LEVEL II SCOUR ANALYSIS FOR BRIDGE 46 (ENOSVT01080046) on STATE ROUTE 108, crossing an UNNAMED "THE BRANCH" TRIBUTARY, ENOSBURG, VERMONT

U.S. Geological Survey
Open-File Report 96-585

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

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By Erick M. Boehmler and Laura Medalie

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Pembroke, New Hampshire

1996

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

U.S. GEOLOGICAL SURVEY
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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 46 (ENOSVT01080046) ON STATE ROUTE 108, CROSSING AN UNNAMED "THE BRANCH" TRIBUTARY, ENOSBURG, VERMONT

By **Erick M. Boehmler and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ENOSVT01080046 on State Route 108 crossing an unnamed "The Branch" tributary, 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 (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in north-central Vermont. The 1.55-mi^2 drainage area is in a predominantly rural, pasture and forested basin. In the vicinity of the study site, the surface cover is pasture.

In the study area, this unnamed "The Branch" tributary has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 45 ft and an average channel depth of 3 ft. The predominant channel bed material is gravel and cobbles with a median grain size (D_{50}) of 42.4 mm (0.139 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 29, 1995, indicated that the reach was laterally unstable. Block failure slumping of bank material was evident at an upstream cut-bank and another minor cut-bank was noted downstream.

The State Route 108 crossing of this unnamed "The Branch" tributary is a 25-ft-long, two-lane bridge consisting of one 22-foot concrete span (Vermont Agency of Transportation, written communication, March 8, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) at the downstream end of the downstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.3 to 0.5 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.0 to 8.0 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 others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 ENOSVT01080046 ***Stream*** Unnamed "The Branch" Tributary

County Franklin ***Road*** VT 108 ***District*** 8

Description of Bridge

Bridge length 25 ***ft*** ***Bridge width*** 33.3 ***ft*** ***Max span length*** 22 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 6/29/95

Description of stone fill Type-2 at the downstream end of the downstream left wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 10

There is a moderate channel bend in the upstream reach.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	6/29/95	0	0
Level II	6/29/95	0	0

Potential for debris Moderate. There is no significant vegetation on the banks but some debris accumulation was evident in the reach.

Describe any features near or at the bridge that may affect flow (include observation date) Some debris was noted on 6/29/95 captured by a barbed wire fence across the channel downstream of the bridge.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting, with narrow, flat to irregular flood plains and moderately sloping valley walls.

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

Date of inspection 6/29/95

DS left: Moderately sloping channel bank to a narrow flood plain.

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

US left: Moderately sloping channel bank to a narrow overbank.

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

Description of the Channel

Average top width 45 ***ft*** ***Average depth*** 3 ***ft***

Predominant bed material Gravel / Cobbles ***Bank material*** Sand to boulders

Ephemeral and sinuous with semi-alluvial channel boundaries.

6/29/95

Vegetative co

DS left: Grass

DS right: Grass

US left: Grass

US right: Grass

N

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

Cut-banks on the left side of the channel upstream and downstream of the bridge were noted on 6/29/95. Block failure of the bank material was noted for the upstream cut-bank. The flow approaching this site bends right impacting the left abutment.

The assessment of 6/29/95 noted a barbed wire fence across the channel about 50 feet downstream of this site. The fence has caused accumulation of some minor debris and may effect flood flow conditions.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 1.55 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 425 ***ft³/s*** ***Q500*** 550 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates computed by use of several empirical methods (Benson, 1962; FHWA, 1983; Johnson and Laraway, unpublished draft, 1972; Johnson and Tasker, 1974; Potter, 1957; Talbot, 1887). The median 100- and 500-year discharge was selected from the range of discharges computed.

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

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

Datum tie between USGS survey and VTAOT plans Subtract 46.9 feet from the USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is the center point of a chiseled "X" on top of the concrete curb at the downstream left corner of the bridge deck (elev. 500.67 ft, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the concrete right abutment at its upstream end (elev. 499.87 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-25	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	18	1	Road Grade section
APPRO	58	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. Although this unnamed brook enters "The Branch" about 350 feet downstream of this site, no backwater effects were assumed as the timing of the peak discharges on each waterway probably are not coincident. 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 0.030 to 0.046, and overbank "n" values ranged from 0.032 to 0.035.

The slope-conveyance method, outlined in the user's manual for WSPRO (Shearman, 1990), was used to compute a starting water surface. The slope used was 0.0286 ft/ft, which was estimated from surveyed thalweg points downstream of the EXITX section. However, for the 100- and 500-year discharges, WSPRO assumes critical depth at the exit section for the starting water surface. Analysis of the supercritical and subcritical profiles for the exit section at each discharge indicates that the slope used is a supercritical slope. Since the supercritical solution was close to critical depth, the starting water surface at critical depth was assumed to be a satisfactory solution.

