LEVEL II SCOUR ANALYSIS FOR BRIDGE 22 (TOPSTH00490022) on TOWN HIGHWAY 49, crossing the WAITS RIVER, TOPSHAM, VERMONT

Open-File Report 97-822

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 LORA K. STRIKER AND JAMES R. DEGNAN

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Pembroke, New Hampshire

1997

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	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 22 (TOPSTH00490022) ON TOWN HIGHWAY 49, CROSSING THE WAITS RIVER, TOPSHAM, VERMONT

By **Lora K. Striker 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 TOPSTH00490022 on Town Highway 49 crossing the Waits River, Topsham, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in east-central Vermont. The 33.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly grassy fields with shrubs and brush, while along the immediate banks the surface cover is primarily trees and brush.

In the study area, the Waits River has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 51 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 96.3 mm (0.316 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 28, 1995, indicated that the reach was stable.

The Town Highway 49 crossing of the Waits River is a 38-ft-long, one-lane bridge consisting of one 35-foot steel-beam span (Vermont Agency of Transportation, written communication, March 28, 1995). The opening length of the structure parallel to the bridge face is 33.5 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 5 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the left side of the channel, from the upstream bridge face to approximately 20 ft downstream of the bridge during the Level I assessment. A small scour hole 0.5 ft deeper than the mean thalweg was also observed along the right side of the channel under the bridge. Scour protection measures at the site included: type-4 stone fill (less than 60 inches diameter) along the left and right bank upstream; type-3 stone fill (less than 48 inches diameter) along the entire base length of the right abutment and along the left and right bank downstream; and type-2 stone fill (less than 36 inches diameter) along the entire base length of the upstream and downstream wingwalls and at the ends of the left abutment. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 2.1 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge. Abutment scour ranged from 13.3 to 18.0 ft at the left abutment and from 13.3 to 15.5 ft at the right abutment. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

West Topsham, VT. Quadrangle, 1:24,000, 1981

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 TOPSTH00490022 ***Stream*** Waits River

County Orange ***Road*** TH 49 ***District*** 7

Description of Bridge

Bridge length 38 ***ft*** ***Bridge width*** 16.2 ***ft*** ***Max span length*** 35 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 08/28/95

Description of stone fill Type-2, along the entire base length of the upstream and downstream wingwalls and along the upstream and downstream ends of the LABUT. Type-3, along the entire base length of the right abutment.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a 1.0 ft deep scour hole along the left side of the channel and a 0.5 ft deep scour hole along the right side of the channel.

Y 15

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

Is there a channel bend in the upstream reach? If so, describe (mild, moderate, severe) 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	08/28/95	0	0
Level II	08/28/95	0	0

Potential for debris Low. There was no debris noted at the site as of 08/28/95. The upstream channel is laterally stable with cobble and boulder bank material.

Describe any features near or at the bridge that may affect flow (include observation date) There is a side bar along the upstream right bank, 08/28/95.

Description of the Geomorphic Setting

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

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

Date of inspection 08/28/95

DS left: Moderately sloping channel bank and overbank

DS right: Moderately sloping channel bank/ overbank to Rte 25 and steep valley wall

US left: Moderately sloping channel bank and overbank

US right: Moderately sloping channel bank/overbank to Rte 25 and steep valley wall

Description of the Channel

Average top width 51 *ft* ***Average depth*** 5 *ft*

Predominant bed material Boulder / Cobble ***Bank material*** Cobble/Boulder

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

08/28/95

Vegetative co

DS left: Trees and brush with grass and brush on overbank

DS right: Trees and brush with grass and brush and Rte 25

US left: Trees and brush with grass and brush on overbank

US right: Trees and brush and Rte 25

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

The assessment of 08/28/95 noted low flow conditions will be influenced by a side bar along the upstream right bank.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 33.6 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None.

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

There is a gage on the East Orange Branch of the Waits River, in East Orange, VT with a drainage area of 8.95 square miles. The gage number is 01139800 with records available from June 1958 to the present.

Calculated Discharges

Q100 4,440 ***ft³/s*** ***Q500*** 5,640 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(33.6/37.3)exp 0.67] with bridge number 38 in Topsham. Bridge number 38 crosses the Waits River downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 38 is 37.3 square miles. These values were selected due to the central tendency of the discharge frequency curve with others which were developed from empirical relationships and extended to the 500-year discharge (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream right wingwall (elev. 499.80 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream left wingwall (elev. 499.86 ft, arbitrary survey datum). RM3 is a chiseled X in asphalt road at the intersection of TH 49 and streamward edge of VT 25 (elev. 502.55 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-45	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	51	2	Modelled Approach section (Templated from APTEM)
APTEM	58	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 0.040 to 0.050 and overbank "n" values ranged from 0.045 to 0.060.

Critical depth at the EXITX section was assumed as the starting water surface elevation for the 100-year, 500-year, and incipient overtopping discharges. The computed normal depths for all discharges was within 0.1 ft of critical depth by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0108 ft/ft, which was estimated from the 100-year water surface profile downstream of the bridge documented in the Flood Insurance Study (FIS) for the Town of Topsham (Federal Emergency Management Agency, 1991).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.030 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 incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for this discharge. After analyzing both the supercritical and subcritical profiles for this 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 bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.8 ***ft***
Average low steel elevation 497.7 ***ft***

100-year discharge 4,440 ***ft^3/s***
Water-surface elevation in bridge opening 497.7 ***ft***
Road overtopping? Y ***Discharge over road*** 278 ***ft^3/s***
Area of flow in bridge opening 387 ***ft^2***
Average velocity in bridge opening 10.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.9 ***ft/s***

Water-surface elevation at Approach section with bridge 500.5
Water-surface elevation at Approach section without bridge 495.2
Amount of backwater caused by bridge 5.3 ***t***

500-year discharge 5,640 ***ft^3/s***
Water-surface elevation in bridge opening 497.7 ***ft***
Road overtopping? Y ***Discharge over road*** 1,090 ***^{3}/s***
Area of flow in bridge opening 387 ***ft^2***
Average velocity in bridge opening 11.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.1 ***/s***

Water-surface elevation at Approach section with bridge 501.4
Water-surface elevation at Approach section without bridge 495.9
Amount of backwater caused by bridge 5.5 ***t***

Incipient overtopping discharge 4,000 ***ft^3/s***
Water-surface elevation in bridge opening 493.8 ***t***
Area of flow in bridge opening 255 ***ft^2***
Average velocity in bridge opening 15.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 19.6 ***ft/s***

Water-surface elevation at Approach section with bridge 497.9
Water-surface elevation at Approach section without bridge 494.8
Amount of backwater caused by bridge 3.1 ***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 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 for the 100- and 500-year discharges 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 and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation 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 for the right abutment was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour at the left abutment was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Because the influence of scour processes on the extensive stone fill abutment protection is uncertain, the scour depth at the vertical right abutment wall was computed at the toe of the stone-fill. The computed total scour depth was applied to the elevation at the toe of the stone fill in front of the right abutment and is shown in Tables 1 and 2 and Figure 8.

