LEVEL II SCOUR ANALYSIS FOR BRIDGE 49 (BENNCYHUNT0049) on HUNT STREET, crossing the WALLOOMSAC RIVER, BENNINGTON, VERMONT

U.S. Geological Survey
Open-File Report 97-367

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

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By SCOTT A. OLSON and LAURA MEDALIE

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Pembroke, New Hampshire

1997

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

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 49 (BENNCYHUNT0049) ON HUNT STREET, CROSSING THE WALLOOMSAC RIVER, BENNINGTON VERMONT

***By* Scott A. Olson and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BENNCYHUNT0049 on the Hunt Street crossing of the Walloomsac River, Bennington, 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 southwestern Vermont. The 34.1-mi^2 drainage area is a predominantly rural and forested basin. The bridge site is located within an urban setting in the Town of Bennington with buildings and parking lots on overbanks except for the downstream left bank which is covered by trees and brush.

In the study area, the Walloomsac River has a straight, incised channel. The confluence of the Walloomsac River and Roaring Branch is 140 feet downstream. The channel has a slope of approximately 0.01 ft/ft, an average channel top width of 54 ft and an average bank height of 6 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 76.8 mm (0.252 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 31, 1996, indicated that the reach was stable.

The Hunt Street crossing of the Walloomsac River is a 51-ft-long, two-lane bridge consisting of one 49-foot steel span (Vermont Agency of Transportation, written communication, December 13, 1995). The bridge is supported by vertical, concrete abutments. The right abutment has a spill-through slope along its face. The channel is skewed approximately 25 degrees to the opening and the opening-skew-to-roadway is 20 degrees.

Scour countermeasures at the site include type-2 stone fill (less than 36 inches diameter) on the spill through slope on the right abutment and along the base of the left abutment. Type-2 stone fill also protects the channel banks upstream and downstream of the bridge for a minimum distance of 17 feet from the respective bridge faces. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). 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 computed for all modelled flows ranged from 0.9 to 5.0 ft. The worst-case contraction scour occurred at the 500-year discharge. Computed left abutment scour ranged from 15.3 to 16.5 ft. with the worst-case scour occurring at the incipient roadway-overtopping discharge. Computed right abutment scour ranged from 6.0 to 8.7 ft. with the worst-case scour occurring 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.

Bennington, VT. Quadrangle, 1:24,000, 1954

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 BENNCYHUNT0049 ***Stream*** Walloomsac River

County Bennington ***Road*** Hunt St. ***District*** 1

Description of Bridge

Bridge length 51 ***ft*** ***Bridge width*** 24.7 ***ft*** ***Max span length*** 49 ***ft***

Alignment of bridge to road (on curve or straight) Slight curve.

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

Stone fill on abutment? Yes ***Date of inspection*** 7/31/96

Description of stone fill Type-2 stone fill is located along the base of the left abutment and on the spill-through slope of the right abutment.

Abutments are concrete. The right abutment has a spill-through slope along its face.

Y 25

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

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	7/31/96	0	0
Level II	7/31/96	0	0

Potential for debris Moderate. The bridge is in an urban setting.

Describe any features near or at the bridge that may affect flow (include observation date) July 31, 1996. The low chord is near the elevation of the tops of banks, increasing the potential for the bridge to capture debris. The confluence of Walloomsac River and Roaring Branch is 140 feet downstream.

Description of the Geomorphic Setting

General topography The channel is located on a delta and thus the channel overbanks are flat with no distinct valley.

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

Date of inspection 7/31/96

DS left: Steep channel bank to a wide flood plain.

DS right: Steep, high channel bank to a wide, flat overbank.

US left: Steep, high channel bank to a wide, flat overbank.

US right: Steep channel bank to a wide flood plain.

Description of the Channel

Average top width 54 ***ft*** ***Average depth*** 6 ***ft***

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

The stream is straight and incised with alluvial boundaries.

7/31/96

Vegetative co Heavily vegetated with brush and trees.

DS left: Brush and trees with a parking lot on the overbank.

DS right: Brush and trees with a suburban setting on the overbank.

US left: Brush and trees with a parking lot on the overbank.

US right: Y

Do banks appear stable? July 31, 1996. ***If not, describe location and type of instability and date of observation.***

July 31, 1996. None.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 34.1 ***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***: The drainage is rural, but the bridge is located in an urban setting.

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

USGS gage description Walloomsac River nr N. Bennington, VT

USGS gage number 01334000

Gage drainage area 111 ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 5,300 ***ft***^{3}***/s*** ***Q500*** 8,150 ***ft***^{3}***/s***

The 100- and 500-year discharges were from flood frequency estimates for the Walloomsac River in the Flood Insurance Study for the Town of Bennington (Federal Emergency Management Agency, 1986). These discharges were within a range defined by flood frequency curves determined from several empirical methods and extrapolated to the 500-year recurrance interval (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). The discharges were within eight percent of discharges found in the VTAOT database for this structure (written communication, May 1994).

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 To obtain VTAOT plans' datum, subtract 15.9 ft from the survey datum. To obtain NGVD, add 113.37 ft to survey.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the right end of the downstream bridge curb (elev. 514.62 ft, arbitrary survey datum). RM2 is a chiseled X on top of the left end of the downstream bridge curb (elev. 514.21 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
SECA	-80	2	Downstream section, templated from EXITX, to the location of the FEMA section used for starting water surface.
EXITX	-49	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	76	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 0.040 to 0.047, and overbank "n" values ranged from 0.030 to 0.077.

To determine the starting water surface for this model, the exit section (EXITX) was templated to a location 80 feet downstream of the bridge. Water-surface elevations at this location were available from the Flood Insurance Study model for the Walloomsac River (Federal Emergency Management Agency, 1986). These water-surface elevations from the Flood Insurance Study were found to be supercritical. Since, supercritical flow will not exist in a natural channel for any extended period of time (USGS, 1984), critical depth at the exit section is considered a sufficient solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 514.0 ***ft***
Average low steel elevation 510.3 ***ft***

100-year discharge 5,300 ***ft^3/s***
Water-surface elevation in bridge opening 510.2 ***ft***
Road overtopping? Y ***Discharge over road*** 234 ***ft^3/s***
Area of flow in bridge opening 425 ***ft^2***
Average velocity in bridge opening 11.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.7 ***ft/s***

Water-surface elevation at Approach section with bridge 514.4
Water-surface elevation at Approach section without bridge 509.3
Amount of backwater caused by bridge 5.1 ***ft***

500-year discharge 8,150 ***ft^3/s***
Water-surface elevation in bridge opening 510.2 ***ft***
Road overtopping? Y ***Discharge over road*** 1,760 ***/s***
Area of flow in bridge opening 425 ***ft^2***
Average velocity in bridge opening 14.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 17.3 ***/s***

Water-surface elevation at Approach section with bridge 516.2
Water-surface elevation at Approach section without bridge 512.4
Amount of backwater caused by bridge 3.8

Incipient overtopping discharge 4,530 ***ft^3/s***
Water-surface elevation in bridge opening 510.2 ***ft***
Area of flow in bridge opening 425 ***ft^2***
Average velocity in bridge opening 10.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.4 ***ft/s***

Water-surface elevation at Approach section with bridge 513.2
Water-surface elevation at Approach section without bridge 508.7
Amount of backwater caused by bridge 4.5 ***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.

All modelled discharges resulted in 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 was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2.