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

For the 100- and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. Analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

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

100-year discharge 425 *ft³/s*
Water-surface elevation in bridge opening 493.7 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 50.0 *ft²*
Average velocity in bridge opening 8.5 *ft/s*
Maximum WSPRO tube velocity at bridge 9.7 *ft/s*

Water-surface elevation at Approach section with bridge 495.3
Water-surface elevation at Approach section without bridge 494.3
Amount of backwater caused by bridge 1.0 *ft*

500-year discharge 550 *ft³/s*
Water-surface elevation in bridge opening 494.2 *ft*
Road overtopping? No *Discharge over road* --
Area of flow in bridge opening 59.6 *ft²*
Average velocity in bridge opening 9.2 *ft/s*
Maximum WSPRO tube velocity at bridge 10.6 */s*

Water-surface elevation at Approach section with bridge 495.9
Water-surface elevation at Approach section without bridge 494.6
Amount of backwater caused by bridge 1.3

Incipient overtopping discharge -- *ft³/s*
Water-surface elevation in bridge opening -- *ft*
Area of flow in bridge opening -- *ft²*
Average velocity in bridge opening -- *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The streambed armoring depths computed indicate that armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.3	0.5	--
Depth to armoring	12.6	16.8	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	4.0	4.8	--
Right abutment	7.2	8.0	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	0.9	1.1	--
Right abutment	0.9	1.1	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

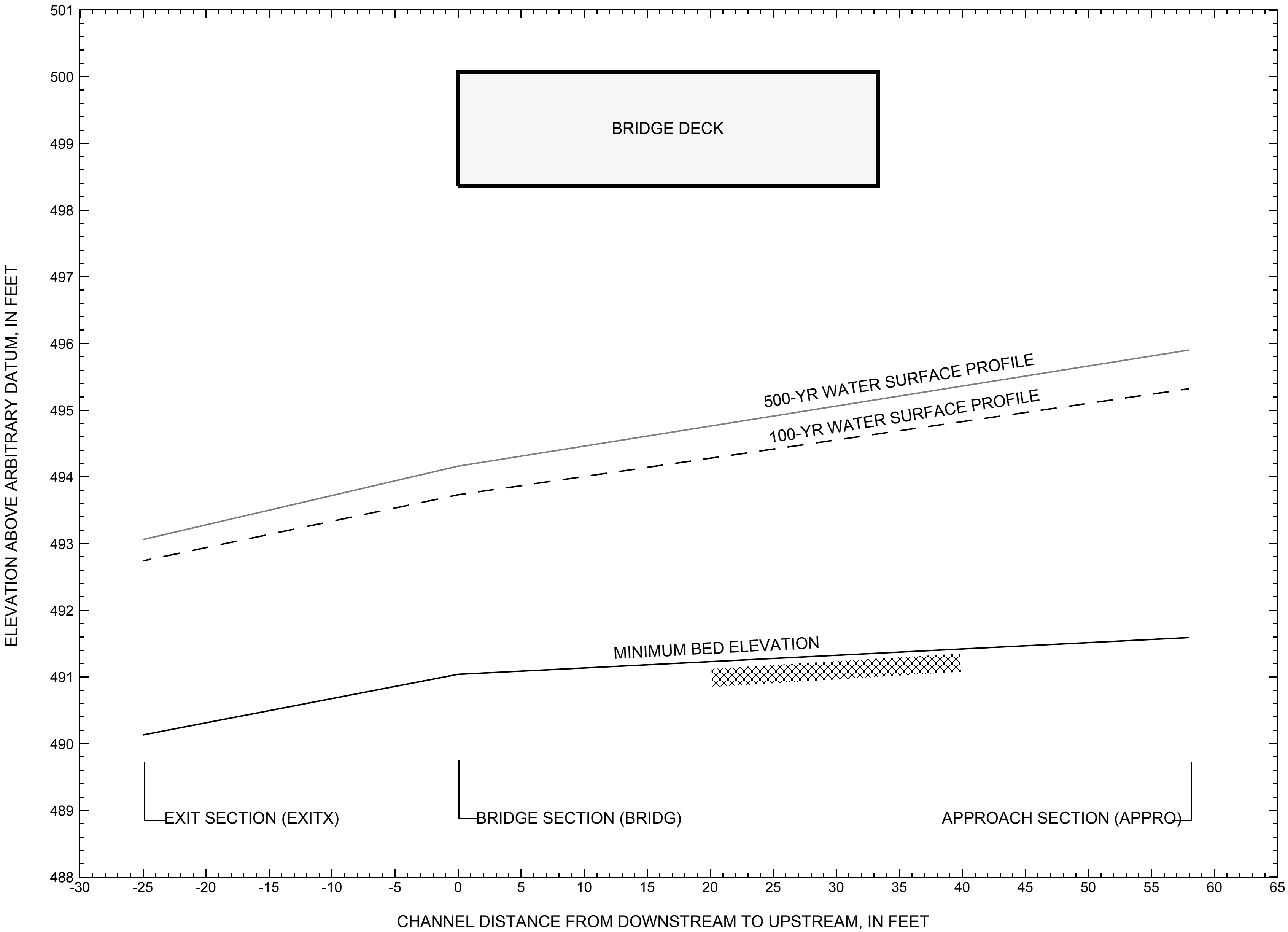

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ENOSVT01080046 on State Route 108, crossing An Unnamed "The Branch" Tributary, Enosburg, Vermont.