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	0.6	2.1
Depth to armoring	37.6	38.8	53.1
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour	17.2	18.0	13.3
Left abutment	14.6	15.5	13.3
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	3.4	3.6	3.2
Left abutment	3.4	3.6	3.2
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

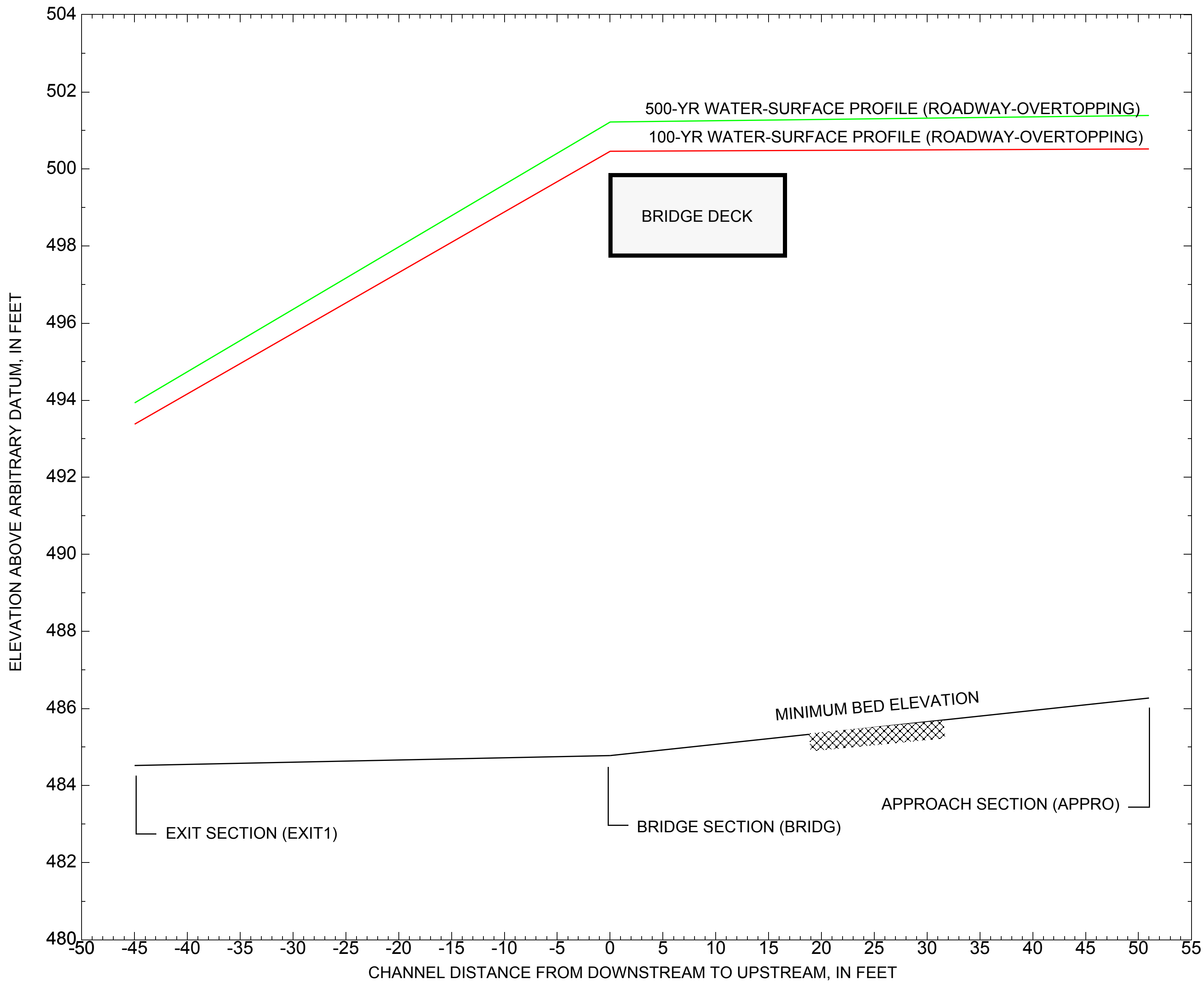

Figure 7. Water-surface profiles for the 100-year and 500-year discharges at structure TOPSTH00490022 on Town Highway 49, crossing the Waits River, Topsham, Vermont.