Additional estimates of contraction scour were also computed by use of Laursen’s clear-water scour equation (Richardson and others, 1995, p. 32, equation 20) and the results are presented in Appendix F. Furthermore, for the discharges resulting in unsubmerged orifice flow, contraction scour was also computed by substituting estimates for the depth of flow at the downstream bridge face into the Laursen’s clear-water equation. Contraction scour results with respect to these substitutions also are provided in Appendix F.

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

Because the influence of scour processes on the spill-through embankment material of the right abutment is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depths computed at the toe of the spill-through embankment were applied for the entire area of the right embankment, as shown in figure 8.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.1	5.0	0.9
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	16.1	15.3	16.5
Right abutment	7.1	8.7	6.0
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	3.3	3.9	3.1
Right abutment	2.9	3.5	2.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

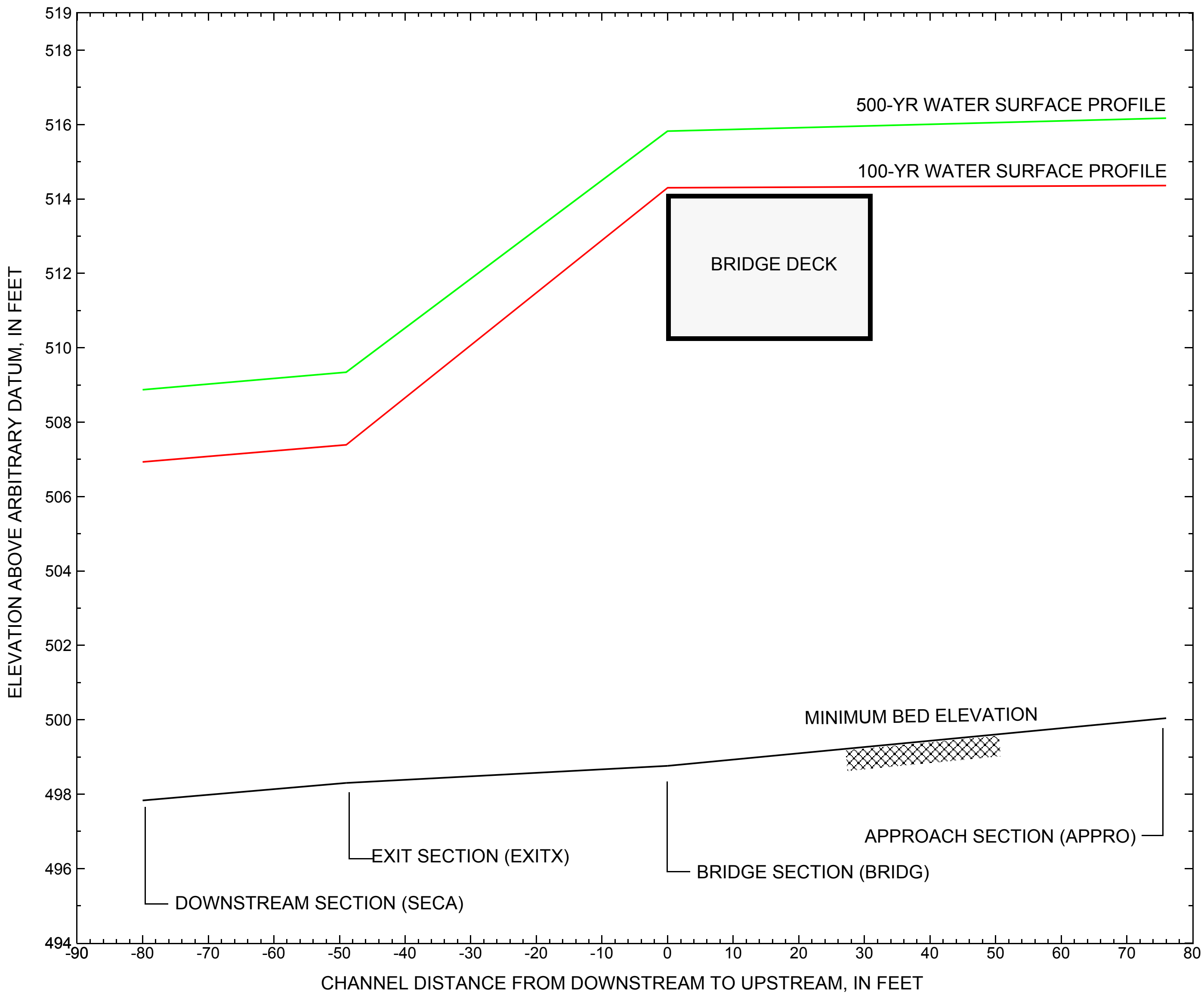

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BENNCYHUNT0049 on Hunt Street, crossing the Walloomsac River, Bennington, Vermont.

