LEVEL II SCOUR ANALYSIS FOR BRIDGE 49 (WALLVT01030049) on STATE HIGHWAY 103, crossing FREEMAN BROOK, WALLINGFORD, VERMONT

U.S. Geological Survey
Open-File Report 97-184

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

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By ROBERT H. FLYNN AND TIMOTHY SEVERANCE

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Pembroke, New Hampshire

1997

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

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 49 (WALLVT01030049) ON STATE HIGHWAY 103, CROSSING FREEMAN BROOK, WALLINGFORD, VERMONT

By ROBERT H. FLYNN AND TIMOTHY SEVERANCE

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WALLVT01030049 on State Highway 103 crossing Freeman Brook, Wallingford, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in south-central Vermont. The 11.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture with trees and brush on the immediate banks except for the upstream left overbank which is tree covered. A levee composed of stone fill was constructed along the upstream left bank in order to keep flow from reaching the flood plain left (south) of the brook.

In the study area, Freeman Brook has an incised, straight channel with a slope of approximately 0.02 ft/ft, an average channel top width of 56 ft and an average channel depth of 6 ft. The predominant channel bed materials are gravel and cobbles with a median grain size (D_{50}) of 62.9 mm (0.206 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 10, 1995, indicated that the reach was stable.

The State Highway 103 crossing of the Freeman Brook is a 54-ft-long, two-lane bridge consisting of one 50-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March 15, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 0.5 ft deeper than the mean thalweg depth was observed along the downstream end of the left abutment and downstream left wingwall during the Level I assessment. The scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the entire base length of the upstream left and downstream right wingwall and type-1 stone fill (less than 12 inches diameter) along the upstream end of the upstream right wingwall. Type-4 stone fill (less than 60 inches diameter) was found along the upstream left and right banks. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 1.4 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 7.6 to 21.4 ft. The worst-case abutment scour was predicted 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.

Wallingford, VT. Quadrangle, 1:24,000, 1986 and
Mount Holly, VT. Quadrangle, 1:24,000, 1986

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 WALLVT01030049 ***Stream*** Freeman Brook

County Rutland ***Road*** VT 103 ***District*** 3

Description of Bridge

Bridge length 54 ***ft*** ***Bridge width*** 33.3 ***ft*** ***Max span length*** 50 ***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*** 10/10/95

Description of stone fill Type-2, along the entire base length of the upstream left and downstream right wingwall and type-1 along the upstream end of the upstream right wingwall.

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

Y

Is bridge skewed to flood flow according to There ***survey?*** 25 ***Angle*** Yes

are mild upstream and downstream bends. The scour hole is present at the channel bend at the point where flows impact the left abutment.

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	10/10/95	0	0
Level II	10/10/95	0	0

Potential for debris Low. The upstream channel is laterally stable and there is no tree debris in the channel.

Describe any features near or at the bridge that may affect flow (include observation date) A stone fill levee was constructed along the upstream left bank in order to keep flow from reaching the left flood plain and there is the potential for backwater from the Mill River which is approximately 400 feet downstream of the bridge (10/10/95).

Description of the Geomorphic Setting

General topography The channel is located within a flat to slightly irregular flood plain in a low relief valley setting.

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

Date of inspection 10/10/95

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

DS right: Moderately sloped channel bank to flood plain.

US left: Steep channel bank (berm) to flood plain.

US right: Steep channel bank to a flood plain.

Description of the Channel

Average top width 56 ***ft*** ***Average depth*** 6 ***ft***

Predominant bed material Gravel / Cobbles ***Bank material*** Gravel/Cobbles

Straight and stable with non-alluvial channel boundaries.

10/10/95

Vegetative co

Trees and brush with short grass lawn beyond.

DS left: Trees and brush with pasture beyond.

DS right: Primarily trees with some brush

US left: Trees and brush with pasture beyond.

US right:

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

Point bar under bridge, to some extent redirects flow along the left abutment. 10/10/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 11.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

-

Calculated Discharges

Q100 2,650 ***ft³/s*** ***Q500*** 3,750 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database. These values were selected due to the central tendency of the discharge frequency curve with others which were developed from empirical relationships and extended to the 500-year discharge (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887)

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

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

Datum tie between USGS survey and VTAOT plans Subtract 321.2 ft from the USGS arbitrary survey datum to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the downstream left abutment (elev. 500.50 ft, arbitrary survey datum). RM2 is the center of an existing chisled square on top of the upstream end of the upstream right abutment (elev. 500.12 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-52	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	17	1	Road Grade section
APPRO	84	2	Modelled Approach section (Templated from APTEM)
APTEM	88	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 were 0.045, and overbank "n" values ranged from 0.035 to 0.040.

The Freeman Brook flows into the Mill River approximately 400 feet downstream of the bridge. The close proximity of the confluence may affect the hydraulics at this bridge site, especially if the flow peaks are simultaneous. However, an analysis of potential backwater from the Mill River is outside of the scope of this study. Therefore, normal depth at the exit section (EXITX) was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0167 ft/ft which was determined from surveyed downstream thalweg points. This slope resulted in a normal depth slightly less than critical depth and WSPRO defaulted to critical depth. Critical depth in the downstream reach for the flows modelled is considered to be a satisfactory solution.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.008 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.9 ***ft***
Average low steel elevation 496.7 ***ft***

100-year discharge 2,650 ***ft^3/s***
Water-surface elevation in bridge opening 496.9 ***ft***
Road overtopping? N ***Discharge over road*** - ***ft^3/s***
Area of flow in bridge opening 325 ***ft^2***
Average velocity in bridge opening 8.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.4 ***ft/s***

Water-surface elevation at Approach section with bridge 498.4
Water-surface elevation at Approach section without bridge 495.6
Amount of backwater caused by bridge 2.8 ***ft***

500-year discharge 3,750 ***ft^3/s***
Water-surface elevation in bridge opening 496.9 ***ft***
Road overtopping? Y ***Discharge over road*** 465 ***ft^3/s***
Area of flow in bridge opening 325 ***ft^2***
Average velocity in bridge opening 10.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.7 ***/s***

Water-surface elevation at Approach section with bridge 500.0
Water-surface elevation at Approach section without bridge 496.1
Amount of backwater caused by bridge 3.9

Incipient overtopping discharge 2,670 ***ft^3/s***
Water-surface elevation in bridge opening 496.9 ***ft***
Area of flow in bridge opening 325 ***ft^2***
Average velocity in bridge opening 8.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.5 ***ft/s***

Water-surface elevation at Approach section with bridge 498.4
Water-surface elevation at Approach section without bridge 495.6
Amount of backwater caused by bridge 2.8 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

All modelled flows resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, the Chang equation (Richardson and others, 1995, p. 145-146) was applied to compute the contraction scour. The results of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) were also computed and can be found in appendix F. The computed depths to streambed armoring suggest armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	1.4	0.0
Depth to armoring	2.1 6.9	2.2	--
Left overbank	--	--	--
Right overbank	--	--	7.6 9.1

Local scour:			
Abutment scour			
Left abutment	7.6	18.6	21.4
Right abutment	18.7–	---	---
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	1.3	1.9

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
	(D_{50} in feet)		
Abutments:			
Left abutment	1.3	1.3	1.9
Right abutment	1.3	--	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--
	--		