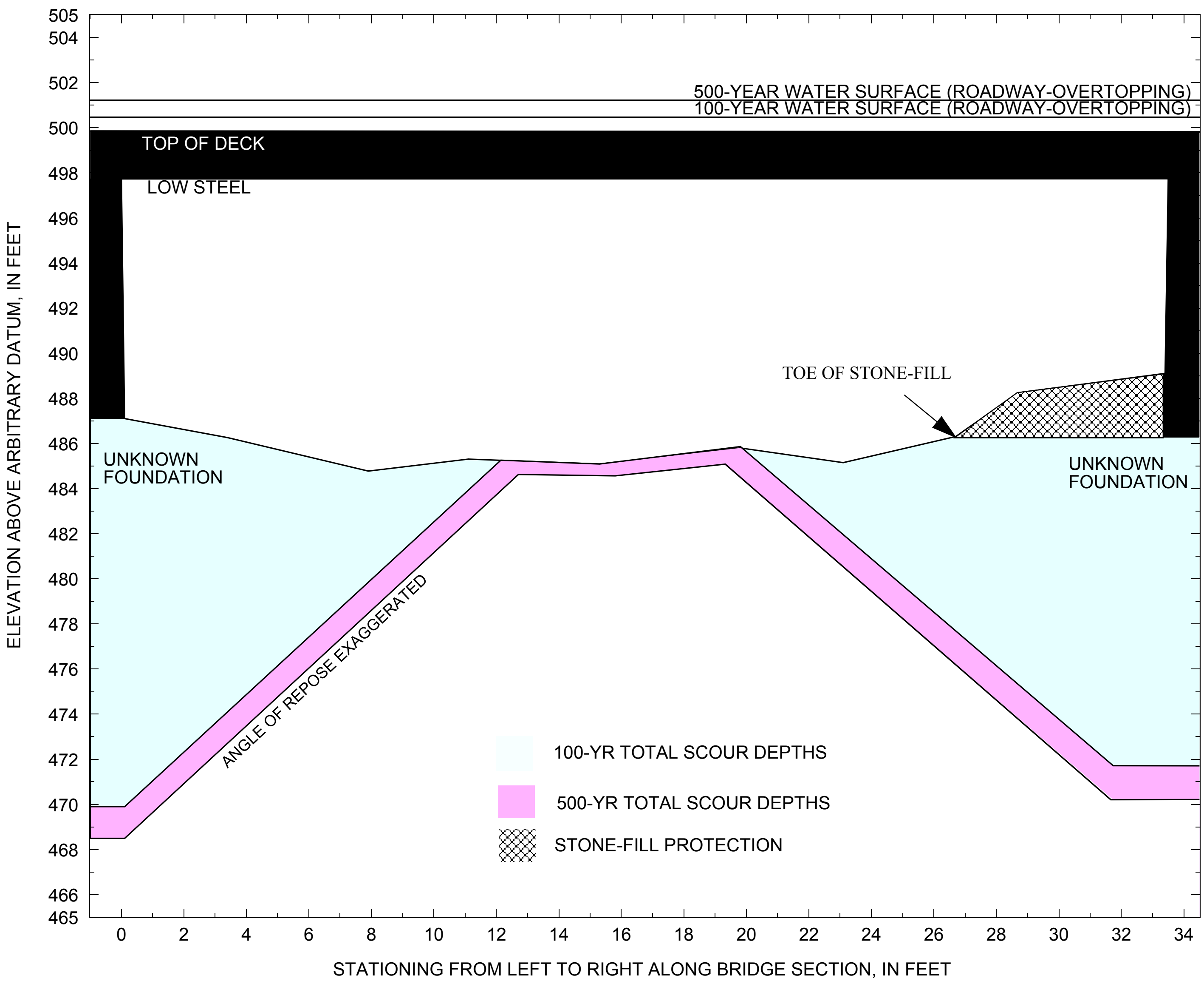

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure TOPSTH00490022 on Town Highway 49, crossing the Waits River, Topsham, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure TOPSTH00490022 on Town Highway 49, crossing Waits River, Topsham, 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 4,440 cubic-feet per second											
Left abutment	0.0	--	497.7	--	487.1	0.0	17.2	--	17.2	469.9	--
Toe of Stone Fill at RABUT	26.7	--	--	--	486.3	0.0	14.6	--	14.6	471.7	--
Right abutment	33.5	--	497.7	--	489.1	--	--	--	--	471.7	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure TOPSTH00490022 on Town Highway 49, crossing Waits River, Topsham, 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 5,640 cubic-feet per second											
Left abutment	0.0	--	497.7	--	487.1	0.6	18.0	--	18.6	468.5	--
Toe of Stone Fill at RABUT	26.7		--	--	486.3	0.6	15.5	--	16.1	470.2	--
Right abutment	33.5	--	497.7	--	489.1	--	--	--	--	470.2	--

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, 1981, West Topsham, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File tops022.wsp
T2        Hydraulic analysis for structure TOPSTH00490022   Date: 11-JUN-97
T3        TH 49 crossing Waits River, 0.05 miles to junction with VT 25
*
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           4440.0   5640.0  4000.0
SK          0.0108   0.0108  0.0108
*
XS   EXIT1    -45           0.
GR         -211.1, 504.76   -203.9, 502.58   -134.0, 496.96   -110.9, 493.03
GR          -54.9, 492.16    -34.3, 490.28     -8.0, 490.42      0.0, 489.76
GR            9.9, 485.95     12.3, 485.22     15.9, 485.47     22.7, 484.60
GR           27.1, 484.52     32.1, 484.63     36.3, 485.82     43.6, 489.71
GR           47.7, 491.99     81.5, 492.06    101.9, 502.13    129.2, 501.71
GR          139.8, 503.01    203.3, 504.40    213.1, 508.22
*
N           0.050        0.050     0.045
SA                   0.0       47.7
*
*
XS   FULLV      0  * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.74       5.0
GR            0.0, 497.73      0.1, 487.10      3.4, 486.26      7.9, 484.78
GR           11.1, 485.31     14.9, 485.09     19.8, 485.80     23.1, 485.15
GR           26.7, 486.31     28.7, 488.23     33.4, 489.11     33.5, 497.74
GR            0.0, 497.73
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      24.4 * *     51.5      5.6
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      9      16.2     2
GR         -226.3, 505.84   -203.6, 503.50   -174.0, 502.65
GR          -95.6, 500.21     -2.0, 499.58      0.0, 499.86     34.0, 499.82
GR           36.2, 499.70    130.9, 502.19    135.1, 503.64    178.0, 504.28
GR          188.2, 509.34
*
*
XT   APTEM     58           0.
GR         -186.7, 504.19   -178.6, 502.35   -160.4, 501.41   -137.7, 496.89
GR         -100.0, 494.86    -48.4, 494.14    -30.8, 493.84    -26.1, 492.96
GR          -10.4, 492.78     -4.8, 491.77      0.0, 487.37      1.4, 486.87
GR            7.5, 486.74     10.1, 486.76     16.1, 486.49     24.1, 486.48
GR           27.2, 486.60     28.8, 487.48     39.3, 491.85     43.2, 493.44
GR           73.1, 495.17    107.0, 503.06    136.9, 503.05    171.4, 504.27
GR          183.9, 508.48
*
AS   APPRO     51 * * * 0.0302
GT
N           0.060        0.050     0.060
SA                -10.4       43.2
*
HP 1 BRIDG   497.74 1 497.74
HP 2 BRIDG   497.74 * * 4160
HP 1 BRIDG   494.34 1 494.34
HP 2 RDWAY   500.46 * *  278
HP 1 APPRO   500.52 1 500.52
HP 2 APPRO   500.52 * * 4440
*
HP 1 BRIDG   497.74 1 497.74
HP 2 BRIDG   497.74 * * 4552
HP 1 BRIDG   494.93 1 494.93
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File tops022.wsp
        Hydraulic analysis for structure TOPSTH00490022   Date: 11-JUN-97
        TH 49 crossing Waits River, 0.05 miles to junction with VT 25
           *** RUN DATE & TIME: 08-14-97  12:32
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      387     38820     0     87                            0
   497.74           387     38820     0     87  1.00      0     34        0

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       497.74     0.0    33.5   386.6   38820.    4160.  10.76

 X STA.        0.0        3.2        5.0        6.6        8.0        9.3
   A(I)            34.1       21.3       19.1       17.9       16.9
   V(I)            6.11       9.74      10.87      11.59      12.32

 X STA.        9.3       10.6       11.9       13.3       14.5       15.8
   A(I)            16.7       16.4       16.3       16.2       16.2
   V(I)           12.45      12.66      12.77      12.84      12.83

 X STA.       15.8       17.2       18.5       19.9       21.3       22.7
   A(I)            16.4       16.2       16.6       16.9       17.1
   V(I)           12.68      12.88      12.49      12.30      12.16

 X STA.       22.7       24.1       25.6       27.4       29.7       33.5
   A(I)            17.6       18.3       20.0       22.8       33.5
   V(I)           11.81      11.36      10.41       9.12       6.21

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      273     32857    33     47                         4446
   494.34           273     32857    33     47  1.00      0     33     4446

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.
         WSEL     LEW     REW    AREA        K        Q    VEL
       500.46  -103.6    65.1    89.0    1778.     278.   3.12

X STA.      -103.6      -74.9      -61.6      -51.7      -43.2      -36.1
   A(I)             7.6        5.8        5.1        4.8        4.5
   V(I)            1.83       2.41       2.72       2.88       3.11

 X STA.      -36.1      -29.7      -24.0      -18.8      -13.9       -9.5
   A(I)             4.3        4.1        3.9        3.8        3.6
   V(I)            3.20       3.43       3.55       3.64       3.85

 X STA.       -9.5       -5.3       -1.2        5.4       12.2       18.9
   A(I)             3.5        3.5        4.1        4.1        4.1
   V(I)            3.92       3.97       3.39       3.36       3.39