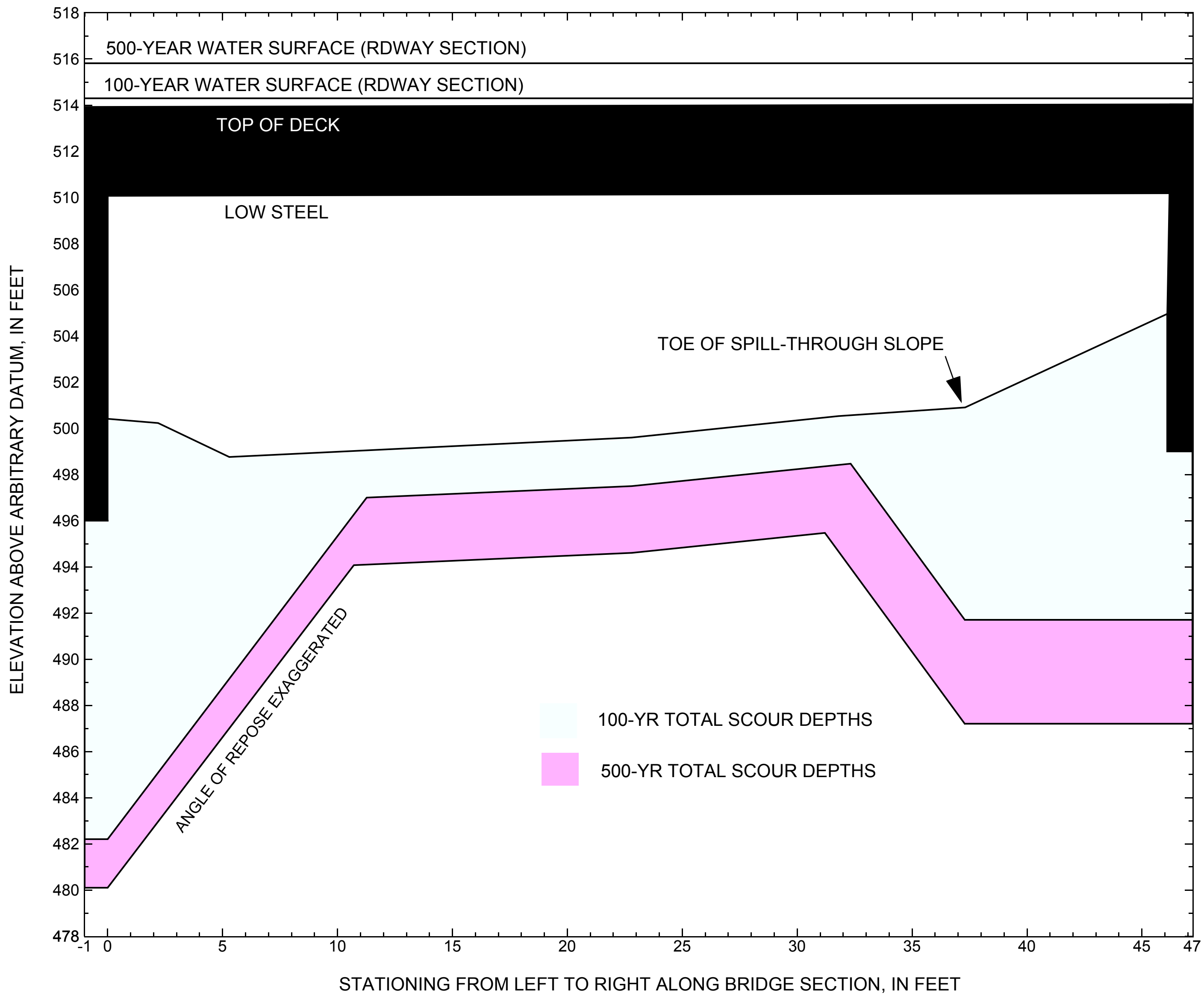

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BENNCYHUNT0049 on Hunt Street, crossing the Walloomsac River, Bennington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BENNCYHUNT0049 on Hunt Street, crossing the Walloomsac River, Bennington, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 5,300 cubic-feet per second											
Left abutment	0.0	494.0	510.1	496	500.4	2.1	16.1	--	18.2	482.2	-14
Right toe	37.3	--	--	--	500.9	2.1	7.1	--	9.2	491.7	--
Right abutment	46.2	494.1	510.2	499	505.0	--	--	--	--	--	-7

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure BENNCYHUNT0049 on Hunt Street, crossing the Walloomsac River, Bennington, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 8,150 cubic-feet per second											
Left abutment	0.0	494.0	510.1	496	500.4	5.0	15.3	--	20.3	480.1	-16
Right toe	37.3	--	--	--	500.9	5.0	8.7	--	13.7	487.2	--
Right abutment	46.2	494.1	510.2	499	505.0	--	--	--	--	--	-12

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File benn049.wsp
T2        Hydraulic analysis for structure BENNCYHUNT0049   Date: 26-DEC-96
T3        BENNINGTON BRIDGE #49 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
Q           5300 8150 4530
WS          505.47 506.36 505.01
*
XT   EXTEM    -49
GR          -84.8, 512.51    -62.1, 513.02    -35.9, 505.06    -14.6, 504.91
GR            0.0, 501.75      7.7, 499.35     13.6, 498.56     23.8, 498.46
GR           34.7, 498.30     35.3, 499.48     44.5, 505.00     65.1, 517.12
*
*             The exit section is templated to 80 feet downstream of the
*             bridge using a slope of 0.015 (determined from thalweg
*             points 126 and 127). At this location, the water surface
*             elevation is known from the Flood Insurance Study Model
*
XS   SECA     -80 * * * 0.015
GT
N           0.077        0.045
SA                   0.0
*
XS   EXITX    -49
GT             0
N           0.077        0.045
SA                   0.0
*
XS   FULLV     0 * * * 0.007
*
BR   BRIDG     0 510.13 20
GR            0.0, 510.07      0.0, 500.41      2.2, 500.23      5.3, 498.76
GR           12.0, 499.14     22.8, 499.60     31.8, 500.53     37.3, 500.90
GR           46.2, 504.96     46.2, 510.18      0.0, 510.07
N             0.040
CD            1      30.9
*
XR   RDWAY    15 25
GR         -104.6, 526.86    -46.0, 513.24      0.0, 513.92     47.6, 514.03
GR           95.6, 514.12    103.6, 517.39
*
AS   APPRO     76
GR          -31.7, 525.17      0.0, 501.09      3.2, 500.72      8.7, 500.14
GR           17.8, 500.04     34.7, 500.50     36.4, 501.18     37.7, 501.38
GR           42.1, 504.60     52.3, 508.86    573.0, 518.31
N           0.047        0.030
SA                  52.3
*
HP 1 BRIDG   510.18 1 510.18
HP 2 BRIDG   510.18 * * 4990
HP 1 BRIDG   508.69 1 508.69
HP 2 RDWAY   514.30 * * 234
HP 1 APPRO   514.36 1 514.36
HP 2 APPRO   514.36 * * 5300
HP 1 BRIDG   510.18 1 510.18
HP 2 BRIDG   510.18 * * 6330
HP 2 RDWAY   515.82 * * 1758
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. Geological Survey WSPRO Input File benn049.wsp
        Hydraulic analysis for structure BENNCYHUNT0049   Date: 26-DEC-96
        BENNINGTON BRIDGE #49 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     425.  40646.     0.   103.                            0.
   510.18          425.  40646.     0.   103.  1.00     0.    46.       0.

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     362.  46423.    43.    57.                         5940.
   508.69          362.  46423.    43.    57.  1.00     0.    46.   5940.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA         K        Q    VEL
       510.18     0.0    46.2   424.6   40646.    4990.  11.75
 X STA.         0.0         3.7         5.9         7.8         9.6        11.4
   A(I)             34.4        22.5        20.6        18.7        19.0
   V(I)             7.25       11.09       12.13       13.33       13.10

 X STA.        11.4        13.2        15.0        16.8        18.7        20.5
   A(I)             18.3        18.7        18.3        18.6        18.5
   V(I)            13.65       13.35       13.65       13.42       13.52

 X STA.        20.5        22.4        24.3        26.3        28.3        30.4
   A(I)             18.4        18.8        19.0        19.6        19.3
   V(I)            13.57       13.30       13.13       12.73       12.92

 X STA.        30.4        32.7        35.0        37.5        40.6        46.2
   A(I)             20.7        20.7        22.1        24.3        34.3
   V(I)            12.07       12.08       11.29       10.27        7.28

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =      15.
         WSEL     LEW     REW    AREA         K        Q    VEL
       514.30   -50.6    96.0    61.8      910.     234.   3.78
 X STA.       -50.6       -45.2       -42.7       -40.3       -37.7       -34.9
   A(I)              3.3         2.5         2.5         2.5         2.5
   V(I)             3.56        4.69        4.73        4.71        4.64

 X STA.       -34.9       -31.9       -28.6       -24.8       -20.7       -15.6
   A(I)              2.6         2.7         2.9         3.0         3.3
   V(I)             4.45        4.28        4.03        3.91        3.58

 X STA.       -15.6        -9.1         0.5         7.8        16.0        24.9
   A(I)              3.7         4.2         2.7         2.9         2.9
   V(I)             3.17        2.75        4.31        4.07        3.97

 X STA.        24.9        34.9        46.0        59.5        75.1        96.0
   A(I)              3.1         3.2         3.5         3.6         4.1
   V(I)             3.74        3.69        3.33        3.22        2.84

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      76.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     771.  114292.    70.    76.                        14555.
             2     833.   81237.   303.   303.                         7842.
   514.36         1605.  195530.   373.   379.  1.13   -17.   355.  17771.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      76.
         WSEL     LEW     REW    AREA         K        Q    VEL
       514.36   -17.5   355.4  1604.8  195530.    5300.   3.30
 X STA.       -17.5        -0.6         4.5         9.0        13.1        17.1
   A(I)            107.9        69.5        62.5        57.9        57.8
   V(I)             2.46        3.81        4.24        4.57        4.59