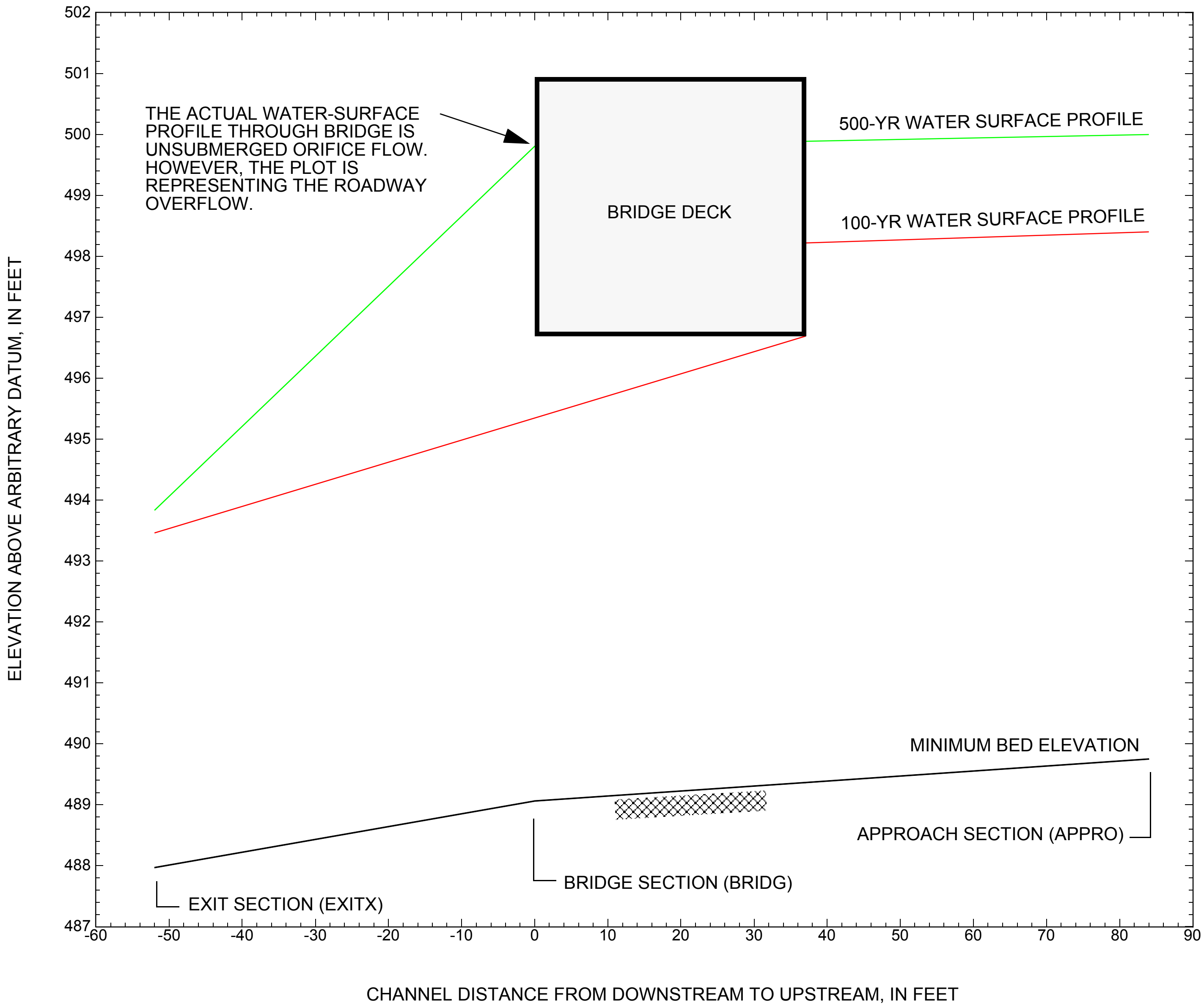

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WALLVT01030049 on State Highway 103, crossing Freeman Brook, Wallingford, Vermont.

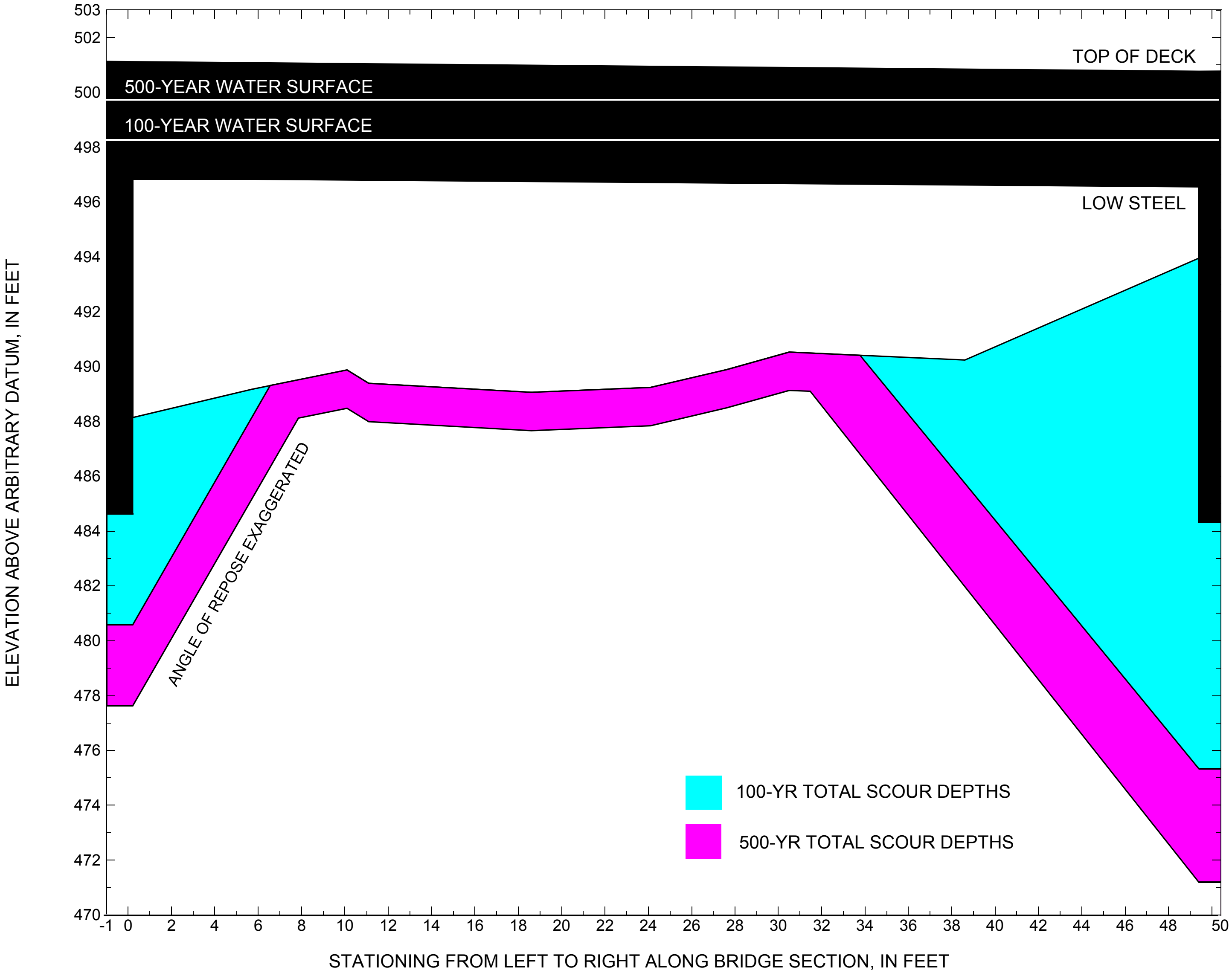

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WALLVT01030049 on State Highway 103, crossing Freeman Brook, Wallingford, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WALLVT01030049 on State Highway 103, crossing Freeman Brook, Wallingford, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,650 cubic-feet per second											
Left abutment	0.0	496.5	496.8	484.6	488.1	0.0	7.6	--	7.6	480.5	-4.1
Right abutment	49.4	496.2	496.5	484.3	494.0	0.0	18.6	--	18.6	475.4	-8.9