 X STA.       18.9       25.4       31.9       37.3       43.6       65.1
   A(I)             4.1        4.1        3.8        4.0        6.1
   V(I)            3.40       3.40       3.70       3.45       2.28

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      818     63783   147    147                        10969
             2      654     99130    54     57                        12949
             3      259     18136    54     54                         3217
   500.52          1730    181049   254    259  1.39   -156     97    21728

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.
       WSEL     LEW     REW    AREA        K        Q    VEL
       500.52  -157.0    97.0  1730.3  181049.    4440.   2.57

 X STA.     -157.0     -110.3      -89.3      -70.6      -53.1      -37.3
   A(I)           162.3      121.3      115.2      112.0      105.4
   V(I)            1.37       1.83       1.93       1.98       2.11

 X STA.      -37.3      -23.2      -10.9       -2.0        2.7        6.6
   A(I)           101.1       97.2       79.7       62.0       54.2
   V(I)            2.20       2.28       2.78       3.58       4.09

 X STA.        6.6       10.4       14.2       17.9       21.7       25.4
   A(I)            53.3       53.6       52.9       53.9       52.3
   V(I)            4.17       4.14       4.19       4.12       4.25

 X STA.       25.4       29.5       34.8       43.4       59.6       97.0
   A(I)            56.8       62.7       77.5      109.9      147.0
   V(I)            3.91       3.54       2.87       2.02       1.51
```

```
       U.S. Geological Survey WSPRO Input File tops022.wsp
       Hydraulic analysis for structure TOPSTH00490022   Date: 11-JUN-97
       TH 49 crossing Waits River, 0.05 miles to junction with VT 25
          *** RUN DATE & TIME: 08-14-97  12:32
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      387     38820      0     87                            0
  497.74           387     38820      0     87  1.00      0     34        0

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      497.74     0.0    33.5   386.6   38820.    4552.  11.77

X STA.        0.0        3.2        5.0        6.6        8.0        9.3
  A(I)            34.1       21.3       19.1       17.9       16.9
  V(I)            6.68      10.66      11.90      12.68      13.48

X STA.        9.3       10.6       11.9       13.3       14.5       15.8
  A(I)            16.7       16.4       16.3       16.2       16.2
  V(I)           13.63      13.85      13.97      14.05      14.04

X STA.       15.8       17.2       18.5       19.9       21.3       22.7
  A(I)            16.4       16.2       16.6       16.9       17.1
  V(I)           13.87      14.09      13.67      13.46      13.31

X STA.       22.7       24.1       25.6       27.4       29.7       33.5
  A(I)            17.6       18.3       20.0       22.8       33.5
  V(I)           12.92      12.43      11.39       9.98       6.80

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      293     36283     33     48                         4933
  494.93           293     36283     33     48  1.00      0     33     4933

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.
        WSEL     LEW     REW    AREA        K        Q    VEL
      501.22  -128.1    94.0   237.5    7712.    1088.   4.58

X STA.     -128.1      -92.3      -79.1      -67.8      -57.8      -48.9
  A(I)            19.8       14.2       13.1       12.3       11.6
  V(I)            2.75       3.84       4.17       4.41       4.70

X STA.      -48.9      -40.4      -32.6      -25.4      -18.5      -12.0
  A(I)            11.5       10.9       10.6       10.4       10.0
  V(I)            4.74       4.99       5.15       5.25       5.42

X STA.      -12.0       -5.8        0.4        8.2       15.8       23.2
  A(I)             9.9        9.8       10.6       10.5       10.3
  V(I)            5.47       5.56       5.15       5.20       5.29

X STA.       23.2       30.7       37.7       45.4       56.3       94.0
  A(I)            10.5       10.1       10.5       12.4       18.7
  V(I)            5.20       5.40       5.17       4.38       2.91

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      948     78959    154    154                        13358
            2      700    111198     54     57                        14360
            3      307     23073     58     58                         4025
  501.39          1955    213229    265    270  1.37   -163    101    25723


   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.
        WSEL     LEW     REW    AREA        K        Q    VEL
      501.39  -164.1   100.7  1955.1  213229.    5640.   2.88

X STA.     -164.1     -113.7      -92.8      -74.7      -57.8      -41.9
  A(I)           184.4      136.6      125.8      122.1      117.9
  V(I)            1.53       2.06       2.24       2.31       2.39

X STA.      -41.9      -27.5      -15.1       -5.1        1.4        5.6
  A(I)           112.3      107.6       90.6       80.8       61.4
  V(I)            2.51       2.62       3.11       3.49       4.59

X STA.        5.6        9.6       13.7       17.7       21.6       25.7
  A(I)            60.7       61.0       60.2       58.8       61.8
  V(I)            4.65       4.63       4.68       4.80       4.56

X STA.       25.7       30.1       35.9       45.6       61.3      100.7
  A(I)            64.0       71.9       89.9      118.7      168.6
  V(I)            4.40       3.92       3.14       2.38       1.67
```

```
        U.S. Geological Survey WSPRO Input File tops022.wsp
        Hydraulic analysis for structure TOPSTH00490022   Date: 11-JUN-97
        TH 49 crossing Waits River, 0.05 miles to junction with VT 25
           *** RUN DATE & TIME: 08-14-97  12:32
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      255     29735     33     46                          4008
   493.79           255     29735     33     46  1.00      0     33     4008

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       493.79     0.0    33.5   255.1   29735.    4000.  15.68

X STA.         0.0        3.4        5.3        6.8        8.1        9.4
  A(I)            23.7       14.8       12.7       11.4       11.2
  V(I)            8.42      13.55      15.78      17.58      17.81

X STA.         9.4       10.6       11.9       13.1       14.3       15.5
  A(I)            10.7       10.7       10.4       10.3       10.4
  V(I)           18.64      18.76      19.28      19.35      19.26

X STA.        15.5       16.7       18.0       19.3       20.7       22.0
  A(I)            10.2       10.7       10.6       11.0       11.1
  V(I)           19.55      18.76      18.89      18.18      17.96

X STA.        22.0       23.3       24.8       26.4       29.0       33.5
  A(I)            11.2       12.0       13.0       16.4       22.6
  V(I)           17.88      16.63      15.39      12.20       8.84

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      451     25226    133    134                          4711
             2      513     66237     54     57                          9008
             3      132      6967     43     43                          1325
   497.90          1097     98429    230    234  1.52   -143     86    11048

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.90  -143.8    85.7  1096.9   98429.    4000.   3.65

X STA.      -143.8      -90.7      -65.4      -44.0      -25.6      -12.0
  A(I)           118.8       90.2       83.1       79.5       71.3
  V(I)            1.68       2.22       2.41       2.52       2.81

X STA.       -12.0       -2.6        1.6        4.7        7.7       10.7
  A(I)            57.3       41.9       35.4       34.0       34.1
  V(I)            3.49       4.77       5.64       5.88       5.87

X STA.        10.7       13.6       16.5       19.3       22.2       25.1
  A(I)            33.2       33.6       32.9       33.5       34.1
  V(I)            6.03       5.96       6.07       5.98       5.86