 X STA.        17.1        21.0        24.9        28.8        32.9        37.1
   A(I)             55.9        55.3        55.1        56.2        58.2
   V(I)             4.74        4.79        4.81        4.72        4.55

 X STA.        37.1        43.6        56.3        69.8        85.1       101.8
   A(I)             71.1        85.6        71.7        77.5        79.3
   V(I)             3.73        3.10        3.70        3.42        3.34

 X STA.       101.8       121.6       145.3       174.2       216.1       355.4
   A(I)             87.5        95.3       102.6       122.0       175.9
   V(I)             3.03        2.78        2.58        2.17        1.51
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      U.S. Geological Survey WSPRO Input File benn049.wsp
      Hydraulic analysis for structure BENNCYHUNT0049   Date: 26-DEC-96
      BENNINGTON BRIDGE #49 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     425.  40646.     0.   103.                            0.
   510.18          425.  40646.     0.   103.  1.00     0.    46.       0.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       510.18     0.0    46.2   424.6   40646.    6330.  14.91
 X STA.         0.0         3.7         5.9         7.8         9.6        11.4
  A(I)             34.4        22.5        20.6        18.7        19.0
  V(I)             9.19       14.06       15.38       16.91       16.62

 X STA.        11.4        13.2        15.0        16.8        18.7        20.5
  A(I)             18.3        18.7        18.3        18.6        18.5
  V(I)            17.32       16.93       17.31       17.03       17.15

 X STA.        20.5        22.4        24.3        26.3        28.3        30.4
  A(I)             18.4        18.8        19.0        19.6        19.3
  V(I)            17.22       16.87       16.66       16.15       16.39

 X STA.        30.4        32.7        35.0        37.5        40.6        46.2
  A(I)             20.7        20.7        22.1        24.3        34.3
  V(I)            15.31       15.32       14.32       13.03        9.24

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =      15.
         WSEL     LEW     REW    AREA        K        Q    VEL
       515.82   -57.1    99.8   292.5   12077.    1758.   6.01
 X STA.       -57.1       -42.6       -35.2       -27.6       -19.6       -10.6
  A(I)             23.0        18.4        17.9        18.1        19.0
  V(I)             3.83        4.78        4.92        4.85        4.63

 X STA.       -10.6        -0.5         5.9        12.3        18.8        25.3
  A(I)             20.0        12.2        11.9        12.1        12.0
  V(I)             4.39        7.19        7.36        7.25        7.31

 X STA.        25.3        32.0        38.8        45.6        52.6        59.5
  A(I)             12.3        12.2        12.3        12.6        12.3
  V(I)             7.13        7.19        7.17        6.99        7.13

 X STA.        59.5        66.6        73.8        81.3        88.7        99.8
  A(I)             12.5        12.6        12.9        12.8        15.3
  V(I)             7.03        6.98        6.82        6.88        5.75

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      76.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     900.  144000.    72.    79.                        18032.
             2    1472.  173474.   403.   403.                        15971.
   516.17         2372.  317474.   475.   482.  1.07   -20.   455.  29053.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      76.
         WSEL     LEW     REW    AREA        K        Q    VEL
       516.17   -19.9   455.1  2372.0  317474.    8150.   3.44
 X STA.       -19.9         0.2         6.7        12.3        17.8        23.0
  A(I)            152.8       100.8        90.0        88.3        83.1
  V(I)             2.67        4.04        4.53        4.62        4.90

 X STA.        23.0        28.3        33.5        39.5        50.8        64.3
  A(I)             84.8        82.1        89.8       116.6        98.2
  V(I)             4.81        4.97        4.54        3.50        4.15

 X STA.        64.3        78.2        93.4       109.7       128.2       149.0
  A(I)             96.5       102.0       104.6       112.6       119.7
  V(I)             4.22        4.00        3.89        3.62        3.40

 X STA.       149.0       172.7       200.3       236.7       287.2       455.1
  A(I)            126.6       134.7       156.1       177.0       255.8
  V(I)             3.22        3.03        2.61        2.30        1.59
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WSPRO OUTPUT FILE (continued)

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         U.S. Geological Survey WSPRO Input File benn049.wsp
         Hydraulic analysis for structure BENNCYHUNT0049   Date: 26-DEC-96
         BENNINGTON BRIDGE #49 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO

     CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     425.   40646.     0.   103.                           0.
    510.18          425.   40646.     0.   103.  1.00     0.    46.      0.

     CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     333.   41027.    43.    55.                        5239.
    508.02          333.   41027.    43.    55.  1.00     0.    46.   5239.

     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        510.18     0.0    46.2   424.6   40646.    4530.  10.67
 X STA.         0.0         3.7         5.9         7.8         9.6        11.4
   A(I)             34.4        22.5        20.6        18.7        19.0
   V(I)             6.58       10.06       11.01       12.10       11.89

 X STA.        11.4        13.2        15.0        16.8        18.7        20.5
   A(I)             18.3        18.7        18.3        18.6        18.5
   V(I)            12.39       12.12       12.39       12.19       12.27

 X STA.        20.5        22.4        24.3        26.3        28.3        30.4
   A(I)             18.4        18.8        19.0        19.6        19.3
   V(I)            12.32       12.07       11.92       11.56       11.73

 X STA.        30.4        32.7        35.0        37.5        40.6        46.2
   A(I)             20.7        20.7        22.1        24.3        34.3
   V(I)            10.96       10.96       10.25        9.32        6.61

     CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      76.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     691.   96702.    68.    74.                       12470.
              2     517.   42930.   239.   239.                        4313.
    513.19         1207.  139632.   307.   313.  1.17   -16.   291.  12543.

     VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      76.
          WSEL     LEW     REW    AREA        K        Q    VEL
        513.19   -15.9   290.9  1207.2  139632.    4530.   3.75
 X STA.       -15.9        -1.1         3.4         7.2        10.7        14.0
   A(I)             83.0        55.0        47.9        45.7        44.0
   V(I)             2.73        4.12        4.73        4.95        5.15

 X STA.        14.0        17.2        20.4        23.7        26.9        30.2
   A(I)             41.5        42.7        41.8        42.5        42.2
   V(I)             5.46        5.30        5.42        5.33        5.37

 X STA.        30.2        33.6        37.2        42.6        54.6        69.2
   A(I)             43.0        44.4        55.2        71.6        60.7
   V(I)             5.27        5.10        4.10        3.16        3.73

 X STA.        69.2        86.2       106.5       131.9       168.7       290.9
   A(I)             66.0        71.5        79.2        93.9       135.5
   V(I)             3.43        3.17        2.86        2.41        1.67
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        U.S. Geological Survey WSPRO Input File benn049.wsp
        Hydraulic analysis for structure BENNCYHUNT0049   Date: 26-DEC-96
        BENNINGTON BRIDGE #49 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
 ===015 WSI IN WRONG FLOW REGIME AT SECID "SECA ":  USED WSI = CRWS.
                            WSI,CRWS =    505.47     506.93
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
SECA :XS   ******   -44.     468.  2.66 *****  509.59  506.93   5300.  506.93
      -80. ******    49.   45620.  1.34 ***** *******    1.02   11.31

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.04     507.32     507.39
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   506.43     517.12    0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   506.43     517.12     507.39
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "EXITX"
                   WSBEG,WSEND,CRWS =    507.39     517.12     507.39

EXITX:XS      31.   -44.     468.  2.66 *****  510.06  507.39   5300.  507.39
      -49.    31.    49.   45620.  1.34 ***** *******    1.02   11.31

