LEVEL II SCOUR ANALYSIS FOR BRIDGE 10 (GRAFTH00020010) on TOWN HIGHWAY 2 (VT 121), crossing the SAXTONS RIVER, GRAFTON, VERMONT

U.S. Geological Survey
Open-File Report 98-538

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

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By ERICK M. BOEHMLER AND ROBERT E. HAMMOND

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Pembroke, New Hampshire

1998

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CONTENTS

Conversion Factors, Abbreviations, and Vertical Datum iv
Introduction and Summary of Results 1
Level II summary 7
Description of Bridge 7
Description of the Geomorphic Setting 8
Description of the Channel 8
Hydrology 9
Calculated Discharges 9
Description of the Water-Surface Profile Model (WSPRO) Analysis 10
Cross-Sections Used in WSPRO Analysis 10
Data and Assumptions Used in WSPRO Model 11
Bridge Hydraulics Summary 12
Scour Analysis Summary 13
Special Conditions or Assumptions Made in Scour Analysis 13
Scour Results 14
Riprap Sizing 14
Selected References 18

Appendices:
A. WSPRO input file 19
B. WSPRO output file 22
C. Bed-material particle-size distribution 29
D. Historical data form 31
E. Level I data form 37
F. Scour computations 47

FIGURES

1. Map showing location of study area on USGS 1:25,000 scale map 3
2. Map showing location of study area on Vermont Agency of Transportation town highway map 4
3. Structure GRAFTH00020010 viewed from upstream (August 21, 1996) 5
4. Downstream channel viewed from structure GRAFTH00020010 (August 21, 1996). 5
5. Upstream channel viewed from structure GRAFTH00020010 (August 21, 1996). 6
6. Structure GRAFTH00020010 viewed from downstream (August 21, 1996). 6
7. Water-surface profiles for the 100- and 500-year discharges at structure GRAFTH00020010 on Town Highway 2, crossing the Saxtons River, Grafton, Vermont. 15
8. Scour elevations for the 100- and 500-year discharges at structure GRAFTH00020010 on Town Highway 2, crossing the Saxtons River, Grafton, Vermont. 16

TABLES

1. Remaining footing/pile depth at abutments for the 100-year discharge at structure GRAFTH00020010 on Town Highway 2, crossing the Saxtons River, Grafton, Vermont 17
2. Remaining footing/pile depth at abutments for the 500-year discharge at structure GRAFTH00020010 on Town Highway 2, crossing the Saxtons River, Grafton, Vermont 17

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 10 (GRAFTH00020010) ON TOWN HIGHWAY 2 (VT 121), CROSSING THE SAXTONS RIVER, GRAFTON, VERMONT

By **Erick M. Boehmler And Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure GRAFTH00020010 on Town Highway 2 crossing the Saxtons River, Grafton, Vermont (figures 1–8). Town Highway 2 also is designated as State Route 121. A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (Federal Highway Administration, 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 Southeastern Vermont. The 10.8-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of forest on the upstream left bank, brush on the upstream right bank and row crops on both banks downstream.

In the study area, the Saxtons River has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 50 ft and an average bank height of 7 ft. The channel bed materials range from sand to boulders with a median grain size (D_{50}) of 57.0 mm (0.187 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 21, 1996, indicated that the reach was stable.

The Town Highway 2 crossing of the Saxtons River is a 52-ft-long, two-lane bridge consisting of one 50-foot concrete span (Vermont Agency of Transportation, written communication, March 29, 1995). The opening length of the structure parallel to the bridge face is 46.9 feet. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 60 degrees to the opening while the computed opening-skew-to-roadway is 45 degrees.

A scour hole 1.0 foot deeper than the mean thalweg depth was observed along the left bank protection upstream of and under the bridge during the Level I assessment. Another scour hole 0.5 feet deeper than the mean thalweg depth was observed at the downstream end of the left abutment wall. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) on the left and right banks upstream and downstream of the bridge and on all four wingwalls. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 0 to 1.4 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 5.7 to 14.2 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 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.

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

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 GRAFTH00020010 ***Stream*** Saxtons River

County Windham ***Road*** TH 2 ***District*** 2

Description of Bridge

Bridge length 52 ***ft*** ***Bridge width*** 28.0 ***ft*** ***Max span length*** 50 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/21/96

Description of stone fill Type-2 on all four wingwalls and the left and right banks upstream and downstream of the site.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a one-half foot deep scour hole at the downstream end of the left abutment and a 1-foot deep scour holy along the upstream end of the left abutment.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 60

There is a mild channel bend in the upstream reach. The scour hole has developed in the location where the flow impacts the upstream left bank protection.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	8/21/96	0	0
Level II	8/21/96	0	0

Potential for debris Moderate. There is significant vegetation cover on the banks upstream.

Describe any features near or at the bridge that may affect flow (include observation date) The upstream left bank protection, evident on 8/21/96, partially blocks flows immediately upstream of the bridge opening.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with a narrow, irregular flood plain, and steep valley walls on both sides.

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

Date of inspection 8/21/96

DS left: Moderately sloping channel bank to a narrow overbank

DS right: Moderately sloping channel bank to a narrow flood plain

US left: Steep channel bank and valley wall

US right: Moderately sloping channel bank to a narrow, irregular flood plain

Description of the Channel

Average top width 50 ***ft*** ***Average depth*** 7 ***ft***

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

Perennial and straight with semi-alluvial channel boundaries and irregular point and lateral bars.

8/21/96

Vegetative co Shrubs and a few trees

DS left: Shrubs and a few trees

DS right: Trees

US left: Shrubs, brush and a few trees

US right:

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

None were observed on 8/21/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 10.8 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

Is there a USGS gage on the stream of interest? Yes

USGS gage description Saxtons River at Saxtons River, VT

USGS gage number 01154000 (Discontinued)

Gage drainage area 72.2 ***mi²***

Is there a lake/p No

-

Calculated Discharges

Q100 2,520 ***ft³/s*** ***Q500*** 3,700 ***ft³/s***

The 100- and 500-year discharges were selected from flood frequency curve values available for this site in the VTAOT database (VTAOT, written communication, May 1995). The VTAOT values were within a range defined by several flood frequency curves computed by use of empirical methods (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957a&b; and Talbot, 1887). Each curve was extended graphically to the 500-year event.

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 Add 1.7 feet to the USGS arbitrary survey datum to obtain the VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a metallic tablet set in the left abutment concrete at the upstream end (elev. 499.05 feet, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the right abutment concrete at the downstream end (elev. 499.93 feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-40	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	22	1	Road Grade section
APPRO	76	2	Modelled Approach section (Templated from APTEM)
APTEM	103	1	Approach section as surveyed (Used as a template)
APPR2	278	2	Additional upstream section (Templated from APTEM)

[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. Also, flow was assumed to align with the abutments. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.050, and overbank "n" values ranged from 0.035 to 0.050.

