LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (NEWBTH00840028) on TOWN HIGHWAY 84, crossing HALLS BROOK, NEWBURY, VERMONT

Open-File Report 98-551

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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By RONDA L. BURNS and ERICK M. BOEHMLER

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1998

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (NEWBTH00840028) ON TOWN HIGHWAY 84, CROSSING HALLS BROOK, NEWBURY, VERMONT

By **Ronda L. Burns and Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure NEWBTH00840028 on Town Highway 84 crossing Halls Brook, Newbury, 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 (FHWA, 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 east-central Vermont. The 25.0-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 upstream left bank and on the downstream right bank, while the immediate banks have dense woody vegetation. The downstream left bank is forested and the upstream right bank is shrub and brushland.

In the study area, Halls Brook has a sinuous channel with a slope of approximately 0.003 ft/ft, an average channel top width of 30 ft and an average bank height of 3 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 47.9 mm (0.157 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 30, 1995, indicated that the reach was stable.

The Town Highway 84 crossing of Halls Brook is a 49-ft-long, two-lane bridge consisting of one 45-foot concrete tee-beam span (Vermont Agency of Transportation, written communication, March 27, 1995). The opening length of the structure parallel to the bridge face is 44.4 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening and the computed opening-skew-to-roadway is 15 degrees.

Channel scour 3.0 ft deeper than the mean thalweg depth was observed in the downstream reach during the Level I assessment. Scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the downstream left bank and a 60 inch concrete block at the upstream end of the downstream 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 Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 1.9 to 3.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 19.7 to 25.2 ft. Right abutment scour ranged from 13.2 to 16.8 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 Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Newbury, VT. Quadrangle, 1:24,000, 1973

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 NEWBTH00840028 ***Stream*** Halls Brook

County Orange ***Road*** TH84 ***District*** 7

Description of Bridge

Bridge length 49 ***ft*** ***Bridge width*** 23.4 ***ft*** ***Max span length*** 45 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/30/95

Description of stone fill There is a 60 inch concrete block at the upstream end of the downstream left wingwall.

Abutments and wingwalls are concrete.

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

There is a mild channel bend in the upstream reach.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	8/30/95	0	0
Level II	8/30/95	0	0

Potential for debris Moderate. There is a lot of vegetation on the banks and the drainage area is predominantely forested.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 8/30/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a narrow flood plain.

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

Date of inspection 8/30/95

DS left: Moderately sloped overbank

DS right: Narrow flood plain

US left: Narrow flood plain

US right: Moderately sloped overbank

Description of the Channel

Average top width 30 ft ***Average depth*** 3 ft

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

Sinuous with semi-alluvial channel boundaries, irregular point bars, and random width variations.

8/30/95

Vegetative co Trees and brush

DS left: Trees and brush with pasture on the overbank

DS right: Trees and brush with pasture on the overbank

US left: Trees and brush with pasture on the overbank

US right:

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

The assessment of 8/30/95 noted the U.S. Route 5 crossing of Halls Brook is 0.1 miles downstream.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 25.0 ***mi***^{2}

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***: None.

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 3,880 ***ft***^{3}***/s*** ***Q500*** 5,970 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(25.0/23.4)exp 0.67] with bridge number 16 in Newbury. Bridge number 16 crosses Halls Brook upstream of this site and has flood frequency estimates available from the VTAOT database (written communication, May 1995). The drainage area above bridge number 16 is 23.4 square miles. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream right end of the concrete bridge curb (elev. 501.64 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream left end of the concrete bridge curb (elev. 501.45 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analvsis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT2	-258	1	U.S. Route 5 bridge Exit section
FLV2	-200	2	U.S. Route 5 bridge Full-valley section (Templated from EXIT2)
BRID2	-200	1	U.S. Route 5 bridge section
APPR2	-59	2	U.S. Route 5 bridge modelled Approach section (Templated from A2TEM)
A2TEM	-35	5	U.S. Route 5 bridge Approach section (Same as EXITX)
EXITX	-35	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	69	2	Modelled Approach section (Templated from APTEM)
APTEM	81	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.

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 0.035 to 0.055, and overbank "n" values ranged from 0.040 to 0.070.

Normal depth at the exit section (EXIT2) 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 0.0029 ft/ft which was estimated from surveyed thalweg points downstream of the U.S. Route 5 bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0063 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

For the 100-year, 500-year, and incipient-overtopping discharges, WSPRO assumes critical depth at the U.S. Route 5 bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the U.S. Route 5 bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.9 ***ft***
Average low steel elevation 497.1 ***ft***

100-year discharge 3,880 ***ft^3/s***
Water-surface elevation in bridge opening 493.5 ***ft***
Road overtopping? No ***Discharge over road*** - ***/s***
Area of flow in bridge opening 309 ***ft^2***
Average velocity in bridge opening 12.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.3 ***ft/s***

Water-surface elevation at Approach section with bridge 496.6
Water-surface elevation at Approach section without bridge 495.3
Amount of backwater caused by bridge 1.3 ***t***

500-year discharge 5,970 ***ft^3/s***
Water-surface elevation in bridge opening 497.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 540 ***/s***
Area of flow in bridge opening 459 ***ft^2***
Average velocity in bridge opening 11.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.8 ***/s***

Water-surface elevation at Approach section with bridge 501.2
Water-surface elevation at Approach section without bridge 497.5
Amount of backwater caused by bridge 3.7 ***t***

Incipient overtopping discharge 4,810 ***ft^3/s***
Water-surface elevation in bridge opening 497.2 ***ft***
Area of flow in bridge opening 459 ***ft^2***
Average velocity in bridge opening 10.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.0 ***ft/s***

Water-surface elevation at Approach section with bridge 499.8
Water-surface elevation at Approach section without bridge 496.4
Amount of backwater caused by bridge 3.4 ***t***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 500-year and the incipient road-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 Davis, 1995, p. 145-146). Results of this scour analysis are shown in tables 1 and 2 and figure 8.

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

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.2	3.8	1.9
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	19.7	25.2	22.7
Right abutment	13.2	16.8	16.0
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	2.9	2.9	2.8
Right abutment	2.9	2.9	2.8
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