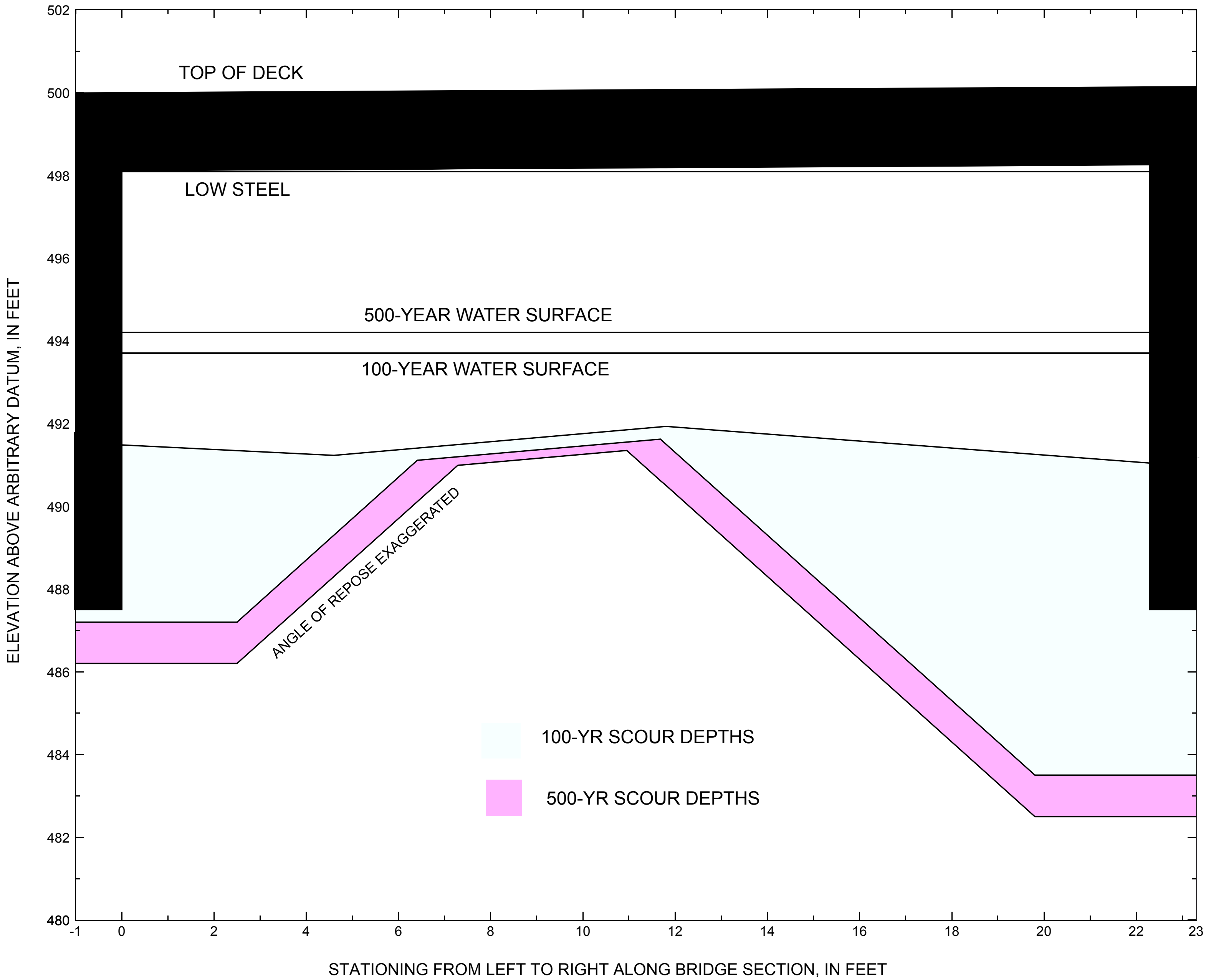

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ENOSVT01080046 on State Route 108, crossing An Unnamed "The Branch" Tributary, Enosburg, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ENOSVT01080046 on State Route 108, crossing An Unnamed "The Branch" Tributary, 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 425 cubic-feet per second											
Left abutment	0.0	451.5	498.3	487.6	491.5	0.3	4.0	--	4.3	487.2	-0.4
Right abutment	22.3	451.5	498.5	487.6	491.0	0.3	7.2	--	7.5	483.5	-4.1

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 ENOSVT01080046 on State Route 108, crossing An Unnamed "The Branch" Tributary, 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 elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 550 cubic-feet per second											
Left abutment	0.0	451.5	498.3	487.6	491.5	0.5	4.8	--	5.3	486.2	-1.4
Right abutment	22.3	451.5	498.5	487.6	491.0	0.5	8.0	--	8.5	482.5	-5.1

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

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U.S. Geological Survey, 1986, 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

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T1        U.S. Geological Survey WSPRO Input File enos046.wsp
T2        Hydraulic analysis for structure ENOSVT01080046   Date: 12-SEP-96
T3        State Route 108 Over an Unnamed “The Branch” Trib., Enosburg, VT   EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q            425.0    550.0
SK          0.0286   0.0286
*
XS   EXITX    -25
GR         -180.8, 498.12   -173.9, 493.53     -4.8, 493.77
GR            0.0, 491.29      2.8, 490.98      5.5, 490.24      7.4, 490.13
GR           11.4, 490.98     18.1, 491.25     31.7, 491.30     39.3, 493.57
GR          152.9, 495.59    204.3, 498.75
*
N           0.033        0.046        0.032
SA                  -4.8         39.3
*
*           Removed: -161.3, 491.82 to keep WSPRO from putting water
*                     where in reality it is not part of streamflow.
*                     the point was taken in a localized swale and will
*                     not convey streamflow.
*
XS   FULLV      0  * * *   0.0167
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    498.36      0.0
GR            0.0, 498.25      0.0, 491.48      4.6, 491.23     11.8, 491.93
GR           22.3, 491.04     22.3, 498.47      0.0, 498.25
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      46.8 * *     60.0      6.2
N          0.030
*
*         Type 4 opening was attempted. However, since the appro ws was not
*             above the upstream ends of the wingwalls or along the road
*             embankments, flow “sees” a type 1 bridge opening.
*
*                    BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
*        CD            4      36.1      2.8    500.0     60.0
*        N            0.030
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     18      33.3     1
GR         -202.7, 503.33   -159.4, 498.80      0.0, 499.99      0.2, 502.13
GR           21.8, 502.15     21.8, 500.14     22.7, 500.18    192.5, 499.31
GR          222.1, 498.00    265.8, 500.21
*
*
AS   APPRO     58
GR         -106.0, 505.79    -66.9, 498.45    -38.4, 496.60     -9.1, 496.29
GR           -8.1, 496.03      0.0, 492.70      4.5, 491.83      7.6, 491.59
GR           18.8, 492.31     26.8, 491.99     36.8, 495.77     49.2, 496.42
GR           89.8, 497.06    119.7, 496.05    143.4, 496.07    162.4, 499.31
GR          201.5, 500.37
*
N           0.035        0.041        0.035
SA                  -9.1         36.8
*
HP 1 BRIDG 493.73 1 493.73
HP 2 BRIDG 493.73 * *  425
HP 1 APPRO 495.32 1 495.32
HP 2 APPRO 495.32 * *  425
*
HP 1 BRIDG 494.16 1 494.16
HP 2 BRIDG 494.16 * *  550
HP 1 APPRO 495.90 1 495.90
HP 2 APPRO 495.90 * *  550
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File enos046.wsp
        Hydraulic analysis for structure ENOSVT01080046   Date: 12-SEP-96
        State Route 108 Over an Unnamed “The Branch” Trib., Enosburg, VT   EMB
           *** RUN DATE & TIME: 09-13-96  07:34