Normal depth at the exit section (EXITX) was assumed as the starting water surface for the 100-year and incipient roadway-overtopping discharges. Critical depth was assumed as the starting water surface for the 500-year discharge. Normal depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0115 ft/ft, which was estimated from the 100-year water surface profile documented in the Flood Insurance Study for the Town of Grafton (FEMA, 1987). For the 500-year event, the normal water surface was within 0.1 foot of the critical water surface. Therefore, the critical water surface was assumed to be a satisfactory starting water surface.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0103 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. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles, it was assumed that the water surface profile passes through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.1 ***ft***
Average low steel elevation 498.4 ***ft***

100-year discharge 2,520 ***ft^3/s***
Water-surface elevation in bridge opening 498.4 ***ft***
Road overtopping? Yes ***Discharge over road*** 481 ***ft^3/s***
Area of flow in bridge opening 301 ***ft^2***
Average velocity in bridge opening 6.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.2 ***ft/s***

Water-surface elevation at Approach section with bridge 499.4
Water-surface elevation at Approach section without bridge 495.7
Amount of backwater caused by bridge 3.7 ***ft***

500-year discharge 3,700 ***ft^3/s***
Water-surface elevation in bridge opening 498.6 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,310 ***ft^3/s***
Area of flow in bridge opening 302 ***ft^2***
Average velocity in bridge opening 7.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.8 ***/s***

Water-surface elevation at Approach section with bridge 500.0
Water-surface elevation at Approach section without bridge 498.4
Amount of backwater caused by bridge 1.6

Incipient overtopping discharge 1,900 ***ft^3/s***
Water-surface elevation in bridge opening 494.0 ***ft***
Area of flow in bridge opening 155 ***ft^2***
Average velocity in bridge opening 12.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.7 ***ft/s***

Water-surface elevation at Approach section with bridge 496.9
Water-surface elevation at Approach section without bridge 495.2
Amount of backwater caused by bridge 1.7 ***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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The 100-year and 500-year discharges resulted in orifice flow conditions at the bridge. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 100- and 500-year events were computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). 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 also was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Furthermore, for the 100- and 500-year discharges, which resulted 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 alternative computations are provided in appendix F.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	1.4
Depth to armoring	4.7	5.0	N/A
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	9.7	10.9	8.2
Right abutment	12.6	14.2	5.7
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	1.8	2.0	2.0
Right abutment	1.8	2.0	2.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

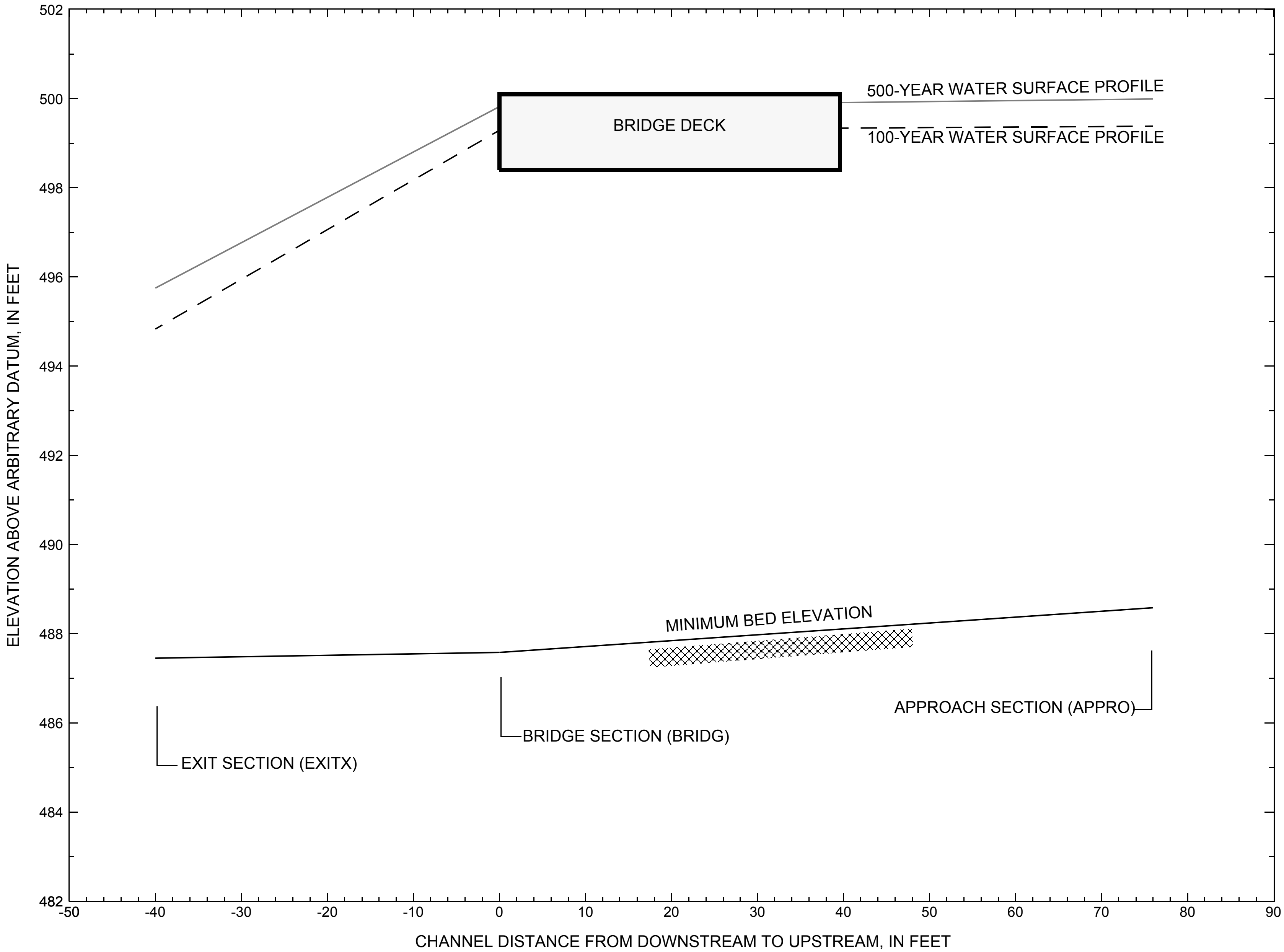

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure GRAFTH00020010 on Town Highway 2, crossing the Saxtons River, Grafton, Vermont.