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure WALLVT01030049 on State Highway 103, crossing Freeman Brook, Wallingford, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 3,750 cubic-feet per second											
Left abutment	0.0	496.5	496.8	484.6	488.1	1.4	9.1	--	10.5	477.6	-7.0
Right abutment	49.4	496.2	496.5	484.3	494.0	1.4	21.4	--	22.8	471.2	-13.1

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, 1986, Wallingford, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File wall049.wsp
T2        Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
T3        Bridge #49 over Freeman Brook. RF
*
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           2650.0   3750.0   2670.0
SK          0.0167   0.0167   0.0167
*
XS   EXITX    -52
GR         -149.2, 500.00   -149.2, 495.83    -26.7, 493.49
GR          -17.8, 495.73    -10.6, 488.94     -6.1, 488.38      0.0, 488.37
GR            5.3, 488.04      8.6, 487.97     15.9, 488.88     28.6, 491.27
GR           34.0, 491.40    278.4, 493.26    341.7, 497.00    394.0, 496.57
*
N           0.040        0.045        0.040
SA                 -17.8         34.0
*
XS   FULLV      0  * * *   0.01898
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.69       0.0
GR            0.0, 496.85      0.2, 488.14      5.7, 489.17     10.1, 489.88
GR           11.1, 489.39     18.6, 489.06     24.1, 489.24     27.6, 489.89
GR           30.5, 490.53     38.6, 490.24     49.4, 493.96     49.4, 496.53
GR            0.0, 496.85
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      37.7 * *     17.3      9.8
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     17      33.3     1
GR         -131.8, 502.00
GR         -131.8, 500.82      0.0, 501.12      0.1, 503.13     49.8, 502.83
GR           49.9, 500.77    145.0, 499.61    240.3, 498.45    367.3, 502.00
*
*
XT   APTEM     88
GR          -13.3, 502.60
GR           -3.7, 496.79      4.2, 491.97      9.7, 490.96     16.2, 490.69
GR           18.6, 489.78     23.8, 490.14     32.1, 490.11     34.0, 490.71
GR           45.2, 496.17     68.9, 493.49    155.2, 494.49    207.1, 497.21
GR          232.1, 499.12    367.3, 502.00
*
AS   APPRO     84 * * * 0.0082
GT
N            0.045       0.035
SA                  45.2
*
HP 1 BRIDG   496.85 1 496.85
HP 2 BRIDG   496.85 * * 2649
HP 1 APPRO   498.40 1 498.40
HP 2 APPRO   498.40 * * 2650
*
HP 1 BRIDG   496.85 1 496.85
HP 2 BRIDG   496.85 * * 3286
HP 1 APPRO   500.00 1 500.00
HP 2 APPRO   500.00 * * 3750
HP 2 RDWAY   499.81 * * 465
*
HP 1 BRIDG   496.85 1 496.85
HP 2 BRIDG   496.85 * * 2668
HP 1 APPRO   498.43 1 498.43
HP 2 APPRO   498.43 * * 2670
*
EX
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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

        U.S. Geological Survey WSPRO Input File wall049.wsp
        Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
        Bridge #49 over Freeman Brook. RF
           *** RUN DATE & TIME: 01-27-97  10:51
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      325.   22085.     0.   111.                          0.
   496.85           325.   22085.     0.   111.  1.00     0.    49.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.85     0.0    49.4   325.4   22085.    2649.   8.14

X STA.        0.0        3.0        5.0        7.0        9.0       11.1
  A(I)            24.2       15.9       15.2       14.6       15.3
  V(I)            5.47       8.35       8.69       9.07       8.66

X STA.       11.1       13.0       15.0       16.8       18.7       20.5
  A(I)            14.1       14.4       14.1       14.1       14.0
  V(I)            9.37       9.17       9.40       9.42       9.43

X STA.       20.5       22.4       24.3       26.4       28.6       31.2
  A(I)            14.3       14.6       14.5       15.6       16.3
  V(I)            9.27       9.08       9.13       8.52       8.11

X STA.       31.2       33.9       36.5       39.2       42.6       49.4
  A(I)            16.1       16.4       17.0       19.2       25.5
  V(I)            8.22       8.08       7.77       6.90       5.20



    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      84.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      326.   35306.    52.    55.                       4646.
             2      613.   59413.   178.   178.                       6451.
   498.40           939.   94719.   230.   233.  1.01    -6.   223.  10722.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      84.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.40    -6.4   223.1   938.5   94719.    2650.   2.82

X STA.       -6.4        8.1       13.7       18.7       23.1       27.5
  A(I)            60.6       42.1       40.1       37.4       36.2
  V(I)            2.19       3.14       3.31       3.55       3.66

X STA.       27.5       31.9       37.7       55.8       66.8       75.1
  A(I)            37.1       41.6       61.1       44.9       40.5
  V(I)            3.57       3.19       2.17       2.95       3.27

X STA.       75.1       83.4       92.4      101.4      111.0      121.0
  A(I)            40.4       42.1       41.8       43.0       44.2
  V(I)            3.28       3.15       3.17       3.08       3.00

X STA.      121.0      131.9      143.3      156.0      172.8      223.1
  A(I)            46.5       47.6       50.7       58.1       82.6
  V(I)            2.85       2.79       2.62       2.28       1.60
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      U.S. Geological Survey WSPRO Input File wall049.wsp
      Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
      Bridge #49 over Freeman Brook. RF
         *** RUN DATE & TIME: 01-27-97  10:51
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     325.   22085.     0.   111.                          0.
 496.85          325.   22085.     0.   111.  1.00     0.    49.      0.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     496.85     0.0    49.4   325.4   22085.    3286.  10.10

X STA.        0.0        3.0        5.0        7.0        9.0       11.1
  A(I)           24.2       15.9       15.2       14.6       15.3
  V(I)           6.79      10.36      10.78      11.25      10.74

X STA.       11.1       13.0       15.0       16.8       18.7       20.5
  A(I)           14.1       14.4       14.1       14.1       14.0
  V(I)          11.62      11.38      11.66      11.69      11.70

X STA.       20.5       22.4       24.3       26.4       28.6       31.2
  A(I)           14.3       14.6       14.5       15.6       16.3
  V(I)          11.50      11.26      11.32      10.57      10.06

X STA.       31.2       33.9       36.5       39.2       42.6       49.4
  A(I)           16.1       16.4       17.0       19.2       25.5
  V(I)          10.19      10.02       9.64       8.56       6.45


  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      84.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     411.   50034.    54.    58.                       6409.
           2     928.  100133.   230.   230.                      10586.
 500.00         1339.  150168.   284.   288.  1.01    -9.   275.  16410.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      84.