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       50      3713     22     27                          425
   493.73            50      3713     22     27  1.00      0     22      425

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.73     0.0    22.3    50.0    3713.     425.   8.50

X STA.        0.0        1.7        2.8        3.7        4.6        5.5
  A(I)             3.9        2.5        2.4        2.2        2.2
  V(I)            5.48       8.39       8.99       9.71       9.68

X STA.        5.5        6.4        7.4        8.5        9.6       10.8
  A(I)             2.2        2.2        2.2        2.4        2.4
  V(I)            9.65       9.46       9.50       9.03       8.98

X STA.       10.8       12.2       13.5       14.7       15.8       16.8
  A(I)             2.5        2.5        2.3        2.4        2.3
  V(I)            8.48       8.53       9.07       8.99       9.40

X STA.       16.8       17.8       18.8       19.8       20.8       22.3
  A(I)             2.3        2.3        2.3        2.5        4.0
  V(I)            9.20       9.30       9.24       8.33       5.30

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      111      7571     42     43                         1025
   495.32           111      7571     42     43  1.00     -5     36     1025

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.32    -6.4    35.6   111.1    7571.     425.   3.83

X STA.       -6.4        0.3        2.5        4.1        5.6        6.9
  A(I)             9.2        6.1        5.4        5.2        4.9
  V(I)            2.30       3.46       3.95       4.08       4.36

X STA.        6.9        8.2        9.5       10.8       12.2       13.6
  A(I)             4.7        4.7        4.7        4.8        4.8
  V(I)            4.50       4.54       4.54       4.45       4.43

X STA.       13.6       15.1       16.6       18.2       19.9       21.6
  A(I)             4.8        5.0        5.1        5.1        5.1
  V(I)            4.42       4.28       4.20       4.18       4.17

X STA.       21.6       23.2       24.8       26.5       28.6       35.6
  A(I)             5.2        5.2        5.5        6.2        9.4
  V(I)            4.07       4.06       3.88       3.41       2.26
```

```
         U.S. Geological Survey WSPRO Input File enos046.wsp
         Hydraulic analysis for structure ENOSVT01080046   Date: 12-SEP-96
         State Route 108 Over an Unnamed “The Branch” Trib., Enosburg, VT   EMB
            *** RUN DATE & TIME: 09-13-96  07:34

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       60      4873     22     28                          552
    494.16            60      4873     22     28  1.00      0     22      552

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        494.16     0.0    22.3    59.6    4873.     550.   9.23

 X STA.        0.0        1.7        2.8        3.8        4.8        5.7
   A(I)            4.7        3.1        2.9        2.6        2.6
   V(I)            5.79       8.87       9.58      10.44      10.55

 X STA.        5.7        6.6        7.6        8.6        9.7       10.9
   A(I)            2.6        2.6        2.7        2.7        2.8
   V(I)           10.57      10.39      10.34      10.10       9.93

 X STA.       10.9       12.1       13.4       14.5       15.6       16.6
   A(I)            2.8        2.9        2.7        2.7        2.7
   V(I)            9.71       9.53      10.05      10.09      10.25

 X STA.       16.6       17.7       18.6       19.6       20.7       22.3
   A(I)            2.8        2.7        2.8        3.2        4.9
   V(I)            9.91      10.24       9.73       8.71       5.60

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              2      136     10207     45     46                         1351
              3        0         1      2      2                            0
    495.90           136     10208     47     49  1.00     -7     39     1316

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

          WSEL     LEW     REW    AREA        K        Q    VEL
        495.90    -7.8    39.3   136.4   10208.     550.   4.03

 X STA.       -7.8       -0.4        2.0        3.8        5.3        6.8
   A(I)           11.3        7.8        7.0        6.2        6.1
   V(I)            2.43       3.53       3.95       4.45       4.50

 X STA.        6.8        8.1        9.5       10.9       12.3       13.8
   A(I)            5.8        5.8        5.7        5.8        5.9
   V(I)            4.78       4.73       4.82       4.72       4.68

 X STA.       13.8       15.3       16.9       18.6       20.3       22.0
   A(I)            5.9        6.1        6.0        6.2        6.1
   V(I)            4.69       4.53       4.59       4.40       4.51

 X STA.       22.0       23.7       25.3       27.1       29.3       39.3
   A(I)            6.3        6.4        6.8        7.6       11.7
   V(I)            4.33       4.33       4.02       3.63       2.36
```