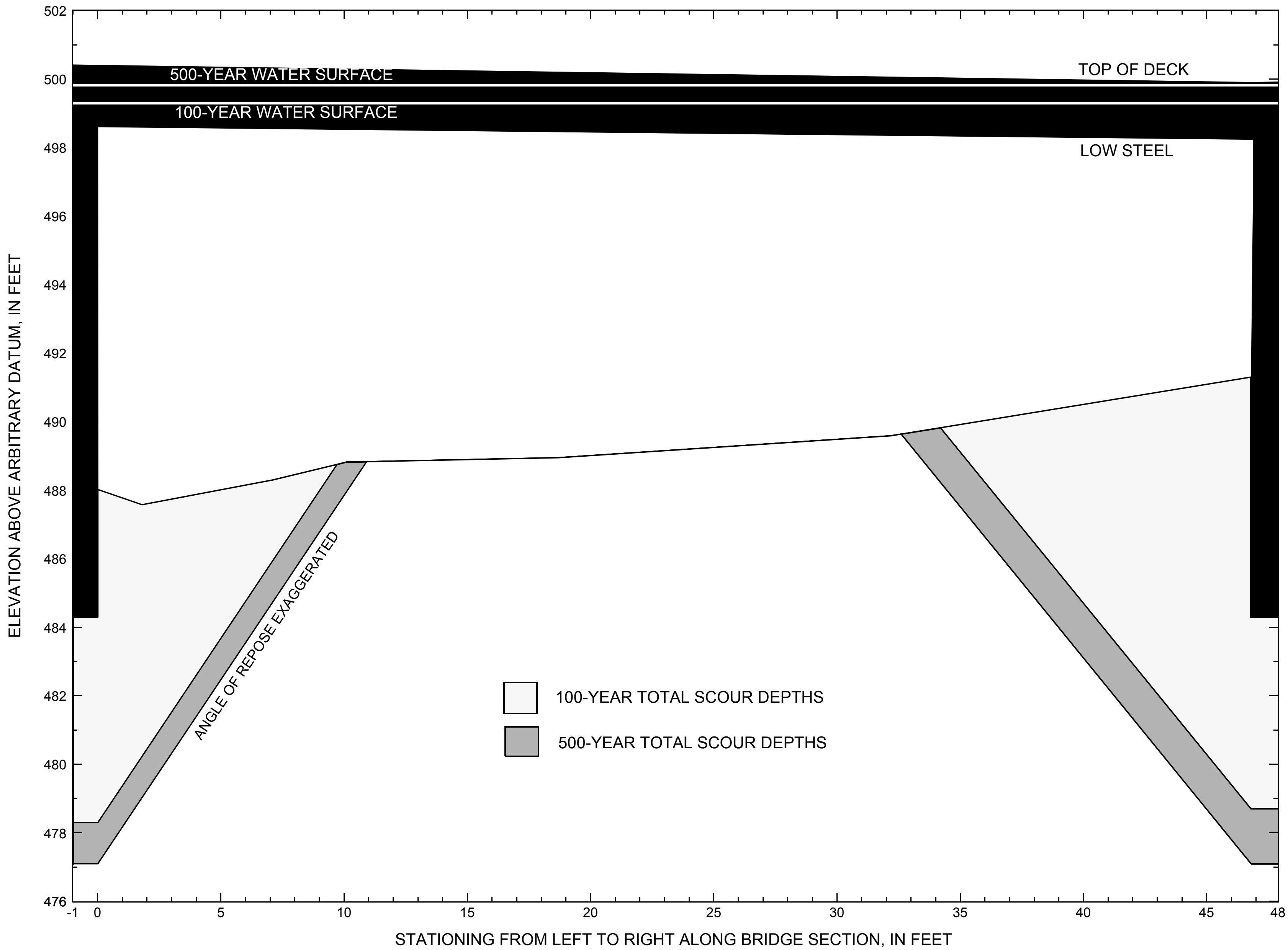

Figure 8. Scour elevations for the 100- and 500-year discharges at structure GRAFTH00020010 on Town Highway 2, crossing the Saxtons River, Grafton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure GRAFTH00020010 on Town Highway 2, crossing the Saxtons River, Grafton, 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-year discharge is 2,520 cubic-feet per second											
Left abutment	0.0	500.3	498.6	484.3	488.0	0.0	9.7	--	9.7	478.3	-6.0
Right abutment	46.9	499.8	498.3	484.3	491.3	0.0	12.6	--	12.6	478.7	-5.6

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure GRAFTH00020010 on Town Highway 2, crossing the Saxtons River, Grafton, 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-year discharge is 3,700 cubic-feet per second											
Left abutment	0.0	500.3	498.6	484.3	488.0	0.0	10.9	--	10.9	477.1	-7.2
Right abutment	46.9	499.8	498.3	484.3	491.3	0.0	14.2	--	14.2	477.1	-7.2

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, 1984, Saxtons River, Vermont 7.5 by 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1977, Contour interval, 6 meters, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File graf010.wsp
T2        Hydraulic analysis for structure GRAFTH00020010   Date: 21-FEB-97
T3        Town Highway 2 (VT 121) over the Saxtons River, Grafton  EMB
*
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           2520.0   3700.0
SK          0.0115   0.0115
*
XS   EXITX    -40
GR          -87.8, 509.51    -70.1, 499.26    -59.0, 499.46    -29.2, 499.83
GR          -10.7, 493.01      0.0, 488.56      1.9, 487.65      5.9, 487.45
GR           12.8, 487.95     18.7, 488.50     25.5, 490.27     33.5, 492.83
GR          156.7, 495.08    206.4, 494.85    238.2, 509.54
*
N           0.035        0.050        0.050
SA                 -29.2          33.5
*
XS   FULLV      0  * * *  0.0033
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.43      45.0
GR            0.0, 498.62      0.0, 488.02      1.8, 487.58      7.1, 488.30
GR           10.1, 488.82     18.7, 488.95     32.2, 489.59     46.8, 491.30
GR           46.9, 498.25      0.0, 498.62
*
*        BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      47.8 * *     24.9     15.5
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     22       28.0     2
GR          -50.3, 509.34    -35.7, 499.41    -27.6, 499.46      0.0, 500.38
GR           49.3, 499.90    132.2, 498.94    184.3, 498.58    257.3, 498.42
GR          334.3, 498.82    399.3, 500.11
*
XT   APTEM     103
GR          -17.9, 510.14     -2.2, 495.61      0.0, 490.41      3.3, 489.60
GR            7.2, 489.46     13.2, 488.86     18.9, 489.28     21.4, 489.49
GR           30.6, 493.53     36.8, 496.88    103.8, 497.34    181.8, 497.54
GR          277.8, 497.97    326.8, 499.03    449.8, 500.26    531.8, 501.50
*
AS   APPRO      76  * * *  0.0103
GT
N           0.050        0.035
SA                  36.8
*
HP 1 BRIDG 498.43 1 498.43
HP 2 BRIDG 498.43 * * 2037
HP 1 BRIDG 495.66 1 495.66
HP 2 RDWAY 499.29 * * 481
HP 1 APPRO 499.38 1 499.38
HP 2 APPRO 499.38 * * 2520
*
HP 1 BRIDG 498.62 1 498.62
HP 2 BRIDG 498.62 * * 2396
HP 1 BRIDG 496.48 1 496.48
HP 2 RDWAY 499.82 * * 1307
HP 1 APPRO 499.99 1 499.99
HP 2 APPRO 499.99 * * 3700
*
EX
ER
```

WSPRO INPUT FILE (continued)

```
T1        U.S. Geological Survey WSPRO Input File graf010.io.wsp
T2        Hydraulic analysis for structure GRAFTH00020010   Date: 21-FEB-97
T3        Town Highway 2 (VT 121) over the Saxtons River, Grafton  EMB
*
*             This model was done with an additional section upstream of
*             the bridge. Both sections upstream were drawn with a vertical
*             wall on the top of right bank (the crest of Town Highway 2).
*             This was done to determine when the profile elevation between
*             the APPRO AND APPR2 sections would exceed the minimum road
*             grade elevation as TH 2 is parallel to the river upstream of
*             this site.
*
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           1900.0
SK          0.0115
*
XS   EXITX    -40
GR          -87.8, 509.51    -70.1, 499.26    -59.0, 499.46    -29.2, 499.83
GR          -10.7, 493.01      0.0, 488.56      1.9, 487.65      5.9, 487.45
GR           12.8, 487.95     18.7, 488.50     25.5, 490.27     33.5, 492.83
GR          156.7, 495.08    206.4, 494.85    238.2, 509.54
*
N           0.035         0.050         0.050
SA                 -29.2          33.5
*
XS   FULLV      0  * * *   0.0033
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.43      45.0
GR            0.0, 498.62      0.0, 488.02      1.8, 487.58      7.1, 488.30
GR           10.1, 488.82     18.7, 488.95     32.2, 489.59     46.8, 491.30
GR           46.9, 498.25      0.0, 498.62
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD          1       47.8 * *      24.9     15.5
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     22       28.0     2
GR          -50.3, 509.34    -35.7, 499.41    -27.6, 499.46      0.0, 500.38
GR           49.3, 499.90    132.2, 498.94    184.3, 498.58    257.3, 498.42
GR          334.3, 498.82    399.3, 500.11
*
XT   APTEM     103
GR          -17.9, 510.14     -2.2, 495.61      0.0, 490.41      3.3, 489.60
GR            7.2, 489.46     13.2, 488.86     18.9, 489.28     21.4, 489.49
GR           30.6, 493.53     36.8, 496.88     49.3, 499.90     49.4, 502.00
*
AS   APPRO      76   * * *  0.0103
GT
N           0.050         0.035
SA                  36.8
*
XS   APPR2     278   * * * 0.0111
GT
*
HP 1 BRIDG 494.00 1 494.00
HP 2 BRIDG 494.00 * * 1900
HP 1 APPRO 496.90 1 496.90
HP 2 APPRO 496.90 * * 1900
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File graf010.wsp
        Hydraulic analysis for structure GRAFTH00020010   Date: 21-FEB-97
        Town Highway 2 (VT 121) over the Saxtons River, Grafton  EMB
           *** RUN DATE & TIME: 06-10-98  15:44