       WSEL     LEW     REW    AREA        K        Q    VEL
     500.00    -9.1   275.0  1338.7  150168.    3750.   2.80

X STA.       -9.1        7.9       14.6       20.2       25.4       30.7
  A(I)           84.5       61.2       54.5       52.1       52.4
  V(I)           2.22       3.07       3.44       3.60       3.58

X STA.       30.7       36.6       50.7       62.4       71.1       79.6
  A(I)           54.9       74.1       60.3       54.5       54.5
  V(I)           3.42       2.53       3.11       3.44       3.44

X STA.       79.6       88.2       97.3      106.6      116.8      127.2
  A(I)           54.8       57.4       57.3       61.6       61.8
  V(I)           3.42       3.27       3.27       3.04       3.03

X STA.      127.2      138.5      150.8      165.1      184.9      275.0
  A(I)           65.5       69.3       77.2       89.0      141.9
  V(I)           2.86       2.70       2.43       2.11       1.32


  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      17.

       WSEL     LEW     REW    AREA        K        Q    VEL
     499.81   128.6   289.0   109.1    3141.     465.   4.26

X STA.      128.6      171.2      184.0      192.8      200.0      206.1
  A(I)           11.0        7.6        6.5        6.0        5.5
  V(I)           2.11       3.05       3.60       3.90       4.25

X STA.      206.1      211.3      215.9      220.1      224.0      227.6
  A(I)            5.1        4.8        4.6        4.4        4.3
  V(I)           4.56       4.89       5.06       5.26       5.39

X STA.      227.6      231.1      234.3      237.5      240.5      243.7
  A(I)            4.2        4.1        4.1        4.1        4.1
  V(I)           5.51       5.68       5.66       5.64       5.68

X STA.      243.7      247.3      251.4      256.7      264.0      289.0
  A(I)            4.4        4.6        5.1        5.9        8.7
  V(I)           5.31       5.02       4.57       3.93       2.68
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        U.S. Geological Survey WSPRO Input File wall049.wsp
        Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
        Bridge #49 over Freeman Brook. RF
           *** RUN DATE & TIME: 01-27-97  10:51
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     325.   22085.     0.   111.                          0.
  496.85           325.   22085.     0.   111.  1.00     0.    49.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.85     0.0    49.4   325.4   22085.    2668.   8.20

X STA.         0.0         3.0         5.0         7.0         9.0        11.1
  A(I)             24.2        15.9        15.2        14.6        15.3
  V(I)             5.51        8.41        8.75        9.13        8.72

X STA.        11.1        13.0        15.0        16.8        18.7        20.5
  A(I)             14.1        14.4        14.1        14.1        14.0
  V(I)             9.44        9.24        9.46        9.49        9.50

X STA.        20.5        22.4        24.3        26.4        28.6        31.2
  A(I)             14.3        14.6        14.5        15.6        16.3
  V(I)             9.34        9.15        9.19        8.58        8.17

X STA.        31.2        33.9        36.5        39.2        42.6        49.4
  A(I)             16.1        16.4        17.0        19.2        25.5
  V(I)             8.28        8.13        7.83        6.95        5.24


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      84.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     327.   35561.    52.    55.                       4677.
             2     618.   60190.   178.   179.                       6528.
  498.43           945.   95751.   230.   234.  1.01    -6.   223.  10832.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      84.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.43    -6.5   223.5   945.4   95751.    2670.   2.82

X STA.        -6.5         8.1        13.8        18.8        23.2        27.6
  A(I)             61.0        43.4        39.4        37.6        36.5
  V(I)             2.19        3.07        3.39        3.55        3.66

X STA.        27.6        32.0        37.8        56.2        66.9        75.3
  A(I)             37.3        41.7        62.7        44.4        41.0
  V(I)             3.58        3.20        2.13        3.01        3.26

X STA.        75.3        83.7        92.4       101.6       111.2       121.4
  A(I)             40.8        41.2        43.1        43.3        45.5
  V(I)             3.27        3.24        3.10        3.09        2.94

X STA.       121.4       132.1       143.6       156.2       172.5       223.5
  A(I)             45.8        47.9        51.0        57.0        84.8
  V(I)             2.91        2.79        2.62        2.34        1.57
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        U.S. Geological Survey WSPRO Input File wall049.wsp
        Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
        Bridge #49 over Freeman Brook. RF
           *** RUN DATE & TIME: 01-27-97  10:51

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                           WSI,CRWS =   493.10     493.46

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

EXITX:XS   ******   -15.     477.  0.67 *****  494.13  493.46   2650.  493.46
      -52. ******   282.   27522.  1.40 ***** *******    0.91    5.55
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.96     500.99    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.96     500.99     494.45
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "FULLV"
                  WSBEG,WSEND,CRWS =   494.45     500.99     494.45

FULLV:FV      52.   -15.     477.  0.67 *****  495.12  494.45   2650.  494.45
        0.    52.   282.   27522.  1.40 ***** *******    0.91    5.55
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    2.97     494.11     495.60
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.95     502.57    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.95     502.57     495.60
 ===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 =   495.60     502.57     495.60

APPRO:AS      84.    -2.     362.  0.95 *****  496.55  495.60   2650.  495.60
       84.    84.   177.   24514.  1.14 ***** *******    0.95    7.32
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.57     497.45     497.75     496.69

 ===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      52.     0.     325.  1.03 *****  497.88  494.57   2649.  496.85
        0. ******    49.   22085.  1.00 ***** *******    0.56    8.14

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.456  0.000  496.69 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      17.        <<<<<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      46.    -6.     939.  0.13  0.18  498.53  495.60   2650.  498.40
       84.    55.   223.   94730.  1.01  0.82    0.00    0.25    2.82

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.36

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

        U.S. Geological Survey WSPRO Input File wall049.wsp
        Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
        Bridge #49 over Freeman Brook. RF
           *** RUN DATE & TIME: 01-27-97  10:51
   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -52.   -15.   282.   2650.   27522.     477.    5.55  493.46
    FULLV:FV       0.   -15.   282.   2650.   27522.     477.    5.55  494.45
    BRIDG:BR       0.     0.    49.   2649.   22085.     325.    8.14  496.85
    RDWAY:RG      17.**************      0.       0.*********    1.00********
    APPRO:AS      84.    -6.   223.   2650.   94730.     939.    2.82  498.40
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    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File wall049.wsp
        Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
        Bridge #49 over Freeman Brook. RF
           *** RUN DATE & TIME: 01-27-97  10:51
  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.46    0.91  487.97  500.00************  0.67  494.13  493.46
   FULLV:FV    494.45    0.91  488.96  500.99************  0.67  495.12  494.45
   BRIDG:BR    494.57    0.56  488.14  496.85************  1.03  497.88  496.85
   RDWAY:RG  ****************  498.45  503.13************  0.12  498.61********
   APPRO:AS    495.60    0.25  489.75  502.57  0.18  0.82  0.13  498.53  498.40
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File wall049.wsp
        Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
        Bridge #49 over Freeman Brook. RF
           *** RUN DATE & TIME: 01-27-97  10:51
  ===015 WSI IN WRONG FLOW REGIME AT SECID “EXITX”:  USED WSI = CRWS.
                             WSI,CRWS =   493.53     493.83

