LEVEL II SCOUR ANALYSIS FOR BRIDGE 48 (ENOSTH00020048) on TOWN HIGHWAY 2, crossing the TYLER BRANCH MISSISQUOI RIVER, ENOSBURG, VERMONT

Open-File Report 98-377

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

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

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By ERICK M. BOEHMLER

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Pembroke, New Hampshire

1998

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 48 (ENOSTH00020048) ON TOWN HIGHWAY 2, CROSSING THE TYLER BRANCH MISSISQUOI RIVER, ENOSBURG, VERMONT

By **Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ENOSTH00020048 on Town Highway 2 crossing the Tyler Branch Missisquoi River, Enosburg, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in north-central Vermont. The 17.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture, except for the upstream left overbank area, where the surface cover is shrubs and brush.

In the study area, the Tyler Branch Missisquoi River has a sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 74 ft and an average bank height of 5 ft. The channel bed material ranges from sand to cobbles with a median grain size (D_{50}) of 73.4 mm (0.241 ft). Bedrock is exposed at the surface along the right side of the channel through the bridge and across the downstream channel. The geomorphic assessment at the time of the Level I and Level II site visit on July 10, 1995, indicated that the reach was laterally unstable. Localized channel anabranching, point bars, and cut-banks were common features observed, particularly upstream of this site.

The Town Highway 2 crossing of the Tyler Branch Missisquoi River is a 47-ft-long, two-lane bridge consisting of one 43-foot steel-beam span (Vermont Agency of Transportation, written communication, March 8, 1995). The opening length of the structure parallel to the bridge face is 41.4 ft. The bridge is supported by vertical, concrete abutments. There also is a stone retaining wall along the right bank downstream. The channel is skewed zero degrees to the opening and the opening-skew-to-roadway is zero degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the downstream end of the right abutment and the retaining wall during the Level I assessment. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the right abutment, type-3 stone fill (less than 48 inches diameter) on the right bank upstream and a mortared stone retaining wall on the right bank downstream. 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 0.7 to 1.7 ft. The worst-case contraction scour occurred at the 100-year discharge. Abutment scour ranged from 21.3 to 24.1 ft at the left abutment and from 15.0 to 15.9 ft at the right abutment. The worst-case abutment scour occurred at the incipient roadway-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 ENOSTH00020048 ***Stream*** Tyler Branch Missisquoi River

County Franklin ***Road*** TH 2 ***District*** 8

Description of Bridge

Bridge length 47 ***ft*** ***Bridge width*** 20.2 ***ft*** ***Max span length*** 43 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 7/10/95

Description of stone fill Type-1 was observed along the right abutment. There also was type-3 stone fill observed along the right bank upstream and a mortared stone retaining wall along the right bank downstream.

Brief description of piers/abutments The abutments are stone walls with a concrete surface.

No

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

There is a moderate channel bend in the upstream reach. A scour hole has developed in the location where flow impacts the right abutment wall and retaining wall.

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	7/10/95	0	0
Level II	7/10/95	0	0

Potential for debris Moderate. Some debris has accumulated on the US point bar.

Describe any features near or at the bridge that may affect flow (include observation date) None were observed on 7/10/95.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with an irregular flood plain and moderately sloping walls on both sides.

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

Date of inspection 7/10/95

DS left: Moderately sloping channel bank and overbank.

DS right: Vertical bank and a moderately sloping overbank.

US left: Mildly sloping channel bank and a moderately sloping overbank (TH 2).

US right: Steep channel bank and a moderately sloping overbank.

Description of the Channel

Average top width 74 ***ft*** ***Average depth*** 5 ***ft***

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

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

7/10/95

Vegetative co Small trees, grass and brush

DS left: Trees

DS right: Shrubs and brush with a few trees

US left: Grass, shrubs, brush, and trees.

US right: No

Do banks appear stable? Lateral instability was indicated particularly upstream of this site. Channel anabranching, point bars, and a cut-bank with block failure of bank material were observed in the upstream reach.

date of observation.

None were observed on 7/10/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 17.7 ***mi***^{2}

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 -- ***mi***^{2}

Is there a lake/p _ No

-

Calculated Discharges

Q100 3,300 ***ft***^{3}***/s*** ***Q500*** 4,700 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(17.7/10.3)exp 0.67] with flood frequency estimates available from the VTAOT database (written communication, May 1995) for bridge number 47 in Enosburg. Bridge number 47 crosses the nearby Bogue Branch of the Missisquoi River and has a drainage area of 10.3 square miles. The selected discharges were within a range defined by flood frequency curves derived by use of several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; 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 None

Description of reference marks used to determine USGS datum. RM1 is a chiseled "X" in the asphalt pavement at the downstream right corner of the bridge deck, one foot from the concrete guard rail (elev. 499.47 ft, arbitrary survey datum). RM2 is a chiseled "X" on top of the second concrete, cable-guard-rail post from the left abutment on the upstream edge of the roadway (elev. 500.39 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT2	0	1	Downstream-most Cross-section
EX1A	199	2	Cross-section at channel slope inflection point, templated from EXIT2
EXIT1	307	1	Exit section
FULLV	370	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	370	1	Bridge section
RDWAY	380	1	Road Grade section
APPRO	433	1	Approach section

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.035 to 0.050, and overbank "n" values ranged from 0.050 to 0.070.

Normal depth at the downstream-most section (EXIT2) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0118 ft/ft, which was estimated from points surveyed at and downstream of the EXIT2 section.

The approach section (APPRO) was surveyed one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

For the 100-year 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 can be determined that the water surface profile does pass 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 499.4 *ft*
Average low steel elevation 496.0 *ft*

100-year discharge 3,300 *ft³/s*
Water-surface elevation in bridge opening 492.1 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 239 *ft²*
Average velocity in bridge opening 13.8 *ft/s*
Maximum WSPRO tube velocity at bridge 17.4 *ft/s*

Water-surface elevation at Approach section with bridge 496.0
Water-surface elevation at Approach section without bridge 493.9
Amount of backwater caused by bridge 2.1 *ft*

500-year discharge 4,700 *ft³/s*
Water-surface elevation in bridge opening 496.6 *ft*
Road overtopping? Yes *Discharge over road* 247 *ft³/s*
Area of flow in bridge opening 401 *ft²*
Average velocity in bridge opening 11.1 *ft/s*
Maximum WSPRO tube velocity at bridge 13.5 */s*

Water-surface elevation at Approach section with bridge 499.5
Water-surface elevation at Approach section without bridge 494.8
Amount of backwater caused by bridge 4.7 *ft*

Incipient overtopping discharge 4,140 *ft³/s*
Water-surface elevation in bridge opening 496.6 *ft*
Area of flow in bridge opening 401 *ft²*
Average velocity in bridge opening 10.3 *ft/s*
Maximum WSPRO tube velocity at bridge 12.6 *ft/s*

Water-surface elevation at Approach section with bridge 498.8
Water-surface elevation at Approach section without bridge 494.4
Amount of backwater caused by bridge 4.4 *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. However, a bedrock exposure along the right bank at the lowest part of the channel upstream and under the bridge, and another exposure across the channel downstream, were observed at this site and may limit the depth of scour. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 500-year and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison contraction scour for the 500-year and incipient roadway-overtopping discharges 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 those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these 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.