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     301.   27073.    17.    67.                         7163.
   498.43          301.   27073.    17.    67.  1.00     0.    47.   7163.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.43     0.0    46.9   300.5   27073.    2037.   6.78

X STA.         0.0         4.6         6.0         7.5         9.1        10.7
  A(I)             34.9        10.2        10.8        10.9        11.0
  V(I)             2.92       10.00        9.42        9.38        9.29

X STA.        10.7        12.3        13.9        15.7        17.4        18.9
  A(I)             11.0        11.1        11.6        11.4        10.0
  V(I)             9.23        9.20        8.75        8.95       10.17

X STA.        18.9        20.1        21.6        23.2        25.1        27.5
  A(I)              8.4        10.0        10.2        12.3        15.6
  V(I)            12.18       10.16        9.99        8.26        6.52

X STA.        27.5        29.9        32.5        35.1        38.1        46.9
  A(I)             15.3        15.9        16.2        17.5        46.1
  V(I)             6.64        6.40        6.29        5.82        2.21

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     210.   19306.    33.    45.                         3003.
   495.66          210.   19306.    33.    45.  1.00     0.    47.   3003.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      22.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.29   102.0   358.0   147.7    3051.     481.   3.26

X STA.       102.0       162.6       174.8       184.5       193.3       202.0
  A(I)             19.1         7.3         6.6         6.3         6.4
  V(I)             1.26        3.28        3.63        3.82        3.75

X STA.       202.0       210.1       218.2       225.9       233.3       240.5
  A(I)              6.2         6.3         6.1         6.0         6.0
  V(I)             3.90        3.84        3.95        3.99        4.04

X STA.       240.5       247.7       254.9       261.9       269.2       277.2
  A(I)              6.0         6.1         6.0         6.0         6.3
  V(I)             3.99        3.91        3.99        4.00        3.81

X STA.       277.2       285.6       295.0       305.7       318.1       358.0
  A(I)              6.3         6.5         6.9         7.3        13.9
  V(I)             3.82        3.68        3.48        3.30        1.73

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     346.   37393.    43.    50.                         5556.
             2     603.   36685.   353.   353.                         4472.
   499.38          949.   74078.   396.   403.  1.27    -7.   390.   7408.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.38    -6.6   389.6   949.3   74078.    2520.   2.65

X STA.        -6.6         4.6         7.2         9.8        12.4        15.0
  A(I)             68.0        27.0        27.2        27.1        27.4
  V(I)             1.85        4.67        4.64        4.64        4.61

X STA.        15.0        17.6        20.3        23.4        27.5        34.1
  A(I)             27.7        28.2        31.0        33.7        39.8
  V(I)             4.54        4.47        4.06        3.74        3.17

X STA.        34.1        51.6        69.1        88.1       109.2       131.2
  A(I)             49.8        45.8        47.3        49.8        50.1
  V(I)             2.53        2.75        2.67        2.53        2.52

X STA.       131.2       154.2       179.1       204.4       234.1       389.6
  A(I)             51.0        53.8        52.4        57.9       154.5
  V(I)             2.47        2.34        2.40        2.18        0.82
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WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File graf010.wsp
        Hydraulic analysis for structure GRAFTH00020010   Date: 21-FEB-97
        Town Highway 2 (VT 121) over the Saxtons River, Grafton  EMB
           *** RUN DATE & TIME: 06-10-98  15:44

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     302.   23451.     0.    84.                     ********
   498.62          302.   23451.     0.    84.  1.00     0.    47.********

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

         WSEL     LEW     REW    AREA        K        Q     VEL
       498.62     0.0    46.9   302.1   23451.    2396.   7.93

X STA.          0.0        4.5        6.2        7.8        9.6       11.5
  A(I)             34.6       12.2       12.2       12.7       12.8
  V(I)             3.47       9.80       9.80       9.44       9.34

X STA.         11.5       13.4       15.2       17.1       19.1       21.0
  A(I)             12.7       12.6       12.9       13.1       13.0
  V(I)             9.44       9.50       9.29       9.12       9.20

X STA.         21.0       23.0       25.0       27.0       29.1       31.2
  A(I)             12.9       13.2       12.9       13.2       13.2
  V(I)             9.28       9.11       9.25       9.06       9.06

X STA.         31.2       33.3       35.6       38.0       40.5       46.9
  A(I)             13.4       13.7       13.9       14.0       32.8
  V(I)             8.94       8.74       8.65       8.54       3.65

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     237.   23092.    33.    47.                        3603.
   496.48          237.   23092.    33.    47.  1.00     0.    47.   3603.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      22.

         WSEL     LEW     REW    AREA        K        Q     VEL
       499.82   -36.3   384.7   307.8    8622.    1307.   4.25

X STA.        -36.3      139.5      154.7      167.1      178.5      188.9
  A(I)             45.2       14.9       13.4       13.2       12.8
  V(I)             1.44       4.39       4.86       4.95       5.10

X STA.        188.9      199.0      208.6      218.2      227.5      236.5
  A(I)             12.7       12.4       12.5       12.3       12.1
  V(I)             5.17       5.27       5.24       5.32       5.40

X STA.        236.5      245.6      254.7      263.6      273.0      282.8
  A(I)             12.4       12.6       12.4       12.7       12.6
  V(I)             5.25       5.18       5.29       5.16       5.17

X STA.        282.8      293.2      304.4      316.2      329.7      384.7
  A(I)             12.9       13.2       13.3       14.3       29.9
  V(I)             5.06       4.95       4.91       4.58       2.19

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     373.   41814.    44.    51.                        6162.
             2     837.   56981.   414.   414.                        6754.
   499.99         1210.   98795.   458.   465.  1.20    -7.   450.  10197.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

         WSEL     LEW     REW    AREA        K        Q     VEL
       499.99    -7.2   450.3  1209.8   98795.    3700.   3.06

X STA.         -7.2        5.2        8.4       11.5       14.6       17.7
  A(I)             81.4       35.1       33.9       35.0       35.6
  V(I)             2.27       5.27       5.45       5.28       5.19

X STA.         17.7       21.1       25.1       30.9       46.0       62.5
  A(I)             36.3       40.6       46.0       59.9       53.9
  V(I)             5.09       4.56       4.03       3.09       3.43

X STA.         62.5       78.3       96.2      115.7      135.8      156.3
  A(I)             49.9       54.5       57.3       57.6       57.9
  V(I)             3.71       3.40       3.23       3.21       3.20

X STA.        156.3      177.9      200.0      223.9      250.3      450.3
  A(I)             59.9       59.4       62.1       65.5      228.1
  V(I)             3.09       3.12       2.98       2.82       0.81
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WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File graf010.io.wsp
        Hydraulic analysis for structure GRAFTH00020010   Date: 21-FEB-97
        Town Highway 2 (VT 121) over the Saxtons River, Grafton  EMB
           *** RUN DATE & TIME: 05-02-98  14:50

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

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     155.  12247.    33.    42.                       1905.
   494.00          155.  12247.    33.    42.  1.00     0.    47.   1905.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.00     0.0    46.8   155.1   12247.    1900.  12.25

X STA.         0.0        4.2        5.6        7.2        8.7       10.4
  A(I)             18.6        6.1        6.2        6.2        6.4
  V(I)             5.12      15.70      15.36      15.27      14.86

X STA.        10.4       12.2       14.0       15.8       17.6       19.4
  A(I)              6.4        6.4        6.7        6.5        6.5
  V(I)            14.82      14.93      14.28      14.53      14.62

X STA.        19.4       21.3       23.2       25.1       27.2       29.3
  A(I)              6.5        6.6        6.5        6.8        6.7
  V(I)            14.50      14.32      14.64      13.87      14.08

X STA.        29.3       31.4       33.7       36.2       39.1       46.8
  A(I)              6.9        6.8        7.4        7.8       17.1
  V(I)            13.86      13.87      12.86      12.19       5.55

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     242.  21653.    41.    47.                       3353.
             2       0.      2.     1.     1.                          0.
   496.90          242.  21655.    42.    48.  1.00    -4.    38.   3305.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.90    -3.9    38.0   242.4   21655.    1900.   7.84

X STA.        -3.9        2.9        4.2        5.5        6.7        8.0
  A(I)             31.2        9.8        9.6        9.7        9.6
  V(I)             3.04       9.68       9.89       9.80       9.86

X STA.         8.0        9.2       10.4       11.6       12.8       14.0
  A(I)              9.8        9.8        9.6        9.6        9.7
  V(I)             9.74       9.71       9.89       9.86       9.77

X STA.        14.0       15.1       16.3       17.5       18.7       19.9
  A(I)              9.6        9.5        9.5        9.6        9.5
  V(I)             9.86       9.96       9.96       9.94      10.01

X STA.        19.9       21.1       22.5       24.0       25.9       38.0
  A(I)              9.6       10.0       10.8       11.4       34.4
  V(I)             9.93       9.54       8.78       8.32       2.76
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File graf010.wsp
        Hydraulic analysis for structure GRAFTH00020010   Date: 21-FEB-97
        Town Highway 2 (VT 121) over the Saxtons River, Grafton  EMB
           *** RUN DATE & TIME: 06-10-98  15:44

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

EXITX:XS   ******   -16.     351.  1.10 *****  495.94  494.67   2520.  494.83
      -40. ******   143.   23479.  1.38 ***** *******    1.00    7.18

FULLV:FV      40.   -18.     498.  0.60  0.33  496.26 *******   2520.  495.66
        0.    40.   208.   32428.  1.50  0.00   -0.01    0.73    5.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     1.05     495.53     495.70

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.16     509.86    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.16     509.86     495.70

 ===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 =   495.70     509.86     495.70

APPRO:AS      76.    -3.     195.  2.60 *****  498.30  495.70   2520.  495.70
       76.    76.    35.   15923.  1.00 ***** *******    1.00   12.93
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.91       0.00     494.96     498.42

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   500.65         0.      2520.

 ===280 REJECTED FLOW CLASS 4 SOLUTION.

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      40.     0.     301.  0.71 *****  499.14  494.23   2037.  498.43
        0. ******    47.   27073.  1.00 ***** *******    0.47    6.78

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.411  0.000  498.43 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       22.    48.  0.06  0.14  499.47    0.00    481.  499.29

             Q    WLEN    LEW    REW   DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    15.    -36.   -21.   0.3   0.2   2.6   4.2   0.4   2.7
   RT:    481.   256.    102.   358.   0.9   0.6   3.7   3.2   0.8   2.9

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

APPRO:AS      28.    -7.     951.  0.14  0.07  499.52  495.70   2520.  499.38
       76.    28.   390.   74239.  1.27  0.00    0.00    0.34    2.65

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS      -40.   -16.   143.   2520.   23479.     351.    7.18  494.83
   FULLV:FV        0.   -18.   208.   2520.   32428.     498.    5.06  495.66
   BRIDG:BR        0.     0.    47.   2037.   27073.     301.    6.78  498.43
   RDWAY:RG       22.*******     0.    481.       0.*********    2.00  499.29
   APPRO:AS       76.    -7.   390.   2520.   74239.     951.    2.65  499.38

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    494.67    1.00  487.45  509.54************  1.10  495.94  494.83
   FULLV:FV  ********    0.73  487.58  509.67  0.33  0.00  0.60  496.26  495.66
   BRIDG:BR    494.23    0.47  487.58  498.62************  0.71  499.14  498.43
   RDWAY:RG  ****************  498.42  509.34  0.06******  0.14  499.47  499.29
   APPRO:AS    495.70    0.34  488.58  509.86  0.07  0.00  0.14  499.52  499.38
```

WSPRO OUTPUT FILE (continued)

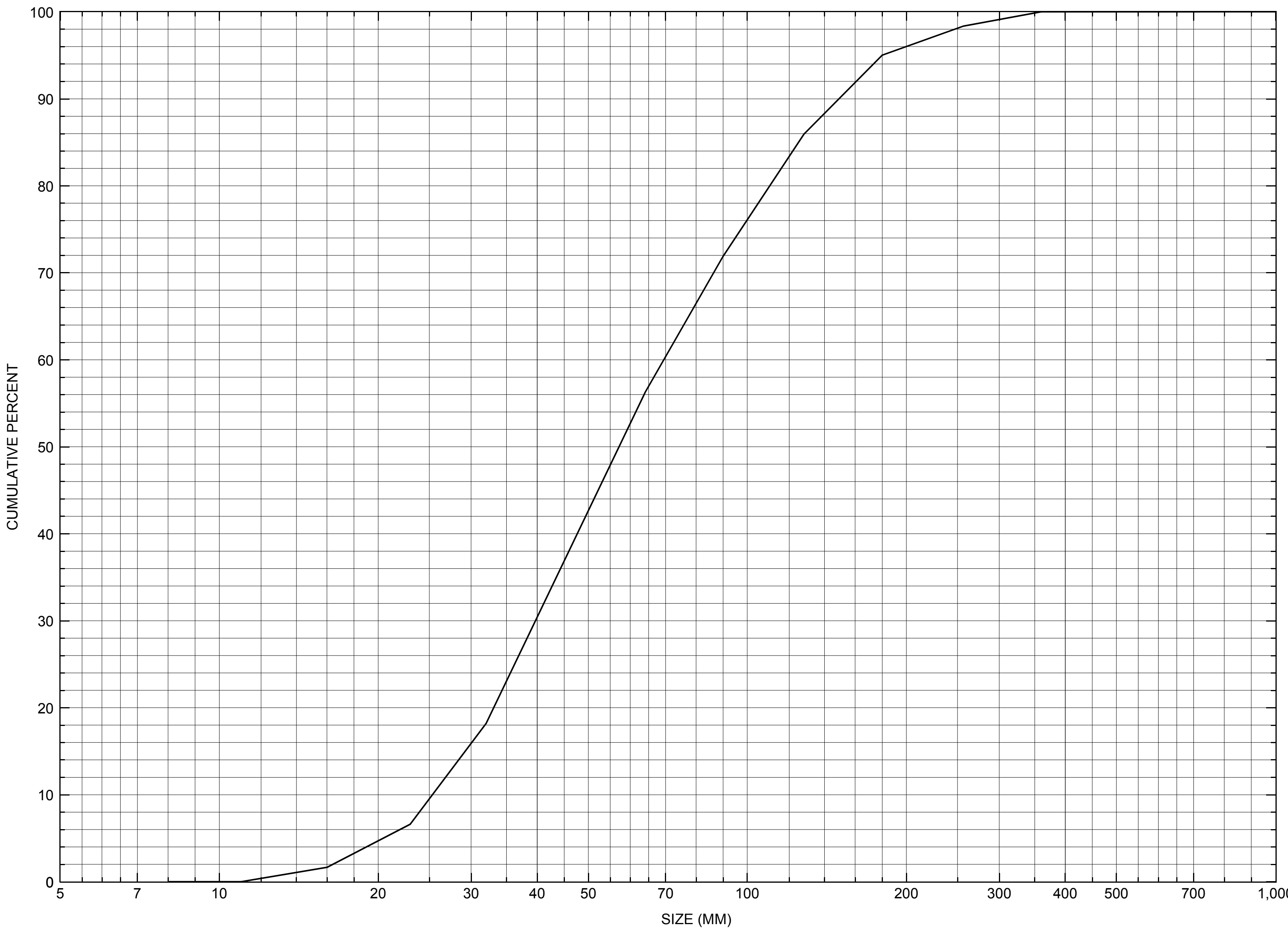
```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File graf010.wsp
        Hydraulic analysis for structure GRAFTH00020010   Date: 21-FEB-97
        Town Highway 2 (VT 121) over the Saxtons River, Grafton  EMB
           *** RUN DATE & TIME: 06-10-98  15:44

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                     WSI,CRWS =    495.65     495.75

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

EXITX:XS   ******   -18.     548.  1.03 *****  496.78  495.75   3700.  495.75
      -40. ******   208.   36295.  1.46 ***** *******    0.92    6.75

FULLV:FV      40.   -20.     686.  0.61  0.31  497.09 *******   3700.  496.48
        0.    40.   210.   48237.  1.34  0.00    0.00    0.64    5.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   495.98     509.86    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   495.98     509.86     498.39

 ===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 =   498.39     509.86     498.39

APPRO:AS      76.    -6.     605.  0.83 *****  499.23  498.39   3700.  498.39
       76.    76.   310.   44319.  1.43 ***** *******    0.93    6.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   501.48       0.00     496.61     498.42

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.84     499.35     499.60     498.43

 ===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      40.     0.     302.  0.98 *****  499.60  494.77   2396.  498.62
        0. ******    47.   23451.  1.00 ***** *******    0.55    7.93

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.451  0.000  498.43 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      22.    48.  0.07  0.17  500.09    0.00   1307.  499.82

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    21.    19.   -36.   -17.   0.4   0.3   3.0   4.1   0.5   2.7
   RT:  1286.   328.    57.   384.   1.4   0.9   4.9   4.3   1.2   3.0

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

APPRO:AS      28.    -7.    1209.  0.17  0.15  500.16  498.39   3700.  499.99
       76.    38.   450.   98668.  1.20  0.98    0.00    0.36    3.06

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD     LEW     REW       Q        K      AREA     VEL    WSEL
   EXITX:XS      -40.    -18.    208.   3700.   36295.      548.    6.75  495.75
   FULLV:FV        0.    -20.    210.   3700.   48237.      686.    5.40  496.48
   BRIDG:BR        0.      0.     47.   2396.   23451.      302.    7.93  498.62
   RDWAY:RG       22.*******     21.   1307.        0.*********    2.00  499.82
   APPRO:AS       76.     -7.    450.   3700.   98668.     1209.    3.06  499.99

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO   VHD     EGL    WSEL
   EXITX:XS    495.75    0.92  487.45  509.54************  1.03  496.78  495.75
   FULLV:FV  ********    0.64  487.58  509.67  0.31  0.00  0.61  497.09  496.48
   BRIDG:BR    494.77    0.55  487.58  498.62************  0.98  499.60  498.62
   RDWAY:RG  ****************  498.42  509.34  0.07******  0.17  500.09  499.82
   APPRO:AS    498.39    0.36  488.58  509.86  0.15  0.98  0.17  500.16  499.99
  ER
```

WSPRO OUTPUT FILE (continued)

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File graf010.io.wsp
        Hydraulic analysis for structure GRAFTH00020010   Date: 21-FEB-97
        Town Highway 2 (VT 121) over the Saxtons River, Grafton  EMB
           *** RUN DATE & TIME: 05-02-98  14:50

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

EXITX:XS   ******   -14.     262.  1.03 *****  495.23  493.74   1900.  494.20
      -40. ******   109.   17705.  1.26 ***** *******    0.98    7.25

FULLV:FV      40.   -16.     348.  0.64  0.35  495.58 *******   1900.  494.94
        0.    40.   142.   23246.  1.37  0.00    0.00    0.76    5.47
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     0.86     495.20     494.68

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   494.44     509.86    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   494.44     509.86     494.68

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.60

APPRO:AS      76.    -2.     177.  1.80  0.85  497.01  494.68   1900.  495.21
       76.    76.    34.   13909.  1.00  0.58    0.00    0.86   10.74
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1900.     494.00

            <<<<<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      40.     0.     155.  2.33 *****  496.33  494.00   1900.  494.00
        0.    40.    47.   12261.  1.00 ***** *******    1.00   12.24

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.43 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      22.          <<<<<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      28.    -4.     243.  0.96  0.38  497.86  494.68   1900.  496.90
       76.    28.    38.   21682.  1.00  1.15    0.02    0.57    7.83

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.000   21596.    -7.    40.   496.53

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

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

APPR2:XS     202.    -3.     221.  1.15  1.78  499.74 *******   1900.  498.59
      278.   202.    36.   18919.  1.00  0.10    0.01    0.64    8.60

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K      AREA     VEL   WSEL
   EXITX:XS      -40.   -14.   109.   1900.   17705.     262.    7.25  494.20
   FULLV:FV        0.   -16.   142.   1900.   23246.     348.    5.47  494.94
   BRIDG:BR        0.     0.    47.   1900.   12261.     155.   12.24  494.00
   RDWAY:RG       22.**************      0.******************    2.00********
   APPRO:AS       76.    -4.    38.   1900.   21682.     243.    7.83  496.90

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -7.    40.   21596.

    XSID:CODE     SRD    LEW    REW       Q        K      AREA     VEL   WSEL
   APPR2:XS      278.    -3.    36.   1900.   18919.     221.    8.60  498.59

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXITX:XS     493.74    0.98  487.45  509.54************  1.03  495.23  494.20
   FULLV:FV    ********   0.76  487.58  509.67  0.35  0.00  0.64  495.58  494.94
   BRIDG:BR     494.00    1.00  487.58  498.62************  2.33  496.33  494.00
   RDWAY:RG   ****************  498.42  509.34**********************************
   APPRO:AS     494.68    0.57  488.58  509.86  0.38  1.15  0.96  497.86  496.90
   APPR2:XS    ********   0.64  490.80  512.08  1.78  0.10  1.15  499.74  498.59
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure GRAFTH00020010, in Grafton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number GRAFTH00020010

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 29 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 025

Town *(FIPS place code; I - 4; nnnnn)* 28900

Mile marker *(I - 11; nnn.nnn)* 004240

Waterway *(I - 6)* SAXTONS RIVER

Road Name *(I - 7):* -

Route Number TH002

Vicinity *(I - 9)* 8.3 MI E JCT VT 11

Topographic Map Saxtons River

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43113

Longitude *(i - 17; nnnnn.n)* 72370

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20012600101306

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

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

Year built *(I - 27; YYYY)* 1977

Structure length *(I - 49; nnnnnn)* 000052

Average daily traffic, ADT *(I - 29; nnnnnn)* 001330

Deck Width *(I - 52; nn.n)* 280

Year of ADT *(I - 30; YY)* 91

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

Opening skew to Roadway *(I - 34; nn)* 40

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

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

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

Structure type *(I - 43; nnn)* 502

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*) 007.5

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

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

Comments:

The structural inspection report of 8/8/94 indicates this is a prestressed concrete slab type bridge. This bridge is part of the Federal Aid System and is listed under the route number FAS 126. The abutment walls and wingwalls are concrete. They are reported in "like-new" condition except for a few hairline vertical shrinkage cracks. The footings are reported as not in view at the surface. The waterway is noted as making a slight bend into the crossing. The streambed consists of stone and gravel. The banks are well protected with stone fill. There are no channel scour, bank erosion, or point bar / debris accumulation problems reported at this bridge site.

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} **1300** Q_{25} **1750**
Q_{50} **2100** Q_{100} **2520** Q_{500} -

Record flood date *(MM / DD / YY)*: - / / Water surface elevation *(ft)*: **6.1**

Estimated Discharge *(cfs)*: **1750** Velocity at Q **25** *(ft/s)*: **7.8**

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*)	-	**5.2**	**6.3**	**7.2**	**8.1**
Velocity (*ft / sec*)	-	-	**7.8**	-	-

Long term stream bed changes: -

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

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

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

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

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

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft²*): -

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

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

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

Comments:

The structures records indicate a hydraulic report was generated for this site, but there was no folder found in the hydraulics section for this site.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **10.79** mi^2

Lake and pond area **0.06** mi^2

Watershed storage *(ST)* **0.5** %

Bridge site elevation **942** ft

Headwater elevation **2894** ft

Main channel length **7.85** mi

10% channel length elevation **1083** ft

85% channel length elevation **1831** ft

Main channel slope *(S)* **127.04** 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)*: 10 / 1976

Project Number ER 35(6) (DR-2-60) Minimum channel bed elevation: 490.5

Low superstructure elevation: USLAB 498.91 DSLAB 500.28 USRAB 498.46 DSRAB 499.82

Benchmark location description:

BM#2 is a spike in the root of an 18 inch maple tree, elevation 494.91. The tree is located 100 feet behind the downstream end of the left abutment and 100 feet from the center line of the roadway to the right bank of the river.

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 2.0 Footing bottom elevation: 486.0

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

There are no other points on the bridge with elevation data available.

Cross-sectional Data

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

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

Comments: **Several cross sections are printed and kept with the plans and may be retrieved when needed. There were reproducible bridge cross sections.**

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: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **9/26/96**

Computerized by: **EW** Date: **9/26/96**

Reviewd by: **EMB** Date: **3/17/97**

Structure Number **GRAFTH00020010**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. HAMMOND** Date *(MM/DD/YY)* **08** / **21** / 19**96**

2. Highway District Number **02** Mile marker **004240**

County **Windham (025)** Town **Grafton (28900)**

Waterway *(I - 6)* **Saxtons River** Road Name **Houghtonville Road**

Route Number **TH 2** Hydrologic Unit Code: **01080107**

3. Descriptive comments:
This bridge is located 8.3 miles east of the intersection with VT 121 in Grafton and approximately 1.0 mile northwest from the intersection with Main Street.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **2** LBDS **3** RBDS **3** Overall **3**
*(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 **1** *(**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 **52** *(feet)* Span length **50** *(feet)* Bridge width **28** *(feet)*

Road approach to bridge:

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

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

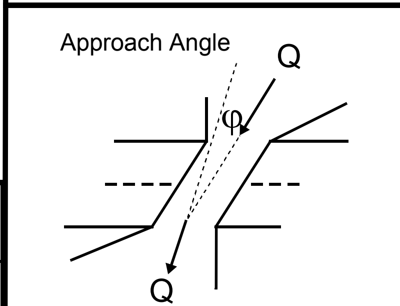
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

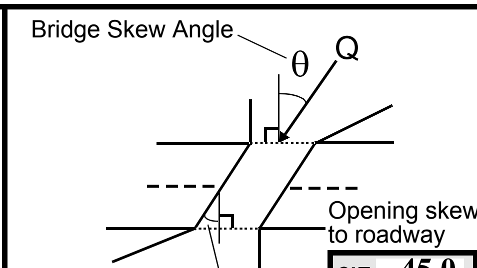
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	2	0
RBUS	2	1	0	-
RBDS	0	-	2	0
LBDS	0	-	0	-

*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: **20** 16. Bridge skew: **60**





α= **45.0**

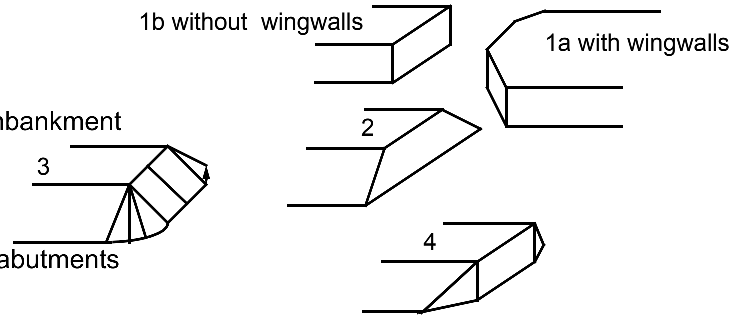
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **37** feet **US** *(US, UB, DS)* to **15** feet **DS**

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

*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 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.)

#4 Surface cover on the right bank upstream consists of brush and woods along the stream and the TH2 roadway surface on the overbank. A house, a couple of barns, a store, and rows of raspberry and blueberry bushes make up the surface cover on the right bank downstream. The surface cover on the left bank downstream is a field of Christmas trees.
#7: The measured bridge length, upstream and downstream span lengths, and the bridge width were 52.2 feet, 48.6 feet, 48.1 feet and 28.1 feet respectively.