X STA.        25.1       28.2       32.2       37.6       50.6       85.7
  A(I)            35.3       39.7       44.3       65.1       99.6
  V(I)            5.67       5.04       4.51       3.07       2.01
```

```
        U.S. Geological Survey WSPRO Input File tops022.wsp
        Hydraulic analysis for structure TOPSTH00490022   Date: 11-JUN-97
        TH 49 crossing Waits River, 0.05 miles to junction with VT 25
           *** RUN DATE & TIME: 08-14-97  12:32

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXIT1":  USED WSI = CRWS.
                           WSI,CRWS =   493.30     493.38

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT1:XS   ******   -112      570  1.36 *****  494.74  493.38    4440  493.38
       -44 ******     84    44272  1.45 ***** *******    0.97    7.79

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.45

FULLV:FV       45   -118      763  0.71  0.31  495.05 *******    4440  494.34
         0     45     86    64076  1.35  0.00    0.00    0.62    5.82
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   493.84     508.27    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   493.84     508.27     495.15
 ===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 =   495.15     508.27     495.15

APPRO:AS       51   -108      517  1.69 *****  496.84  495.15    4440  495.15
        51     51     74    41853  1.47 ***** *******    1.09    8.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.33     498.62     498.76     497.74
 ===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       45      0      387  1.80 *****  499.54  493.98    4160  497.74
         0 ******     34    38820  1.00 ***** *******    0.56   10.76

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.457  0.000  497.74 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    35.  0.02  0.14  500.64    0.00    278.  500.46

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    203.   119.  -104.    16.   0.9   0.5   3.5   3.1   0.7   2.8
   RT:     75.    50.    16.    65.   0.8   0.5   3.4   3.1   0.7   2.8

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

APPRO:AS       27   -156     1729  0.14  0.08  500.66  495.15    4440  500.52
        51     30     97   180908  1.39  0.45    0.00    0.20    2.57

       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
   EXIT1:XS     -45.  -113.    84.   4440.   44272.     570.    7.79  493.38
   FULLV:FV       0.  -119.    86.   4440.   64076.     763.    5.82  494.34
   BRIDG:BR       0.     0.    34.   4160.   38820.     387.   10.76  497.74
   RDWAY:RG       9.*******   203.    278.******************    2.00  500.46
   APPRO:AS      51.  -157.    97.   4440.  180908.    1729.    2.57  500.52

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXIT1:XS    493.38    0.97  484.52  508.22************  1.36  494.74  493.38
   FULLV:FV  ********    0.62  484.52  508.22  0.31  0.00  0.71  495.05  494.34
   BRIDG:BR    493.98    0.56  484.78  497.74************  1.80  499.54  497.74
   RDWAY:RG  ****************  499.58  509.34  0.02******  0.14  500.64  500.46
   APPRO:AS    495.15    0.20  486.27  508.27  0.08  0.45  0.14  500.66  500.52
```

```
        U.S. Geological Survey WSPRO Input File tops022.wsp
       Hydraulic analysis for structure TOPSTH00490022   Date: 11-JUN-97
       TH 49 crossing Waits River, 0.05 miles to junction with VT 25
          *** RUN DATE & TIME: 08-14-97  12:32

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXIT1":  USED WSI = CRWS.
                          WSI,CRWS =   493.89     493.93

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT1:XS   ******   -115      680  1.49 *****  495.42  493.93    5640  493.93
       -44 ******     85    55096  1.39 ***** *******    0.94    8.30

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "FULLV"     KRATIO =  1.42

FULLV:FV       45   -121      885  0.82  0.33  495.75 *******    5640  494.93
         0     45     87    78329  1.30  0.00    0.00    0.62    6.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   494.43     508.27    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   494.43     508.27     495.89
 ===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 =   495.89     508.27     495.89

APPRO:AS       51   -122      658  1.77 *****  497.66  495.89    5640  495.89
        51     51     77    53693  1.55 ***** *******    1.04    8.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   500.94       0.00     495.77     499.58
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.45     500.32     500.45     497.74
 ===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       45      0      387  2.16 *****  499.90  494.48    4552  497.74
         0 ******     34    38820  1.00 ***** *******    0.61   11.77

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.476  0.000  497.74 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    35.  0.02  0.18  501.54    0.00   1088.  501.22

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    766.   144.  -128.    16.   1.6   1.1   5.4   4.7   1.5   3.0
   RT:    322.    78.    16.    94.   1.5   0.9   4.9   4.5   1.3   2.9

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS       27   -163     1955  0.18  0.10  501.57  495.89    5640  501.39
        51     30    101   213230  1.37  0.45    0.00    0.22    2.88

       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
   EXIT1:XS     -45.  -116.    85.   5640.   55096.     680.    8.30  493.93
   FULLV:FV      0.  -122.    87.   5640.   78329.     885.    6.37  494.93
   BRIDG:BR      0.     0.    34.   4552.   38820.     387.   11.77  497.74
   RDWAY:RG      9.*******   766.   1088.******************    2.00  501.22
   APPRO:AS     51.  -164.   101.   5640.  213230.    1955.    2.88  501.39

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

  SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#   YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    493.93    0.94  484.52  508.22************  1.49  495.42  493.93
   FULLV:FV  ********    0.62  484.52  508.22  0.33  0.00  0.82  495.75  494.93
   BRIDG:BR    494.48    0.61  484.78  497.74************  2.16  499.90  497.74
   RDWAY:RG  ****************  499.58  509.34  0.02******  0.18  501.54  501.22
   APPRO:AS    495.89    0.22  486.27  508.27  0.10  0.45  0.18  501.57  501.39
```

```
        U.S. Geological Survey WSPRO Input File tops022.wsp
        Hydraulic analysis for structure TOPSTH00490022   Date: 11-JUN-97
        TH 49 crossing Waits River, 0.05 miles to junction with VT 25
           *** RUN DATE & TIME: 08-14-97  12:32

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXIT1":  USED WSI = CRWS.
                          WSI,CRWS =   493.05     493.18

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT1:XS   ******   -111      531  1.29 *****  494.47  493.18    4000  493.18
       -44 ******     84    40666  1.46 ***** *******    0.97    7.54

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "FULLV"     KRATIO =  1.44

FULLV:FV       45   -116      712  0.68  0.30  494.77 *******    4000  494.09
         0     45     86    58540  1.38  0.00    0.00    0.62    5.61
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   493.59     508.27    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   493.59     508.27     494.77
 ===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 =   494.77     508.27     494.77

APPRO:AS       51   -101      449  1.71 *****  496.49  494.77    4000  494.77
        51     51     70    36622  1.39 ***** *******    1.15    8.90
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                SECID "BRIDG"     Q,CRWS =    4000.     493.79

            <<<<<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       45      0      255  3.82 *****  497.61  493.79    4000  493.79
         0     45     33    29734  1.00 ***** *******    1.00   15.68

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.74 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS       27   -143     1097  0.31  0.16  498.21  494.77    4000  497.90
        51     29     86    98400  1.52  0.44    0.02    0.36    3.65

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.806  0.439   54902.     0.    33.   497.84