```
+++ BEGINNING PROFILE CALCULATIONS --   2

        U.S. Geological Survey WSPRO Input File enos046.wsp
        Hydraulic analysis for structure ENOSVT01080046   Date: 12-SEP-96
        State Route 108 Over an Unnamed "The Branch" Trib., Enosburg, VT   EMB
           *** RUN DATE & TIME: 09-13-96  07:34

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                             WSI,CRWS =    492.72     492.74

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

EXITX:XS   ******     -2       60  0.77 *****  493.52  492.74     425  492.74
       -24 ******     37     2562  1.00 ***** *******    1.00    7.05

FULLV:FV       25     -2       73  0.52  0.51  494.01 *******     425  493.49
         0     25     38     3452  1.00  0.00   -0.02    0.76    5.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       58     -3       69  0.59  0.80  494.84 *******     425  494.26
        58     58     33     3797  1.00  0.03    0.00    0.79    6.13
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =      425.     493.73

            <<<<<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       25      0       50  1.13 *****  494.85  493.73     425  493.73
         0     25     22     3702  1.00 ***** *******    1.00    8.52

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.36 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      18.        <<<<<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       11     -5      111  0.23  0.08  495.55  493.95     425  495.32
        58     12     36     7589  1.00  0.62   -0.02    0.41    3.82

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.390  0.207    6081.     2.    25.   495.25

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -25.    -3.    37.    425.    2562.      60.    7.05  492.74
   FULLV:FV       0.    -3.    38.    425.    3452.      73.    5.79  493.49
   BRIDG:BR       0.     0.    22.    425.    3702.      50.    8.52  493.73
   RDWAY:RG      18.**************      0.******************    1.00********
   APPRO:AS      58.    -6.    36.    425.    7589.     111.    3.82  495.32

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    25.    6081.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    492.74    1.00  490.13  498.75************  0.77  493.52  492.74
   FULLV:FV  ********    0.76  490.55  499.17  0.51  0.00  0.52  494.01  493.49
   BRIDG:BR    493.73    1.00  491.04  498.47************  1.13  494.85  493.73
   RDWAY:RG  ****************  498.00  503.33**********************************
   APPRO:AS    493.95    0.41  491.59  505.79  0.08  0.62  0.23  495.55  495.32
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File enos046.wsp
       Hydraulic analysis for structure ENOSVT01080046   Date: 12-SEP-96
       State Route 108 Over an Unnamed “The Branch” Trib., Enosburg, VT   EMB
          *** RUN DATE & TIME: 09-13-96  07:34

 ===015 WSI IN WRONG FLOW REGIME AT SECID “EXITX”:  USED WSI = CRWS.
                            WSI,CRWS =   493.00     493.06

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

EXITX:XS   ******     -2       73  0.88 *****  493.94  493.06     550  493.06
       -24 ******     38     3424  1.00 ***** *******    1.00    7.53

FULLV:FV       25     -3       87  0.62  0.50  494.43 *******     550  493.81
         0     25     39     4444  1.00  0.00   -0.01    0.78    6.33
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.81     494.59     494.29

 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.31     505.79    0.50

 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.31     505.79     494.29

APPRO:AS       58     -4       82  0.70  0.81  495.30  494.29     550  494.60
        58     58     34     4871  1.00  0.04    0.02    0.81    6.70
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID “BRIDG”     Q,CRWS =     550.     494.16

            <<<<<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       25      0       60  1.33 *****  495.49  494.16     550  494.16
         0     25     22     4872  1.00 ***** *******    1.00    9.23

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.36 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      18.        <<<<<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       11     -7      137  0.25  0.07  496.16  494.29     550  495.90
        58     12     39    10226  1.00  0.60    0.00    0.42    4.03

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.418  0.231    7879.     3.    25.   495.83

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -25.    -3.    38.    550.   3424.      73.    7.53  493.06
   FULLV:FV       0.    -4.    39.    550.   4444.      87.    6.33  493.81
   BRIDG:BR       0.     0.    22.    550.   4872.      60.    9.23  494.16
   RDWAY:RG      18.**************      0.******************    1.00********
   APPRO:AS      58.    -8.    39.    550.  10226.     137.    4.03  495.90

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    25.    7879.