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.81     508.69     507.74
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   506.89     517.46    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   506.89     517.46     507.74

FULLV:FV      49.   -47.     558.  1.90  0.53  510.58  507.74   5300.  508.69
        0.    49.    50.   56708.  1.35  0.00    0.00    0.81    9.49

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.95     509.29     508.34
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   508.19     525.17    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   508.19     525.17     508.34

APPRO:AS      76.   -11.     438.  2.31  0.79  511.59  508.34   5300.  509.27
       76.    76.    75.   47382.  1.02  0.21    0.00    0.95   12.09
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   508.08     511.83     512.13     510.13
 ===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      49.     0.     425.  2.15 *****  512.33  507.79   4990.  510.18
        0. ******    46.   40646.  1.00 ***** *******    0.68   11.75
     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.492  0.000  510.13 ****** ****** ******
    XSID:CODE     SRD   FLEN     HF    VHD      EGL      ERR       Q     WSEL
   RDWAY:RG       15.     51.  0.04  0.19  514.51    -0.01     234.  514.30
            Q   WLEN     LEW     REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    162.    71.    -51.     20.   1.1   0.6   4.2   3.8   0.8   3.1
   RT:     73.    76.     20.     96.   0.3   0.3   3.1   3.8   0.5   3.0

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS      45.   -17.    1605.  0.19  0.15  514.55  508.34   5300.  514.36
       76.    46.   355.  195530.  1.13  0.50   -0.01    0.30    3.30

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

   FIRST USER DEFINED TABLE.
     XSID:CODE     SRD     LEW     REW        Q         K      AREA     VEL    WSEL
    SECA :XS      -80.    -44.     49.   5300.   45620.      468.   11.31  506.93
    EXITX:XS      -49.    -44.     49.   5300.   45620.      468.   11.31  507.39
    FULLV:FV        0.    -47.     50.   5300.   56708.      558.    9.49  508.69
    BRIDG:BR        0.      0.     46.   4990.   40646.      425.   11.75  510.18
    RDWAY:RG       15.*******    162.     234.*********        0.    1.00  514.30
    APPRO:AS       76.    -17.    355.   5300.  195530.     1605.    3.30  514.36

 SECOND USER DEFINED TABLE.
     XSID:CODE     CRWS      FR#    YMIN     YMAX     HF     HO   VHD      EGL     WSEL
    SECA :XS     506.93     1.02  497.83  516.65************  2.66  509.59  506.93
    EXITX:XS     507.39     1.02  498.30  517.12************  2.66  510.06  507.39
    FULLV:FV     507.74     0.81  498.64  517.46  0.53  0.00  1.90  510.58  508.69
    BRIDG:BR     507.79     0.68  498.76  510.18************  2.15  512.33  510.18
    RDWAY:RG   ****************  513.24  526.86  0.04******  0.19  514.51  514.30
    APPRO:AS     508.34     0.30  500.04  525.17  0.15  0.50  0.19  514.55  514.36
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        U.S. Geological Survey WSPRO Input File benn049.wsp
        Hydraulic analysis for structure BENNCYHUNT0049   Date: 26-DEC-96
        BENNINGTON BRIDGE #49 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
 ===015 WSI IN WRONG FLOW REGIME AT SECID "SECA ":  USED WSI = CRWS.
                            WSI,CRWS =   506.36     508.87
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
SECA :XS   ******   -50.     657.  3.26 *****  512.13  508.87   8150.  508.87
      -80. ******    52.   69642.  1.36 ***** *******    1.00   12.41

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.02     509.28     509.34
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   508.37     517.12    0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   508.37     517.12     509.34
 ===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 "EXITX"
                  WSBEG,WSEND,CRWS =   509.34     517.12     509.34

EXITX:XS      31.   -50.     657.  3.26 *****  512.59  509.34   8150.  509.34
      -49.    31.    52.   69642.  1.36 ***** *******    1.00   12.41

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81     510.75     509.68
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   508.84     517.46    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   508.84     517.46     509.68

FULLV:FV      49.   -54.     770.  2.37  0.55  513.14  509.68   8150.  510.76
        0.    49.    54.   85386.  1.36  0.00    0.00    0.81   10.58

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.84     512.36     511.68
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   510.26     525.17    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   510.26     525.17     511.68

APPRO:AS      76.   -15.     974.  1.30  0.54  513.67  511.68   8150.  512.37
       76.    76.   246.  109604.  1.19  0.00   -0.01    0.83    8.37

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   510.76     510.13

            <<<<<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      49.     0.     425.  3.46 *****  513.64  509.06   6330.  510.18
        0. ******    46.   40646.  1.00 ***** *******    0.87   14.91
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  510.13 ****** ****** ******
    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       15.    51.  0.03  0.20  516.33   -0.01   1758.  515.82
            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    950.    78.   -57.    21.   2.6   2.0   7.3   6.1   2.5   3.1
   RT:    808.    79.    21.   100.   1.8   1.7   6.8   5.9   2.2   3.1

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS      45.   -20.    2370.  0.20  0.21  516.36  511.68   8150.  516.17
       76.    51.   455.  317204.  1.07  0.50   -0.01    0.28    3.44

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW    REW       Q         K      AREA     VEL    WSEL
   SECA :XS      -80.   -50.    52.   8150.   69642.     657.   12.41  508.87
   EXITX:XS      -49.   -50.    52.   8150.   69642.     657.   12.41  509.34
   FULLV:FV        0.   -54.    54.   8150.   85386.     770.   10.58  510.76
   BRIDG:BR        0.     0.    46.   6330.   40646.     425.   14.91  510.18
   RDWAY:RG       15.*******   950.   1758.******************    1.00  515.82
   APPRO:AS       76.   -20.   455.   8150.  317204.    2370.    3.44  516.17

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS      FR#    YMIN    YMAX     HF     HO  VHD      EGL    WSEL
   SECA :XS     508.87     1.00  497.83  516.65************  3.26  512.13  508.87
   EXITX:XS     509.34     1.00  498.30  517.12************  3.26  512.59  509.34
   FULLV:FV     509.68     0.81  498.64  517.46  0.55  0.00  2.37  513.14  510.76
   BRIDG:BR     509.06     0.87  498.76  510.18************  3.46  513.64  510.18
   RDWAY:RG   ****************  513.24  526.86  0.03******  0.20  516.33  515.82
   APPRO:AS     511.68     0.28  500.04  525.17  0.21  0.50  0.20  516.36  516.17
```

```
        U.S. Geological Survey WSPRO Input File benn049.wsp
        Hydraulic analysis for structure BENNCYHUNT0049   Date: 26-DEC-96
        BENNINGTON BRIDGE #49 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
 ===015 WSI IN WRONG FLOW REGIME AT SECID "SECA ":  USED WSI = CRWS.
                            WSI,CRWS =   505.01     506.30
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SECA :XS   ******   -42.     412.  2.48 *****  508.78  506.30   4530.  506.30
      -80. ******    48.   38998.  1.32 ***** *******    1.04   11.01

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.06     506.69     506.77
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   505.80     517.12    0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   505.80     517.12     506.77
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "EXITX"
                   WSBEG,WSEND,CRWS =   506.77     517.12     506.77

EXITX:XS      31.   -42.     412.  2.48 *****  509.25  506.77   4530.  506.77
      -49.    31.    48.   38997.  1.32 ***** *******    1.04   11.01