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -45.  -112.    84.   4000.   40666.     531.    7.54  493.18
   FULLV:FV       0.  -117.    86.   4000.   58540.     712.    5.61  494.09
   BRIDG:BR       0.     0.    33.   4000.   29734.     255.   15.68  493.79
   RDWAY:RG       9.**************      0.*****************    2.00********
   APPRO:AS      51.  -144.    86.   4000.   98400.    1097.    3.65  497.90

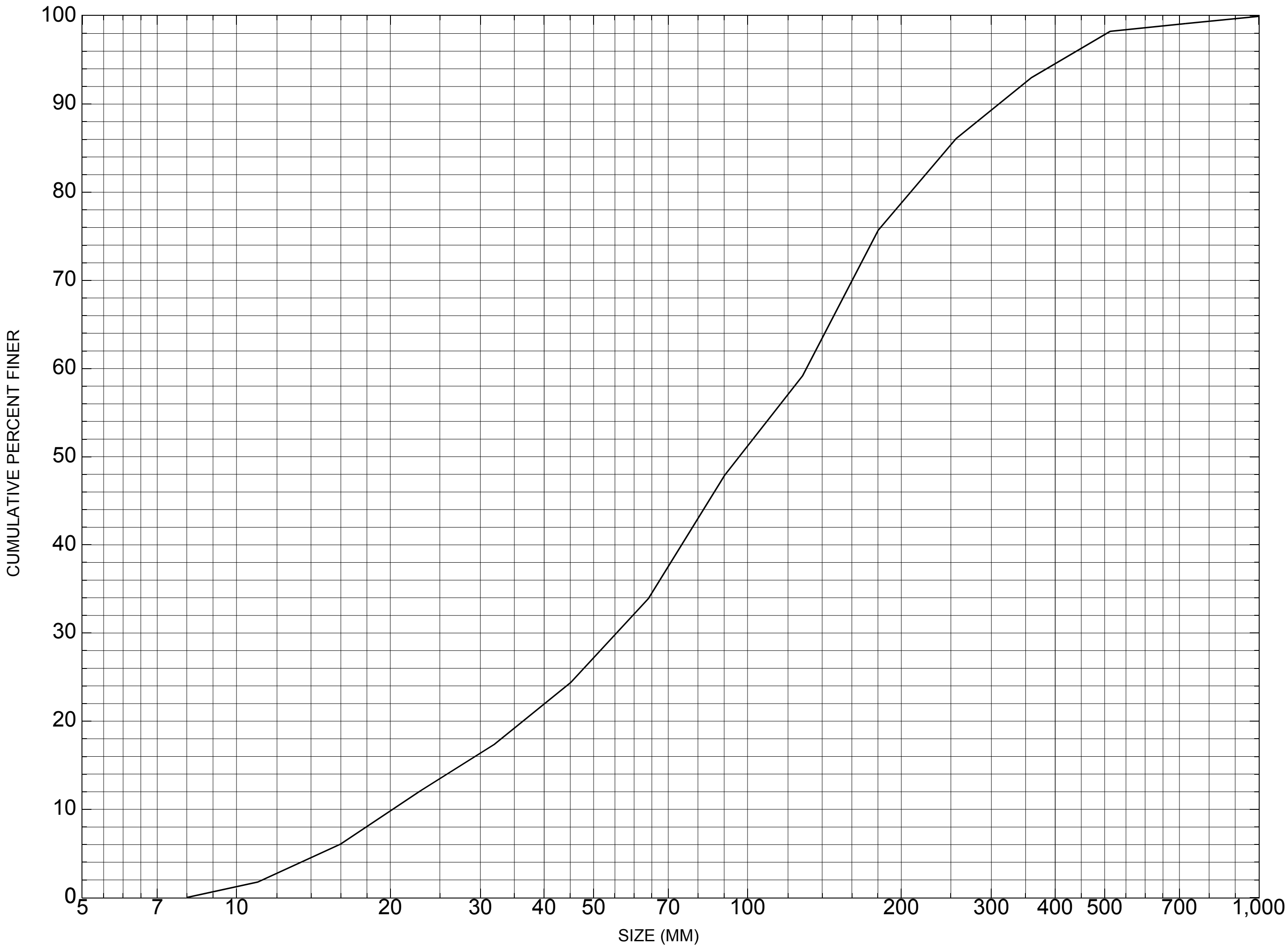
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       0.    33.   54902.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    493.18    0.97  484.52  508.22************  1.29  494.47  493.18
   FULLV:FV  ********    0.62  484.52  508.22  0.30  0.00  0.68  494.77  494.09
   BRIDG:BR    493.79    1.00  484.78  497.74************  3.82  497.61  493.79
   RDWAY:RG  ****************  499.58  509.34**********************************
   APPRO:AS    494.77    0.36  486.27  508.27  0.16  0.44  0.31  498.21  497.90
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure TOPSTH00490022, in Topsham, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **TOPSTH00490022**

General Location Descriptive

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

Date *(MM/DD/YY)* **03 / 28 / 95**

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

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

Town *(FIPS place code; I - 4; nnnnn)* **73075**

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

Waterway *(I - 6)* **WAITS RIVER**

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

Route Number **TH049**

Vicinity *(I - 9)* **0.05 MI JCT TH 49 + VT25**

Topographic Map **West Topsham**

Hydrologic Unit Code: **01080103**

Latitude *(I - 16; nnnn.n)* **44061**

Longitude *(i - 17; nnnnn.n)* **72182**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10091200220912**

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

Maximum span length *(I - 48; nnnn)* **0035**

Year built *(I - 27; YYYY)* **1974**

Structure length *(I - 49; nnnnnn)* **000038**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000040**

Deck Width *(I - 52; nn.n)* **162**

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

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

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

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

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

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

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

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*) **011.2**

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

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

Comments:

The structural inspection report of 8/30/93 indicates that the structure is a steel stringer type bridge with a timber deck. The abutment walls and wingwalls are concrete, and are in good condition with only a few minor cracks. The footings are noted as not visible and there has been no settling noted at this site. Boulder fill is noted as placed in front of the right abutment and on all four wingwalls. The stone fill on the left abutment is reported as having been partially eroded away. There is also stone fill reported on the banks up- and downstream. Point bars and debris accumulation problems are noted as minor at this bridge site. The streambed consists of primarily of gravel and boulders.

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} **650** Q_{25} **1000**

Q_{50} **1200** 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*): **Y** *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*): **1.3** Town: **Topsham** Year Built: **1919**
Highway No. : **57** Structure No. : **38** Structure Type: **302**
Clear span (*ft*): **-** Clear Height (*ft*): **9.0** Full Waterway (ft^2): **-**

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **33.72** mi^2 Lake/pond/swamp area **0.22** mi^2
Watershed storage *(ST)* **0.7** %
Bridge site elevation **950** ft Headwater elevation **3123** ft
Main channel length **10.67** mi
10% channel length elevation **1010** ft 85% channel length elevation **2140** ft
Main channel slope *(S)* **141.2** 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:

There is no benchmark information available.

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:

There is no foundation material information available.