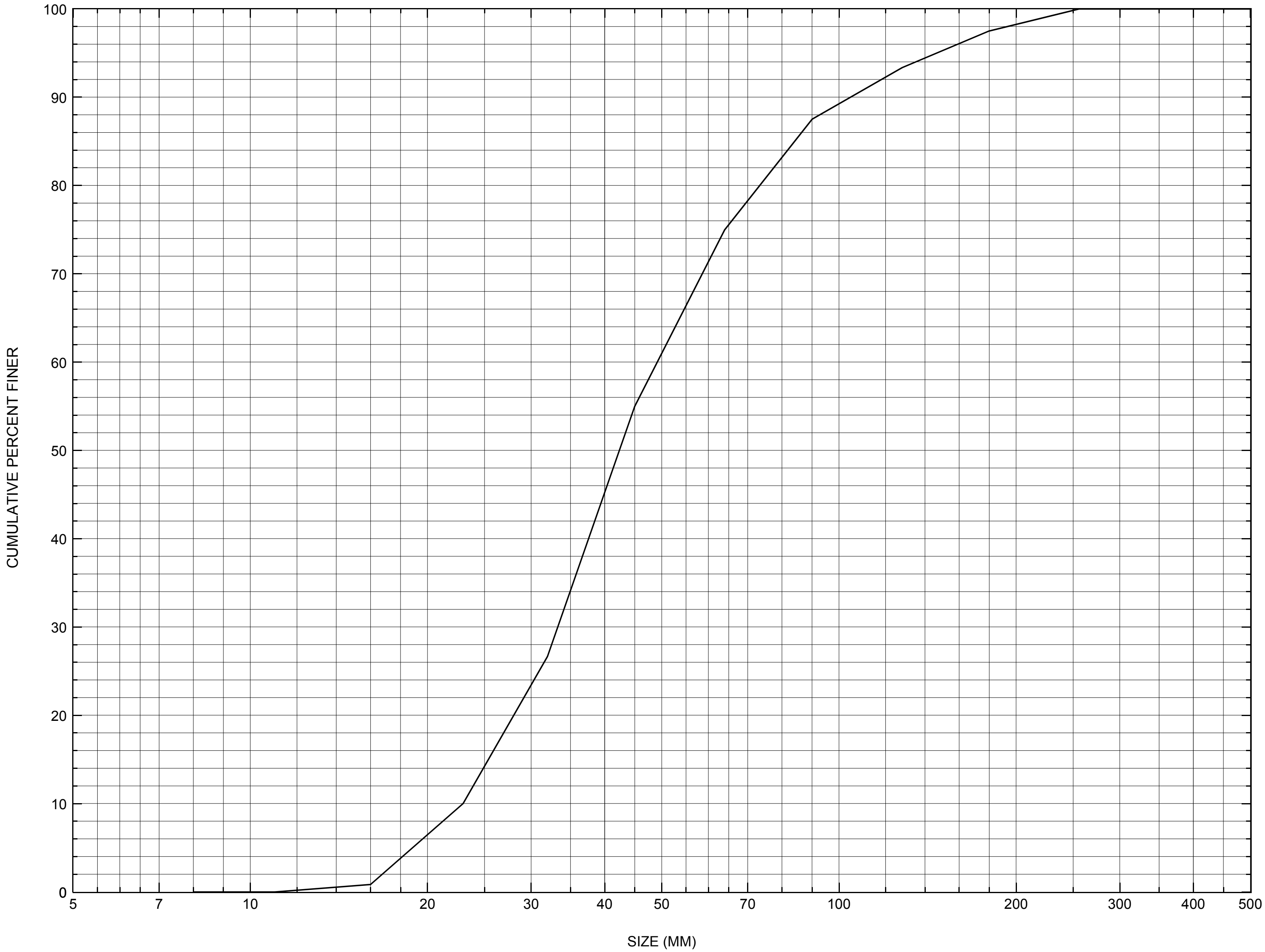
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    493.06    1.00  490.13  498.75************  0.88  493.94  493.06
   FULLV:FV  ********    0.78  490.55  499.17  0.50  0.00  0.62  494.43  493.81
   BRIDG:BR    494.16    1.00  491.04  498.47************  1.33  495.49  494.16
   RDWAY:RG  ****************  498.00  503.33**********************************
   APPRO:AS    494.29    0.42  491.59  505.79  0.07  0.60  0.25  496.16  495.90
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one pebble count transect at the channel approach of structure ENOSVT01080046, in Enosburg, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ENOSVT01080046

General Location Descriptive

Data collected by *(First Initial, Full last name)* L. MEDALIE

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)* 000880

Waterway *(I - 6)* Unnamed “The Branch” Tributary

Road Name *(I - 7):* -

Route Number VT108

Vicinity *(I - 9)* 4.2 MI S JCT. VT.105 W

Topographic Map Bakersfield

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44511

Longitude *(i - 17; nnnnn.n)* 72482

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20002700460603

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

Maximum span length *(I - 48; nnnn)* 0022

Year built *(I - 27; YYYY)* 1952

Structure length *(I - 49; nnnnnn)* 000025

Average daily traffic, ADT *(I - 29; nnnnnn)* 001110

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

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

Channel & Protection *(I - 61; n)* 8

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

Waterway adequacy *(I - 71; n)* 4

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

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

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 22.0

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

Vertical clearance from streambed (*nnn.n ft*) 7.0

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

Waterway of full opening (*nnn.n* ft^2) 154.0

Comments:

The structural inspection report of 8/2/93 indicates the structure is a concrete slab type bridge. The concrete abutment walls are reported in “like new” condition. The wingwalls have some hairline cracks with areas of minor to moderate leakage noted. The footings are not exposed. The waterway makes a moderate turn through structure. The structure also is used as cattle pass. There is no apparent settlement noted. The report indicates extremely low flow. No bank erosion or debris problems are noted. The riprap present is natural stone according to the report.

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: Stone and gravel

Discharge Data (*cfs*): $Q_{2.33}$ - Q_{10} - Q_{25} -

Q_{50} - Q_{100} - Q_{500} -

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

Estimated Discharge (*cfs*): - Velocity at Q - (*ft/s*): -

Ice conditions (*Heavy, Moderate, Light*) : - Debris (*Heavy, Moderate, Light*): -

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): -

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

Watershed storage area (*in percent*): - %

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*)	-	-	-	-	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

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

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

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

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

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

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

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 1.55 mi^2 Lake and pond area 0 mi^2
Watershed storage *(ST)* 0 %
Bridge site elevation 453 ft Headwater elevation 1404 ft
Main channel length 3.05 mi
10% channel length elevation 505 ft 85% channel length elevation 1030 ft
Main channel slope *(S)* 229.51 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)*: 07 / 1951

Project Number F 151(3) Minimum channel bed elevation: 464.5

Low superstructure elevation: USLAB 451.46 DSLAB 451.46 USRAB 451.50 DSRAB 451.50

Benchmark location description:

Benchmark #8, [spike in trunk or root of] a 42 inch maple tree, elevation 449.32, located approximately 80 feet right bankward from the right abutment and 40 feet upstream, perpendicularly from the roadway centerline.

