MC, cfs              1500     1758     1610
Vc, critical velocity, ft/s         10.65    10.89    10.72
Va, velocity MC approach, ft/s      6.20     6.46     6.13
Main channel width (normal), ft     30.7     30.7     30.7
Cum. width of piers in MC, ft       0.0      0.0      0.0
W, adjusted width, ft               30.7     30.7     30.7
qbr, unit discharge, ft2/s          48.8     57.2     52.4
Area of full opening, ft2           187.0    185.0    188.0
Hb, depth of full opening, ft       6.09     6.02     6.12
Fr, Froude number, bridge MC        0.58     0.69     0.62
Cf, Fr correction factor (<=1.0)    1.00     1.00     1.00
**Area at downstream face, ft2      128      143      135
**Hb, depth at downstream face, ft  4.17     4.65     4.39
**Fr, Froude number at DS face      1.01     1.00     1.00
**Cf, for downstream face (<=1.0)   1.00     1.00     1.00
Elevation of Low Steel, ft          496.46   496.46   496.46
Elevation of Bed, ft                490.37   490.44   490.34
Elevation of Approach, ft           498.27   499.27   498.63
```

Friction loss, approach, ft	0.47	0.5	0.53
Elevation of WS immediately US, ft	497.80	498.77	498.10
ya, depth immediately US, ft	7.43	8.33	7.76
Mean elevation of deck, ft	498.48	498.48	498.48
w, depth of overflow, ft (>=0)	0.00	0.29	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.93	0.94
**Cc, for downstream face (<=1.0)	0.80	0.83	0.82
Ys, scour w/Chang equation, ft	-1.27	-0.36	-0.92
Ys, scour w/Umbrell equation, ft	-0.18	0.54	-0.01

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

**Ys, scour w/Chang equation, ft	1.56	1.65	1.61
**Ys, scour w/Umbrell equation, ft	1.74	1.91	1.71

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	4.38	5.02	4.66
WSEL at downstream face, ft	494.51	495.00	494.73
Depth at downstream face, ft	4.17	4.65	4.39
Ys, depth of scour (Laursen), ft	0.22	0.37	0.26

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	1500	1970	1610	1500	1970	1610
a', abut.length blocking flow, ft	36.3	42.2	40.9	4.6	5.5	4.9
Ae, area of blocked flow ft2	53.34	89.67	66.75	15.43	15.23	17.26
Qe, discharge blocked abut.,cfs	148.08	__	191.19	55.65	__	60.68
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.78	3.41	2.86	3.61	3.68	3.52
ya, depth of f/p flow, ft	1.47	2.12	1.63	3.35	2.77	3.52
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	100	100	100	80	80	80
K2	1.01	1.01	1.01	0.98	0.98	0.98
Fr, froude number f/p flow	0.404	0.405	0.395	0.347	0.331	0.330
ys, scour depth, ft	7.80	10.48	8.62	7.86	7.01	8.14

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)	36.3	42.2	40.9	4.6	5.5	4.9
y1 (depth f/p flow, ft)	1.47	2.12	1.63	3.35	2.77	3.52
a'/y1	24.70	19.86	25.06	1.37	1.99	1.39
Skew correction (p. 49, fig. 16)	1.02	1.02	1.02	0.98	0.98	0.98
Froude no. f/p flow	0.40	0.41	0.40	0.35	0.39	0.33
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	8.93	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	7.32	ERR	ERR	ERR
spill-through	ERR	ERR	4.91	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream Yields most conservative result

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	1	1	1	1
y, depth of flow in bridge, ft	4.17	4.65	4.39	4.17	4.65	4.39
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	1.74	1.95	1.84	1.74	1.95	1.84