#11: The upstream right bank protection extends up to the road level.

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
50.5	**5.0**			**7.5**	**4**	**2**	**543**	**320**	**1**	**2**

23. Bank width **65.0** 24. Channel width **25.0** 25. Thalweg depth **39.0** 29. Bed Material **432**

30 .Bank protection type: LB **2** RB **2** 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.):
#28: Right bank cut-bank is located upstream of protection.

#30: Left bank protection extends from 37 feet upstream to 11 feet under bridge. It protects the wingwall from the bed to halfway up the wingwall.
Right bank protection extends from 30 feet upstream to 90 feet upstream.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **0 DS** 35. Mid-bar width: **25**

36. Point bar extent: **37** feet **US** (US, UB) to **30** feet **DS** (US, UB, DS) positioned **15** %LB to **100** %RB

37. Material: **342**

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

Additional point bar extends from approximately 200 feet upstream to 55 feet upstream. It is positioned 0% LB to 50% RB. It is 20 feet wide at 158 feet upstream. This bar is covered by grass with some small woody plants at the upstream end.

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

41. Mid-bank distance: **140** 42. Cut bank extent: **200** feet **US** (US, UB) to **90** 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.):

Tree roots are undercut and exposed from 150 feet upstream to 120 feet upstream. Undercutting is most severe at 140 feet upstream.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **0**

47. Scour dimensions: Length **51** Width **6** Depth : **1.0** Position **0** %LB to **25** %RB

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

Average thalweg ranges from 0.3 to 0.5 feet (i.e. riffle to pool). The maximum scour depth is 1.5 feet. The scour is along the edge of the left bank protection and the upstream end of the left abutment wall.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB **2** RB ____ (*1*- natural bank; *2*- abutment; *3*- artificial levee)

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
21.5		0.5		2	7	7	-

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.):

342

-

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

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

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

70. Debris and Ice Comments:

1

Trees along the left bank show scars up to the bridge deck level. Bridge does not constrict channel very much, therefore ice blockage potential should be minimal.

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	0	90.0
RABUT	1	0	90			2	0	33.0

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

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

-

-

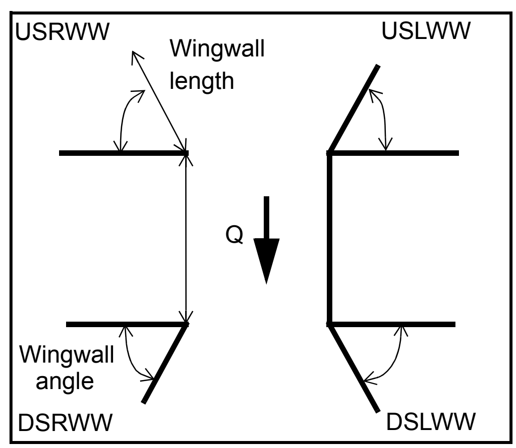
1

#73: Both abutments are almost even.

#75: Maximum depth of water is 1.0 feet.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						33.0	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	42.5	
DSRWW:	1		0		-	43.5	



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	Y	-	1	1	-	-
Condition	Y	-	1	-	1	2	-	-
Extent	1	-	0	2	2	0	0	-

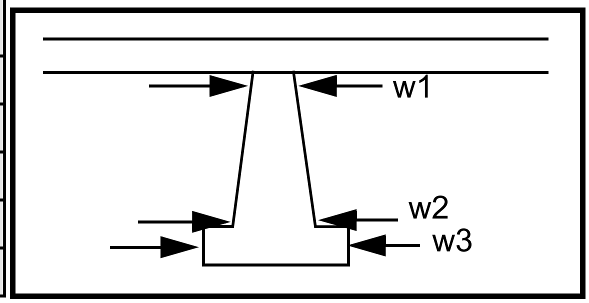
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
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			**5.0**	**45.0**	**10.0**	**24.0**
Pier 2	**5.0**			**21.5**	**90.0**	**10.5**
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
-	-			-	-	NO	PIE	RS		

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.):

1
1
7
7
1
1
345
2
2
1
1
The right bank protection extends from 15 feet under bridge to more than 230 feet downstream.
The left bank protection extends from 20 feet downstream to more than 230 feet downstream.

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

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

105. Drop structure comments (eg. downstream scour depth):
both banks, the bank material is boulder fill and concrete blocks were placed in order to extend the farmer's fields to the stream.

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 **N** *(US, UB, DS)* positioned **-** %LB to **NO** %RB

Material: **DR**

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

OP STRUCTURE

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

Cut bank extent: **195** feet **20** *(US, UB, DS)* to **120** feet **DS** *(US, UB, DS)*

Bank damage: **230** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
40
345

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

Scour dimensions: Length **the** Width **upst** Depth: **rea** Positioned **m** %LB to **cha** %RB

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

nnel assessment for a description of this point bar which begins upstream and continues to just downstream of the bridge.

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

Confluence 1: Distance **100** Enters on **85** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **120** Enters on **DS** *(LB or RB)* Type **1** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

The maximum tree roots exposure and bank undercutting is located 100 feet downstream. Further downstream, the undermining diminishes.

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
10
15
4
0.5
0
10
The scour hole exists from 0 feet downstream to 15 feet downstream.
An additional scour hole from 120 feet downstream to 140 feet downstream exists behind a large boulder (6 feet in diameter). The maximum depth is 1.0 and maximum width is 8 feet. It is positioned 50% LB to 90% RB.
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: GRAFTH00020010 Town: Grafton
Road Number: TH 1 (VT 121) County: Windham
Stream: Saxtons River

Initials EMB Date: 3/14/97 Checked: RLB

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2520	3700	1900
Main Channel Area, ft2	346	373	242
Left overbank area, ft2	0	0	0
Right overbank area, ft2	603	837	0
Top width main channel, ft	43	44	41
Top width L overbank, ft	0	0	0
Top width R overbank, ft	353	414	1
D50 of channel, ft	0.1872	0.1872	0.1872
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.0	8.5	5.9
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	1.7	2.0	0.0
Total conveyance, approach	74078	98795	21655
Conveyance, main channel	37393	41814	21653
Conveyance, LOB	0	0	0
Conveyance, ROB	36685	56981	2
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1272.0	1566.0	1899.8
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	1248.0	2134.0	0.2
Vm, mean velocity MC, ft/s	3.7	4.2	7.9
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.1	2.5	ERR
Vc-m, crit. velocity, MC, ft/s	9.1	9.2	8.6
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

Armoring
Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2037	2396	1900
Main channel area (DS), ft2	210	237	155.1
Main channel width (normal), ft	33.2	33.2	33.1
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	33.2	33.2	33.1
D90, ft	0.4888	0.4888	0.4888
D95, ft	0.5896	0.5896	0.5896
Dc, critical grain size, ft	0.3703	0.3837	0.6673
Pc, Decimal percent coarser than Dc	0.191	0.187	0.038
Depth to armoring, ft	4.71	5.00	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	2520	3700	1900
(Q) discharge thru bridge, cfs	2037	2396	1900
Main channel conveyance	27073	23451	12247
Total conveyance	27073	23451	12247
Q2, bridge MC discharge,cfs	2037	2396	1900
Main channel area, ft2	301	302	155
Main channel width (normal), ft	33.2	33.2	33.1
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.2	33.2	33.1
y_bridge (avg. depth at br.), ft	9.05	9.10	4.69
Dm, median (1.25*D50), ft	0.234	0.234	0.234
y2, depth in contraction,ft	6.39	7.34	6.03
ys, scour depth (y2-ybridge), ft	-2.66	-1.76	1.35

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	2520	3700	1900
Q, thru bridge MC, cfs	2037	2396	1900
Vc, critical velocity, ft/s	9.08	9.16	8.62
Va, velocity MC approach, ft/s	3.68	4.20	7.85
Main channel width (normal), ft	33.2	33.2	33.1
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.2	33.2	33.1
qbr, unit discharge, ft2/s	61.4	72.2	57.4
Area of full opening, ft2	300.5	302.0	155.1
Hb, depth of full opening, ft	9.05	9.10	4.69
Fr, Froude number, bridge MC	0.47	0.55	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	210	237	N/A
**Hb, depth at downstream face, ft	6.33	7.14	N/A
**Fr, Froude number at DS face	0.68	0.67	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	498.43	498.43	0
Elevation of Bed, ft	489.38	489.33	-4.69
Elevation of Approach, ft	499.38	499.99	0
Friction loss, approach, ft	0.07	0.15	0
Elevation of WS immediately US, ft	499.31	499.84	0.00
ya, depth immediately US, ft	9.93	10.51	4.69
Mean elevation of deck, ft	500.14	500.14	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.98	0.96	1.00
**Cc, for downstream face (<=1.0)	0.877699	0.899293	ERR
Ys, scour w/Chang equation, ft	-2.14	-0.93	N/A
Ys, scour w/Umbrell equation, ft	-2.71	-1.86	N/A

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

**Ys, scour w/Chang equation, ft	1.38	1.63	N/A
**Ys, scour w/Umbrell equation, ft	0.02	0.10	ERR

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

y2, from Laursen's equation, ft	6.39	7.34	7.24
WSEL at downstream face, ft	495.66	496.48	--
Depth at downstream face, ft	6.33	7.14	N/A
Ys, depth of scour (Laursen), ft	0.06	0.20	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)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	2520	3700	1900	2520	3700	1900
a', abut.length blocking flow, ft	6.6	7.2	3.9	244.8	244.8	4.9
Ae, area of blocked flow ft2	40.1	47.3	17.9	399.6	419.8	13.9
Qe, discharge blocked abut.,cfs	74.2	107.4	54.5	--	--	38.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.85	2.27	3.04	2.07	2.61	2.77
ya, depth of f/p flow, ft	6.08	6.57	4.59	1.63	1.71	2.84
--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	135	135	135	45	45	45
K2	1.05	1.05	1.05	0.91	0.91	0.91
Fr, froude number f/p flow	0.132	0.156	0.250	0.277	0.329	0.290
ys, scour depth, ft	9.67	10.89	8.20	12.57	14.21	5.70

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)	6.6	7.2	3.9	244.8	244.8	4.9
y1 (depth f/p flow, ft)	6.08	6.57	4.59	1.63	1.71	2.84
a'/y1	1.09	1.10	0.85	149.97	142.77	1.73
Skew correction (p. 49, fig. 16)	1.10	1.10	1.10	0.80	0.80	0.80
Froude no. f/p flow	0.13	0.16	0.25	0.28	0.33	0.29
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	6.22	6.91	ERR
vertical w/ ww's	ERR	ERR	ERR	5.10	5.67	ERR
spill-through	ERR	ERR	ERR	3.42	3.80	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.68	0.67	1	0.68	0.67	1
y, depth of flow in bridge, ft	6.33	7.14	4.69	6.33	7.14	4.69
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.81	1.98	ERR	1.81	1.98	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	1.96	ERR	ERR	1.96