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: 440.7

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? Y *If no, type ctrl-n bi* Number of borings taken: 3

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

Briefly describe material at foundation bottom elevation or around piles:

Gravel

Comments:

Other elevation points are at the top of the upstream left and right wingwalls 453.09 and 453.13, respectively.

Cross-sectional Data

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

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

Comments: **Upstream channel cross section at stationing 0 + 38.5, 11.5 feet from the centerline of the road way on the bridge deck. The channel baseline runs along the right bank parallel to and 6 feet from the streamward face of the right abutment.**

Station	-29.1	-28.9	-27.0	-12.0	-10.0	-8.3	-7.3	-6.0			
Feature	LCL	BLB	footing edge			footing edge	BRB	LCR			
Low cord elevation	451.5							451.5			
Bed elevation		444.5	t442.7	444.5	444.7	t442.7	444.4				
Low cord to bed length			b440.7			b440.7					

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

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

Comments: **Downstream channel cross section at stationing 0 + 61.5, 11.5 feet from the centerline of the roadway on the bridge deck.**

Station	-29.3	-29.0	-27.0	-19.3	-18.0	-10.0	-8.4	-6.7	-6.5		
Feature	LCL	BLB	footing edge				footing edge	BRB	LCR		
Low cord elevation	451.5								451.5		
Bed elevation		444.5	t442.7	444.5	443.8	444.4	t442.7	444.5			
Low cord to bed length			b440.7				b440.7				

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **3/12/96**
Computerized by: **RB** Date: **3/12/96**
Reviewd by: **EMB** Date: **9/12/96**

Structure Number **ENOSVT01080046**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. MEDALIE** Date *(MM/DD/YY)* **6** / **29** / 19**95**

2. Highway District Number **08** Mile marker **000880**

County **Franklin (011)** Town **ENOSBURG (23875)**

Waterway *(I - 6)* **UNNAMED BROOK** Road Name **VT 108**

Route Number **VT 108** Hydrologic Unit Code: **02010007**

3. Descriptive comments:
Located 4.2 miles south of the junction with VT 105.

B. Bridge Deck Observations

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

5. Ambient water surface... US **2** UB **2** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **25** *(feet)* Span length **22** *(feet)* Bridge width **33.3** *(feet)*

Road approach to bridge:

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

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

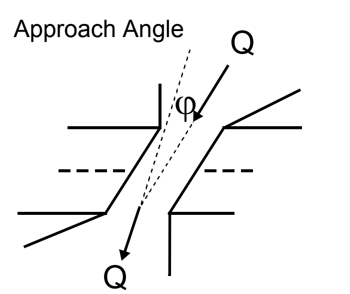
10. Embankment slope (*run / rise in feet / foot*):
US left **3.1:1** US right **2.6:1**

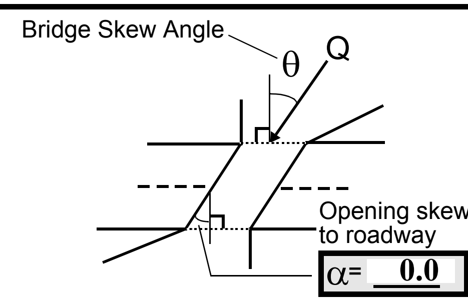
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

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





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **68** feet **US** *(US, UB, DS)* to **120** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **42** feet **DS** *(US, UB, DS)* to **70** feet **DS**

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

18. Bridge Type: **4**

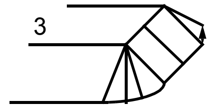
1a- Vertical abutments with wingwalls

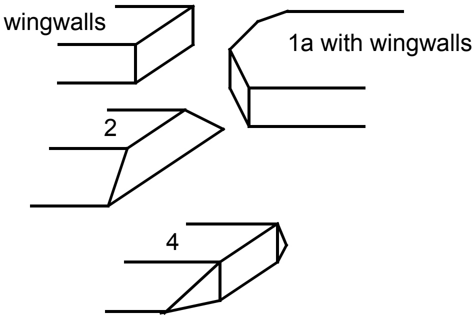
1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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





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

7. Values are from the VT AOT files. Measured span length = 22.8 feet, bridge length = 25.8 feet, and bridge width = 33.8 feet.

8. The road on the right bank gets slightly lower than the bridge 40 feet away.

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
25.5	**3.5**			**4.0**	**1**	**1**	**542**	**243**	**1**	**1**

23. Bank width **20.0** 24. Channel width **20.0** 25. Thalweg depth **46.0** 29. Bed Material **342**

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

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

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

26. There is no tree coverage on the banks; there is only pasture grass and brush.

27. On the left bank there is a bedrock outcrop from 43 to 51 feet US.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **80** 35. Mid-bar width: **6**

36. Point bar extent: **55** feet **US** (US, UB) to **90** feet **US** (US, UB, DS) positioned **30** %LB to **80** %RB

37. Material: **34**

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

This bar is not vegetated.