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

 EXITX:XS   ******   -45.     592.  0.81 *****  494.64  493.83   3750.  493.83
       -52. ******   288.   36618.  1.29 ***** *******    0.94    6.33
  ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.33     500.99    0.50
  ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.33     500.99     494.84
  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “FULLV”
                  WSBEG,WSEND,CRWS =   494.84     500.99     494.84

 FULLV:FV      52.   -46.     599.  0.79 *****  495.63  494.84   3750.  494.84
        0.     52.   288.   37152.  1.29 ***** *******    0.92    6.27
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
  ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    2.82     494.67     496.14
  ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.34     502.57    0.50
  ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.34     502.57     496.14
  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “APPRO”
                  WSBEG,WSEND,CRWS =   496.14     502.57     496.14

 APPRO:AS      84.    -3.     461.  1.12 *****  497.26  496.14   3750.  496.14
       84.     84.   187.   33664.  1.09 ***** *******    0.96    8.14
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.44       0.00     495.73     498.45
  ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.63     499.03     499.27     496.69
  ===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      52.     0.     325.  1.59 *****  498.44  495.27   3286.  496.85
        0. ******    49.   22085.  1.00 ***** *******    0.69   10.10

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.493  0.000  496.69 ****** ****** ******

    XSID:CODE     SRD   FLEN     HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG      17.     51.  0.03  0.12  500.09     0.00     465.  499.81

            Q   WLEN     LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0. ****** ****** ****** ***** ***** ***** ***** ***** *****
   RT:    465.   161.   128.   289.   1.4   0.7   4.5   4.2   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      46.    -9.    1338.  0.12  0.21  500.12  496.14   3750.  500.00
        84.    57.   275.  150014.  1.01  0.80    0.00    0.23    2.80

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

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

         U.S. Geological Survey WSPRO Input File wall049.wsp
         Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
         Bridge #49 over Freeman Brook. RF
            *** RUN DATE & TIME: 01-27-97  10:51
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -52.   -45.   288.   3750.   36618.     592.    6.33  493.83
    FULLV:FV       0.   -46.   288.   3750.   37152.     599.    6.27  494.84
    BRIDG:BR       0.     0.    49.   3286.   22085.     325.   10.10  496.85
    RDWAY:RG      17.*******     0.    465.       0.*********    1.00  499.81
    APPRO:AS      84.    -9.   275.   3750.  150014.    1338.    2.80  500.00

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS  **********************
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File wall049.wsp
         Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
         Bridge #49 over Freeman Brook. RF
            *** RUN DATE & TIME: 01-27-97  10:51
  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    493.83    0.94  487.97  500.00************  0.81  494.64  493.83
    FULLV:FV    494.84    0.92  488.96  500.99************  0.79  495.63  494.84
    BRIDG:BR    495.27    0.69  488.14  496.85************  1.59  498.44  496.85
    RDWAY:RG  ****************  498.45  503.13  0.03******  0.12  500.09  499.81
    APPRO:AS    496.14    0.23  489.75  502.57  0.21  0.80  0.12  500.12  500.00
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File wall049.wsp
         Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
         Bridge #49 over Freeman Brook. RF
            *** RUN DATE & TIME: 01-27-97  10:51
  ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                              WSI,CRWS =    493.11     493.48

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

 EXITX:XS   ******   -15.     482.  0.67 *****  494.14  493.48   2670.  493.48
       -52. ******   282.   27890.  1.39 ***** *******    0.91    5.54
  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                    WSLIM1,WSLIM2,DELTAY =   492.98     500.99    0.50
  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                    WSLIM1,WSLIM2,CRWS =   492.98     500.99     494.46
  ===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 "FULLV"
                    WSBEG,WSEND,CRWS =   494.46     500.99     494.46

 FULLV:FV      52.   -15.     482.  0.67 *****  495.13  494.46   2670.  494.46
         0.    52.   282.   27890.  1.39 ***** *******    0.91    5.54
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
               FNTEST,FR#,WSEL,CRWS =  0.80     2.94     494.15     495.61
  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                    WSLIM1,WSLIM2,DELTAY =   493.96     502.57    0.50
  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                    WSLIM1,WSLIM2,CRWS =   493.96     502.57     495.61
  ===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 =   495.61     502.57     495.61

 APPRO:AS      84.    -2.     365.  0.95 *****  496.56  495.61   2670.  495.61
        84.    84.   177.   24737.  1.14 ***** *******    0.95    7.32
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
            WS3,WSIU,WS1,LSEL =   494.59     497.49     497.78     496.69
  ===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      52.     0.     325.  1.05 *****  497.90  494.59   2668.  496.85
         0. ******    49.   22085.  1.00 ***** *******    0.56    8.20

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.458  0.000  496.69 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      17.        <<<<<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      46.    -6.     946.  0.12  0.19  498.56  495.61   2670.  498.43
        84.    55.   224.   95917.  1.01  0.82    0.00    0.25    2.82

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.40

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

         U.S. Geological Survey WSPRO Input File wall049.wsp
         Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
         Bridge #49 over Freeman Brook. RF
            *** RUN DATE & TIME: 01-27-97  10:51
   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -52.   -15.   282.   2670.   27890.     482.    5.54  493.48
   FULLV:FV       0.   -15.   282.   2670.   27890.     482.    5.54  494.46
   BRIDG:BR       0.     0.    49.   2668.   22085.     325.    8.20  496.85
   RDWAY:RG      17.**************      0.       0.*********    1.00********
   APPRO:AS      84.    -6.   224.   2670.   95917.     946.    2.82  498.43