Comments:

There are no bridge plans available.

Cross-sectional Data

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

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

Comments: **There is no cross-section information available.**

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

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

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

Comments: **There is no cross-section information available.**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 03/25/96
Computerized by: EW Date: 03/25/96
Reviewd by: LKS Date: 08/28/97

Structure Number TOPSTH00490022

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 08 / 28 / 1995

2. Highway District Number 07 Mile marker -

County Orange (017) Town Topsham (73075)

Waterway *(I - 6)* Waits River Road Name -

Route Number TH049 Hydrologic Unit Code: 01080108

3. Descriptive comments:

The bridge is a steel stringer bridge with a timber deck and concrete abutments and wingwalls. The bridge is locate 0.05 miles from the junction with VT 25.

B. Bridge Deck Observations

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

5. Ambient water surface... US 2 UB 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 38 *(feet)* Span length 35 *(feet)* Bridge width 16 *(feet)*

Road approach to bridge:

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

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

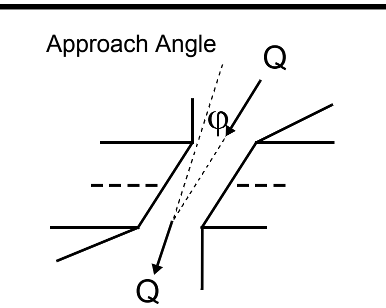
10. Embankment slope (*run / rise in feet / foot*):
US left 2.5:1 US right 3.4:1

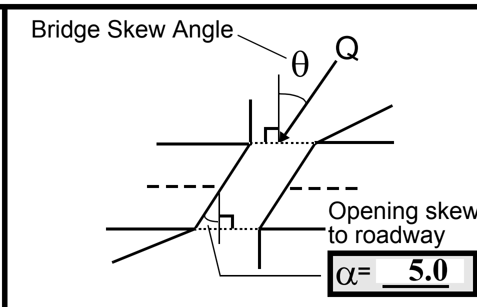
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	2	3	2	2
LBDS	0	-	2	2

*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 1
Range? 0 feet US *(US, UB, DS)* to 10 feet DS

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 62 feet US *(US, UB, DS)* to 20 feet US

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

18. Bridge Type: 1a

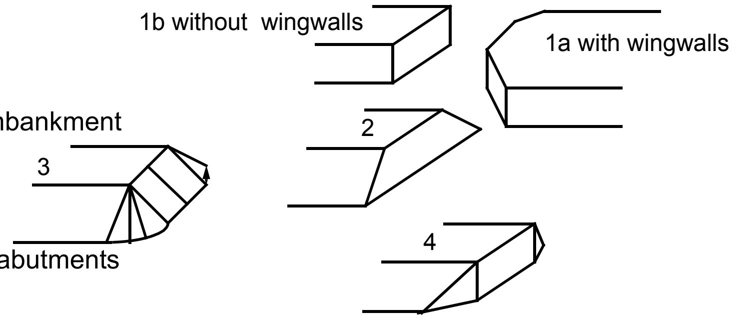
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#4: The surface cover is predominantly field with shrubs, brush, and trees.

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
41.0	5.5			6.0	3	3	543	543	1	0

23. Bank width 25.0 24. Channel width 20.0 25. Thalweg depth 53.5 29. Bed Material 543

30 .Bank protection type: LB 4 RB 4 31. Bank protection condition: LB 2 RB 2

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

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

RB protection extends from 34 to 0 feet US.
LB protection extends from 22 to 0 feet US.
Bank protection is comprised of stone fill.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **146** 35. Mid-bar width: **14**

36. Point bar extent: **250** feet **US** *(US, UB)* to **62** feet **US** *(US, UB, DS)* positioned **66** %LB to **100** %RB

37. Material: **543**

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

Side bar material coarsely grades from US to DS. A confluence cuts through the side bar.

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

41. Mid-bank distance: **33** 42. Cut bank extent: **48** feet **US** *(US, UB)* to **24** 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.):

-

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.):

There is no channel scour present upstream at this site. There is local scour behind boulders.

49. Are there major confluences? **Y** *(Y or if N type ctrl-n mc)* 50. How many? **1**

51. Confluence 1: Distance **170** 52. Enters on **RB** *(LB or RB)* 53. Type **1** *(**1**- perennial; **2**- ephemeral)*

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

54. Confluence comments (eg. confluence name):

There is a confluence of the East Orange Branch of the Waits River.

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
29.5		1.0		2	7	7	0

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

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

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

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

543

-

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 1____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

1

-

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		-	90	2	0	0	0	90.0
RABUT	1	15	90			2	0	33.5

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.):

0

0

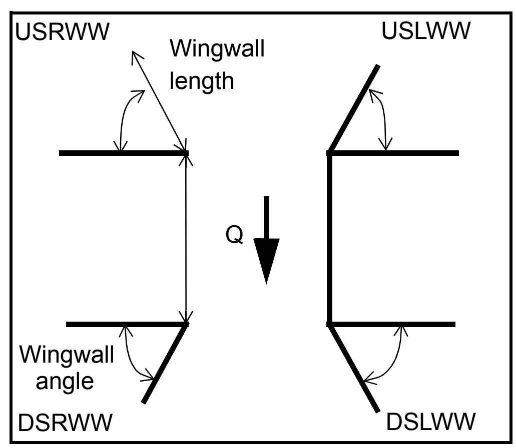
1

There is some aggradation along the LABUT between the boulder protection.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						33.5	
USRWW:	Y		1		0	1.5	
DSLWW:	0		0		Y	17.5	
DSRWW:	1		0		0	17.5	

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	1	1	3	2
Condition	Y	0	1	0	1	1	4	1
Extent	1	0	0	2	2	2	3	-

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

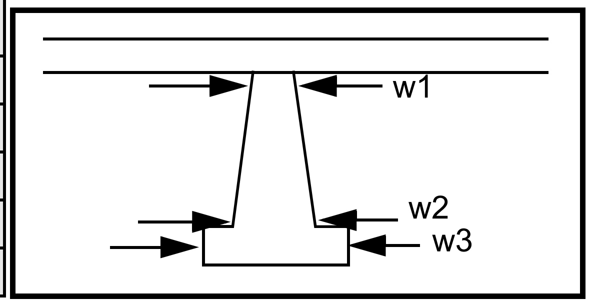
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
2
1
1
2
1
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**9.0**	**9.0**	**55.0**	**50.0**	**50.0**
Pier 2	**9.0**	**9.0**	-	**45.0**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	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
-	-			-	-	The	re	are	no	pier

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

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.):

1
1
543
543
1
1
543
3
3
1

101. Is a drop structure present? **1** *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

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

105. Drop structure comments (eg. downstream scour depth):
protection extends from 0 ft DS to 64 ft DS.
RB protection extends from 0 ft DS to > 300 ft DS.

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: **N**

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

-

There is no drop structure downstream at this site.