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.81     508.03     507.11
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   506.27     517.46    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   506.27     517.46     507.11

FULLV:FV      49.   -45.     495.  1.75  0.53  509.77  507.11   4530.  508.02
        0.    49.    49.   48766.  1.34  0.00   -0.01    0.81    9.16

APPRO:AS      76.   -10.     395.  2.04  0.78  510.70 *******   4530.  508.66
       76.    76.    52.   41131.  1.00  0.15    0.01    0.80   11.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   507.32     510.35     510.74     510.13
 ===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      49.     0.     425.  1.76 *****  511.94  507.32   4522.  510.18
        0. ******    46.   40646.  1.00 ***** *******    0.62   10.65

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.477  0.000  510.13 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<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      45.   -16.    1206.  0.26  0.16  513.44  507.62   4530.  513.19
       76.    46.   291.  139430.  1.17  0.50    0.00    0.36    3.76

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   513.13

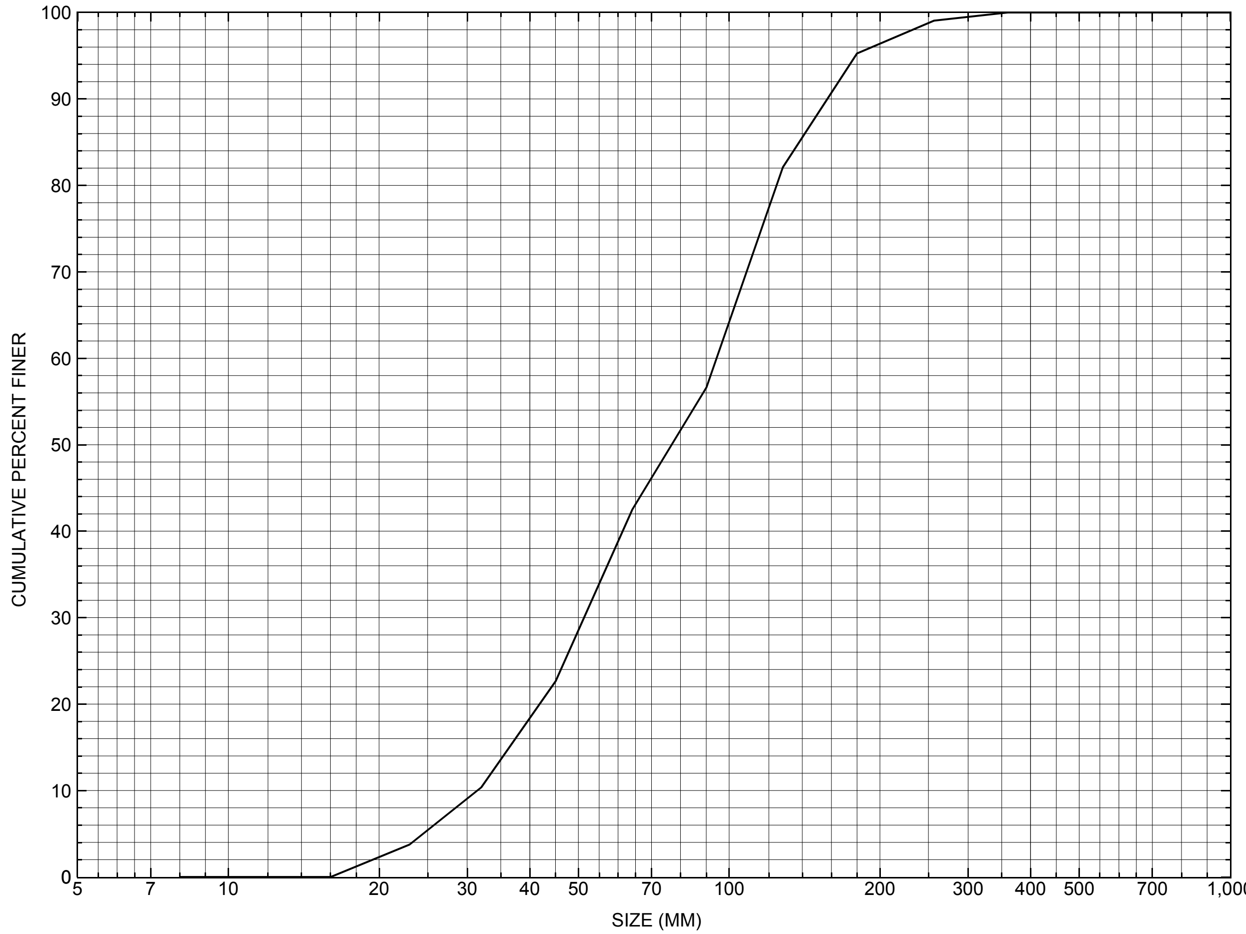
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   SECA :XS     -80.   -42.    48.   4530.   38998.     412.   11.01  506.30
   EXITX:XS     -49.   -42.    48.   4530.   38997.     412.   11.01  506.77
   FULLV:FV       0.   -45.    49.   4530.   48766.     495.    9.16  508.02
   BRIDG:BR       0.     0.    46.   4522.   40646.     425.   10.65  510.18
   RDWAY:RG      15.**************       0.*********       0.    1.00********
   APPRO:AS      76.   -16.   291.   4530.  139430.    1206.    3.76  513.19

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN     YMAX    HF    HO   VHD      EGL    WSEL
   SECA :XS     506.30    1.04  497.83  516.65************  2.48  508.78  506.30
   EXITX:XS     506.77    1.04  498.30  517.12************  2.48  509.25  506.77
   FULLV:FV     507.11    0.81  498.64  517.46  0.53  0.00  1.75  509.77  508.02
   BRIDG:BR     507.32    0.62  498.76  510.18************  1.76  511.94  510.18
   RDWAY:RG   ****************  513.24  526.86************  0.23  513.60********
   APPRO:AS     507.62    0.36  500.04  525.17  0.16  0.50  0.26  513.44  513.19
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BENNCYHUNT0049, in Bennington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BENNCYHUNT0049

General Location Descriptive

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

Date *(MM/DD/YY)* 12 / 13 / 95

Highway District Number *(I - 2; nn)* 01

County *(FIPS county code; I - 3; nnn)* 003

Town *(FIPS place code; I - 4; nnnnn)* 04750

Mile marker *(I - 11; nnn.nnn)* 000100

Waterway *(I - 6)* WALLOOMSAC RIVER

Road Name *(I - 7)*: HUNT STREET EXT

Route Number -

Vicinity *(I - 9)* -

Topographic Map Bennington

Hydrologic Unit Code: 2020003

Latitude *(I - 16; nnnn.n)* 42537

Longitude *(i - 17; nnnnn.n)* 73121

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20102800490202

Maintenance responsibility *(I - 21; nn)* 04

Maximum span length *(I - 48; nnnn)* 0049

Year built *(I - 27; YYYY)* 1975

Structure length *(I - 49; nnnnnn)* 000051

Average daily traffic, ADT *(I - 29; nnnnnn)* 001200

Deck Width *(I - 52; nn.n)* 247

Year of ADT *(I - 30; YY)* 89

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

Opening skew to Roadway *(I - 34; nn)* 20

Waterway adequacy *(I - 71; n)* 8

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*) 45

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

Vertical clearance from streambed (*nnn.n ft*) 10

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

Waterway of full opening (*nnn.n* ft^2) 450

Comments:

According to the structural inspection report dated 6/1/94, the structure is a single span rolled beam bridge.Both abutments are protected with heavy stone fill, as are the channel banks for a short distance US and DS. The channel takes a slight turn into and is straight leaving the structure.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **33.7**

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} **3200** Q_{25} **4200**

Q_{50} **4900** Q_{100} **5700** 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*)	-	-	**493.8**	**494.6**	**495.1**
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 (*ft²*): -

Comments:

--

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **34.11** mi^2 Lake and pond area **0.753** mi^2

Watershed storage *(ST)* **2.21** %

Bridge site elevation **625** ft Headwater elevation **2900** ft

Main channel length **11.02** mi

10% channel length elevation **670** ft 85% channel length elevation **1240** ft

Main channel slope *(S)* **68.95** 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)*: - / 1975

Project Number STF 94-26 Minimum channel bed elevation: 484.0

Low superstructure elevation: USLAB 493.96 DSLAB 494.43 USRAB 494.12 DSRAB 494.64

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness 2 Footing bottom elevation: 483

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: 1

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

Briefly describe material at foundation bottom elevation or around piles:

Bottom of right abutment footing is in sand and boulders at 483'. Bedrock encountered at 476.1'.

Comments:

Average low steel elevation is 494.0 feet. Footing bottom elevation is 483' for the right abutment; 480' for the left abutment. The low superstructure elevations are bridge seat elevations.

Cross-sectional Data

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

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

Comments:

Station	550	554	576	588	597	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low cord elevation	627.5	624.0	624.1	624.2	624.3	-	-	-	-	-	-
Bed elevation	614.5	612.0	613.0	614.5	620.0	-	-	-	-	-	-
Low cord to bed length					-	-	-	-	-	-	-

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 9/30/96
Computerized by: EW Date: 9/30/96
Reviewd by: SAO Date: 4/15/97

Structure Number BENNCYHUNT0049

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE   Date *(MM/DD/YY)* 07 / 31 / 1996

2. Highway District Number 01   Mile marker 000100

County BENNINGTON 03   Town BENNINGTON 04750

Waterway *(I - 6)* WALLOOMSAC RIVER   Road Name HUNT STREET

Route Number -   Hydrologic Unit Code: 02020003

3. Descriptive comments:

THE STRUCTURE IS LOCATED ON HUNT STREET EXTENSION.

B. Bridge Deck Observations

4. Surface cover... LBUS 2   RBUS 1   LBDS 6   RBDS 1   Overall 1
*(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 51 *(feet)*   Span length 49 *(feet)*   Bridge width 24.7 *(feet)*

Road approach to bridge:

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

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

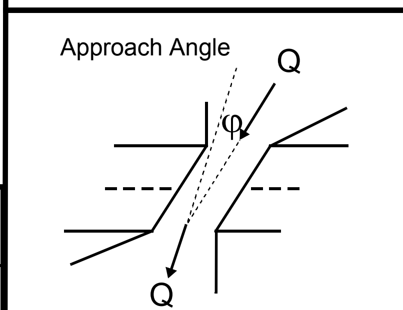
10. Embankment slope (*run / rise in feet / foot*):
US left ______   US right ______

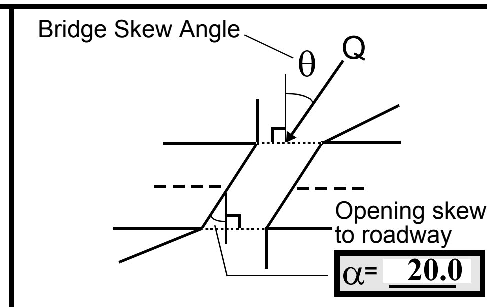
	Protection: 11.Type	Protection: 12.Cond.	13.Erosion	14.Severity
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: 0   16. Bridge skew: 25





17. Channel impact zone 1:   Exist? Y *(Y or N)*
Where? LB *(LB, RB)*   Severity 2
Range? 85 feet US *(US, UB, DS)* to 150 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/3**

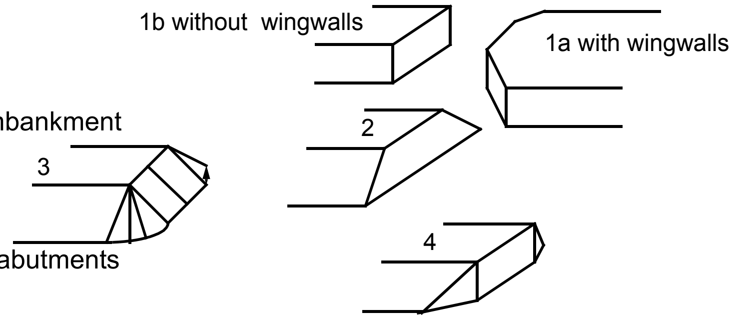
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#4: LBUS is covered by trees to 50 feet from the banks, then the surface cover is suburban. RBDS is a gas station and parking lot. RBUS is also a parking lot.

#7: Measured bridge length = 51 feet; span length = 49 feet; and deck width (without measuring sidewalk and curb) = 24 feet.

#18: The left abutment is vertical. The right abutment has a stone-fill spill-through slope.

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
45.5	**7.5**			**7.5**	**4**	**3**	**3462**	**34**	**2**	**1**

23. Bank width **35.0** 24. Channel width **25.0** 25. Thalweg depth **62.6** 29. Bed Material **435**

30 .Bank protection type: LB **2** RB **2** 31. Bank protection condition: LB **1** RB **1**

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

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

#27: Mostly sandy bank 2 feet above left edge of water.

#30: RB protection extends from bridge to 30 feet upstream. LB protection extends from bridge to 17 feet upstream.

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

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

37. Material: -

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

NO POINT BARS

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: 120 42. Cut bank extent: 150 feet US (US, UB) to 20 feet US (US, UB, DS)

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

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

Bedrock exists along left bank where river bends upstream. As a result, the bank is eroding and a scour hole exists in channel.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 125

47. Scour dimensions: Length 40 Width 6 Depth : 1 Position 35 %LB to 50 %RB

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

The depth is relative to the average upstream thalweg of 1.0 foot.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
37.5		1.0		2	7	7	-

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

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

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

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

54

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

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

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

70. Debris and Ice Comments:

1

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		**0**	**90**	**2**	**0**	**-**	**-**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**0**	**43.5**

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.):

-

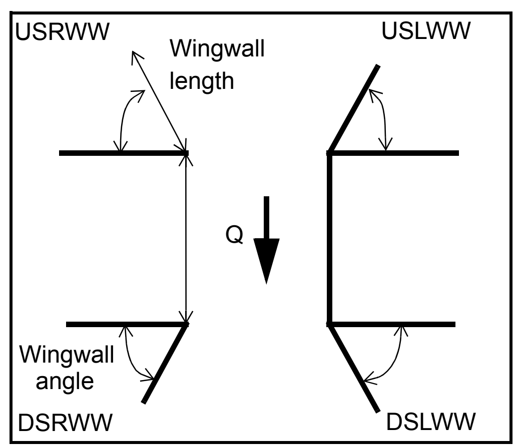
-

1

Main flow runs along the left abutment. There is no attack angle as the flow runs straight through.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**43.5**	
USRWW:	**N**		**-**		**-**	**1.5**	
DSLWW:	**-**		**-**		**N**	**30.0**	
DSRWW:	**-**		**-**		**-**	**31.5**	



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

82. **Bank / Bridge Protection**:

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

*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*

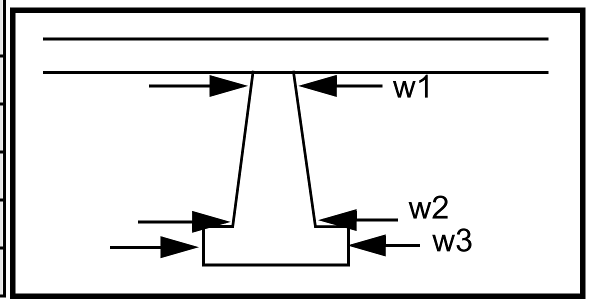
*Protection extent: **1**- entire base length; **2**- US end; **3**- DS end; **4**- other*

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

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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	NO	PIE	RS		

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

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

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

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

4
3
452
45
1
1
435
2
2
1
1
LB protection extends from bridge to 26 feet downstream.
RB protection extends from bridge to 19 feet downstream.