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

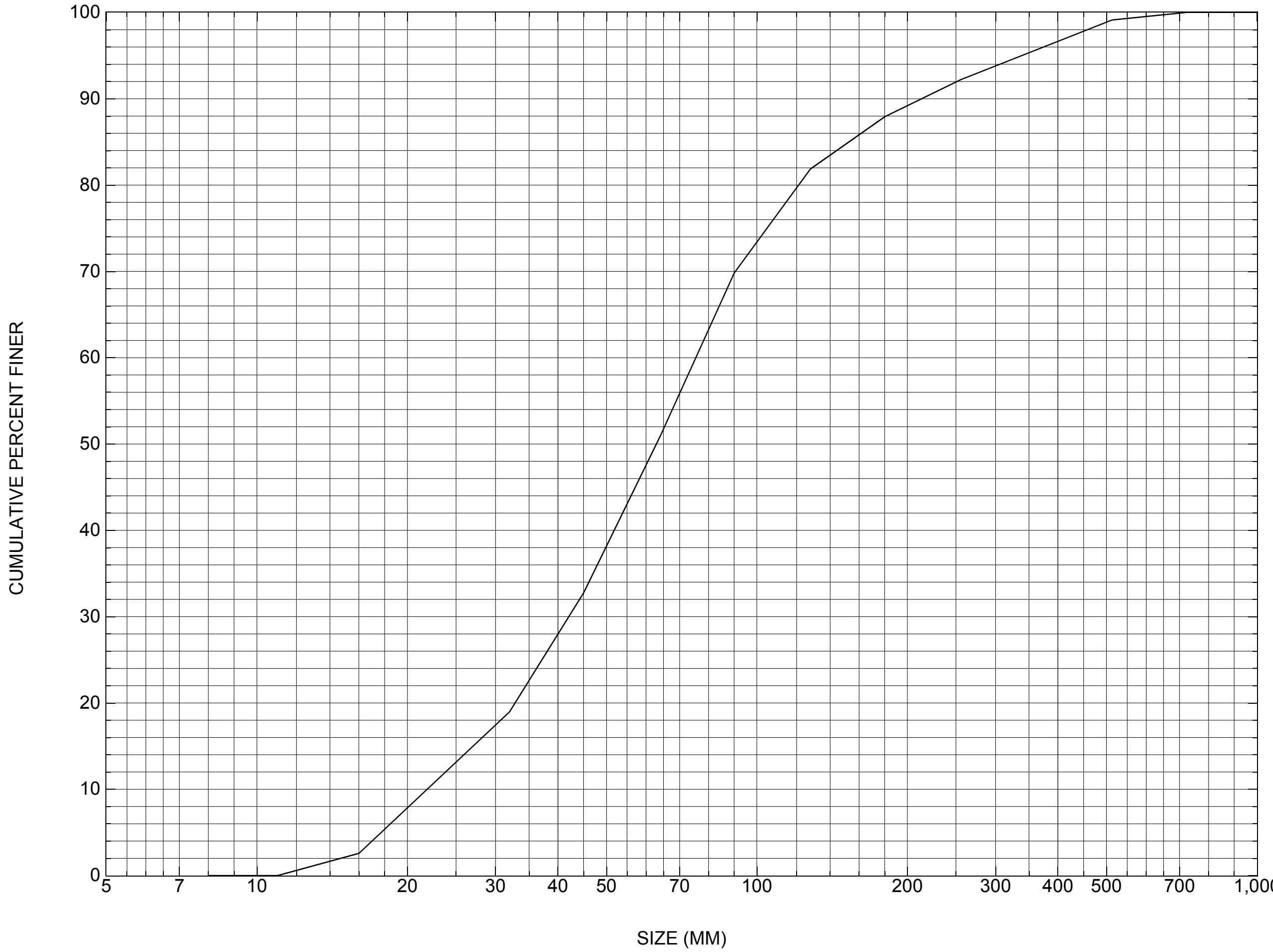
         U.S. Geological Survey WSPRO Input File wall049.wsp
         Hydraulic analysis for structure wallvt01030049   Date: 03-OCT-96
         Bridge #49 over Freeman Brook. RF
            *** RUN DATE & TIME: 01-27-97  10:51
  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    493.48    0.91  487.97  500.00************  0.67  494.14  493.48
   FULLV:FV    494.46    0.91  488.96  500.99************  0.67  495.13  494.46
   BRIDG:BR    494.59    0.56  488.14  496.85************  1.05  497.90  496.85
   RDWAY:RG  ****************  498.45  503.13************  0.12  498.61********
   APPRO:AS    495.61    0.25  489.75  502.57  0.19  0.82  0.12  498.56  498.43
  ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WALLVT01030049, in Wallingford, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WALLVT01030049

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 15 / 95

Highway District Number *(I - 2; nn)* 03

County *(FIPS county code; I - 3; nnn)* 021

Town *(FIPS place code; I - 4; nnnnn)* 75925

Mile marker *(I - 11; nnn.nnn)* 001770

Waterway *(I - 6)* FREEMAN BROOK

Road Name *(I - 7):* -

Route Number VT103

Vicinity *(I - 9)* 1.9 MI N JCT. VT.140

Topographic Map Wallingford

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 43285

Longitude *(i - 17; nnnnn.n)* 72526

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20002500491125

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0050

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

Structure length *(I - 49; nnnnnn)* 000054

Average daily traffic, ADT *(I - 29; nnnnnn)* 004440

Deck Width *(I - 52; nn.n)* 333

Year of ADT *(I - 30; YY)* 92

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

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

Waterway adequacy *(I - 71; n)* 5

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

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

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

Year Reconstructed *(I - 106)* 1969

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

Clear span (*nnn.n ft*) 050.0

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

Vertical clearance from streambed (*nnn.n ft*) 008.0

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

Waterway of full opening (*nnn.n ft*^{2}) 400.0

Comments:

The structural inspection report of 9/21/93 indicates the structure is a concrete T-beam type bridge. The widened portion of the left abutment wall has areas of scaling and cracking reported. The original portion of the left abutment wall has horizontal cracking noted near the upstream end and some scaling along the bottom. The upstream left wingwall has cracks and heavy scaling reported, and some concrete spalling at the top. There is no footing exposed on the left abutment or its wingwalls. The widened portion of the right abutment wall is in good condition except for some minor cracking and scaling noted. Its' upstream wingwall is in good condition while its' downstream wingwall, which **(Continued, page 34)**

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: -

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} (*ft^3/ 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 (*ft^2*): -

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

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

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

Comments:

is part of the original bridge, has areas of cracking and minor scaling reported. The original portion of the right abutment wall has areas of cracking and scaling reported. The channel is noted proceeding straight through the structure. There is cobble and stone build up noted on the upstream end of the left abutment and the downstream end of the right abutment. Vegetation is noted growing along both banks up- and downstream of the bridge.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **11.7** mi^2 Lake and pond area **0.015** mi^2

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

Bridge site elevation **1050** ft Headwater elevation **3286** ft

Main channel length **5.866** mi

10% channel length elevation **1161** ft 85% channel length elevation **1960** ft

Main channel slope *(S)* **181.61** ft / mi

Watershed Precipitation Data

Average site precipitation ______ in Average headwater precipitation ______ in

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

Average seasonal snowfall *(Sn)* ______ ft

Bridge Plan Data

Are plans available? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **06** / **1968**

Project Number **FR 9-A** Minimum channel bed elevation: **168.5**

Low superstructure elevation: USLAB **175.28** DSLAB **-** USRAB **174.98** DSRAB **-**

Benchmark location description:

No specific benchmark is shown on the plans. A couple points provided with elevations are: 1) on the top bankward edge of the upstream right wingwall where the concrete slope changes from horizontal to downward, elevation 178.93, and 2) at the corner where the upstream left wingwall meets the upstream end of the left abutment wall on the top streamward edge, elevation 179.23.