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

41. Mid-bank distance: **94** 42. Cut bank extent: **68** feet **US** (US, UB) to **120** 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.):

-

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
27.0		**-**		**2**	**7**	**7**	**0**

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

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

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

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

43

63. There is about equal distribution of gravel and cobble for the bed.

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- 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

65. Some debris is caught in a barbed wire fence, which crosses the channel DS. There was no debris accumulation under the bridge or upstream.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		10	90	0	0	-	-	90.0
RABUT	1	0	90			0	0	22.5

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

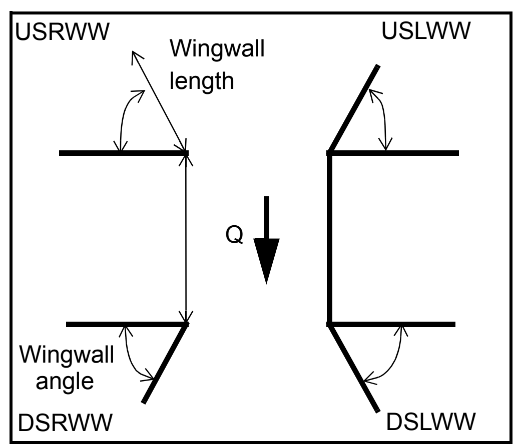
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

-
-
1
-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						22.5	
USRWW:	Y		1		0	-	
DSLWW:	-		-		Y	36.0	
DSRWW:	1		0		-	36.0	

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

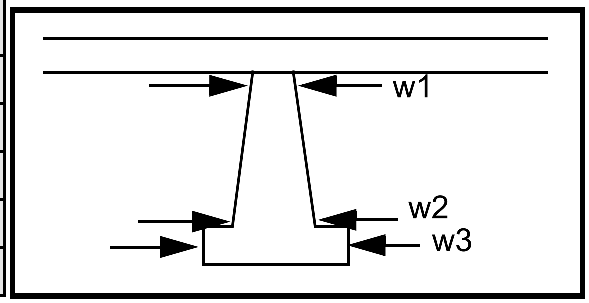
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
3
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				60.0	12.0	60.0
Pier 2				12.5	60.0	12.5
Pier 3			-	60.0	12.5	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	ere	tly	walls	nstre	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	are	large	.	am	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	mino	r	Larg	end	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	r	crac	e,	of	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	crac	ks in	class	the	*Y- yes; N- no*
91. Attack ∠ (BF)	ks in	the	2,	DS	
92. Pushed	all	US	boul-	right	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	the	left	ders	wing	
95. Cross-members	wing	and	pro-	wall.	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	walls	DS	tect		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	,	left	the		
98. Exposure depth	sligh	wing	dow		

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

N
-
-
-

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

Bank width (BF) - Channel width (Amb) - Thalweg depth (Amb) - Bed Material -

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

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

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

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

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

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

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

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

Material: -_____

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

-

NO PIERS

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

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

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

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

1
342
524
1

Is channel scour present? 0____ *(Y or if N type ctrl-n cs)* Mid-scour distance: 342____

Scour dimensions: Length 0_____ Width 0_____ Depth: -_____ Positioned -____ %LB to The %RB

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

re is a single large tree 78 feet DS on the left bank. There is a debris pile across the channel at 33 feet and another at 50 feet DS. However, flows would not be impeded because of broad low bank across the DS face and exit of the bridge. A barbed wire fence also goes across the channel at 50 feet DS but would not affect flow.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

N

-

NO DROP STRUCTURE

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: ENOSVT01080046 Town: Enosburg
Road Number: VT 108 County: Franklin
Stream: Unnamed “The Branch” tributary

Initials EMB Date: 9/13/96 Checked:

I. 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	425	550	0
Main Channel Area, ft2	111	136	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	42	45	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	2	0
D50 of channel, ft	0.139	0.139	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	2.6	3.0	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	0.0	ERR
Total conveyance, approach	7571	10208	0
Conveyance, main channel	7571	10208	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	425.0	550.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	3.8	4.0	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	6.8	7.0	N/A
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	0.0	N/A

Results

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

Main Channel	0	0	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)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	111	136	0
Main channel width, ft	42	45	0
y1, main channel depth, ft	2.64	3.02	ERR
Bridge Section			
(Q) total discharge, cfs	425	550	0
(Q) discharge thru bridge, cfs	425	550	
Main channel conveyance	3713	4873	
Total conveyance	3713	4873	
Q2, bridge MC discharge,cfs	425	550	ERR
Main channel area, ft2	50	60	0
Main channel width (skewed), ft	22.3	22.3	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	22.3	22.3	0
y_bridge (avg. depth at br.), ft	2.24	2.67	ERR
Dm, median (1.25*D50), ft	0.17375	0.17375	0
y2, depth in contraction,ft	2.55	3.18	ERR
ys, scour depth (y2-ybridge), ft	0.31	0.51	N/A

ARMORING			
D90	0.343	0.343	
D95	0.4813	0.4813	
Critical grain size,Dc, ft	0.3798	0.4139	ERR
Decimal-percent coarser than Dc	0.083	0.069	
Depth to armoring,ft	12.59	16.75	ERR

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	425	550	0	425	550	0
a', abut.length blocking flow, ft	6.4	7.8	0	13.3	17	0
Ae, area of blocked flow ft2	8.8	12.6	0	29.2	37.7	0
Qe, discharge blocked abut.,cfs	20.3	32.1	0	97	132.7	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.31	2.55	ERR	3.32	3.52	ERR
ya, depth of f/p flow, ft	1.38	1.62	ERR	2.20	2.22	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	0	90	90	0
K2	1.00	1.00	0.00	1.00	1.00	0.00
Fr, froude number f/p flow	0.347	0.353	ERR	0.395	0.417	ERR
ys, scour depth, ft	3.97	4.75	N/A	7.23	8.03	N/A

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

a'(abut length blocked, ft)	6.4	7.8	0	13.3	17	0
y1 (depth f/p flow, ft)	1.38	1.62	ERR	2.20	2.22	ERR
a'/y1	4.65	4.83	ERR	6.06	7.67	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	0.00	1.00	1.00	0.00
Froude no. f/p flow	0.35	0.35	N/A	0.40	0.42	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	1		1	1	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	2.2	2.7		2.2	2.7	
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0
Fr>0.8 (vertical abut.)	0.92	1.13	ERR	0.92	1.13	ERR