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

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

105. Drop structure comments (eg. downstream scour depth):
t bank is composed of cobbles and boulders at the edge of water, overlain with sand.

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

Point bar extent: ______ feet ____ *(US, UB, DS)* to ______ feet **N** *(US, UB, DS)* positioned **-** %LB to **NO** %RB

Material: **DR**

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

OP STRUCTURE

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

Cut bank extent: **-** 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? **NO** *(Y or if N type ctrl-n cs)* Mid-scour distance: **POIN**

Scour dimensions: Length **T** Width **BAR** Depth: **S** Positioned ____ %LB to ____ %RB

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

N
-
-

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 **NO** Enters on **CU** *(LB or RB)* Type **T** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

BANKS

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 CHANNEL SCOUR

Y

109. G. Plan View Sketch

1

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: BENNCYHUNT0049 Town: Bennington
Road Number: Hunt Street County: Bennington
Stream: Walloomsac River

Initials SAO Date: 3-20-97 Checked: RF

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	5300	8150	4530
Main Channel Area, ft2	771	900	691
Left overbank area, ft2	0	0	0
Right overbank area, ft2	833	1472	517
Top width main channel, ft	70	72	68
Top width L overbank, ft	0	0	0
Top width R overbank, ft	303	403	239
D50 of channel, ft	0.252	0.252	0.252
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	11.0	12.5	10.2
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	2.7	3.7	2.2
Total conveyance, approach	195530	317474	139632
Conveyance, main channel	114292	144000	96702
Conveyance, LOB	0	0	0
Conveyance, ROB	81237	173474	42930
Percent discrepancy, conveyance	0.0005	0.0000	0.0000
Qm, discharge, MC, cfs	3098.0	3696.7	3137.2
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	2202.0	4453.3	1392.8
Vm, mean velocity MC, ft/s	4.0	4.1	4.5
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.6	3.0	2.7
Vc-m, crit. velocity, MC, ft/s	10.6	10.8	10.4
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

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

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

Armoring
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	4990	6330	4530

Main channel area (DS), ft2	362	425	333
Main channel width (normal), ft	43.4	43.4	43.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	43.4	43.4	43.4
D90, ft	0.5153	0.5153	0.5153
D95, ft	0.5863	0.5863	0.5863
Dc, critical grain size, ft	0.6859	0.7544	0.6896
Pc, Decimal percent coarser than Dc	0.031	0.021	0.031
Depth to armoring, ft	64.11	106.02	65.54

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section

(Q) total discharge, cfs	5300	8150	4530
(Q) discharge thru bridge, cfs	4990	6330	4530
Main channel conveyance	40646	40646	40646
Total conveyance	40646	40646	40646
Q2, bridge MC discharge,cfs	4990	6330	4530
Main channel area, ft2	425	425	425
Main channel width (normal), ft	43.4	43.4	43.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	43.4	43.4	43.4
y_bridge (avg. depth at br.), ft	9.79	9.79	9.79
Dm, median (1.25*D50), ft	0.315	0.315	0.315
y2, depth in contraction,ft	10.05	12.32	9.25
ys, scour depth (y2-ybridge), ft	0.26	2.53	-0.54
Depth at downstream face, ft	8.35	ERR	7.68
Ys, depth of scour (y2-yfullv), ft	1.70	N/A	1.57

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	5300	8150	4530
Q, thru bridge, cfs	4990	6330	4530
Total Conveyance, bridge	40646	40646	40646
Main channel(MC) conveyance, bridge	40646	40646	40646
Q, thru bridge MC, cfs	4990	6330	4530
Vc, critical velocity, ft/s	10.56	10.79	10.42
Vc, critical velocity, m/s	3.22	3.29	3.18
Main channel width (skewed), ft	43.4	43.4	43.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	43.4	43.4	43.4
qbr, unit discharge, ft2/s	115.0	145.9	104.4
qbr, unit discharge, m2/s	10.7	13.5	9.7
Area of full opening, ft2	425.0	425.0	425.0
Hb, depth of full opening, ft	9.79	9.79	9.79

Hb, depth of full opening, m	2.98	2.98	2.98
Fr, Froude number, bridge MC	0.68	0.87	0.62
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	510.13	510.13	510.13
Elevation of Bed, ft	500.34	500.34	500.34
Elevation of Approach, ft	514.36	516.17	513.19
Friction loss, approach, ft	0.15	0.21	0.16
Elevation of WS immediately US, ft	514.21	515.96	513.03
ya, depth immediately US, ft	13.87	15.62	12.69
ya, depth immediately US, m	4.23	4.76	3.87
Mean elevation of deck, ft	513.98	513.98	513.98
w, depth of overflow, ft (>=0)	0.23	1.98	0.00
Cc, vert contrac correction (<=1.0)	0.92	0.92	0.94
Ys, depth of scour, ft	2.10	4.97	0.91

Abutment Scour

Froehlich's Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1

(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	5300	8150	4530	5300	8150	4530
a', abut.length blocking flow, ft	20	22.4	18.4	313.7	413.4	249.2
Ae, area of blocked flow ft2	140.4	143.1	127	905.8	1479.6	587.6
Qe, discharge blocked abut.,cfs	--	--	407.7	--	--	1623.3
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.84	2.93	3.21	2.68	3.05	2.76
ya, depth of f/p flow, ft	7.02	6.39	6.90	2.89	3.58	2.36
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	110	110	110	70	70	70
K2	1.03	1.03	1.03	0.97	0.97	0.97
Fr, froude number f/p flow	0.183	0.178	0.215	0.276	0.275	0.317
ys, scour depth, ft	16.13	15.30	16.51	14.83	18.75	12.85

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)	20	22.4	18.4	313.7	413.4	249.2
y1 (depth f/p flow, ft)	7.02	6.39	6.90	2.89	3.58	2.36
a'/y1	2.85	3.51	2.67	108.64	115.50	105.69
Skew correction (p. 49, fig. 16)	1.04	1.04	1.04	0.93	0.93	0.93
Froude no. f/p flow	0.18	0.18	0.22	0.28	0.28	0.32

Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	12.81	15.86	10.95
vertical w/ ww's	ERR	ERR	ERR	10.51	13.01	8.98
spill-through	ERR	ERR	ERR	7.05	8.72	6.02

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 (DS)	0.84	0.87	0.86	0.84	0.87	0.86
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge (DS), ft	8.35	9.79	7.68	8.35	9.79	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.)	3.33	3.94	3.08	3.33	3.94	3.08
Fr<=0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (spillthrough abut.)	2.94	3.48	2.72	2.94	3.48	2.72