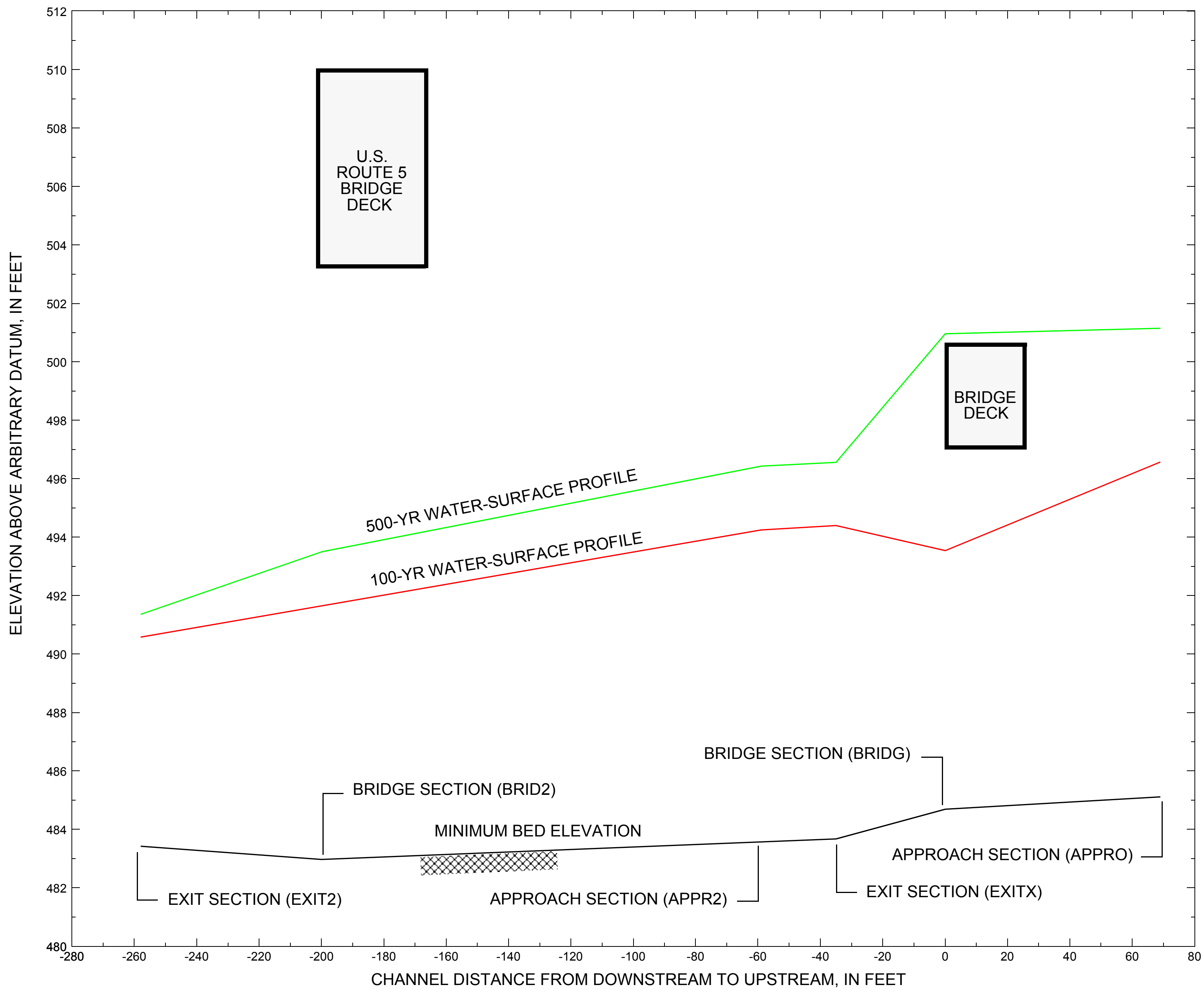

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure NEWBTH00840028 on Town Highway 84, crossing Halls Brook, Newbury, Vermont.

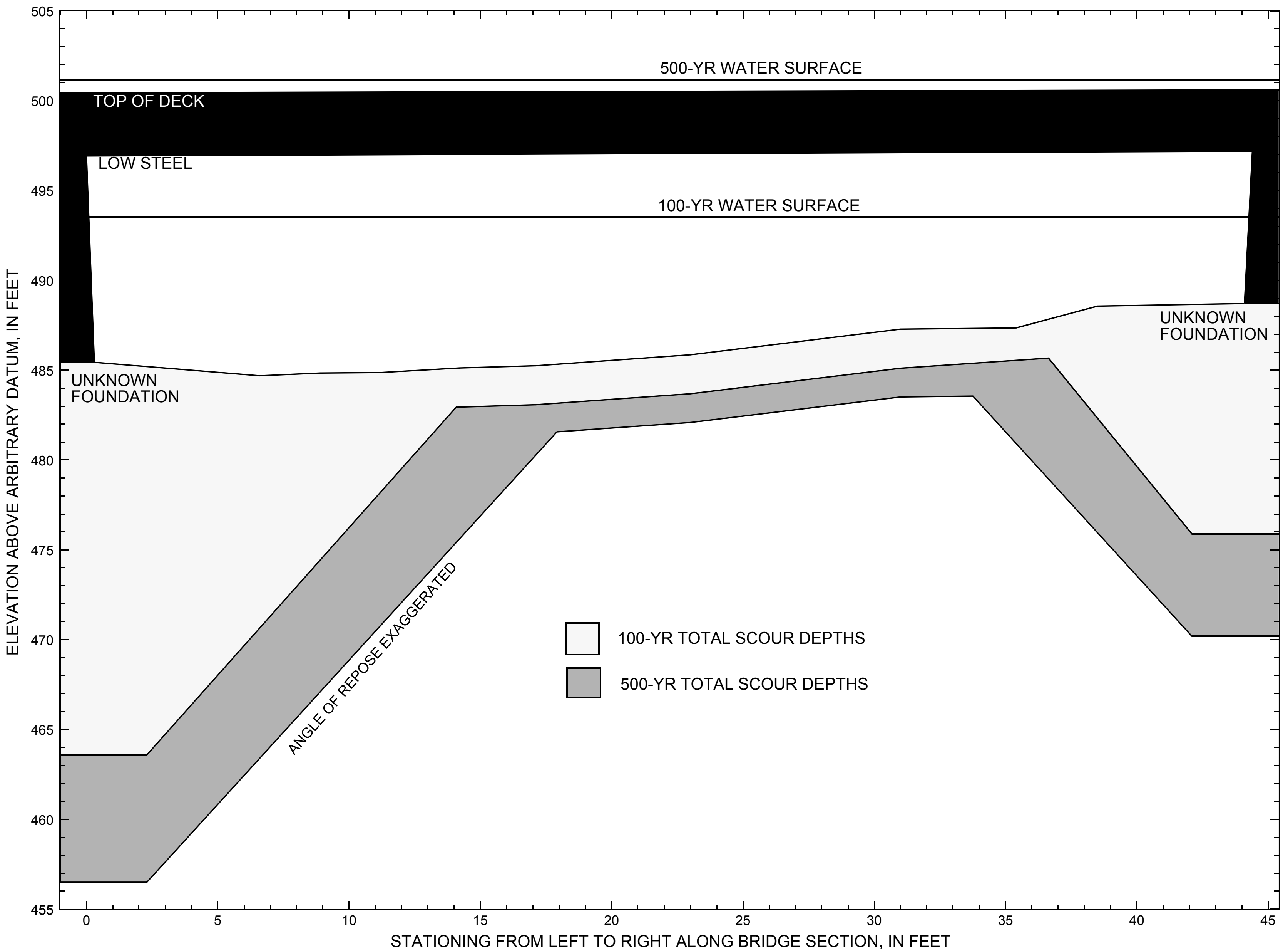

Figure 8. Scour elevations for the 100- and 500-yr discharges at structure NEWBTH00840028 on Town Highway 84, crossing Halls Brook, Newbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure NEWBTH00840028 on Town Highway 84, crossing Halls Brook, Newbury, 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-year discharge is 3,880 cubic-feet per second											
Left abutment	0.0	--	496.9	--	485.4	2.2	19.7	--	21.9	463.5	--
Right abutment	44.4	--	497.2	--	488.7	2.2	13.2	--	15.4	473.3	--

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 NEWBTH00840028 on Town Highway 84, crossing Halls Brook, Newbury, 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-year discharge is 5,970 cubic-feet per second											
Left abutment	0.0	--	496.9	--	485.4	3.8	25.2	--	29.0	456.4	--
Right abutment	44.4	--	497.2	--	488.7	3.8	16.8	--	20.6	468.1	--

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

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U.S. Geological Survey, 1973, Newbury, Vermont 7.5 x 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File test.wsp
T2        Hydraulic analysis for structure NEWBUS0005       Date: 05-SEP-97
T3        TH 84 CROSSING HALLS BROOK IN NEWBURY, VT                        RLB
*
*
J1         * *  0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3880.0   5970.0    4810.0
SK          0.0029   0.0029    0.0029
*
*
XS   EXIT2   -258           0.
GR         -388.5, 505.39   -286.1, 492.64   -233.6, 488.75    -49.8, 488.33
GR           -7.3, 487.98     -4.8, 486.16     -0.1, 484.18      6.6, 483.99
GR           11.2, 483.42     15.3, 484.09     18.7, 486.06     21.0, 487.35
GR           73.1, 489.09    163.5, 488.49    389.2, 487.20    434.6, 504.00
*
N          0.070          0.055         0.060
SA                 -7.3          21.0
*
XS   FLV2    -200  * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRID2   -200   503.47       0.0
GR          -32.9, 504.03    -32.8, 502.44     -7.7, 488.55     -5.8, 486.18
GR           -0.1, 483.21     11.1, 482.97     15.8, 483.71     18.6, 485.93
GR           28.6, 486.95     43.8, 487.76     69.7, 501.22     70.3, 502.91
GR          -32.9, 504.03
*
*         BRTYPE  BRWDTH   EMBSS   EMBELV
CD           3      35.0     1.0   510.13
N          0.045          0.035
SA                 15.8
*
PW        482.97, 5.0   503.47, 3.5
*
XT   A2TEM    -35
GR         -138.4, 506.92   -102.4, 502.70    -82.8, 498.50
GR          -48.8, 497.02    -32.9, 496.84    -18.8, 495.65    -10.9, 491.37
GR           -4.1, 488.47      0.0, 485.21      1.1, 484.93      1.7, 484.61
GR            4.9, 483.98      7.9, 483.67     10.4, 483.90     13.6, 484.10
GR           17.4, 484.92     18.2, 485.17     19.7, 487.35     39.7, 488.28
GR           50.4, 490.60     54.3, 490.43     84.8, 490.75    108.7, 497.26
*
AS   APPR2    -59  * * *  0.0042
GT
N           0.060        0.055        0.050
SA                  -4.1         19.7
*
*
XS   EXITX    -35           0.
GR         -138.4, 506.92   -102.4, 502.70    -82.8, 498.50    -48.8, 497.02
GR          -32.9, 496.84    -18.8, 495.65    -10.9, 491.37     -4.1, 488.47
GR            0.0, 485.21      1.1, 484.93      1.7, 484.61      4.9, 483.98
GR            7.9, 483.67     10.4, 483.90     13.6, 484.10     17.4, 484.92
GR           18.2, 485.17     19.7, 487.35     39.7, 488.28     50.4, 490.60
```

```
GR          54.3, 490.43     84.8, 490.75    108.7, 497.26
*
N          0.060        0.055        0.050
SA                   -4.1         19.7
*
XS   FULLV      0  * * *   0.0086
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.06      15.0
GR           0.0, 496.93      0.3, 485.44      1.9, 485.22      3.6, 485.02
GR           6.6, 484.69      8.9, 484.85     11.2, 484.87     14.2, 485.12
GR          17.1, 485.25     23.0, 485.86     31.0, 487.28     35.4, 487.36
GR          38.5, 488.57     44.1, 488.72     44.4, 497.19      0.0, 496.93
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      25.6      2.2    500.9     68.9
N          0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      23.4     1
GR        -204.3, 509.85   -191.3, 510.07   -130.1, 506.77    -21.5, 500.72
GR           2.7, 500.44      2.9, 501.46     50.3, 501.58
GR          50.7, 500.60    124.4, 499.79    151.1, 499.81
GR         183.1, 500.36    232.1, 501.62    276.6, 503.63    318.0, 506.25
GR         391.2, 512.34    449.0, 519.10
*
XT   APTEM     81           0.
GR        -173.6, 504.51   -163.0, 499.73   -159.4, 497.28   -150.5, 492.65
GR        -136.7, 490.94   -110.3, 491.14    -49.4, 492.43    -12.2, 492.56
GR           0.0, 489.12      3.2, 486.48      7.3, 485.67     10.4, 485.34
GR          13.5, 485.19     20.0, 485.20     29.5, 485.31     30.5, 485.71
GR          31.8, 486.23     35.3, 488.97     48.0, 490.85     63.7, 491.68
GR          89.6, 493.02     96.5, 492.06    117.9, 492.07    163.3, 495.22
GR         224.9, 499.63    279.1, 504.13    289.3, 506.93    293.7, 505.96
GR         324.0, 505.92    328.3, 507.79    371.1, 517.87    391.1, 526.24
*
AS   APPRO     69  * * *   0.0063
GT
N          0.040        0.050        0.050
SA                    0.0         35.3
*
HP 1 BRIDG  493.54 1 493.54
HP 2 BRIDG  493.54 * * 3880
HP 1 APPRO  496.57 1 496.57
HP 2 APPRO  496.57 * * 3880
*
HP 1 BRIDG  497.19 1 497.19
HP 2 BRIDG  497.19 * * 5457
HP 1 BRIDG  496.71 1 496.71
HP 2 RDWAY  500.96 * * 540
HP 1 APPRO  501.15 1 501.15
HP 2 APPRO  501.15 * * 5970
*
HP 1 BRIDG  497.19 1 497.19
HP 2 BRIDG  497.19 * * 4810
HP 1 BRIDG  495.58 1 495.58
HP 1 APPRO  499.79 1 499.79
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File test.wsp
       Hydraulic analysis for structure NEWBUS0005       Date: 05-SEP-97
       TH 84 CROSSING HALLS BROOK IN NEWBURY, VT                    RLB
          *** RUN DATE & TIME: 05-06-98  10:27

   CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     309.  32031.    43.    56.                        4714.
  493.54          309.  32031.    43.    56.  1.00     0.    44.   4714.

   VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      493.54     0.1    44.3   308.8   32031.    3880.  12.56

X STA.        0.1        4.9        6.4        7.8        9.2       10.7
  A(I)           38.5       12.4       11.9       11.8       12.3
  V(I)           5.04      15.64      16.27      16.44      15.79

X STA.       10.7       12.1       13.7       15.2       16.8       18.4
  A(I)           12.3       12.4       12.6       12.7       12.6
  V(I)          15.80      15.65      15.45      15.22      15.41

X STA.       18.4       19.9       21.6       23.3       25.1       27.1
  A(I)           12.3       12.8       12.7       12.9       13.3
  V(I)          15.76      15.12      15.22      14.99      14.55

X STA.       27.1       29.2       31.4       33.8       36.3       44.3
  A(I)           13.8       13.8       14.5       14.5       38.5
  V(I)          14.05      14.01      13.34      13.38       5.04

   CROSS-SECTION PROPERTIES:  ISEQ =  9;  SECID = APPRO;  SRD =      69.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     752.  78593.   158.   160.                        9295.
            2     381.  53235.    35.    37.                        7096.
            3     558.  40226.   148.   148.                        6151.
  496.57         1690. 172054.   341.   346.  1.18  -158.   183.  19622.

   VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = APPRO;  SRD =      69.

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.57  -158.2   183.2  1690.3  172054.    3880.   2.30

X STA.     -158.2     -134.1     -120.9     -107.5      -93.2      -76.9
  A(I)           97.2       74.2       74.3       75.4       81.3
  V(I)           2.00       2.61       2.61       2.57       2.39

X STA.      -76.9      -58.7      -38.3      -16.0       -1.1        6.4
  A(I)           83.9       86.4       92.6       78.0       70.0
  V(I)           2.31       2.24       2.10       2.49       2.77

X STA.        6.4       11.7       16.6       21.7       26.8       32.2
  A(I)           59.0       56.8       57.3       58.0       60.3
  V(I)           3.29       3.41       3.38       3.34       3.22

X STA.       32.2       42.7       58.6       81.5      108.6      183.2
  A(I)           80.3       91.3      106.1      115.1      192.9
  V(I)           2.42       2.12       1.83       1.69       1.01
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File test.wsp
       Hydraulic analysis for structure NEWBUS0005       Date: 05-SEP-97
       TH 84 CROSSING HALLS BROOK IN NEWBURY, VT                    RLB
          *** RUN DATE & TIME: 05-06-98  10:27

   CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     459.   40529.     0.   106.                          0.
  497.19          459.   40529.     0.   106.  1.00     0.    44.      0.

   VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.19     0.0    44.4   459.4   40529.    5457.  11.88

X STA.         0.0        4.5        6.2        7.7        9.4       11.0
  A(I)            49.8       19.2       18.5       19.4       19.0
  V(I)            5.48      14.23      14.77      14.05      14.39

X STA.        11.0       12.6       14.3       16.0       17.7       19.5
  A(I)            19.0       19.2       19.5       19.9       19.6
  V(I)           14.39      14.22      13.96      13.72      13.90

X STA.        19.5       21.2       23.0       24.9       26.8       28.9
  A(I)            19.0       19.9       19.8       20.2       20.6
  V(I)           14.35      13.69      13.78      13.50      13.23

X STA.        28.9       31.1       33.4       35.5       38.2       44.4
  A(I)            21.0       21.6       20.8       23.4       50.1
  V(I)           13.00      12.65      13.15      11.67       5.45

   CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     444.   54677.    43.    62.                       8120.
  496.71          444.   54677.    43.    62.  1.00     0.    44.   8120.

   VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = RDWAY;  SRD =      13.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.96   -25.8   206.4   132.1    3224.     540.   4.09

X STA.       -25.8       61.2       76.9       87.0       94.8      101.4
  A(I)            14.2        8.8        7.1        6.2        5.8
  V(I)            1.91       3.08       3.78       4.33       4.62

X STA.       101.4      107.4      112.7      117.7      122.4      126.8
  A(I)             5.7        5.4        5.3        5.3        5.2
  V(I)            4.77       5.02       5.09       5.09       5.22

X STA.       126.8      131.3      135.7      140.2      144.6      149.1
  A(I)             5.2        5.2        5.2        5.2        5.1
  V(I)            5.22       5.23       5.19       5.24       5.28

X STA.       149.1      153.6      158.5      164.2      171.1      206.4
  A(I)             5.1        5.3        5.5        6.0       15.4
  V(I)            5.28       5.12       4.87       4.51       1.75

   CROSS-SECTION PROPERTIES:  ISEQ =  9;  SECID = APPRO;  SRD =      69.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1    1493.  237672.   166.   169.                      25395.
            2     542.   96016.    35.    37.                      12066.
            3    1380.  144468.   209.   209.                      20121.
  501.15         3415.  478156.   410.   416.  1.13  -166.   244.  52539.

   VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = APPRO;  SRD =      69.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.15  -166.3   244.1  3415.4  478156.    5970.   1.75

X STA.      -166.3     -135.6     -122.3     -108.8      -94.7      -79.8
  A(I)           209.1      136.3      136.3      140.0      143.2
  V(I)            1.43       2.19       2.19       2.13       2.08

X STA.       -79.8      -64.0      -47.3      -30.0      -12.7        0.8
  A(I)           146.0      149.3      151.5      150.9      141.0
  V(I)            2.05       2.00       1.97       1.98       2.12

X STA.         0.8       10.3       18.1       26.0       35.8       50.6
  A(I)           141.8      125.5      125.8      145.7      164.2
  V(I)            2.11       2.38       2.37       2.05       1.82

X STA.        50.6       68.6       90.3      111.0      132.0      244.1
  A(I)           175.8      189.2      186.6      185.4      471.6
  V(I)            1.70       1.58       1.60       1.61       0.63
```

```
        U.S. Geological Survey WSPRO Input File test.wsp
        Hydraulic analysis for structure NEWBUS0005       Date: 05-SEP-97
        TH 84 CROSSING HALLS BROOK IN NEWBURY, VT                     RLB
           *** RUN DATE & TIME: 05-06-98  10:27

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     459.  40529.     0.   106.                           0.
   497.19          459.  40529.     0.   106.  1.00     0.    44.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.19     0.0    44.4   459.4   40529.    4810.  10.47

X STA.         0.0        4.5        6.2        7.7        9.4       11.0
  A(I)            49.8       19.2       18.5       19.4       19.0
  V(I)            4.83      12.54      13.02      12.38      12.68

X STA.        11.0       12.6       14.3       16.0       17.7       19.5
  A(I)            19.0       19.2       19.5       19.9       19.6
  V(I)           12.69      12.53      12.30      12.09      12.25

X STA.        19.5       21.2       23.0       24.9       26.8       28.9
  A(I)            19.0       19.9       19.8       20.2       20.6
  V(I)           12.65      12.07      12.15      11.90      11.66

X STA.        28.9       31.1       33.4       35.5       38.2       44.4
  A(I)            21.0       21.6       20.8       23.4       50.1
  V(I)           11.46      11.15      11.59      10.28       4.80

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     396.  46247.    43.    60.                        6835.
   495.58          396.  46247.    43.    60.  1.00     0.    44.   6835.

    CROSS-SECTION PROPERTIES:  ISEQ =  9;  SECID = APPRO;  SRD =      69.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1269. 183652.   163.   166.                       20081.
             2     494.  82276.    35.    37.                       10501.
             3    1107. 105663.   192.   193.                       15060.
   499.79         2870. 371590.   391.   396.  1.14  -163.   228.  41370.

    VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = APPRO;  SRD =      69.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.79  -163.3   227.7  2870.4  371590.    4810.   1.68

X STA.      -163.3     -135.6     -122.7     -109.1      -94.9      -80.2
  A(I)           169.7      114.1      119.2      122.0      121.1
  V(I)            1.42       2.11       2.02       1.97       1.99

X STA.       -80.2      -64.2      -47.3      -29.3      -11.5        1.6
  A(I)           126.4      128.4      132.6      131.1      122.6
  V(I)            1.90       1.87       1.81       1.83       1.96

X STA.         1.6        9.8       17.1       24.1       31.7       44.4
  A(I)           113.2      106.3      103.3      108.7      137.5
  V(I)            2.12       2.26       2.33       2.21       1.75

X STA.        44.4       61.1       81.8      104.2      124.4      227.7
  A(I)           147.4      161.0      166.0      155.6      384.1
  V(I)            1.63       1.49       1.45       1.55       0.63
```

```
        U.S. Geological Survey WSPRO Input File test.wsp
        Hydraulic analysis for structure NEWBUS0005       Date: 05-SEP-97
        TH 84 CROSSING HALLS BROOK IN NEWBURY, VT                    RLB
           *** RUN DATE & TIME: 05-06-98  10:27

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

EXIT2:XS   ******  -258.    1585.  0.13 *****  490.71  489.54   3880.  490.58
     -258. ******   398.   72034.  1.35 ***** *******    0.32    2.45

FLV2 :FV      58.  -261.    1702.  0.11  0.15  490.87 *******   3880.  490.76
     -200.    58.   399.   80285.  1.31  0.00    0.01    0.29    2.28
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPR2":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   490.26     506.82    0.50
 ===115 WSEL NOT FOUND AT SECID "APPR2":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   490.26     506.82     492.46
 ===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 "APPR2"
                   WSBEG,WSEND,CRWS =   492.46     506.82     492.46

APPR2:AS     141.   -13.     406.  1.75 *****  494.21  492.46   3880.  492.46
      -59.   141.    91.   30936.  1.23 ***** *******    0.95    9.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRID2"     Q,CRWS =    3880.      491.68

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRID2:BR      58.   -13.     345.  1.97 *****  493.65  491.68   3880.  491.68
     -200.    58.    51.   37650.  1.00 ***** *******    0.86   11.26

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  1.000  0.118  503.47 ****** ****** ******

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

APPR2:AS     106.   -16.     602.  0.74  0.79  494.99  492.46   3880.  494.25
      -59.   107.    98.   54018.  1.15  0.54    0.00    0.53    6.45

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.414  0.144    46291.   -12.    53.   493.70
                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>

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

EXITX:XS      24.   -17.     608.  0.72  0.12  495.13 *******   3880.  494.40
      -35.    24.    98.   54849.  1.14  0.00    0.02    0.52    6.38

FULLV:FV      35.   -16.     593.  0.76  0.18  495.34 *******   3880.  494.58
        0.    35.    98.   52952.  1.15  0.02    0.01    0.54    6.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  2.17

APPRO:AS      69.  -156.    1278.  0.18  0.17  495.51 *******   3880.  495.33
       69.    69.   166.  115093.  1.25  0.00    0.00    0.30    3.04
         <<<<<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      35.     0.     309.  2.46  0.30  495.99  492.67   3880.  493.54
        0.    35.    44.   32023.  1.00  0.56    0.00    0.82   12.57

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  497.06 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<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      43.  -158.    1691.  0.10  0.16  496.67  493.24   3880.  496.57
       69.    59.   183.  172100.  1.18  0.52    0.01    0.20    2.29
```

```
      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.862  0.651   59908.   -10.    34.   496.55
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXIT2:XS    -258.  -258.   398.   3880.   72034.    1585.    2.45  490.58
   FLV2 :FV    -200.  -261.   399.   3880.   80285.    1702.    2.28  490.76
   BRID2:BR    -200.   -13.    51.   3880.   37650.     345.   11.26  491.68
   APPR2:AS     -59.   -16.    98.   3880.   54018.     602.    6.45  494.25

    XSID:CODE   XLKQ   XRKQ      KQ
   APPR2:AS     -12.    53.   46291.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -35.   -17.    98.   3880.   54849.     608.    6.38  494.40
   FULLV:FV       0.   -16.    98.   3880.   52952.     593.    6.54  494.58
   BRIDG:BR       0.     0.    44.   3880.   32023.     309.   12.57  493.54
   RDWAY:RG      13.**************      0.*****************     1.00********
   APPRO:AS      69.  -158.   183.   3880.  172100.    1691.    2.29  496.57

    XSID:CODE   XLKQ   XRKQ      KQ
   APPRO:AS     -10.    34.   59908.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT2:XS    489.54    0.32  483.42  505.39************  0.13  490.71  490.58
   FLV2 :FV  ********    0.29  483.42  505.39  0.15  0.00  0.11  490.87  490.76
   BRID2:BR    491.68    0.86  482.97  504.03************  1.97  493.65  491.68
   APPR2:AS    492.46    0.53  483.57  506.82  0.79  0.54  0.74  494.99  494.25
   EXITX:XS  ********    0.52  483.67  506.92  0.12  0.00  0.72  495.13  494.40
   FULLV:FV  ********    0.54  483.97  507.22  0.18  0.02  0.76  495.34  494.58
   BRIDG:BR    492.67    0.82  484.69  497.19  0.30  0.56  2.46  495.99  493.54
   RDWAY:RG  ****************  499.79  519.10**********************************
   APPRO:AS    493.24    0.20  485.11  526.16  0.16  0.52  0.10  496.67  496.57

       U.S. Geological Survey WSPRO Input File test.wsp
       Hydraulic analysis for structure NEWBUS0005       Date: 05-SEP-97
       TH 84 CROSSING HALLS BROOK IN NEWBURY, VT                    RLB
          *** RUN DATE & TIME: 05-06-98  10:27

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

EXIT2:XS   ******  -269.    2097.  0.15 *****  491.51  489.90   5970.  491.36
     -258. ******   400.  110843.  1.22 ***** *******    0.31    2.85

FLV2 :FV      58.  -271.    2217.  0.14  0.15  491.67 *******   5970.  491.53
     -200.    58.   401.  120826.  1.20  0.00    0.01    0.29    2.69
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPR2":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.03     506.82     0.50
 ===115 WSEL NOT FOUND AT SECID "APPR2":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.03     506.82     493.68
 ===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 "APPR2"
                  WSBEG,WSEND,CRWS =   493.68     506.82     493.68

APPR2:AS     141.   -15.     538.  2.23 *****  495.91  493.68   5970.  493.68
      -59.   141.    96.   46015.  1.17 ***** *******    0.96   11.10
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRID2"     Q,CRWS =    5970.     493.50

             <<<<<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

BRID2:BR      58.   -17.     468.  2.53 *****  496.03  493.50   5970.  493.50
     -200.    58.    55.   58514.  1.00 ***** *******    0.88   12.75

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  1.000  0.104  503.47 ****** ****** ******

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

APPR2:AS     106.   -29.     869.  0.83  0.73  497.26  493.68   5970.  496.43
      -59.   108.   106.   90220.  1.13  0.51    0.00    0.51    6.87

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.423  0.166   75274.   -13.    58.   495.92
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

WSPRO OUTPUT FILE (continued)

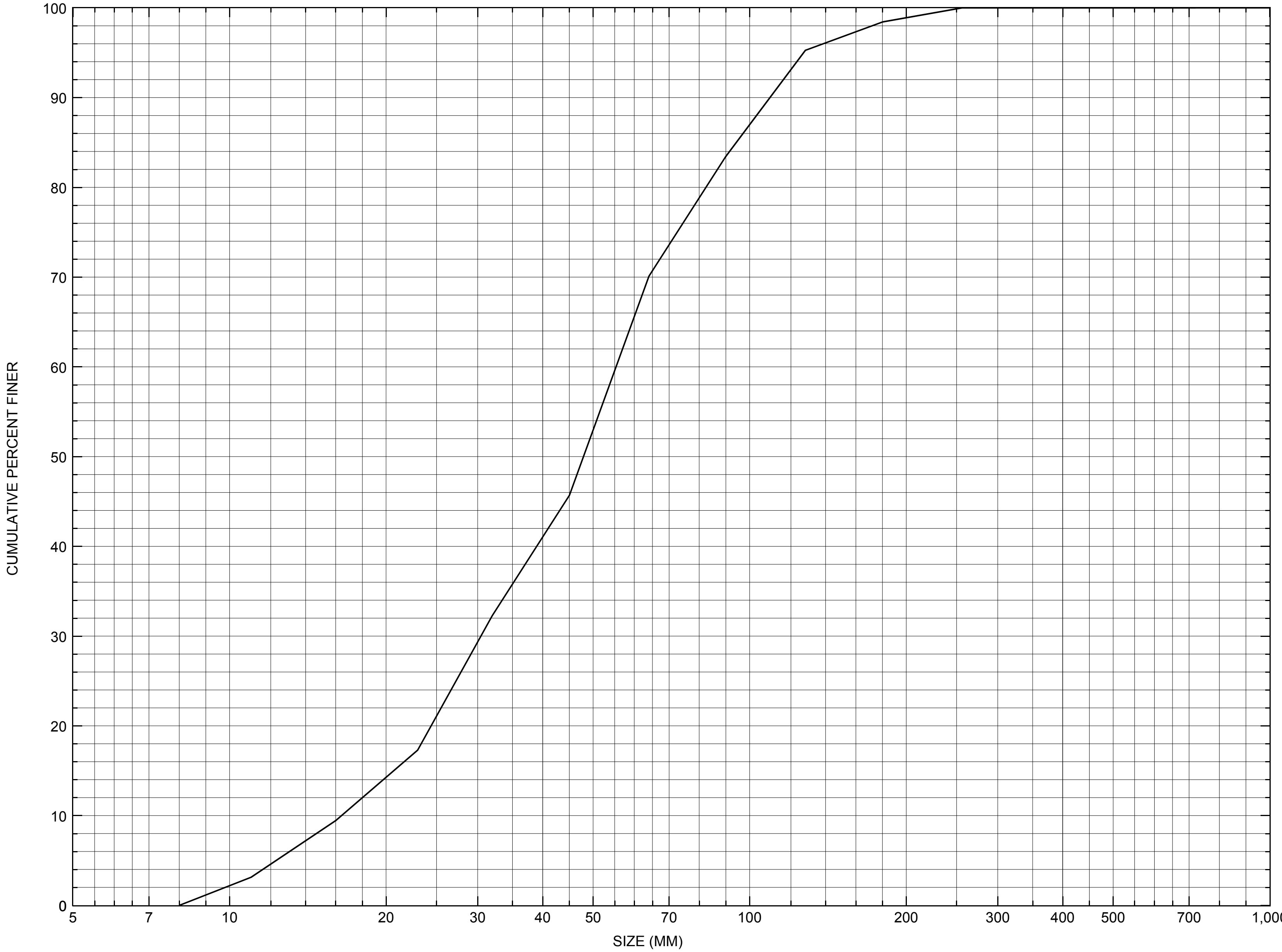
```
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS      24.   -30.     872.  0.83  0.10  497.38 *******   5970.  496.56
      -35.    24.   106.   90715.  1.13  0.00    0.02    0.51    6.84

FULLV:FV      35.   -28.     852.  0.87  0.16  497.57 *******   5970.  496.71
        0.    35.   106.   87886.  1.13  0.02    0.01    0.52    7.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  2.55

APPRO:AS      69.  -160.    2029.  0.16  0.12  497.70 *******   5970.  497.54
       69.    69.   197.  224248.  1.16  0.00    0.00    0.23    2.94
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.90     499.65     499.79     497.06
 ===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      35.     0.     459.  2.19 *****  499.38  494.29   5457.  497.19
        0. ******    44.   40529.  1.00 ***** *******    0.65   11.88

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.488  0.104  497.06 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    46.  0.01  0.05  501.20    0.00    540.  500.96

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     39.    29.   -26.     3.   0.5   0.3   3.5   3.9   0.6   3.1
   RT:    502.   156.    51.   207.   1.2   0.8   4.7   4.1   1.0   3.1

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

APPRO:AS      43.  -166.    3417.  0.05  0.10  501.21  493.89   5970.  501.15
       69.    61.   244.  478392.  1.13  0.58    0.00    0.11    1.75

       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
   EXIT2:XS     -258.  -269.   400.   5970.  110843.    2097.    2.85  491.36
   FLV2 :FV     -200.  -271.   401.   5970.  120826.    2217.    2.69  491.53
   BRID2:BR     -200.   -17.    55.   5970.   58514.     468.   12.75  493.50
   APPR2:AS      -59.   -29.   106.   5970.   90220.     869.    6.87  496.43

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR2:AS     -13.    58.   75274.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS      -35.   -30.   106.   5970.   90715.     872.    6.84  496.56
   FULLV:FV        0.   -28.   106.   5970.   87886.     852.    7.01  496.71
   BRIDG:BR        0.     0.    44.   5457.   40529.     459.   11.88  497.19
   RDWAY:RG       13.*******    39.    540.******************    1.00  500.96
   APPRO:AS       69.  -166.   244.   5970.  478392.    3417.    1.75  501.15

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

  SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXIT2:XS    489.90    0.31  483.42  505.39************  0.15  491.51  491.36
   FLV2 :FV  ********    0.29  483.42  505.39  0.15  0.00  0.14  491.67  491.53
   BRID2:BR    493.50    0.88  482.97  504.03************  2.53  496.03  493.50
   APPR2:AS    493.68    0.51  483.57  506.82  0.73  0.51  0.83  497.26  496.43
   EXITX:XS  ********    0.51  483.67  506.92  0.10  0.00  0.83  497.38  496.56
   FULLV:FV  ********    0.52  483.97  507.22  0.16  0.02  0.87  497.57  496.71
   BRIDG:BR    494.29    0.65  484.69  497.19************  2.19  499.38  497.19
   RDWAY:RG  ****************  499.79  519.10  0.01******  0.05  501.20  500.96
   APPRO:AS    493.89    0.11  485.11  526.16  0.10  0.58  0.05  501.21  501.15

       U.S. Geological Survey WSPRO Input File test.wsp
       Hydraulic analysis for structure NEWBUS0005        Date: 05-SEP-97
       TH 84 CROSSING HALLS BROOK IN NEWBURY, VT                    RLB
          *** RUN DATE & TIME: 05-06-98  10:27
```

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

EXIT2:XS   ******  -263.    1824.  0.14 *****  491.08  489.72   4810.  490.94
     -258. ******   399.   89298.  1.28 ***** *******    0.32    2.64

FLV2 :FV      58.  -266.    1942.  0.12  0.15  491.24 *******   4810.  491.12
     -200.    58.   400.   98373.  1.25  0.00    0.01    0.29    2.48
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPR2":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   490.62     506.82    0.50
 ===115 WSEL NOT FOUND AT SECID "APPR2":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   490.62     506.82     493.04
 ===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 "APPR2"
                  WSBEG,WSEND,CRWS =   493.04     506.82     493.04

APPR2:AS     141.   -14.     467.  1.97 *****  495.00  493.04   4810.  493.04
      -59.   141.    94.   37687.  1.19 ***** *******    0.95   10.30
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRID2"     Q,CRWS =    4810.      492.54

            <<<<<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

BRID2:BR      58.   -15.     401.  2.24 *****  494.77  492.54   4810.  492.54
     -200.    58.    53.   46880.  1.00 ***** *******    0.87   11.99

     TYPE PPCD FLOW      C     P/A    LSEL    BLEN    XLAB    XRAB
       3.   0.   1.  1.000  0.111  503.47 ****** ****** ******

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

APPR2:AS     106.   -18.     723.  0.77  0.76  496.05  493.04   4810.  495.28
      -59.   108.   102.   70266.  1.12  0.52    0.00    0.51    6.65

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.419  0.162   58897.   -12.    56.   494.73
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

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

EXITX:XS      24.   -18.     728.  0.76  0.11  496.18 *******   4810.  495.42
      -35.    24.   102.   70916.  1.12  0.00    0.02    0.50    6.61

FULLV:FV      35.   -18.     710.  0.80  0.17  496.38 *******   4810.  495.58
        0.    35.   101.   68508.  1.12  0.02    0.01    0.52    6.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  2.36

APPRO:AS      69.  -158.    1618.  0.16  0.14  496.52 *******   4810.  496.36
       69.    69.   180.  161488.  1.19  0.00    0.00    0.26    2.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
         WS3,WSIU,WS1,LSEL =   494.21     497.85     498.00     497.06
 ===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      35.     0.     459.  1.69 *****  498.88  493.63   4794.  497.19
        0. ******    44.   40529.  1.00 ***** *******    0.57   10.44

     TYPE PPCD FLOW      C     P/A    LSEL    BLEN    XLAB    XRAB
       4. ****   2.  0.464  0.111  497.06 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<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      43.  -163.    2870.  0.05  0.09  499.84  493.54   4810.  499.79
       69.    60.   228.  371483.  1.14  0.55    0.00    0.12    1.68
```

```
     M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
   ****** ****** ******** ****** ******   499.78
                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
  EXIT2:XS    -258.  -263.   399.   4810.   89298.    1824.    2.64  490.94
  FLV2 :FV    -200.  -266.   400.   4810.   98373.    1942.    2.48  491.12
  BRID2:BR    -200.   -15.    53.   4810.   46880.     401.   11.99  492.54
  APPR2:AS     -59.   -18.   102.   4810.   70266.     723.    6.65  495.28

   XSID:CODE   XLKQ   XRKQ      KQ
  APPR2:AS     -12.    56.   58897.

   XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
  EXITX:XS     -35.   -18.   102.   4810.   70916.     728.    6.61  495.42
  FULLV:FV      0.   -18.   101.   4810.   68508.     710.    6.77  495.58
  BRIDG:BR      0.     0.    44.   4794.   40529.     459.   10.44  497.19
  RDWAY:RG      13.**************      0.******************    1.00********
  APPRO:AS      69.  -163.   228.   4810.  371483.    2870.    1.68  499.79

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

SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
  EXIT2:XS    489.72    0.32  483.42  505.39************  0.14  491.08  490.94
  FLV2 :FV  ********    0.29  483.42  505.39  0.15  0.00  0.12  491.24  491.12
  BRID2:BR    492.54    0.87  482.97  504.03************  2.24  494.77  492.54
  APPR2:AS    493.04    0.51  483.57  506.82  0.76  0.52  0.77  496.05  495.28
  EXITX:XS  ********    0.50  483.67  506.92  0.11  0.00  0.76  496.18  495.42
  FULLV:FV  ********    0.52  483.97  507.22  0.17  0.02  0.80  496.38  495.58
  BRIDG:BR    493.63    0.57  484.69  497.19************  1.69  498.88  497.19
  RDWAY:RG  ****************  499.79  519.10************  0.04  500.73********
  APPRO:AS    493.54    0.12  485.11  526.16  0.09  0.55  0.05  499.84  499.79
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure NEWBTH00840028, in Newbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number NEWBTH00840028

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 27 / 95

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

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 48175

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

Waterway *(I - 6)* HALLS BROOK

Road Name *(I - 7):* -

Route Number TH084

Vicinity *(I - 9)* 0.1 MI JCT TH 84 + TH 1

Topographic Map Newbury

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 44027

Longitude *(i - 17; nnnnn.n)* 72049

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10090700280907

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

Maximum span length *(I - 48; nnnn)* 0045

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

Structure length *(I - 49; nnnnnn)* 000049

Average daily traffic, ADT *(I - 29; nnnnnn)* 000100

Deck Width *(I - 52; nn.n)* 234

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

Channel & Protection *(I - 61; n)* 5

Opening skew to Roadway *(I - 34; nn)* 14

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 011.9

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

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

Comments:

The structural inspection report of 10/11/93 indicates the structure is a concrete T-beam bridge. The abutment walls and wingwalls are concrete, with minor cracks and spalls reported overall. The upstream left wingwall is reported as cracked off vertically at the abutment end, with deep spalling along the crack line and large sections of concrete chipped out with reinforcing bar exposed. A large concrete patch that was originally poured over the crack line is reported as broken off. A vegetation covered sand and gravel point bar near the downstream end of the right abutment blocks about three quarters of the channel and directs the flow mostly towards the left abutment wall. **(Continued, page 36)**

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:

A few boulders are noted as stone fill placed around the end of the downstream left wingwall. Boulders are also reported on the banks upstream and downstream of the bridge.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **25.04** mi^2 Lake/pond/swamp area **0.44** mi^2

Watershed storage *(ST)* **1.8** %

Bridge site elevation **400** ft Headwater elevation **1440** ft

Main channel length **10.81** mi

10% channel length elevation **500** ft 85% channel length elevation **950** ft

Main channel slope *(S)* **42** 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? Y *If no, type ctrl-n xs*

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

Comments: **This cross-section is the upstream face. The low chord elevations are from the survey log done for this report on 8/30/95. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 10/11/93. The sketch was done on 10/13/93.**

Station	0	19	27	38	45	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	496.9	497.0	497.1	497.1	497.2	-	-	-	-	-	-
Bed elevation	487.0	484.5	485.2	485.5	487.5	-	-	-	-	-	-
Low chord to bed	9.9	12.5	11.9	11.6	9.7	-	-	-	-	-	-

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

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

Comments: -

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 03/13/96
Computerized by: EW Date: 03/14/96
Reviewd by: RB Date: 1/26/98

Structure Number NEWBH00840028

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. BOEHMLER Date *(MM/DD/YY)* 08 / 30 / 1995
2. Highway District Number 07 Mile marker -
County ORANGE (017) Town NEWBURY (48175)
Waterway *(I - 6)* HALLS BROOK Road Name -
Route Number TH84 Hydrologic Unit Code: 01080104
3. Descriptive comments:
Located 0.1 miles south of the intersection of TH84 with TH01, and approximately 0.1 miles upstream from the U.S. Route 5 bridge, also over Halls Brook.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 5 LBDS 6 RBDS 4 Overall 4
*(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 49 *(feet)* Span length 45 *(feet)* Bridge width 23.4 *(feet)*

Road approach to bridge:

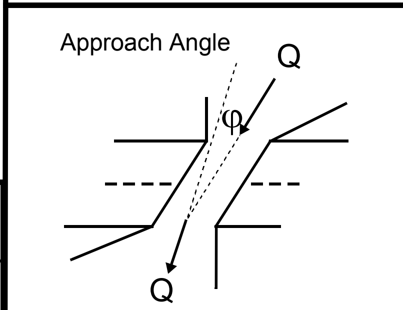
8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 2.2:1 US right 2.1:1

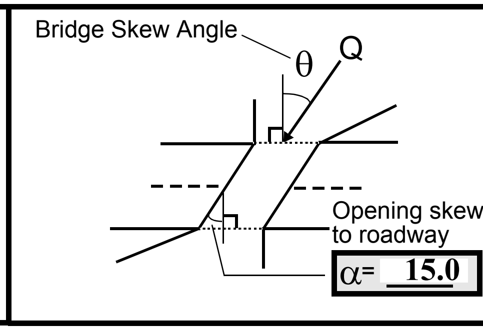
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	3
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*
*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 10 16. Bridge skew: 15



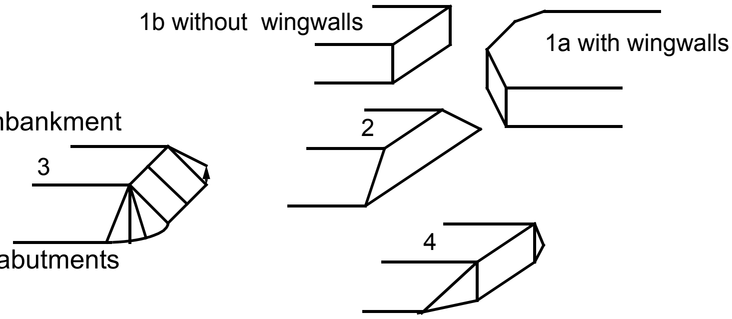


17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 7 feet UB *(US, UB, DS)* to 25 feet DS
Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 95 feet US *(US, UB, DS)* to 55 feet US

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

18. Bridge Type: **4**

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



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

#4: The USLB is pasture beyond a strip of brush, trees and shrubs along the road embankment. The USRB has a more extensive area of brush and trees along the bank and road embankment, but opens to pasture about 50 feet from the USRB. The DSLB is mostly trees with some thick undergrowth of shrubs and brush in places, especially along the road embankment. The DSRB is all pasture except for one narrow (about 25 feet) strip of trees along the channel.
#7: Values are from the VTAOT files. The measured bridge length= 49 feet; span length= 45.5 feet; and bridge width= 23.4 feet.

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
54.5	**2.5**			**2.5**	**2**	**2**	**234**	**234**	**1**	**1**

23. Bank width **40.0** 24. Channel width **40.0** 25. Thalweg depth **35.5** 29. Bed Material **324**

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.):

The US channel consists of one major cut-bank and a point bar on the left bank at a sharp channel bend, then a series of three alternate bars on a nearly straight reach to the bridge. The cut-bank and point bar are located beyond two bridge lengths US.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **32** 35. Mid-bar width: **10**

36. Point bar extent: **49** feet **US** (US, UB) to **15** feet **US** (US, UB, DS) positioned **75** %LB to **100** %RB

37. Material: **342**

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

An additional side bar is from 105 feet US to 60 feet US and is positioned 0%LB to 40%RB. It is 13 feet wide at 80 feet US, vegetated with grass and brush, and has a sandy composition. This side bar is the result of a massive bank slump which never washed away. A third side bar extends from 110 feet US to 95 feet US and is positioned 60%LB to 100%RB. It is 11 feet wide at 103 feet US and the material is gravel, cobble and sand. A sandy point bar on the RB side is from 155 feet US to 117 feet US and is 15 feet wide at 138 feet US.

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

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

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

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

NO CUT BANKS

There is a cut-bank from 185 feet US to 105 feet US on the LB.

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

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
28.5		0.5		1	7	2	-

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.):

324

A sand ridge has developed along the RABUT which is as high as the banks US and DS and is considered an UB bank. A concrete slab projects out into the channel 10 feet from the LABUT and USLWW. It appears to have been placed there to channel water away from the corner of the USLWW and LABUT where road wash comes through a gaping corner crack. The channel runs through the bridge mainly along the LB side. A point bar exists on the RB side and extends DS.

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

67. Debris Potential - ____ (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:

2

The channel is sinuous to meandering and has some trees on the banks. With the presence of the bars, debris and ice are likely to build up underneath and just DS of the bridge.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		10	90	2	0	0	0	90.0
RABUT	1	-	90			1	0	43.0

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

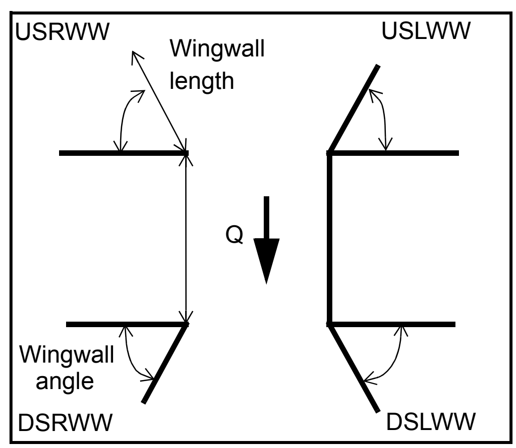
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
0
1

The abutments are in good condition except at the US end of the LABUT. At this point, road wash penetrates through the joint of the abutment and USLWW.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						43.0	
USRWW:	Y		1		0	0.5	
DSLWW:	0		0		Y	25.5	
DSRWW:	1		0		0	25.5	



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	0	Y	0	-	-	-	-
Condition	Y	0	1	0	-	-	-	-
Extent	1	0	0	0	0	0	0	0