The length to depth ratio of the embankment blocking flow exceeded 25 for all modelled discharges at the left abutment. Although the HIRE equation (Richardson and others, 1993, p. 50, equation 25) generally is applicable when this ratio exceeds 25, the results from the HIRE equation were not used. Hydraulic Engineering Circular 18 recommends that the field conditions be similar to those from which the HIRE equation was derived (Richardson and others, 1993). Since the equation was developed from U.S. Army Corps. of Engineers' data for spur dikes in the Mississippi River, the HIRE equation was not adopted for the narrow, incised, upland valley at this site.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.7	1.5	0.7
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	21.3	24.0	24.1
Right abutment	15.0	15.7	15.9
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.5	3.2	3.0
Right abutment	2.5	3.2	3.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

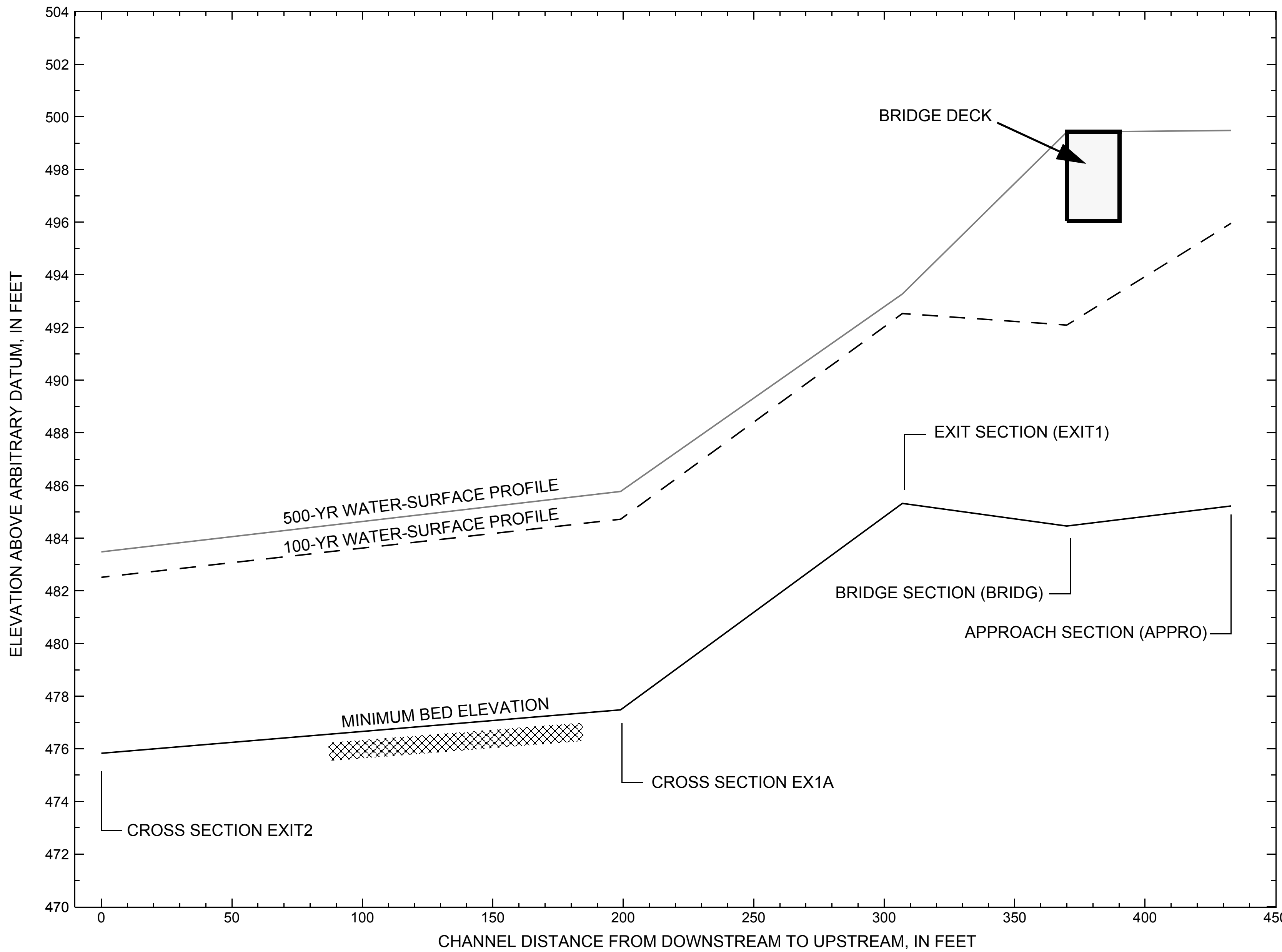

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure ENOSTH00020048 on Town Highway 2, crossing the Tyler Branch Missisquoi River, Enosburg, Vermont.

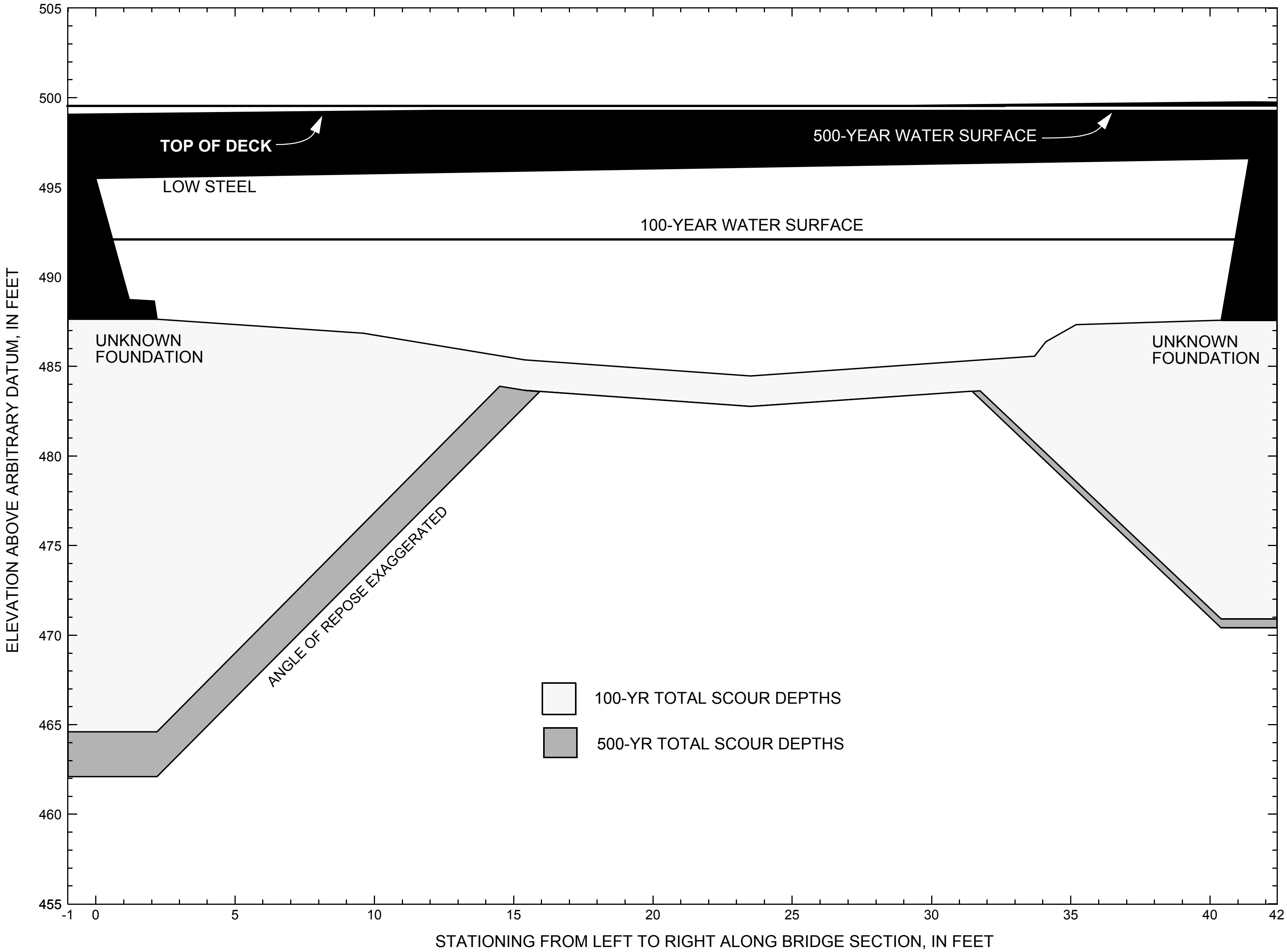

Figure 8. Scour elevations for the 100- and 500-year discharges at structure ENOSTH00020048 on Town Highway 2, crossing the Tyler Branch Missisquoi River, Enosburg, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ENOSTH00020048 on Town Highway 2, crossing the Tyler Branch Missisquoi River, Enosburg, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 3,300 cubic-feet per second											
Left abutment	0.0	--	495.5	--	487.6	1.7	21.3	--	23.0	464.6	--
Right abutment	41.4	--	496.6	--	487.6	1.7	15.0	--	16.7	470.9	--

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 ENOSTH00020048 on Town Highway 2, crossing the Tyler Branch Missisquoi River, Enosburg, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 4,700 cubic-feet per second											
Left abutment	0.0	--	495.5	--	487.6	1.5	24.0	--	25.5	462.1	--
Right abutment	41.4	--	496.6	--	487.6	1.5	15.7	--	17.2	470.4	--

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, Bakersfield, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Aerial Photography, 1981; Contour interval, 6 meters; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File enos048.wsp
T2        Hydraulic analysis for structure ENOSTH00020048   Date: 19-DEC-97
T3        Town Highway 2 Over the Tyler Branch Missisquoi River, Enosburg.   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           3300.0   4700.0   4140.0
SK          0.0118   0.0118   0.0118
*
XS   EXIT2      0
GR         -238.1, 504.66   -203.2, 486.30    -35.7, 486.18    -17.0, 484.83
GR           -8.2, 477.92      0.0, 476.49      5.0, 475.83     12.4, 475.98
GR           17.1, 476.24     23.0, 476.48     25.4, 476.61     39.8, 478.92
GR           63.7, 480.24    124.8, 483.36    133.7, 485.74    145.1, 486.30
GR          158.0, 486.10    211.2, 488.33    245.7, 495.89    278.1, 500.07
*
N           0.055        0.050        0.055
SA                -17.0         63.7
*
XS   EX1A     199   * * *   0.00827
*
XS   EXIT1    307
GR         -745.9, 511.67   -692.5, 507.05   -629.3, 504.24   -605.7, 501.28
GR         -428.9, 498.47   -333.2, 500.22   -263.6, 499.31   -246.1, 495.73
GR         -184.5, 493.91   -123.1, 490.68    -59.8, 492.30    -47.4, 490.63
GR           -7.0, 490.59      0.0, 487.01     10.9, 487.12     11.6, 486.36
GR           11.8, 485.32     19.4, 485.40     27.9, 485.77     33.6, 485.32
GR           38.0, 488.96     38.4, 485.60     38.6, 486.35     44.2, 496.57
GR           83.3, 497.06     99.5, 499.99    113.2, 500.41    125.8, 500.41
GR          125.8, 500.41    130.2, 504.42    166.6, 507.34    252.1, 522.47
*
N           0.055        0.050        0.040        0.070
SA               -263.6        -7.0         44.2
*
*
XS   FULLV    370   * * *   0.0
*
*              SRD     LSEL    XSSKEW
BR   BRIDG   370    496.05       0.0
GR            0.0, 495.49      1.2, 488.73      2.1, 488.65      2.2, 487.63
GR            9.6, 486.85     11.8, 486.26     15.4, 485.36     23.5, 484.46
GR           28.2, 484.93     33.7, 485.57     34.1, 486.37     35.2, 487.33
GR           40.4, 487.58     41.4, 496.60      0.0, 495.49
*
*         BRTYPE  BRWDTH
CD           1      20.9
N           0.035
*
*
*              SRD    EMBWID   IPAVE
XR   RDWAY    380       20.2      1
GR         -753.3, 515.95   -557.6, 505.11   -535.6, 503.83   -390.0, 501.29
GR         -209.6, 499.48    -91.4, 498.75      0.0, 499.09      0.1, 503.55
GR           41.7, 502.54     41.8, 499.77     60.2, 500.30    139.5, 506.56
GR          263.9, 522.58
*
```

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*

AS   APPRO    433
GR         -753.3, 515.95   -557.6, 505.11   -535.6, 503.83   -390.0, 501.29
GR         -226.9, 499.01   -206.5, 498.61   -181.4, 497.12   -174.2, 495.19
GR         -138.4, 492.67    -52.1, 490.90    -31.1, 490.94    -18.7, 487.95
GR           -9.9, 488.64     -4.7, 487.73      0.0, 488.79      6.9, 488.63
GR           12.7, 487.70     15.6, 486.95     17.9, 486.51     23.1, 486.60
GR           27.4, 486.04     30.5, 485.77     34.9, 485.22     39.4, 486.42
GR           41.3, 487.18     51.6, 486.84     55.8, 491.58     65.5, 498.84
GR          109.7, 502.84    125.1, 503.89    139.1, 504.33    157.2, 504.88
GR          163.1, 508.75    239.1, 520.67
*
N           0.055        0.045        0.050
SA                 -31.1         65.5
*
HP 1 BRIDG 492.09 1 492.09
HP 2 BRIDG 492.09 * * 3300
HP 1 APPRO 495.96 1 495.96
HP 2 APPRO 495.96 * * 3300
*
HP 1 BRIDG 496.60 1 496.60
HP 2 BRIDG 496.60 * * 4451
HP 1 BRIDG 494.33 * 494.33
HP 2 RDWAY 499.42 * * 247
HP 1 APPRO 499.48 1 499.48
HP 2 APPRO 499.48 * * 4700
*
HP 1 BRIDG 496.60 1 496.60
HP 2 BRIDG 496.60 * * 4140
HP 1 BRIDG 494.03 * 494.03
HP 1 APPRO 498.77 1 498.77
HP 2 APPRO 498.77 * * 4140
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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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 enos048.wsp
        Hydraulic analysis for structure ENOSTH00020048   Date: 19-DEC-97
        Town Highway 2 Over the Tyler Branch Missisquoi River, Enosburg.   EMB
           *** RUN DATE & TIME: 02-12-98  08:50

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =     370.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     239.  29174.    40.    49.                        3305.
   492.09          239.  29174.    40.    49.  1.00     1.    41.   3305.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = BRIDG;  SRD =     370.

         WSEL     LEW     REW    AREA         K        Q    VEL
       492.09     0.6    40.9   239.1   29174.    3300.  13.80

X STA.         0.6        7.2        9.5       11.5       13.3       14.9
  A(I)            28.3       11.7       11.1       10.6       10.2
  V(I)            5.84      14.15      14.88      15.58      16.11

X STA.        14.9       16.4       17.8       19.2       20.5       21.8
  A(I)            10.0        9.7        9.8        9.6        9.8
  V(I)           16.43      17.01      16.81      17.24      16.90

X STA.        21.8       23.1       24.4       25.7       27.0       28.3
  A(I)             9.7        9.5        9.6        9.6        9.7
  V(I)           17.00      17.36      17.15      17.23      17.06

X STA.        28.3       29.7       31.1       32.5       34.5       40.9
  A(I)             9.5       10.0        9.6       12.4       28.8
  V(I)           17.37      16.50      17.25      13.27       5.73

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPRO;  SRD =     433.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     540.  34950.   146.   146.                        5892.
             2     730.  92558.    93.    98.                       11629.
   495.96         1270.  127508.   239.   244.  1.27  -177.    62.  14748.

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = APPRO;  SRD =     433.

         WSEL     LEW     REW    AREA         K        Q    VEL
       495.96  -177.1    61.7  1270.2  127508.    3300.   2.60

X STA.      -177.1     -115.0      -91.3      -71.7      -54.6      -38.8
  A(I)           156.4       95.0       87.3       83.0       79.6
  V(I)            1.05       1.74       1.89       1.99       2.07

X STA.       -38.8      -25.3      -18.0      -11.6       -5.1        1.5
  A(I)            72.1       52.6       49.4       50.2       50.0
  V(I)            2.29       3.14       3.34       3.28       3.30

X STA.         1.5        8.4       14.5       19.4       24.1       28.5
  A(I)            50.5       49.3       45.1       43.9       43.3
  V(I)            3.27       3.35       3.66       3.76       3.81

X STA.        28.5       32.7       36.6       41.3       46.4       61.7
  A(I)            42.3       42.0       44.8       45.1       88.3
  V(I)            3.90       3.93       3.68       3.66       1.87
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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 enos048.wsp
        Hydraulic analysis for structure ENOSTH00020048   Date: 19-DEC-97
        Town Highway 2 Over the Tyler Branch Missisquoi River, Enosburg.   EMB
           *** RUN DATE & TIME: 02-12-98  08:50

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =     370.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     401.  43415.     0.    99.                           0.
   496.60          401.  43415.     0.    99.  1.00     0.    41.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = BRIDG;  SRD =     370.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.60     0.0    41.4   400.7   43415.    4451.  11.11

X STA.          0.0        6.3        8.5       10.6       12.6       14.3
  A(I)             44.5       19.1       18.9       18.2       17.9
  V(I)             5.00      11.65      11.76      12.21      12.46

X STA.         14.3       16.0       17.5       19.1       20.6       22.1
  A(I)             17.1       16.9       17.0       16.8       16.6
  V(I)            13.04      13.18      13.06      13.21      13.39

X STA.         22.1       23.5       25.0       26.4       27.8       29.3
  A(I)             16.6       16.7       16.7       16.4       16.6
  V(I)            13.39      13.33      13.30      13.53      13.40

X STA.         29.3       30.8       32.4       34.0       36.1       41.4
  A(I)             16.8       16.8       18.2       19.5       43.2
  V(I)            13.27      13.25      12.25      11.39       5.15

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =     370.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     330.  47093.    41.    54.                        5319.
   494.33          330.  47093.    41.    54.  1.00     0.    41.   5319.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = RDWAY;  SRD =     380.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.42  -199.9     0.0    82.0    1359.     247.   3.01

X STA.       -199.9     -129.6     -121.2     -114.1     -107.8     -102.3
  A(I)             15.3        3.9        3.6        3.5        3.2
  V(I)             0.81       3.19       3.46       3.57       3.81

X STA.       -102.3      -97.1      -92.3      -87.7      -82.8      -78.3
  A(I)              3.2        3.1        3.1        3.2        2.9
  V(I)             3.87       3.97       4.03       3.92       4.28

X STA.        -78.3      -73.2      -67.2      -61.0      -54.5      -47.5
  A(I)              3.1        3.5        3.5        3.5        3.6
  V(I)             3.96       3.50       3.50       3.49       3.41

X STA.        -47.5      -40.1      -31.7      -22.5      -11.6        0.0
  A(I)              3.7        3.9        3.9        4.3        4.1
  V(I)             3.36       3.18       3.14       2.87       3.02

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPRO;  SRD =     433.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1129.  88328.   229.   230.                       14204.
             2    1065. 168042.    97.   102.                       20061.
             3       2.     31.     7.     7.                           7.
   499.48         2196. 256402.   333.   339.  1.35  -261.    73.  27514.

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = APPRO;  SRD =     433.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.48  -260.5    72.6  2195.7  256402.    4700.   2.14

X STA.       -260.5     -117.0      -99.8      -84.6      -69.8      -56.1
  A(I)            435.2      127.5      118.0      119.6      114.6
  V(I)             0.54       1.84       1.99       1.96       2.05

X STA.        -56.1      -42.7      -29.9      -21.2      -14.4       -7.1
  A(I)            114.6      109.5       86.2       77.1       80.1
  V(I)             2.05       2.15       2.73       3.05       2.94

X STA.         -7.1       -0.3        7.0       13.9       19.5       25.0
  A(I)             77.6       78.3       78.7       71.1       71.5
  V(I)             3.03       3.00       2.99       3.30       3.29

X STA.         25.0       30.3       35.2       40.4       46.3       72.6
  A(I)             70.6       69.4       70.0       72.4      153.8
  V(I)             3.33       3.39       3.36       3.25       1.53
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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 enos048.wsp
        Hydraulic analysis for structure ENOSTH00020048   Date: 19-DEC-97
        Town Highway 2 Over the Tyler Branch Missisquoi River, Enosburg.   EMB
           *** RUN DATE & TIME: 02-12-98  08:50

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =     370.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     401.   43415.     0.    99.                           0.
   496.60          401.   43415.     0.    99.  1.00     0.    41.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = BRIDG;  SRD =     370.

         WSEL     LEW     REW    AREA         K        Q    VEL
       496.60     0.0    41.4   400.7   43415.    4140.  10.33

X STA.         0.0         6.3         8.5        10.6        12.6        14.3
  A(I)             44.5        19.1        18.9        18.2        17.9
  V(I)             4.65       10.84       10.93       11.36       11.59

X STA.        14.3        16.0        17.5        19.1        20.6        22.1
  A(I)             17.1        16.9        17.0        16.8        16.6
  V(I)            12.13       12.26       12.14       12.29       12.45

X STA.        22.1        23.5        25.0        26.4        27.8        29.3
  A(I)             16.6        16.7        16.7        16.4        16.6
  V(I)            12.45       12.40       12.37       12.58       12.47

X STA.        29.3        30.8        32.4        34.0        36.1        41.4
  A(I)             16.8        16.8        18.2        19.5        43.2
  V(I)            12.35       12.32       11.39       10.59        4.79

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =     370.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     318.   44547.    41.    53.                        5030.
   494.03          318.   44547.    41.    53.  1.00     0.    41.   5030.

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPRO;  SRD =     433.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     983.   81410.   184.   184.                       12911.
             2     996.  150507.    97.   102.                       18163.
   498.77         1979.  231917.   280.   286.  1.25  -215.    65.  26662.

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = APPRO;  SRD =     433.

         WSEL     LEW     REW    AREA         K        Q    VEL
       498.77  -214.7    65.4  1979.4  231917.    4140.   2.09

X STA.      -214.7      -124.9      -106.6       -89.6       -73.6       -59.2
  A(I)            299.4       120.2       117.7       116.2       109.2
  V(I)             0.69        1.72        1.76        1.78        1.90

X STA.       -59.2       -45.2       -31.4       -22.0       -15.0        -7.8
  A(I)            110.2       107.7        83.8        74.0        74.7
  V(I)             1.88        1.92        2.47        2.80        2.77

X STA.        -7.8        -0.9         6.7        13.4        19.2        24.7
  A(I)             73.3        75.9        72.3        69.0        66.6
  V(I)             2.82        2.73        2.86        3.00        3.11

X STA.        24.7        29.8        34.8        39.8        45.7        65.4
  A(I)             65.2        66.0        64.8        68.5       144.7
  V(I)             3.17        3.14        3.20        3.02        1.43
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WSPRO OUTPUT FILE (continued)

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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 enos048.wsp
        Hydraulic analysis for structure ENOSTH00020048   Date: 19-DEC-97
        Town Highway 2 Over the Tyler Branch Missisquoi River, Enosburg.   EMB
           *** RUN DATE & TIME: 02-12-98  08:50

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

EXIT2:XS   ******   -14.     407.  1.15 *****  483.66  481.85   3300.  482.51
        0. ******   108.   30374.  1.13 ***** *******    0.83    8.10

EX1A :XS     199.   -15.     479.  0.85  1.91  485.57 *******   3300.  484.72
      199.   199.   119.   37421.  1.16  0.00    0.00    0.69    6.89

 ===105 WSMIN BELOW YMIN AT SECID "EXIT1":  USED WSMIN = CRWS.
                        YMIN,WSMIN,CRWS =   485.32     484.22     492.53
 ===110 WSEL NOT FOUND AT SECID "EXIT1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   492.53     522.47     0.50
 ===115 WSEL NOT FOUND AT SECID "EXIT1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =    492.53     522.47     492.53
 ===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 "EXIT1"
                   WSBEG,WSEND,CRWS =    492.53     522.47     492.53

EXIT1:XS     108.  -158.     470.  1.20 *****  493.73  492.53   3300.  492.53
      307.   108.    42.   36090.  1.57 ***** *******    1.01    7.01

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.51

FULLV:FV      63.  -177.     677.  0.56  0.35  494.07 *******   3300.  493.51
      370.    63.    43.   54642.  1.52  0.00    0.00    0.60    4.88
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      63.  -156.     798.  0.35  0.18  494.25 *******   3300.  493.90
      433.    63.    59.   68898.  1.31  0.00   -0.01    0.43    4.13
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    3300.      492.09

            <<<<<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      63.     1.     239.  3.60 *****  495.69  492.09   3300.  492.09
      370.    63.    41.   29174.  1.21 ***** *******    1.10   13.80

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.907 ******  496.05 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG     380.        <<<<<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      42.  -177.    1271.  0.13  0.14  496.09  491.42   3300.  495.96
      433.    48.    62.  127548.  1.27  0.27    0.01    0.22    2.60

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.810  0.627   47492.    -7.    33.   495.93

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K      AREA     VEL   WSEL
   EXIT2:XS       0.    -14.   108.   3300.   30374.     407.    8.10  482.51
   EX1A :XS     199.    -15.   119.   3300.   37421.     479.    6.89  484.72
   EXIT1:XS     307.   -158.    42.   3300.   36090.     470.    7.01  492.53
   FULLV:FV     370.   -177.    43.   3300.   54642.     677.    4.88  493.51
   BRIDG:BR     370.      1.    41.   3300.   29174.     239.   13.80  492.09
   RDWAY:RG     380.**************       0.*****************    1.00********
   APPRO:AS     433.   -177.    62.   3300.  127548.    1271.    2.60  495.96

    XSID:CODE   XLKQ   XRKQ      KQ
   APPRO:AS      -7.    33.   47492.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO   VHD      EGL    WSEL
   EXIT2:XS     481.85    0.83  475.83  504.66************  1.15  483.66  482.51
   EX1A :XS   ********    0.69  477.48  506.31  1.91  0.00  0.85  485.57  484.72
   EXIT1:XS     492.53    1.01  485.32  522.47************  1.20  493.73  492.53
   FULLV:FV   ********    0.60  485.32  522.47  0.35  0.00  0.56  494.07  493.51
   BRIDG:BR     492.09    1.10  484.46  496.60************  3.60  495.69  492.09
   RDWAY:RG   ****************  498.75  522.58**********************************
   APPRO:AS     491.42    0.22  485.22  520.67  0.14  0.27  0.13  496.09  495.96
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WSPRO OUTPUT FILE (continued)

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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 enos048.wsp
        Hydraulic analysis for structure ENOSTH00020048   Date: 19-DEC-97
        Town Highway 2 Over the Tyler Branch Missisquoi River, Enosburg.   EMB
           *** RUN DATE & TIME: 02-12-98  08:50

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

EXIT2:XS   ******   -15.     536.  1.40 *****  484.89  482.88   4700.  483.48
        0. ******   125.   43229.  1.17 ***** *******    0.86    8.78

EX1A :XS     199.   -16.     627.  1.02  1.90  486.79 *******   4700.  485.77
      199.   199.   128.   53602.  1.17  0.00    0.01    0.68    7.49

 ===105 WSMIN BELOW YMIN AT SECID "EXIT1":  USED WSMIN = CRWS.
                        YMIN,WSMIN,CRWS =   485.32     485.27     493.27
 ===110 WSEL NOT FOUND AT SECID "EXIT1":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.27     522.47     0.50
 ===115 WSEL NOT FOUND AT SECID "EXIT1":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.27     522.47     493.27
 ===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 "EXIT1"
                   WSBEG,WSEND,CRWS =   493.27     522.47     493.27

EXIT1:XS     108.  -172.     624.  1.36 *****  494.63  493.27   4700.  493.27
      307.   108.    42.   49578.  1.54 ***** *******    0.97    7.53

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.48

FULLV:FV      63.  -199.     864.  0.68  0.38  495.01 *******   4700.  494.33
      370.    63.    43.   73314.  1.48  0.00    0.00    0.62    5.44
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      63.  -168.     987.  0.46  0.21  495.22 *******   4700.  494.76
      433.    63.    60.   90584.  1.31  0.00    0.00    0.46    4.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.68     498.55     498.66     496.05
 ===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      63.     0.     401.  1.92 *****  498.52  493.41   4451.  496.60
      370. ******    41.   43415.  1.00 ***** *******    0.63   11.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.482 ******  496.05 ****** ****** ******

   XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
  RDWAY:RG      380.    43.  0.01  0.10  499.56    0.00    247.  499.42

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
  LT:    247.   200.  -200.     0.   0.7   0.4   3.4   3.0   0.5   3.0
  RT:      0.    20.    42.    61.   0.6   0.3   3.7   4.9   0.7   3.0

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

APPRO:AS      42.  -260.    2194.  0.10  0.09  499.57  492.51   4700.  499.48
      433.    49.    73.  256258.  1.35  0.27    0.00    0.17    2.14

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD     LEW     REW       Q          K      AREA     VEL    WSEL
   EXIT2:XS        0.    -15.    125.   4700.   43229.      536.    8.78  483.48
   EX1A :XS      199.    -16.    128.   4700.   53602.      627.    7.49  485.77
   EXIT1:XS      307.   -172.     42.   4700.   49578.      624.    7.53  493.27
   FULLV:FV      370.   -199.     43.   4700.   73314.      864.    5.44  494.33
   BRIDG:BR      370.      0.     41.   4451.   43415.      401.   11.11  496.60
   RDWAY:RG      380.*******    247.    247.*********        0.    1.00  499.42
   APPRO:AS      433.   -260.     73.   4700.  256258.     2194.    2.14  499.48

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS      FR#    YMIN     YMAX     HF     HO   VHD       EGL     WSEL
   EXIT2:XS    482.88     0.86  475.83  504.66************  1.40   484.89  483.48
   EX1A :XS  ********     0.68  477.48  506.31  1.90  0.00  1.02   486.79  485.77
   EXIT1:XS    493.27     0.97  485.32  522.47************  1.36   494.63  493.27
   FULLV:FV  ********     0.62  485.32  522.47  0.38  0.00  0.68   495.01  494.33
   BRIDG:BR    493.41     0.63  484.46  496.60************  1.92   498.52  496.60
   RDWAY:RG  ***************  498.75  522.58  0.01******  0.10   499.56  499.42
   APPRO:AS    492.51     0.17  485.22  520.67  0.09  0.27  0.10   499.57  499.48
```

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 enos048.wsp
        Hydraulic analysis for structure ENOSTH00020048   Date: 19-DEC-97
        Town Highway 2 Over the Tyler Branch Missisquoi River, Enosburg.   EMB
           *** RUN DATE & TIME: 02-12-98  08:50

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

EXIT2:XS   ******   -15.     486.  1.31 *****  484.43  482.50   4140.  483.12
        0. ******   120.   38092.  1.16 ***** *******    0.85    8.52

EX1A :XS     199.   -16.     572.  0.95  1.89  486.34 *******   4140.  485.39
      199.   199.   126.   47258.  1.17  0.00    0.01    0.69    7.24

 ===105 WSMIN BELOW YMIN AT SECID “EXIT1”:  USED WSMIN = CRWS.
                        YMIN,WSMIN,CRWS =   485.32     484.89      492.99
 ===110 WSEL NOT FOUND AT SECID “EXIT1”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   492.99     522.47    0.50
 ===115 WSEL NOT FOUND AT SECID “EXIT1”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   492.99     522.47      492.99
 ===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 “EXIT1”
                   WSBEG,WSEND,CRWS =   492.99     522.47     492.99

EXIT1:XS     108.  -167.     565.  1.30 *****  494.29  492.99   4140.  492.99
      307.   108.    42.   44221.  1.56 ***** *******    0.98    7.32

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             “FULLV”     KRATIO =  1.50

FULLV:FV      63.  -188.     793.  0.63  0.37  494.66 *******   4140.  494.03
      370.    63.    43.   66236.  1.49  0.00    0.00    0.61    5.22
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      63.  -163.     915.  0.42  0.20  494.85 *******   4140.  494.44
      433.    63.    60.   82109.  1.31  0.00    0.00    0.45    4.52
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.08     497.51     497.63      496.05
 ===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      63.     0.     401.  1.66 *****  498.26  493.07   4138.  496.60
      370. ******    41.   43415.  1.00 ***** *******    0.59   10.33

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.468 ******  496.05 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG     380.         <<<<<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      42.  -214.    1978.  0.09  0.08  498.85  492.11   4140.  498.77
      433.    49.    65.  231814.  1.25  0.26    0.00    0.16    2.09

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.75

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL   WSEL
   EXIT2:XS       0.    -15.   120.   4140.   38092.     486.    8.52  483.12
   EX1A :XS     199.    -16.   126.   4140.   47258.     572.    7.24  485.39
   EXIT1:XS     307.  -167.     42.   4140.   44221.     565.    7.32  492.99
   FULLV:FV     370.  -188.     43.   4140.   66236.     793.    5.22  494.03
   BRIDG:BR     370.     0.     41.   4138.   43415.     401.   10.33  496.60
   RDWAY:RG     380.**************      0.       0.       0.    1.00********
   APPRO:AS     433.  -214.     65.   4140.  231814.    1978.    2.09  498.77

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

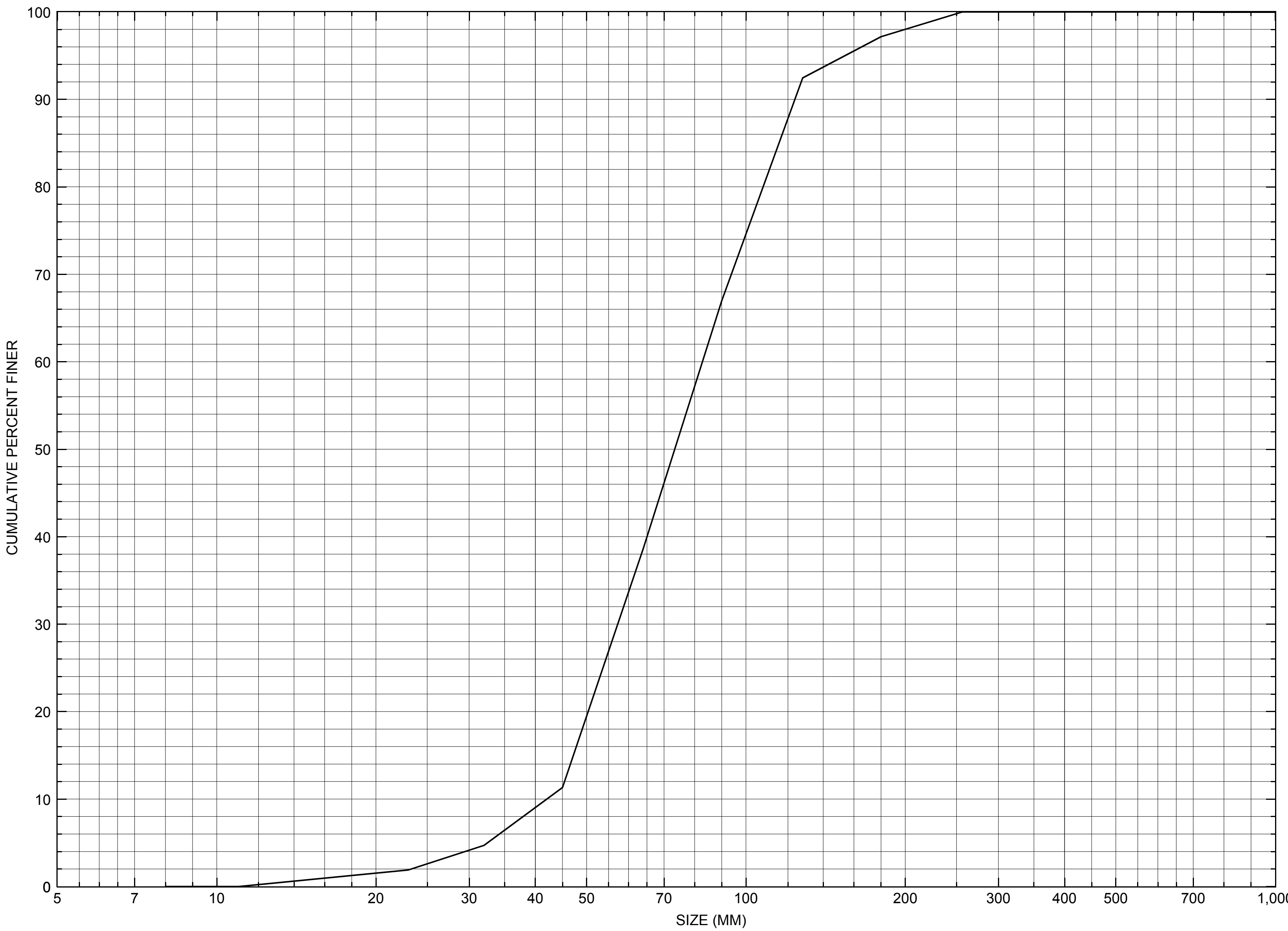
 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO  VHD      EGL    WSEL
   EXIT2:XS     482.50    0.85  475.83  504.66************  1.31  484.43  483.12
   EX1A :XS   ********    0.69  477.48  506.31  1.89  0.00  0.95  486.34  485.39
   EXIT1:XS     492.99    0.98  485.32  522.47************  1.30  494.29  492.99
   FULLV:FV   ********    0.61  485.32  522.47  0.37  0.00  0.63  494.66  494.03
   BRIDG:BR     493.07    0.59  484.46  496.60************  1.66  498.26  496.60
   RDWAY:RG   ****************  498.75  522.58************  0.09  498.84********
   APPRO:AS     492.11    0.16  485.22  520.67  0.08  0.26  0.09  498.85  498.77
  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 ENOSTH00020048, in Enosburg, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ENOSTH00020048

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 08 / 95

Highway District Number *(I - 2; nn)* 08

County *(FIPS county code; I - 3; nnn)* 011

Town *(FIPS place code; I - 4; nnnnn)* 23875

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

Waterway *(I - 6)* Tyler Branch

Road Name *(I - 7)*: -

Route Number TH 2

Vicinity *(I - 9)* AT JCT C2 TH 1

Topographic Map Bakersfield

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44517

Longitude *(i - 17; nnnnn.n)* 72457

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10060300480603

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

Maximum span length *(I - 48; nnnn)* 0043

Year built *(I - 27; YYYY)* 1924

Structure length *(I - 49; nnnnnn)* 000047

Average daily traffic, ADT *(I - 29; nnnnnn)* 000390

Deck Width *(I - 52; nn.n)* 202

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span *(nnn.n ft)* 42.4

Number of spans *(I - 45; nnn)* 01

Vertical clearance from streambed *(nnn.n ft)* 10.1

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

Waterway of full opening *(nnn.n ft^2)* 428.4

Comments:

The structural inspection report of 8/1/94 indicates the structure is a steel stringer type bridge. The abutments are stone walls that have been faced with concrete since construction. There are stone wingwalls / retaining walls. The downstream end of the right abutment is only partially faced with concrete. Deep concrete spalling is present at the bottom of the right abutment. In some sections, the concrete facing is missing, exposing the small voids between the stones of the abutment wall. The concrete footing of the left abutment is exposed and there is some spalling of the facing at the bottom upstream end of the left abutment. A low sand and gravel bar is deposited along the left abutment, **(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:

blocking about 1/3 of the channel. The report indicates bedrock outcrops make up the upstream channel bottom. The upstream channel also has a couple of large, vegetated, coarse gravel bars, which divide the flow (anabranching?) and some boulder riprap along the upstream right bank. The report indicates there has been no settlement and debris buildup is minor.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **17.70** mi^2

Lake/pond/swamp area **0.15** mi^2

Watershed storage *(ST)* **0.8** %

Bridge site elevation **551** ft

Headwater elevation **3117** ft

Main channel length **7.22** mi

10% channel length elevation **597** ft

85% channel length elevation **1713** ft

Main channel slope *(S)* **206.09** ft / mi

Watershed Precipitation Data

Average site precipitation ______ in

Average headwater precipitation ______ in

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

Average seasonal snowfall *(Sn)* ______ ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness ____ Footing bottom elevation: ____

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

If 3: Footing bottom elevation: ____

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

The bed is probably very close to bedrock since bedrock was noted in the upstream channel.

Comments:

-

Cross-sectional Data

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

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

Comments: **The cross section is of the upstream face. The low chord elevation is from the survey log completed as part of this project dated 7/10/95. The low chord to bed length data is from the sketch dated 6/12/92 and attached to a bridge inspection report dated 8/1/94.**

Station	0	1.75	8	18	26	34.25	42.4	-	-	-	-
Feature	LAB	-	-	-	-	-	RAB	-	-	-	-
Low chord elevation	495.49	495.54	495.70	495.96	496.17	496.38	496.60	-	-	-	-
Bed elevation	488.76	485.62	484.78	485.63	485.09	486.21	487.52	-	-	-	-
Low chord to bed	6.73	9.92	10.92	10.33	11.08	10.17	9.08	-	-	-	-

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

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

Comments: -

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 3/13/96
Computerized by: RB Date: 3/13/96
Reviewd by: EMB Date: 2/12/98

Structure Number ENOSTH00020048

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. BOEHMLER Date *(MM/DD/YY)* 7 / 10 / 1995

2. Highway District Number 08 Mile marker 0000

County Franklin (011) Town Enosburg (23875)

Waterway *(I - 6)* Tyler Branch Missisquoi River Road Name -

Route Number TH 2 Hydrologic Unit Code: 02010007

3. Descriptive comments:

The bridge is located at the crossing of TH01 and TH02.

B. Bridge Deck Observations

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

5. Ambient water surface... US 2 UB 1 DS 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 47 *(feet)* Span length 43 *(feet)* Bridge width 20.2 *(feet)*

Road approach to bridge:

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

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

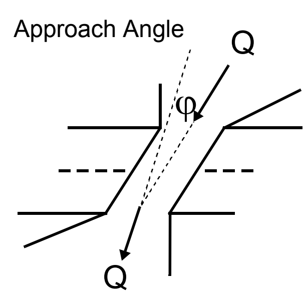
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

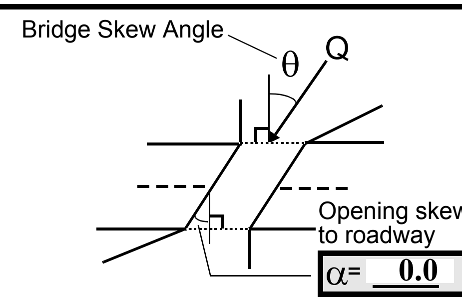
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	5	1	0	0
RBUS	0	-	2	2
RBDS	0	-	0	0
LBDS	5	1	0	0

*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: 40 16. Bridge skew: 40





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 35 feet US *(US, UB, DS)* to 0 feet US

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: **1b**

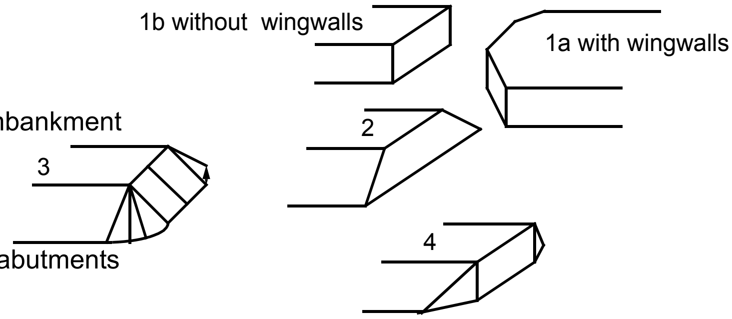
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. Values are from the VTAOT file. Measured bridge dimensions at the time of this assessment match the VTAOT values.
4. The left bank US is mostly shrubs with a few trees. The right bank US is mostly grass with trees only on the immediate bank and a paved cross road bisecting the grassland. The left bank DS is pasture with trees on the bank only. The right bank DS has a house on top of the bank at the edge of the channel with a small grass lawn then a paved cross road just bankward of the house.
13. Roadwash has eroded a small, but significant, gully at the US right bank corner of the bridge where the abutment meets the road embankment fill.

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
43.5	**3.0**			**4.5**	**2**	**2**	**324**	**324**	**0**	**2**

23. Bank width **15.0**   24. Channel width **50.0**   25. Thalweg depth **87.0**   29. Bed Material **342**

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

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

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

30. The right bank protection extends from 0 feet US to about 50 feet US.
There is a complex of mid-channel bars and a point bar US. One mid-channel bar extends from 115 feet US to 55 feet US, is 5 feet wide at 80 feet US, is positioned from 50% LB to 55% RB, and is not vegetated. The other bar is more of an island type feature extending from 110 feet US to 40 feet US, is positioned 65% LB to 75% RB, is about 15 feet wide at 70 feet US, and is 100% covered with shrubs and grass. The material of both mid-channel bars is coarse gravel and cobbles. The right-most bar has a thin layer of sand in which the vegetation is growing. The material of the left bank point bar appears artificially piled from channel material excavation, especially at the US end of the bar. The DS portion of the point bar is 80% covered with mainly tall grass.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **28** 35. Mid-bar width: **14**

36. Point bar extent: **85** feet **US** (US, UB) to **55** feet **DS** (US, UB, DS) positioned **0** %LB to **30** %RB

37. Material: **324**

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

The point bar has mainly gravel and sand on top of cobbles at the US end and grades to mainly coarse gravel near mid-bar, then fines to medium and coarse sand and fine gravel under the bridge along the left abutment. Small shrubs and grass cover approximately 30% of the bar. There are also 2 mid-channel bars. One extends from 55 feet US to 115 feet US, is positioned from 50% LB to 55% RB and is about 5 feet wide. The other is a more distinctive island type feature extending from 110 feet US to 40 feet US and is 15 feet wide at 70 feet US.

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: **65** 42. Cut bank extent: **115** feet **US** (US, UB) to **40** feet **US** (US, UB, DS)

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

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

Block failure is evident from 75 feet US to 40 feet US. Beyond 75 feet US, the damage is minor channel erosion

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)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
70.5		**1.5**		**2**	**7**	**7**	**-**

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

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

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

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

326

For about 40% of the channel width along the right bank side under the bridge, the streambed is bedrock. The material grades from coarse to fine gravel from the middle of the channel toward the left bank on the surface. Medium to coarse sand is observed on top of the point bar for about 25% of the channel from the left abutment.

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

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

70. Debris and Ice Comments:

1

It is most likely that ice and debris build-up will occur at the US bend in the channel. A couple of trees and some branches are on the right-most mid-channel bar US. There are trees along the banks. The channel is sinuous through the valley, leading to a moderate potential for debris accumulation in the channel. However, the channel straightens before passing through the bridge, which is why the capture efficiency is cate-

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	**goriz**	**ed as**	**low.**	**0**	**90**	**2**	**2**	**90.0**
RABUT	**0**	**1.0**	**1**			**5**	**90**	**41.5**

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

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

0

1

1.5

-

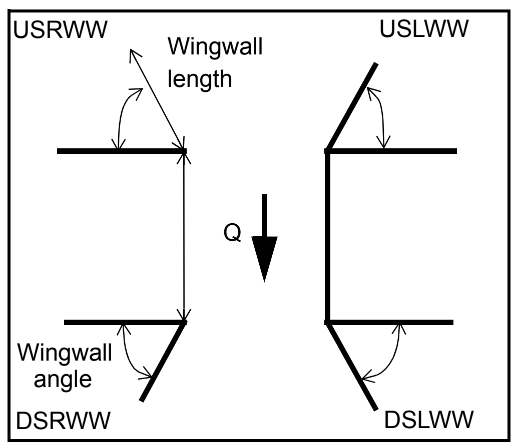
1

The abutments are stone walls with concrete facing. The concrete facing along the bottom of the right abutment has weathered and eroded away. The concrete has eroded to the extent that the original stone wall is visible behind the concrete for the entire base length. The concrete erosion reaches anywhere from 0.5 - 2 feet vertically from the base of the wall. Some stone fill is visible from the US right bank to under the bridge along the right abutment for at least the upstream-most 5 feet of the wall. Exposure of the left abutment footing is

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	**betw**		**een**		**0.5 -**	**41.5**	
USRWW:	**1**		**foot**		**for**	**2.0**	
DSLWW:	**the**		**entir**		**e**	**21.0**	
DSRWW:	**lengt**		**h.**			**21.0**	

*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		**N**	**-**	**-**	**-**	**-**	**N**	**-**
Condition		**-**	**-**	**-**	**N**	**-**	**-**	**-**
Extent		**-**	**N**	**-**	**-**	**-**	**-**	**-**

*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*

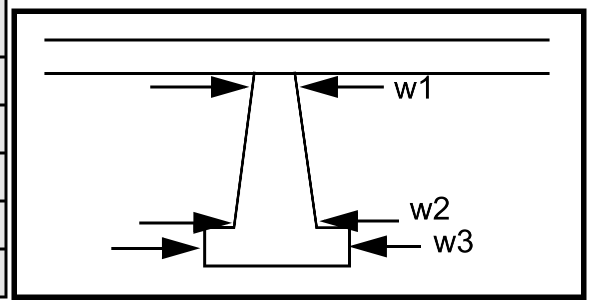
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
1
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	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	-	e are	DS	end of	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	-	no	right	the	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	-	wing	bank	right	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	-	walls	. The	abut	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	-	. But	retai	ment	*Y- yes; N- no*
91. Attack ∠ (BF)	-	there	ning	to	
92. Pushed	-	is a	wall	just	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	-	retai	exte	DS	
95. Cross-members	-	ning	nds	of	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	-	wall	from	the	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	-	on	the	hous	
98. Exposure depth	Ther	the	DS	e.	

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 - Thalweg depth - Bed Material -

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

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

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

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

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

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

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

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

Material: -

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

-
-
-
-

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

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

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

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

Is channel scour present? _____ (Y or if N type ctrl-n cs) Mid-scour distance: 3

Scour dimensions: Length 1 Width 23 Depth: 7 Positioned 0 %LB to 0 %RB

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

324
0
5
-

Are there major confluences? 2 (Y or if N type ctrl-n mc) How many? The

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

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

Confluence comments (eg. confluence name):

right bank completely covers the bank material. The wall extends from the bridge to at least 200 feet DS. Bedrock is the only channel bed material from 70 feet DS to 175 feet DS and forms several small waterfalls down-

F. Geomorphic Channel Assessment

107. Stage of reach evolution str

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)*:

eam. Many small potholes have developed in the rock. Bedrock also outcrops on the bed from 9 feet to 17 feet DS. The bedrock DS controls flow as water is pooled with a water surface over the top of the bedrock here. Gravel, sand and cobbles cover the surface between the bedrock outcrops. A section of the retaining wall stones have slumped near 48 feet DS such that the lower half of the wall is vertical while the remaining sections of the wall are at a 75-80 degree angle, US and DS of the slumped portion.

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:	ENOSTH00020048	Town:	Enosburg
Road Number:	TH 2	County:	Franklin
Stream:	Tyler Branch Missisquoi River		

Initials EMB   Date: 2/12/98 Checked: LKS

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 Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3300	4700	4140
Main Channel Area, ft2	730	1065	996
Left overbank area, ft2	540	1129	983
Right overbank area, ft2	0	2	0
Top width main channel, ft	93	97	97
Top width L overbank, ft	146	229	184
Top width R overbank, ft	0	7	0
D50 of channel, ft	0.2406	0.2406	0.2406
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.8	11.0	10.3
y1, average depth, LOB, ft	3.7	4.9	5.3
y1, average depth, ROB, ft	ERR	0.3	ERR
Total conveyance, approach	127508	256402	231917
Conveyance, main channel	92558	168042	150507
Conveyance, LOB	34950	88328	81410
Conveyance, ROB	0	31	0
Percent discrepancy, conveyance	0.0000	0.0004	0.0000
Qm, discharge, MC, cfs	2395.5	3080.3	2686.7
Ql, discharge, LOB, cfs	904.5	1619.1	1453.3
Qr, discharge, ROB, cfs	0.0	0.6	0.0
Vm, mean velocity MC, ft/s	3.3	2.9	2.7
Vl, mean velocity, LOB, ft/s	1.7	1.4	1.5
Vr, mean velocity, ROB, ft/s	ERR	0.3	ERR
Vc-m, crit. velocity, MC, ft/s	9.8	10.4	10.3
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	3300	4451	4140
Main channel area (DS), ft2	239.1	330	318
Main channel width (normal), ft	40.3	41.4	41.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	40.3	41.4	41.4
D90, ft	0.4059	0.4059	0.4059
D95, ft	0.5048	0.5048	0.5048
Dc, critical grain size, ft	0.7149	0.6113	0.5773
Pc, Decimal percent coarser than Dc	0.000	0.000	0.000
Depth to armoring, ft	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	3300	4700	4140
(Q) discharge thru bridge, cfs	3300	4451	4140
Main channel conveyance	29174	43415	43415
Total conveyance	29174	43415	43415
Q2, bridge MC discharge,cfs	3300	4451	4140
Main channel area, ft2	239	401	401
Main channel width (normal), ft	40.3	41.4	41.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	40.3	41.4	41.4
y_bridge (avg. depth at br.), ft	5.93	9.68	9.68
Dm, median (1.25*D50), ft	0.30075	0.30075	0.30075
y2, depth in contraction,ft	7.61	9.61	9.04
ys, scour depth (y2-ybridge), ft	**1.68**	-0.06	-0.64

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 Davis, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	3300	4700	4140
Q, thru bridge MC, cfs	3300	4451	4140
Vc, critical velocity, ft/s	9.83	10.39	10.28
Va, velocity MC approach, ft/s	3.28	2.89	2.70
Main channel width (normal), ft	40.3	41.4	41.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	40.3	41.4	41.4
qbr, unit discharge, ft2/s	81.9	107.5	100.0
Area of full opening, ft2	239.1	400.7	400.7
Hb, depth of full opening, ft	5.93	9.68	9.68
Fr, Froude number, bridge MC	0	0.63	0.59
Cf, Fr correction factor (<=1.0)	0.00	1.00	1.00
**Area at downstream face, ft2	N/A	330	318
**Hb, depth at downstream face, ft	N/A	7.97	7.68
**Fr, Froude number at DS face	ERR	0.84	0.83
**Cf, for downstream face (<=1.0)	N/A	1.00	1.00
Elevation of Low Steel, ft	496.05	496.05	496.05
Elevation of Bed, ft	490.12	486.37	486.37
Elevation of Approach, ft	0	499.48	498.77
Friction loss, approach, ft	0	0.09	0.08
Elevation of WS immediately US, ft	0.00	499.39	498.69
ya, depth immediately US, ft	-490.12	13.02	12.32
Mean elevation of deck, ft	0	503.04	503.04
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	ERR	0.93	0.94
**Cc, for downstream face (<=1.0)	ERR	0.862299	0.869708
Ys, scour w/Chang equation, ft	N/A	**1.50**	**0.67**
Ys, scour w/Umbrell equation, ft	N/A	-3.05	-3.62

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

**Ys, scour w/Chang equation, ft	N/A	4.02	3.50
**Ys, scour w/Umbrell equation, ft	ERR	-1.34	-1.62

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	7.61	9.61	9.04
WSEL at downstream face, ft	--	494.33	494.03
Depth at downstream face, ft	N/A	7.97	7.68
Ys, depth of scour (Laursen), ft	N/A	1.64	1.35

Abutment Scour

Froehlich’s Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a’/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 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	3300	4700	4140	3300	4700	4140
a’, abut.length blocking flow, ft	177.7	260.5	214.7	20.8	31.2	24
Ae, area of blocked flow ft2	768.8	1381.2	1295.4	137.2	213.9	194.6
Qe, discharge blocked abut.,cfs	1627.5	--	2301.5	344	430.2	357.9
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.12	1.77	1.78	2.51	2.01	1.84
ya, depth of f/p flow, ft	4.33	5.30	6.03	6.60	6.86	8.11
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--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	0.179	0.132	0.127	0.172	0.135	0.114
ys, scour depth, ft	**21.34**	**23.98**	**24.14**	**14.98**	**15.67**	**15.90**

HIRE equation (a’/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

a’(abut length blocked, ft)	177.7	260.5	214.7	20.8	31.2	24
y1 (depth f/p flow, ft)	4.33	5.30	6.03	6.60	6.86	8.11
a’/y1	41.07	49.13	35.58	3.15	4.55	2.96
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.18	0.13	0.13	0.17	0.14	0.11
Ys w/ corr. factor K1/0.55:						
vertical	17.85	19.77	22.24	ERR	ERR	ERR
vertical w/ ww’s	14.63	16.21	18.23	ERR	ERR	ERR
spill-through	9.82	10.87	12.23	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	0.84	0.83	1	0.84	0.83
y, depth of flow in bridge, ft	5.93	7.97	7.68	5.93	7.97	7.68
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.48	3.17	3.05	2.48	3.17	3.05