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

Cut bank extent: **Y** feet **69** *(US, UB, DS)* to **DS** feet **8** *(US, UB, DS)*

Bank damage: **50** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
88
DS
0

Is channel scour present? **20** *(Y or if N type ctrl-n cs)* Mid-scour distance: **235**

Scour dimensions: Length **The** Width **bar** Depth: **is a** Positioned **side** %LB to **bar.** %RB

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

There is an additional side bar beginning at 50 ft downstream and extending to 88 ft downstream on the left bank. The side bar has a mid-bar distance of 69 ft and a mid-bar width of 8 ft.

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

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

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

Confluence comments (eg. confluence name):

There are no cut-banks downstream at this site. RB protection prevents a cut-bank.

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
0 DS
40
7
1
20
50
The scour hole extends from the upstream bridge face to approximately 20 ft downstream of the bridge. There is an additional small scour hole along the right side of the channel which is 0.5 feet deep with a mid-scour distance of 8 ft UB with a length and width of 5 ft.

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:	TOPSTH00490022	Town:	TOPSHAM
Road Number:	TH 49	County:	ORANGE
Stream:	WAITS RIVER		

Initials LKS   Date: 07/16/97 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	4440	5640	4000
Main Channel Area, ft2	654	700	513
Left overbank area, ft2	818	948	451
Right overbank area, ft2	259	307	132
Top width main channel, ft	54	54	54
Top width L overbank, ft	147	154	133
Top width R overbank, ft	54	58	43
D50 of channel, ft	0.316	0.316	0.316
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	12.1	13.0	9.5
y1, average depth, LOB, ft	5.6	6.2	3.4
y1, average depth, ROB, ft	4.8	5.3	3.1
Total conveyance, approach	181049	213229	98429
Conveyance, main channel	99130	111198	66237
Conveyance, LOB	63783	78959	25226
Conveyance, ROB	18136	23073	6967
Percent discrepancy, conveyance	0.0000	-0.0005	-0.0010
Qm, discharge, MC, cfs	2431.0	2941.2	2691.8
Ql, discharge, LOB, cfs	1564.2	2088.5	1025.1
Qr, discharge, ROB, cfs	444.8	610.3	283.1
Vm, mean velocity MC, ft/s	3.7	4.2	5.2
Vl, mean velocity, LOB, ft/s	1.9	2.2	2.3
Vr, mean velocity, ROB, ft/s	1.7	2.0	2.1
Vc-m, crit. velocity, MC, ft/s	11.6	11.7	11.1
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

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	4440	5640	4000
(Q) discharge thru bridge, cfs	4160	4552	4000
Main channel conveyance	38820	38820	29735
Total conveyance	38820	38820	29735
Q2, bridge MC discharge,cfs	4160	4552	4000
Main channel area, ft2	387	387	255
Main channel width (normal), ft	33.4	33.4	33.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.4	33.4	33.4
y_bridge (avg. depth at br.), ft	11.57	11.57	7.62
Dm, median (1.25*D50), ft	0.395	0.395	0.395
y2, depth in contraction,ft	10.09	10.90	9.76
ys, scour depth (y2-ybridge), ft	-1.49	-0.68	**2.14**

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	0	Other Q
Q, discharge thru bridge MC, cfs	4160	4552	4000
Main channel area (DS), ft2	273	293	254.5
Main channel width (normal), ft	33.4	33.4	33.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	33.4	33.4	33.4
D90, ft	1.0174	1.0174	1.0174
D95, ft	1.3479	1.3479	1.3479
Dc, critical grain size, ft	1.1135	1.1226	1.2217
Pc, Decimal percent coarser than Dc	0.082	0.080	0.065
Depth to armoring, ft	**37.60**	**38.77**	**53.11**

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	4440	5640	4000
Q, thru bridge MC, cfs	4160	4552	4000
Vc, critical velocity, ft/s	11.57	11.70	11.11
Va, velocity MC approach, ft/s	3.72	4.20	5.25
Main channel width (normal), ft	33.4	33.4	33.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.4	33.4	33.4
qbr, unit discharge, ft2/s	124.6	136.3	119.8
Area of full opening, ft2	386.6	386.6	254.5
Hb, depth of full opening, ft	11.57	11.57	7.62
Fr, Froude number, bridge MC	0.56	0.61	1
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	273	293	N/A
**Hb, depth at downstream face, ft	8.17	8.77	N/A
**Fr, Froude number at DS face	0.94	0.92	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	497.74	497.74	0
Elevation of Bed, ft	486.17	486.17	-7.62
Elevation of Approach, ft	500.52	501.39	0
Friction loss, approach, ft	0.08	0.1	0
Elevation of WS immediately US, ft	500.44	501.29	0.00
ya, depth immediately US, ft	14.27	15.12	7.62
Mean elevation of deck, ft	499.84	499.84	0
w, depth of overflow, ft (>=0)	0.60	1.45	0.00
Cc, vert contrac correction (<=1.0)	0.96	0.96	1.00
**Cc, for downstream face (<=1.0)	0.851412	0.880279	ERR
Ys, scour w/Chang equation, ft	**-0.35**	**0.57**	N/A
Ys, scour w/Umbrell equation, ft	-3.85	-3.12	N/A

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

**Ys, scour w/Chang equation, ft	4.47	4.46	N/A

**Ys, scour w/Umbrell equation, ft	-0.44	-0.32	ERR

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

y2, from Laursen's equation, ft	10.09	10.90	9.76
WSEL at downstream face, ft	494.34	494.93	--
Depth at downstream face, ft	8.17	8.77	N/A
Ys, depth of scour (Laursen), ft	1.92	2.13	N/A

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	4440	5640	4000	4440	5640	4000
a', abut.length blocking flow, ft	157.1	164.2	143.9	63.6	67.3	52.3
Ae, area of blocked flow ft2	865.96	917.77	526.64	337.56	359.84	198.75
Qe, discharge blocked abut.,cfs	--	--	1326.19	--	--	553.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.03	2.34	2.52	2.06	2.37	2.79
ya, depth of f/p flow, ft	5.51	5.59	3.66	5.31	5.35	3.80
--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	85	85	85	95	95	95
K2	0.99	0.99	0.99	1.01	1.01	1.01
Fr, froude number f/p flow	0.148	0.162	0.232	0.155	0.170	0.252
ys, scour depth, ft	18.92	20.14	17.11	**14.59**	**15.45**	**13.29**

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)	157.1	164.2	143.9	63.6	67.3	52.3
y1 (depth f/p flow, ft)	5.51	5.59	3.66	5.31	5.35	3.80
a'/y1	28.50	29.38	39.32	11.98	12.59	13.76
Skew correction (p. 49, fig. 16)	0.98	0.98	0.98	1.01	1.01	1.01
Froude no. f/p flow	0.15	0.16	0.23	0.16	0.17	0.25
Ys w/ corr. factor K1/0.55:						
vertical	20.98	21.92	16.15	ERR	ERR	ERR
vertical w/ ww's	**17.20**	**17.97**	**13.25**	ERR	ERR	ERR
spill-through	11.54	12.05	8.89	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.94	0.92	1	0.94	0.92	1
y, depth of flow in bridge, ft	8.20	8.80	7.64	8.20	8.80	7.64
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.)	**3.37**	**3.60**	**3.19**	**3.37**	**3.60**	**3.19**