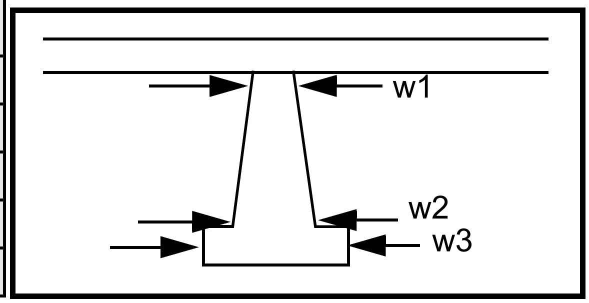
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
0
-
-
4
1
2
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				95.0	13.0	45.0
Pier 2				13.5	50.0	16.0
Pier 3			-	75.0	13.0	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	ft x 2	type-2	are set	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	DSL	ft)	stone	in	**1**- Solid pier, **2**- column, **3**- bent
88. Material	WW	place	fill at	eart	**1**- Wood; **2**- concrete; **3**- metal; **4**- stone
89. Shape	is	d	the	h	**1**- Round; **2**- Square; **3**- Pointed
90. Inclined?	pro-	hori-	upst	back	Y- yes; N- no
91. Attack ∠ (BF)	tecte	zon-	ream	fill	
92. Pushed	d by	tally,	end.	whic	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	a	in	The	h is	
95. Cross-members	con-	addi-	othe	still	**0**- none; **1**- laterals; **2**- diagonals; **3**- both
96. Scour Condition	crete	tion	r	cov-	**0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed
97. Scour depth	bloc	to	wing	ering	
98. Exposure depth	k (5	some	walls	the	

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

bases. There is severe road wash drainage through a vertical crack between the USLWW and the LABUT wall. The re-bar is exposed.

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.):

-
-
-
-

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

Cut bank extent: RS 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.):

Is channel scour present? _____ (Y or if N type ctrl-n cs) Mid-scour distance: 2

Scour dimensions: Length 3 Width 324 Depth: 324 Positioned 0 %LB to 1 %RB

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

324
2
0
1

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

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

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

Confluence comments (eg. confluence name):

narrow than the US channel. There is stone fill on the LB between this bridge and the one DS on U.S. Route 5 (145 feet DS). As the channel width narrows, the water deepens. There is some scour.

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

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: NEWBTH00840028 Town: NEWBURY
Road Number: TH 84 County: ORANGE
Stream: HALLS BROOK

Initials RLB Date: 10/14/97 Checked: RF

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	3880	5970	4810
Main Channel Area, ft2	381	542	494
Left overbank area, ft2	752	1493	1269
Right overbank area, ft2	558	1380	1107
Top width main channel, ft	35	35	35
Top width L overbank, ft	158	166	163
Top width R overbank, ft	148	209	192
D50 of channel, ft	0.1572	0.1572	0.1572
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.9	15.5	14.1
y1, average depth, LOB, ft	4.8	9.0	7.8
y1, average depth, ROB, ft	3.8	6.6	5.8
Total conveyance, approach	172054	478156	371590
Conveyance, main channel	53235	96016	82276
Conveyance, LOB	78593	237672	183652
Conveyance, ROB	40226	144468	105663
Percent discrepancy, conveyance	0.0000	0.0000	-0.0003
Qm, discharge, MC, cfs	1200.5	1198.8	1065.0
Ql, discharge, LOB, cfs	1772.4	2967.4	2377.3
Qr, discharge, ROB, cfs	907.1	1803.8	1367.7
Vm, mean velocity MC, ft/s	3.2	2.2	2.2
Vl, mean velocity, LOB, ft/s	2.4	2.0	1.9
Vr, mean velocity, ROB, ft/s	1.6	1.3	1.2
Vc-m, crit. velocity, MC, ft/s	9.0	9.6	9.4
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	3880	5970	4810
(Q) discharge thru bridge, cfs	3880	5457	4810
Main channel conveyance	32031	40529	40529
Total conveyance	32031	40529	40529
Q2, bridge MC discharge,cfs	3880	5457	4810
Main channel area, ft2	309	459	459
Main channel width (normal), ft	42.7	42.9	42.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	42.7	42.9	42.9
y_bridge (avg. depth at br.), ft	7.23	10.71	10.71
Dm, median (1.25*D50), ft	0.1965	0.1965	0.1965
y2, depth in contraction,ft	9.40	12.54	11.26
ys, scour depth (y2-ybridge), ft	**2.17**	1.83	0.55

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	3880	5457	4810
Main channel area (DS), ft2	308.8	444	396
Main channel width (normal), ft	42.7	42.9	42.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	42.7	42.9	42.9
D90, ft	0.3588	0.3588	0.3588
D95, ft	0.4165	0.4165	0.4165
Dc, critical grain size, ft	0.5255	0.4432	0.4503
Pc, Decimal percent coarser than Dc	0.027	0.042	0.041
Depth to armoring, ft	N/A	N/A	N/A

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	3880	5970	4810
Q, thru bridge MC, cfs	3880	5457	4810
Vc, critical velocity, ft/s	9.01	9.55	9.41
Va, velocity MC approach, ft/s	3.15	2.21	2.16
Main channel width (normal), ft	42.7	42.9	42.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	42.7	42.9	42.9
qbr, unit discharge, ft2/s	90.9	127.2	112.1
Area of full opening, ft2	308.8	459.4	459.4
Hb, depth of full opening, ft	7.23	10.71	10.71
Fr, Froude number, bridge MC	0	0.65	0.57
Cf, Fr correction factor (<=1.0)	0.00	1.00	1.00
**Area at downstream face, ft2	N/A	444	396
**Hb, depth at downstream face, ft	N/A	10.35	9.23
**Fr, Froude number at DS face	ERR	0.67	0.70
**Cf, for downstream face (<=1.0)	N/A	1.00	1.00
Elevation of Low Steel, ft	0	497.06	497.06
Elevation of Bed, ft	-7.23	486.35	486.35
Elevation of Approach, ft	0	501.15	499.79
Friction loss, approach, ft	0	0.1	0.09
Elevation of WS immediately US, ft	0.00	501.05	499.70
ya, depth immediately US, ft	7.23	14.70	13.35
Mean elevation of deck, ft	0	501.52	501.52
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.92	0.95
**Cc, for downstream face (<=1.0)	ERR	0.910052	0.90468
Ys, scour w/Chang equation, ft	N/A	**3.77**	**1.90**
Ys, scour w/Umbrell equation, ft	N/A	-4.00	-4.66

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

**Ys, scour w/Chang equation, ft	N/A	4.28	3.95

**Ys, scour w/Umbrell equation, ft	ERR	-3.65	-3.18

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

y2, from Laursen's equation, ft	9.40	12.54	11.26
WSEL at downstream face, ft	--	496.71	495.58
Depth at downstream face, ft	N/A	10.35	9.23
Ys, depth of scour (Laursen), ft	N/A	2.19	2.02

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	3880	5970	4810	3880	5970	4810
a', abut.length blocking flow, ft	159.1	167.1	164.1	139.6	200.4	184
Ae, area of blocked flow ft2	761.97	1499.39	1279.71	500.23	1164.41	1021.68
Qe, discharge blocked abut.,cfs	1797.73	--	2390.31	765.02	--	1215.76
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.36	1.99	1.87	1.53	1.27	1.19
ya, depth of f/p flow, ft	4.79	8.97	7.80	3.58	5.81	5.55
--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	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.190	0.117	0.118	0.142	0.088	0.089
ys, scour depth, ft	**19.68**	**25.17**	**22.69**	**13.16**	**16.80**	**15.95**

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)	159.1	167.1	164.1	139.6	200.4	184
y1 (depth f/p flow, ft)	4.79	8.97	7.80	3.58	5.81	5.55
a'/y1	33.22	18.62	21.04	38.96	34.49	33.14
Skew correction (p. 49, fig. 16)	1.03	1.03	1.03	0.95	0.95	0.95
Froude no. f/p flow	0.19	0.12	0.12	0.14	0.09	0.09
Ys w/ corr. factor K1/0.55:						
vertical	20.80	ERR	ERR	13.01	18.00	17.27
vertical w/ ww's	17.06	ERR	ERR	10.67	14.76	14.16
spill-through	11.44	ERR	ERR	7.16	9.90	9.50

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	0.82	0.67	0.7	0.82	0.67	0.7
y, depth of flow in bridge, ft	7.23	10.35	9.23	7.23	10.35	9.23
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	**2.87**	**2.80**	ERR	**2.87**	**2.80**
Fr>0.8 (vertical abut.)	**2.86**	ERR	ERR	**2.86**	ERR	ERR