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

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

If 1: Footing Thickness **2.25** Footing bottom elevation: **163.***

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:

-

Comments:

***The bottom of footing elevation left: 163.44 and right: 163.14. The data was taken from plans for the bridge widening construction done on the original structure. The widened abutments and deck were shown built with the same bottom of footing elevation as those on the original structure. The low superstructure elevation was lowered a bit apparently from the plans as two new beams were added to the upstream side of the deck and are shown to sit a couple inches lower that the bridge seat elevations on the original abutments.**

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **2/21/96**

Computerized by: **RB** Date: **2/21/96**

Reviewd by: **RF** Date: **1/15/97**

Structure Number **WALLVTO1030049**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **T. SEVERANCE** Date *(MM/DD/YY)* **10** / **10** / 19**95**

2. Highway District Number **03** Mile marker **001770**

County **RUTLAND 021** Town **WALLINGFORD 75925**

Waterway *(I - 6)* **FREEMAN BROOK** Road Name **-**

Route Number **VT 103** Hydrologic Unit Code: **02010002**

3. Descriptive comments:

1.9 miles north of the junction with VT 140.
Remnants of the old bridge abutments are just DS of the bridge.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **5** LBDS **2** RBDS **54** 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 **2** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **54** *(feet)* Span length **50** *(feet)* Bridge width **33.3** *(feet)*

Road approach to bridge:

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

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

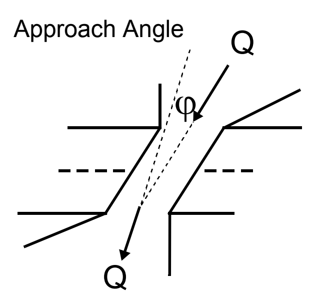
10. Embankment slope *(run / rise in feet / foot)*:
US left **3.5:1** US right **3.4:1**

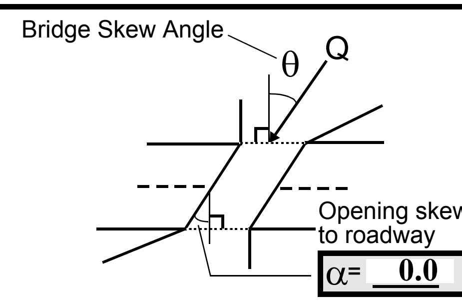
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: **25**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **95** feet **US** *(US, UB, DS)* to **0** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **0** feet **UB** *(US, UB, DS)* to **55** feet **DS**

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

18. Bridge Type: **1a/4**

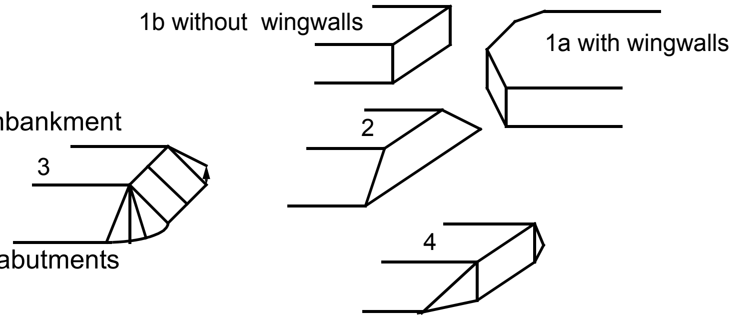
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. Values are from the VT AOT files
Measured bridge length = 54 feet, span length = 52 feet, and bridge width = 35 feet

4. There is a house on the DS left bank, the US left bank is wooded. On both the US and DS right bank there is pasture with trees lining the channel.

The channel is fairly straight through the bridge, but the left abutment is pushed left. The old bridge abutments are within one bridge length DS. The existing bridge was widened on the US side.

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
54.0	**10.5**			**5.5**	**4**	**3**	**43**	**43**	**0**	**0**

23. Bank width **30.0** 24. Channel width **25.0** 25. Thalweg depth **59.0** 29. Bed Material **453**

30 .Bank protection type: LB **4** RB **45** 31. Bank protection condition: LB **1** RB **1**

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.):

There is stone piled up along both US banks. On the rightbank, it extends beyond 150 feet. On the left bank, the material is smaller but there is more of it piled high and extending 90 feet US.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **47** 35. Mid-bar width: **8**

36. Point bar extent: **56** feet **US** (US, UB) to **40** feet **UB** (US, UB, DS) positioned **0** %LB to **33** %RB

37. Material: **4**

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

There is vegetation growing on the US portion of the bar but not beneath the bridge.

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

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
30.0		1.0		2	-	-	-

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **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.):

43

The right bank point bar extends along the right abutment under the bridge.

The old laid-up stone abutment protudes DS right.

There is a small scour hole 3 feet by 5 feet and 1 foot deep. Scour depth under the bridge is 0.75 feet.

The US left bank point bar becomes submerged under the bridge and starts to cross the channel with scour occurring on both sides of the bar, along the left abutment and in the center of the channel under the bridge.

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

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

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

70. Debris and Ice Comments:

1

There is approximately 7 feet vertical clearance beneath the bridge. (center to the right abutment)
At high flows, debris could be a problem.

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		**20**	**90**	**2**	**1**	**0.5**	**-**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**0**	**49.5**

Pushed: LB or RB *Toe Location (Loc.): **0**- even, **1**- set back, **2**- protrudes*
*Scour cond.: **0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**-undermined footing; **4**- piling exposed; **5**- settled; **6**- failed*
Materials: **1**- Concrete; **2**- Stone masonry or drywall; **3**- steel or metal; **4**- wood

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

-

-

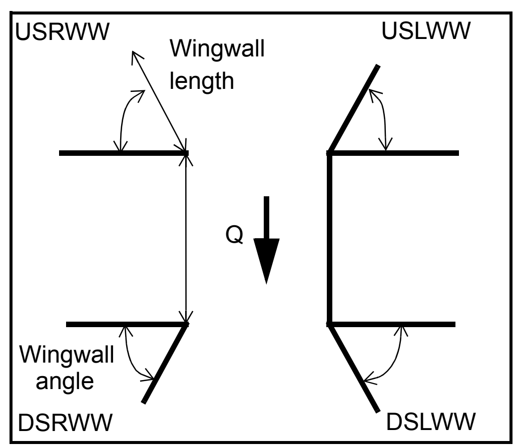
1

75. The water depth along the left abutment is 1.1 feet. Scour depth is 0.5 feet. The footing is not exposed. At lower flow, the stream enters beneath the bridge then goes toward the left abutment and strikes the DS end of the left abutment and the DS left wingwall. At these lower flows, the attack angles would be more like 60 degrees. The flow strikes the left abutment from the DS end to 15 feet back US under the bridge.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**49.5**	
USRWW:	**Y**		**1**		**0**	**1.0**	
DSLWW:	**-**		**-**		**Y**	**35.0**	
DSRWW:	**1**		**0**		**-**	**35.0**	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**1**	**Y**	**-**	**1**	**1**	**-**	**-**
Condition	**Y**	**0.2**	**1**	**-**	**1**	**2**	**-**	**-**
Extent	**1**	**-**	**0**	**2**	**1**	**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*

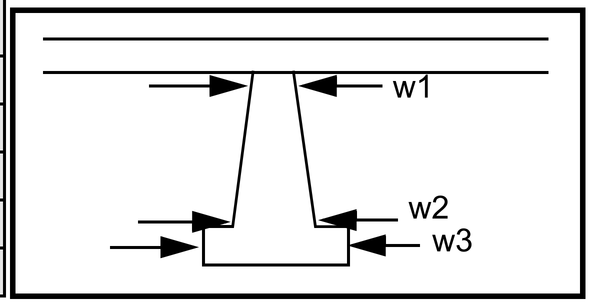
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
2
1
1

Piers:

84. Are there piers? **82.** *(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	**0.0**			**11.5**	**35.0**	**10.0**
Pier 2				**50.0**	**13.5**	**45.0**
Pier 3		**-**	**-**	**11.5**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**e up**	**scou**	**inter**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**US**	**of**	**r**	**sec-**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**left**	**grav**	**alon**	**tion**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**wing**	**el,**	**g the**	**with**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wall**	**cob-**	**left**	**the**	*Y- yes; N- no*
91. Attack ∠ (BF)	**pro-**	**bles,**	**abut**	**DS**	
92. Pushed	**tec-**	**and**	**ment**	**left**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**tion**	**boul-**	**at**	**wing**	
95. Cross-members	**con-**	**ders.**	**the**	**wall.**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**sists**	**80.**	**DS**		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**of fill**	**Ther**	**end**		
98. Exposure depth	**mad**	**e is**	**and**		

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

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 (Amb) - Thalweg depth (Amb) - Bed Material -

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

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

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

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

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

105. Drop structure comments (eg. downstream scour depth):
-
-
-
-
-
-

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

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

Material: -

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

-

NO PIERS

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

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

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

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

2

43

43

1

Is channel scour present? 1 (Y or if N type ctrl-n cs) Mid-scour distance: 34

Scour dimensions: Length 0 Width 0 Depth: - Positioned - %LB to A 9 %RB

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

inch diameter tree has fallen into the channel (from the right bank) at 65 feet DS. The old laid-up stone abutments are at the DS ends of the bridge and act as protection, but there is nothing beyond them. The left bank is higher than the right bank and cobbles have fallen out due to erosion.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

1- *Constructed*
2- *Stable*
3- *Aggraded*
4- *Degraded*
5- *Laterally unstable*
6- *Vertically and laterally unstable*

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

N

-

NO DROP STRUCTURE

Y

Bface

11

33

UB

109. G. Plan View Sketch

- 75

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: WALLVT01030049 Town: Wallingford
Road Number: VT103 County: Rutland
Stream: Freeman Brook

Initials RF Date: 1/15/97 Checked: EB

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	2650	3750	2670
Main Channel Area, ft2	326	411	327
Left overbank area, ft2	0	0	0
Right overbank area, ft2	613	928	618
Top width main channel, ft	52	54	52
Top width L overbank, ft	0	0	0
Top width R overbank, ft	178	230	178
D50 of channel, ft	0.2065	0.2065	0.2065
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.3	7.6	6.3
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	3.4	4.0	3.5
Total conveyance, approach	94719	150168	95751
Conveyance, main channel	35306	50034	35561
Conveyance, LOB	0	0	0
Conveyance, ROB	59413	100133	60190
Percent discrepancy, conveyance	0.0000	0.0007	0.0000
Qm, discharge, MC, cfs	987.8	1249.5	991.6
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	1662.2	2500.5	1678.4
Vm, mean velocity MC, ft/s	3.0	3.0	3.0
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.7	2.7	2.7
Vc-m, crit. velocity, MC, ft/s	9.0	9.3	9.0
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

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

ARMORING

D90	0.6993	0.6993	0.6993
D95	1.1032	1.1032	1.1032
Critical grain size,Dc, ft	0.2969	0.4568	0.3012

Decimal-percent coarser than Dc	0.2998	0.1661	0.2949
Depth to armoring,ft	2.08	6.88	2.16

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	326	411	327
Main channel width, ft	52	54	52
y1, main channel depth, ft	6.27	7.61	6.29

Bridge Section

(Q) total discharge, cfs	2650	3750	2670
(Q) discharge thru bridge, cfs	2649	3286	2668
Main channel conveyance	22085	22085	22085
Total conveyance	22085	22085	22085
Q2, bridge MC discharge,cfs	2649	3286	2668
Main channel area, ft2	325	325	325
Main channel width (skewed), ft	49.4	49.4	49.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	49.4	49.4	49.4
y_bridge (avg. depth at br.), ft	6.59	6.59	6.59
Dm, median (1.25*D50), ft	0.258125	0.258125	0.258125
y2, depth in contraction,ft	5.53	6.66	5.57
ys, scour depth (y2-ybridge), ft	-1.05	0.07	-1.02

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	2650	3750	2670
Q, thru bridge, cfs	2649	3286	2668
Total Conveyance, bridge	22085	22085	22085
Main channel(MC) conveyance, bridge	22085	22085	22085
Q, thru bridge MC, cfs	2649	3286	2668
Vc, critical velocity, ft/s	9.00	9.29	9.00
Vc, critical velocity, m/s	2.74	2.83	2.74
Main channel width (skewed), ft	49.4	49.4	49.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	49.4	49.4	49.4
qbr, unit discharge, ft2/s	53.6	66.5	54.0
qbr, unit discharge, m2/s	5.0	6.2	5.0
Area of full opening, ft2	325.4	325.4	325.4
Hb, depth of full opening, ft	6.59	6.59	6.59
Hb, depth of full opening, m	2.01	2.01	2.01
Fr, Froude number, bridge MC	0.56	0.69	0.56

Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	496.69	496.69	496.69
Elevation of Bed, ft	490.10	490.10	490.10
Elevation of Approach, ft	498.4	500	498.43
Friction loss, approach, ft	0.18	0.21	0.19
Elevation of WS immediately US, ft	498.22	499.79	498.24
ya, depth immediately US, ft	8.12	9.69	8.14
ya, depth immediately US, m	2.47	2.95	2.48
Mean elevation of deck, ft	500.94	500.94	500.94
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.90	0.95
Ys, depth of scour, ft	-0.30	1.37	-0.26

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

y2, from Laursen's equation, ft	5.532875	6.655292	5.566873
Full valley WSEL, ft	494.45	494.84	494.46
Full valley depth, ft	4.347045	4.737045	4.357045
Ys, depth of scour (y2-yfullv), ft	1.185831	1.918247	1.209829

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	2650	3750	2670	2650	3750	2670
a', abut.length blocking flow, ft	6.4	9.1	6.5	173.7	108.55	174.1
Ae, area of blocked flow ft2	26.75	45.23	27.16	604	642.43	608.97
Qe, discharge blocked abut.,cfs	58.48	100.37	59.43	1636.85	1986.04	1651.34
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.19	2.22	2.19	2.71	3.09	2.71
ya, depth of f/p flow, ft	4.18	4.97	4.18	3.48	5.92	3.50
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.188	0.175	0.189	0.256	0.224	0.256
ys, scour depth, ft	7.56	9.12	7.58	18.63	21.37	18.70

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)	6.4	9.1	6.5	173.7	108.55	174.1
y1 (depth f/p flow, ft)	4.18	4.97	4.18	3.48	5.92	3.50
a'/y1	1.53	1.83	1.56	49.95	18.34	49.77
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.19	0.18	0.19	0.26	0.22	0.26
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	16.13	ERR	16.22
vertical w/ ww's	ERR	ERR	ERR	13.23	ERR	13.30
spill-through	ERR	ERR	ERR	8.87	ERR	8.92

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother	Q100	Q500	Qother
Fr, Froude Number	0.56	0.69	0.56	0.56	0.69	0.56
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	6.59	6.59	6.59	6.59	6.59	6.59
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.28	1.94	1.28	1.28	1.94	1.28
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.11	1.69	1.11	1.11	1.69	1.11
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR