LEVEL II SCOUR ANALYSIS FOR BRIDGE 45 (BRNETH00070045) on TOWN HIGHWAY 7, crossing the STEVENS RIVER, BARNET, VERMONT

Open-File Report 97-753

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 45 (BRNETH00070045) on TOWN HIGHWAY 7, crossing the STEVENS RIVER, BARNET, VERMONT

By MICHAEL A. IVANOFF AND ROBERT E. HAMMOND

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
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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 45 (BRNETH00070045) ON TOWN HIGHWAY 7, CROSSING THE STEVENS RIVER, BARNET, VERMONT

By **Michael A. Ivanoff and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRNETH00070045 on Town Highway 7 crossing the Stevens River, Barnet, 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 New England Upland section of the New England physiographic province in east-central Vermont. The 41.5-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream and pasture downstream of the bridge while the immediate banks have dense woody vegetation.

In the study area, the Stevens River has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 100 ft and an average bank height of 17 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 105 mm (0.344 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 22, 1995, indicated that the reach was stable.

The Town Highway 7 crossing of the Stevens River is a 37-ft-long, two-lane bridge consisting of one 34-foot concrete slab span (Vermont Agency of Transportation, written communication, March 16, 1995). The opening length of the structure parallel to the bridge face is 33 ft. 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 20 degrees.

The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the entire left and right abutments, upstream and downstream wingwalls, and upstream and downstream banks. 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) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.8 to 5.4 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was greater than the 100-year discharge. Left abutment scour ranged from 21.8 to 28.6 ft. The worst-case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 14.6 to 17.4 ft. The worst-case right abutment scour occurred at the incipient roadway-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Barnet, VT. Quadrangle, 1:25,000, 1983

NORTH

Figure 1. Location of study area on USGS 1:25,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number BRNETH00070045 ***Stream*** Stevens River

County Caledonia ***Road*** TH 7 ***District*** 7

Description of Bridge

Bridge length 37 ***ft*** ***Bridge width*** 25.4 ***ft*** ***Max span length*** 34 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 8/22/95

Description of stone fill Type-2, along the entire length of the left and right abutments, upstream and downstream wingwalls, and upstream and downstream banks.

Abutments and wingwalls are concrete.

Yes 10

Is bridge skewed to flood flow according to No ***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	8/22/95	0	0
Level II	8/22/95	0	0

Potential for debris Low. There is some debris caught on boulders and trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 8/22/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley.

8/22/95

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

Date of inspection Steep channel

DS left: bank to an overbank.

DS right: Steep channel bank to an overbank.

US left: Steep channel bank to an overbank.

US right: Steep channel bank to an overbank.

Description of the Channel

Average top width 101 ft ***Average depth*** 17 ft

Predominant bed material Gravel - Boulders ***Bank material*** Boulders

Sinuous but stable with non-alluvial channel boundaries and no flood plain.

8/22/95

Vegetative co[illegible] Trees and brush with pasture on the overbank.

DS left: Trees and brush with pasture on the overbank.

DS right: Trees and brush.

US left: Trees and brush.

US right:

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

None 8/22/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 41.5 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None.

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 5,080 ***ft³/s*** ***Q500*** 8,790 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(41.5/43.0)exp 0.67] with discharges for the Stevens River in the Flood Insurance Study for Barnet, VT (Federal Emergency Management Agency, 1988). The drainage area adjusted discharge values are within a range defined by several empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans Add 0.3 ft to the USGS arbitrary survey datum to obtain the National Geodetic Vertical Datum 1929.

Description of reference marks used to determine USGS datum. RM1 is a VTAOT brass tablet on top of the downstream end of the right abutment (elev. 735.13 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the left abutment (elev. 735.26 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	-41	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	16	1	Road Grade section
APPRO	63	2	Modelled Approach section (Templated from APTEM)
APTEM	81	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.065, and overbank "n" values ranged from 0.032 to 0.082.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.015 ft/ft, which was measured from the 100-year water surface profile downstream of the bridge in the Flood Insurance Study for the Town of Barnet, Vermont (Federal Emergency Management Agency, 1988).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0239 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the 100-year and incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After 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 735.7 ***ft***
Average low steel elevation 733.5 ***ft***

100-year discharge 5,080 ***ft^3/s***
Water-surface elevation in bridge opening 722.8 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 291 ***ft^2***
Average velocity in bridge opening 17.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 22.3 ***ft/s***

Water-surface elevation at Approach section with bridge 728.8
Water-surface elevation at Approach section without bridge 726.3
Amount of backwater caused by bridge 2.5 ***ft***

500-year discharge 8,790 ***ft^3/s***
Water-surface elevation in bridge opening 733.7 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,060 ***ft^3/s***
Area of flow in bridge opening 617 ***ft^2***
Average velocity in bridge opening 12.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.2 ***/s***

Water-surface elevation at Approach section with bridge 737.1
Water-surface elevation at Approach section without bridge 730.2
Amount of backwater caused by bridge 6.9 ***ft***

Incipient overtopping discharge 7,680 ***ft^3/s***
Water-surface elevation in bridge opening 725.8 ***ft***
Area of flow in bridge opening 383 ***ft^2***
Average velocity in bridge opening 20.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 26.3 ***ft/s***

Water-surface elevation at Approach section with bridge 733.6
Water-surface elevation at Approach section without bridge 729.2
Amount of backwater caused by bridge 4.4 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and 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 for the 100-year and incipient roadway-overtopping discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The 500-year discharge resulted in an orifice flow solution and contraction scour was computed by use of the Chang pressure-flow scour equation (Richardson and others, 1995, p. 145-146). 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). Results from these computations are presented in Tables 1 and 2 and Figure 8. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the 500-year discharge was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, for the 500-year discharge contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in Appendix F.

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	3.1	0.8	5.4
Depth to armoring	N/A	47.2	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	21.8	28.6	27.9
Right abutment	14.6	16.0	17.4
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	4.0	5.7	5.3
Right abutment	4.0	5.7	5.3
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

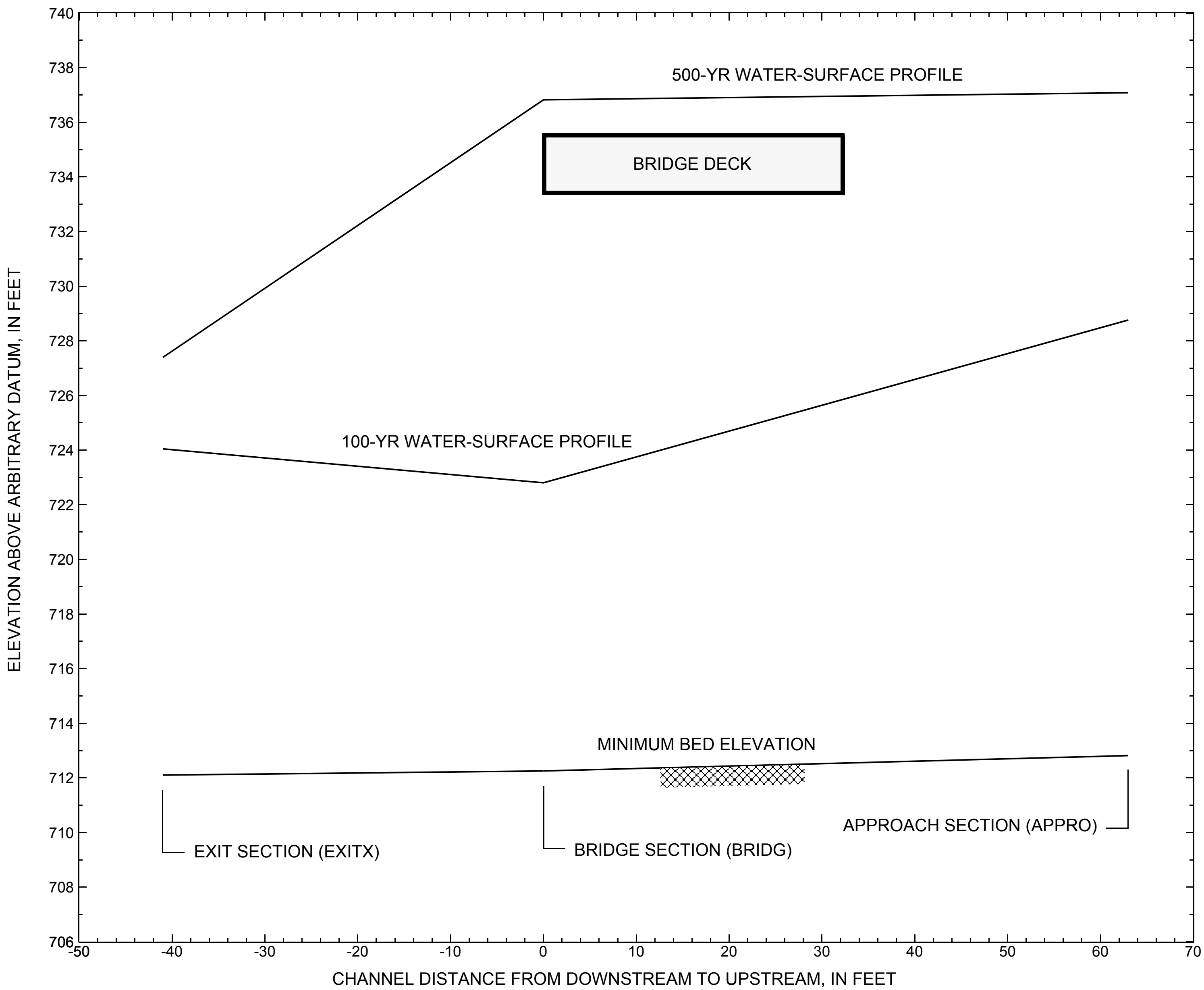

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BRNETH00070045 on Town Highway 7, crossing the Stevens River, Barnet, Vermont.

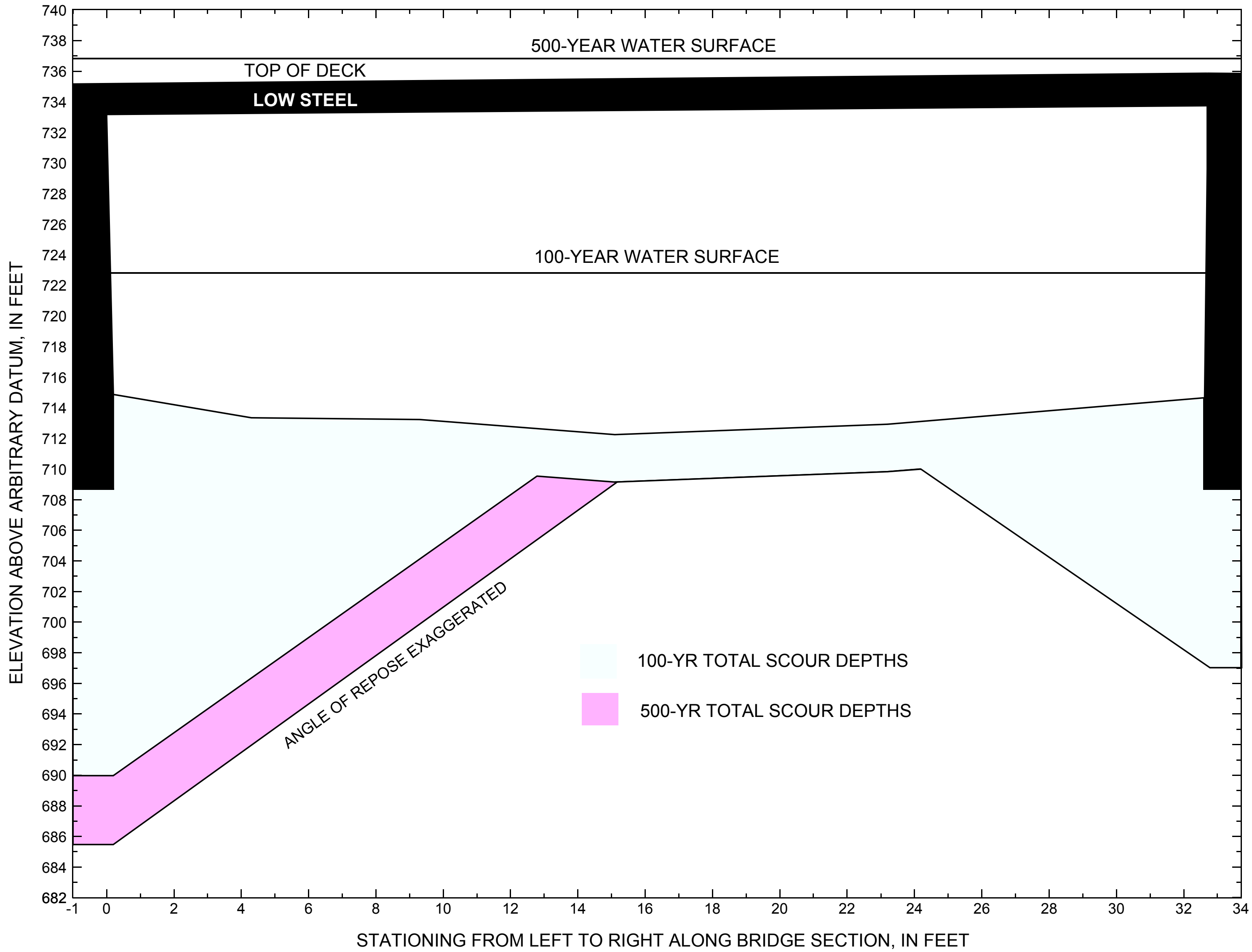

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BRNETH00070045 on Town Highway 7, crossing the Stevens River, Barnet, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRNETH00070045 on Town Highway 7, crossing the Stevens River, Barnet, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 5,080 cubic-feet per second											
Left abutment	0.0	732.9	733.2	708.7	714.9	3.1	21.8	--	24.9	690.0	-18.7
Right abutment	32.7	733.5	733.7	708.7	714.7	3.1	14.6	--	17.7	697.0	-11.7

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 BRNETH00070045 on Town Highway 7, crossing the Stevens River, Barnet, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 8,790 cubic-feet per second											
Left abutment	0.0	732.9	733.2	708.7	714.9	0.8	28.6	--	29.4	685.5	-23.2
Right abutment	32.7	733.5	733.7	708.7	714.7	0.8	16.0	--	16.8	697.9	-10.8

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, 1983, Barnet, Vermont 7.5 X 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File brne045.wsp
T2        Hydraulic analysis for structure BRNETH00070045   Date: 12-AUG-97
T3        Bridge 45 on Town Highway 7 over Stevens River in Barnet, VT  by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5080.0   8790.0   7680.0
SK          0.0150   0.0150   0.0150
*
XS   EXITX    -41          0.
GR         -312.5, 752.12   -207.2, 740.29    -29.7, 728.03     -7.9, 718.05
GR            0.0, 713.20      5.1, 712.60     12.1, 712.28     16.2, 712.10
GR           21.9, 713.00     30.8, 718.26     50.9, 727.83     90.0, 738.23
GR           99.1, 738.35    125.7, 737.32    136.9, 736.45    199.2, 741.68
N           0.032        0.060        0.076
SA                 -29.7         90.0
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG      0    733.46      20.0
GR            0.0, 733.17      0.2, 714.87      4.3, 713.35      9.3, 713.24
GR           15.1, 712.25     23.2, 712.93     28.2, 713.86     32.6, 714.66
GR           32.7, 733.74      0.0, 733.17
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4     32.1      2.1     735.4    44.7
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     16      25.4     1
GR         -371.1, 757.18   -310.1, 749.86   -178.3, 739.33    -86.6, 735.83
GR          -28.0, 734.99      0.0, 735.18      3.3, 735.45      3.5, 736.22
GR           39.4, 736.78     39.7, 735.87     60.7, 736.21     89.7, 736.88
GR          116.3, 736.22    127.2, 735.96    190.8, 739.83
*
XT   APTEM     81
GR         -278.4, 759.62   -230.9, 748.44   -222.9, 743.67   -207.2, 743.16
GR         -196.8, 738.03   -133.0, 729.60    -82.6, 723.15    -10.2, 719.78
GR            0.0, 714.42      6.4, 713.24     12.6, 713.55     18.4, 713.43
GR           25.5, 713.78     28.4, 714.34     36.4, 718.65     53.8, 729.27
GR           71.4, 735.34    101.2, 735.41    179.9, 742.82
*
AS   APPRO    63 * * * 0.0239
GT
N           0.082        0.065        0.076
SA                 -10.2         71.4
*
HP 1 BRIDG   722.80 1 722.80
HP 2 BRIDG   722.80 * * 5080
HP 1 APPRO   728.76 1 728.76
HP 2 APPRO   728.76 * * 5080
*
HP 1 BRIDG   733.74 1 733.74
HP 2 BRIDG   733.74 * * 7878
HP 1 BRIDG   728.38 1 728.38
HP 2 RDWAY   736.82 * * 1060
HP 1 APPRO   737.08 1 737.08
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. Geological Survey WSPRO Input File brne045.wsp
        Hydraulic analysis for structure BRNETH00070045   Date: 12-AUG-97
        Bridge 45 on Town Highway 7 over Stevens River in Barnet, VT  by MAI
           *** RUN DATE & TIME: 08-22-97  15:32
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     291.   36426.    31.    47.                        5085.
   722.80          291.   36426.    31.    47.  1.00     0.    33.   5085.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       722.80     0.1    32.6   290.6   36426.    5080.  17.48

 X STA.         0.1         3.7         5.6         7.2         8.7        10.1
   A(I)             28.1        17.1        14.6        13.3        12.8
   V(I)             9.03       14.90       17.43       19.03       19.78

 X STA.        10.1        11.5        12.8        14.0        15.1        16.3
   A(I)             12.5        12.1        11.7        11.4        11.5
   V(I)            20.40       21.02       21.66       22.25       22.16

 X STA.        16.3        17.5        18.7        19.9        21.1        22.4
   A(I)             11.5        11.4        11.9        11.9        12.2
   V(I)            22.01       22.22       21.42       21.42       20.87

 X STA.        22.4        23.8        25.3        27.0        29.1        32.6
   A(I)             12.8        13.7        14.7        17.2        28.3
   V(I)            19.83       18.50       17.32       14.74        8.99

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     702.   41384.   120.   120.                        9648.
             2     758.   85467.    64.    69.                       14810.
   728.76         1460.  126851.   183.   189.  1.29  -130.    54.  20608.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

         WSEL     LEW     REW    AREA        K        Q    VEL
       728.76  -129.8    53.7  1459.6  126851.    5080.   3.48

 X STA.      -129.8       -79.1       -61.5       -47.7       -35.5       -24.7
   A(I)            164.3       116.0       101.7        96.5        92.0
   V(I)             1.55        2.19        2.50        2.63        2.76

 X STA.       -24.7       -15.0        -7.2        -2.5         1.0         4.1
   A(I)             86.7        74.9        57.4        50.6        47.6
   V(I)             2.93        3.39        4.42        5.02        5.34

 X STA.         4.1         7.1        10.0        13.0        16.1        19.2
   A(I)             46.7        46.9        47.0        48.5        48.2
   V(I)             5.44        5.42        5.41        5.23        5.27

 X STA.        19.2        22.5        25.9        29.8        35.3        53.7
   A(I)             51.6        52.6        58.2        69.1       103.1
   V(I)             4.92        4.83        4.37        3.68        2.46
```

WSPRO OUTPUT FILE (continued)

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       U.S. Geological Survey WSPRO Input File brne045.wsp
       Hydraulic analysis for structure BRNETH00070045   Date: 12-AUG-97
       Bridge 45 on Town Highway 7 over Stevens River in Barnet, VT  by MAI
          *** RUN DATE & TIME: 08-22-97  15:32
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      617.   77805.     0.    99.                          0.
  733.74           617.   77805.     0.    99.  1.00     0.    33.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      733.74     0.0    32.7   617.2   77805.    7878.  12.76

X STA.         0.0         3.6         5.4         7.1         8.6        10.0
  A(I)            62.2        34.6        31.4        28.1        27.1
  V(I)            6.33       11.38       12.55       14.03       14.52

X STA.        10.0        11.4        12.7        14.0        15.2        16.4
  A(I)            25.8        25.1        25.2        24.3        24.4
  V(I)           15.29       15.67       15.65       16.21       16.17

X STA.        16.4        17.7        18.9        20.2        21.4        22.8
  A(I)            24.4        24.4        24.5        25.3        26.1
  V(I)           16.11       16.18       16.05       15.59       15.09

X STA.        22.8        24.2        25.7        27.3        29.3        32.7
  A(I)            26.9        28.3        31.3        36.4        61.5
  V(I)           14.62       13.94       12.58       10.83        6.41

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      461.   68303.    31.    58.                      10160.
  728.38           461.   68303.    31.    58.  1.00     0.    33.  10160.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      16.

        WSEL     LEW     REW    AREA        K        Q    VEL
      736.82  -112.5   141.3   206.6    6829.    1060.   5.13

X STA.      -112.5       -87.0       -78.7       -71.8       -66.1       -60.9
  A(I)            12.5         8.7         7.9         7.1         6.8
  V(I)            4.25        6.10        6.73        7.45        7.76

X STA.       -60.9       -56.2       -51.8       -47.9       -44.1       -40.6
  A(I)             6.6         6.4         6.0         5.9         5.7
  V(I)            8.01        8.32        8.90        9.03        9.31

X STA.       -40.6       -37.3       -34.2       -31.2       -26.9       -20.7
  A(I)             5.5         5.3         5.3         7.8        11.2
  V(I)            9.60        9.95        9.97        6.84        4.73

X STA.       -20.7       -13.8        -5.9         4.5        58.9       141.3
  A(I)            12.2        13.4        15.6        26.3        30.5
  V(I)            4.36        3.95        3.40        2.01        1.74

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     1960.  172573.   183.   184.                      36423.
            2     1382.  198336.    82.    88.                      32267.
            3       87.    2400.    52.    52.                        638.
  737.08          3429.  373309.   316.   324.  1.23  -193.   124.  57841.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

        WSEL     LEW     REW    AREA        K        Q    VEL
      737.08  -192.9   123.5  3428.5  373309.    8790.   2.56

X STA.      -192.9      -117.4       -95.5       -79.3       -66.0       -53.7
  A(I)           375.6       247.5       222.3       197.1       190.1
  V(I)            1.17        1.78        1.98        2.23        2.31

X STA.       -53.7       -42.4       -31.7       -21.8       -12.4        -5.3
  A(I)           181.0       176.4       167.4       163.4       131.5
  V(I)            2.43        2.49        2.62        2.69        3.34

X STA.        -5.3         0.1         4.5         8.9        13.4        17.9
  A(I)           117.1       105.1       104.5       109.0       109.2
  V(I)            3.75        4.18        4.21        4.03        4.02

X STA.        17.9        22.6        27.8        34.1        43.5       123.5
  A(I)           112.7       122.6       137.6       162.3       296.1
  V(I)            3.90        3.58        3.19        2.71        1.48
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         U.S. Geological Survey WSPRO Input File brne045.wsp
         Hydraulic analysis for structure BRNETH00070045   Date: 12-AUG-97
         Bridge 45 on Town Highway 7 over Stevens River in Barnet, VT  by MAI
            *** RUN DATE & TIME: 08-22-97  15:32
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     383.   53299.    31.    53.                       7697.
    725.83          383.   53299.    31.    53.  1.00     0.    33.   7697.


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

          WSEL     LEW     REW    AREA        K        Q    VEL
        725.83     0.1    32.7   383.3   53299.    7680.  20.03

   X STA.         0.1        3.8        5.7        7.3        8.8       10.2
     A(I)            39.4       23.0       19.0       17.4       16.7
     V(I)            9.73      16.72      20.22      22.09      22.98

   X STA.        10.2       11.5       12.8       14.0       15.2       16.3
     A(I)            16.1       15.3       15.1       14.6       14.7
     V(I)           23.83      25.07      25.44      26.26      26.18

   X STA.        16.3       17.5       18.6       19.9       21.1       22.4
     A(I)            14.8       14.7       15.2       15.3       16.1
     V(I)           26.01      26.21      25.21      25.14      23.88

   X STA.        22.4       23.8       25.3       26.9       29.0       32.7
     A(I)            16.2       17.9       19.3       22.9       39.7
     V(I)           23.65      21.45      19.92      16.79       9.67

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1    1371.  105606.   156.   157.                      23043.
              2    1101.  140097.    78.    84.                      23501.
    733.61         2472.  245703.   234.   241.  1.19  -167.    68.  41737.


     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

          WSEL     LEW     REW    AREA        K        Q    VEL
        733.61  -166.6    67.6  2472.5  245703.    7680.   3.11

   X STA.      -166.6     -102.4      -82.9      -68.7      -56.0      -44.7
     A(I)           270.0      187.7      158.6      150.3      140.3
     V(I)            1.42       2.05       2.42       2.55       2.74

   X STA.       -44.7      -34.1      -24.5      -15.3       -7.6       -2.4
     A(I)           136.6      129.4      126.3      110.7       89.4
     V(I)            2.81       2.97       3.04       3.47       4.30

   X STA.        -2.4        1.8        5.6        9.4       13.2       17.2
     A(I)            79.7       78.6       78.0       78.9       81.7
     V(I)            4.82       4.89       4.92       4.87       4.70

   X STA.        17.2       21.4       25.8       30.8       38.1       67.6
     A(I)            85.8       89.5       98.7      119.4      183.1
     V(I)            4.48       4.29       3.89       3.22       2.10
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        U.S. Geological Survey WSPRO Input File brne045.wsp
        Hydraulic analysis for structure BRNETH00070045   Date: 12-AUG-97
        Bridge 45 on Town Highway 7 over Stevens River in Barnet, VT  by MAI
           *** RUN DATE & TIME: 08-22-97  15:32

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

EXITX:XS   ******   -21.     468.  1.83 *****  725.88  722.18   5080.  724.04
      -41. ******    43.   41450.  1.00 ***** *******    0.71   10.85

FULLV:FV      41.   -23.     528.  1.44  0.52  726.39 *******   5080.  724.95
        0.    41.    45.   48630.  1.00  0.00   -0.01    0.61    9.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  1.69

APPRO:AS      63.  -111.    1037.  0.49  0.41  726.79 *******   5080.  726.30
       63.    63.    50.   82314.  1.32  0.00    0.00    0.39    4.90
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    5080.      722.80

            <<<<<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      41.     0.     291.  5.11 *****  727.91  722.80   5080.  722.80
        0.    41.    33.   36411.  1.08 ***** *******    1.04   17.48

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  0.964 ******  733.46 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.        <<<<<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      31.  -130.    1460.  0.24  0.20  729.00  722.16   5080.  728.76
       63.    35.    54.  126896.  1.28  0.90    0.01    0.25    3.48

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.797  0.493  64234.    -9.    23.   728.70


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K      AREA     VEL    WSEL
   EXITX:XS     -41.   -21.    43.   5080.   41450.     468.   10.85  724.04
   FULLV:FV      0.    -23.    45.   5080.   48630.     528.    9.63  724.95
   BRIDG:BR      0.      0.    33.   5080.   36411.     291.   17.48  722.80
   RDWAY:RG     16.**************       0.******************    1.00********
   APPRO:AS     63.  -130.    54.   5080.  126896.    1460.    3.48  728.76

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -9.    23.   64234.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    722.18    0.71  712.10  752.12************  1.83  725.88  724.04
   FULLV:FV  ********    0.61  712.10  752.12  0.52  0.00  1.44  726.39  724.95
   BRIDG:BR    722.80    1.04  712.25  733.74************  5.11  727.91  722.80
   RDWAY:RG ***************  734.99  757.18**********************************
   APPRO:AS    722.16    0.25  712.81  759.19  0.20  0.90  0.24  729.00  728.76
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       U.S. Geological Survey WSPRO Input File brne045.wsp
       Hydraulic analysis for structure BRNETH00070045   Date: 12-AUG-97
       Bridge 45 on Town Highway 7 over Stevens River in Barnet, VT  by MAI
          *** RUN DATE & TIME: 08-22-97  15:32

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

EXITX:XS   ******   -28.     706.  2.41 *****  729.80  725.28   8790.  727.39
      -41. ******    50.   71723.  1.00 ***** *******    0.73   12.45

FULLV:FV      41.   -35.     786.  1.95  0.53  730.33 *******   8790.  728.38
        0.    41.    53.   82718.  1.00  0.00   -0.01    0.66   11.18
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"      KRATIO =  1.90

APPRO:AS      63.  -141.    1734.  0.50  0.37  730.70 *******   8790.  730.20
       63.    63.    58.  156972.  1.25  0.00    0.00    0.34    5.07
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   735.56       0.00     727.01     734.99

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   726.95     735.31     735.47     733.46

 ===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      41.     0.     617.  2.53 *****  736.27  726.04   7878.  733.74
        0. ******    33.   77805.  1.00 ***** *******    0.52   12.76

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.440 ******  733.46 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       16.    38.  0.02  0.13  737.18    0.02   1060.  736.82

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    799.   129.  -112.    16.   1.8   1.2   5.9   5.1   1.6   3.2
   RT:    261.   120.    16.   141.   0.9   0.4   4.1   5.1   0.8   3.1

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

APPRO:AS      31.  -193.    3428.  0.13  0.09  737.20  724.60   8790.  737.08
       63.    37.   123.  373234.  1.23  0.68    0.02    0.15    2.56


  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q         K      AREA     VEL    WSEL
   EXITX:XS     -41.   -28.    50.   8790.   71723.      706.   12.45  727.39
   FULLV:FV       0.   -35.    53.   8790.   82718.      786.   11.18  728.38
   BRIDG:BR       0.     0.    33.   7878.   77805.      617.   12.76  733.74
   RDWAY:RG      16.*******   799.   1060.*********        0.    1.00  736.82
   APPRO:AS      63.  -193.   123.   8790.  373234.     3428.    2.56  737.08

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO   VHD     EGL    WSEL
   EXITX:XS    725.28    0.73  712.10  752.12************  2.41  729.80  727.39
   FULLV:FV  ********    0.66  712.10  752.12  0.53  0.00  1.95  730.33  728.38
   BRIDG:BR    726.04    0.52  712.25  733.74************  2.53  736.27  733.74
   RDWAY:RG  ****************  734.99  757.18  0.02******  0.13  737.18  736.82
   APPRO:AS    724.60    0.15  712.81  759.19  0.09  0.68  0.13  737.20  737.08
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        U.S. Geological Survey WSPRO Input File brne045.wsp
        Hydraulic analysis for structure BRNETH00070045   Date: 12-AUG-97
        Bridge 45 on Town Highway 7 over Stevens River in Barnet, VT  by MAI
           *** RUN DATE & TIME: 08-22-97  15:32

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

EXITX:XS   ******   -26.     638.  2.25 *****  728.75  724.45   7680.  726.50
      -41. ******    48.   62647.  1.00 ***** *******    0.73   12.04

FULLV:FV      41.   -28.     712.  1.81  0.53  729.27 *******   7680.  727.46
        0.    41.    50.   72499.  1.00  0.00   -0.01    0.63   10.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.86

APPRO:AS      63.  -133.    1533.  0.50  0.38  729.65 *******   7680.  729.15
       63.    63.    55.  134744.  1.28  0.00    0.00    0.35    5.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    7680.      725.83

            <<<<<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      41.     0.     383.  7.05 *****  732.88  725.83   7680.  725.83
        0.    41.    33.   53274.  1.13 ***** *******    1.06   20.04

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  0.941 ******  733.46 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.        <<<<<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      31.  -167.    2472.  0.18  0.17  733.79  724.03   7680.  733.61
       63.    37.    68.  245627.  1.19  0.75    0.01    0.18    3.11

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.826  0.607   96437.   -13.    20.   733.57


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -41.   -26.    48.   7680.   62647.     638.   12.04  726.50
   FULLV:FV      0.    -28.    50.   7680.   72499.     712.   10.79  727.46
   BRIDG:BR      0.     0.     33.   7680.   53274.     383.   20.04  725.83
   RDWAY:RG     16.**************       0.******************     1.00********
   APPRO:AS     63.  -167.     68.   7680.  245627.    2472.    3.11  733.61

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -13.    20.   96437.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    724.45    0.73  712.10  752.12************  2.25  728.75  726.50
   FULLV:FV  ********    0.63  712.10  752.12  0.53  0.00  1.81  729.27  727.46
   BRIDG:BR    725.83    1.06  712.25  733.74************  7.05  732.88  725.83
   RDWAY:RG  ****************  734.99  757.18**********************************
   APPRO:AS    724.03    0.18  712.81  759.19  0.17  0.75  0.18  733.79  733.61
```
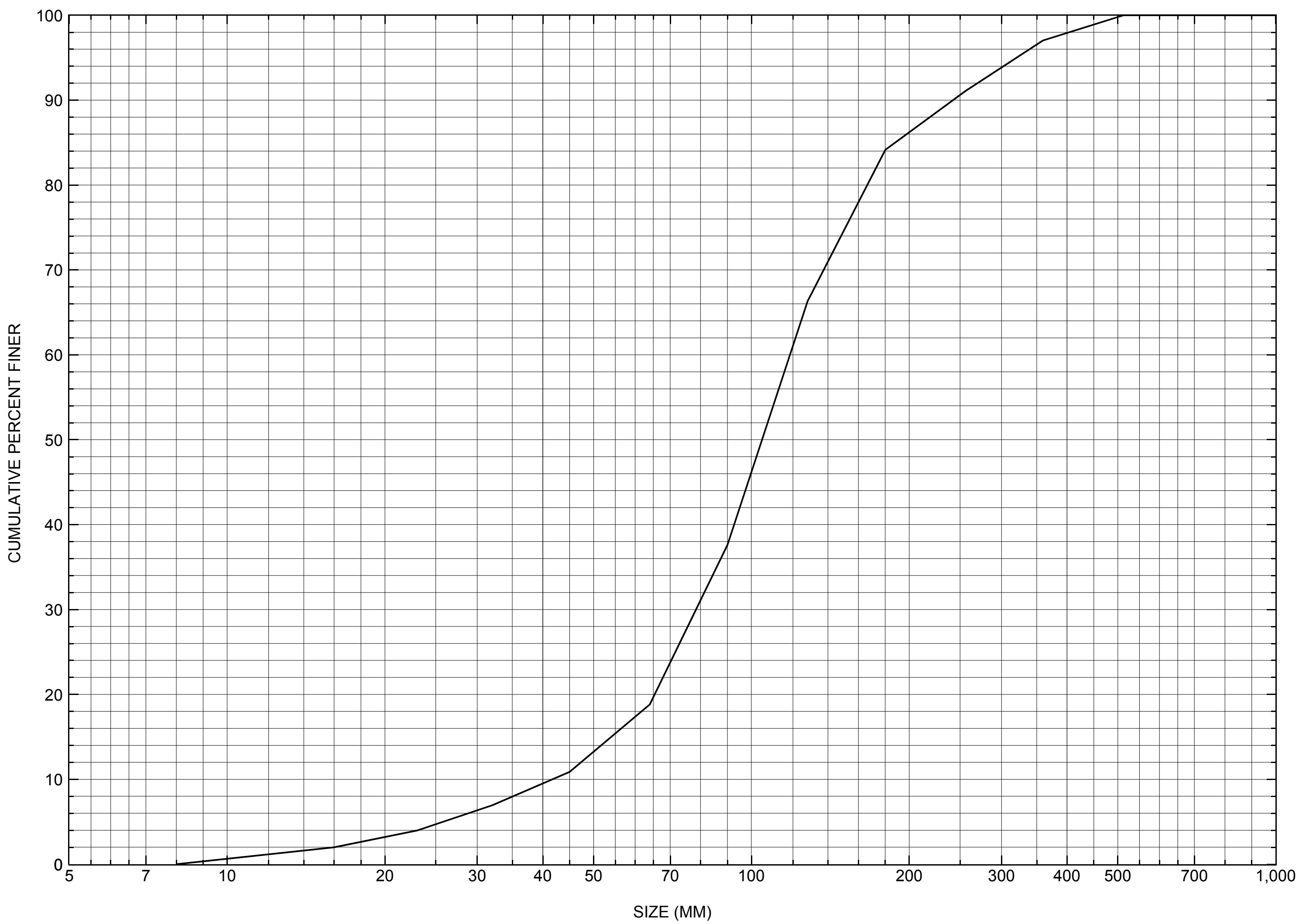

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BRNETH00070045, in Barnet, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BRNETH00070045

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 16 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 02875

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

Waterway *(I - 6)* STEVENS RIVER

Road Name *(I - 7):* -

Route Number TH007

Vicinity *(I - 9)* 0.01 MI TO JCT W CL2 TH1

Topographic Map Barnet

Hydrologic Unit Code: 01080103

Latitude *(I - 16; nnnn.n)* 44186

Longitude *(i - 17; nnnnn.n)* 72055

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030100450301

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

Maximum span length *(I - 48; nnnn)* 0034

Year built *(I - 27; YYYY)* 1987

Structure length *(I - 49; nnnnnn)* 000037

Average daily traffic, ADT *(I - 29; nnnnnn)* 000300

Deck Width *(I - 52; nn.n)* 254

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

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

Opening skew to Roadway *(I - 34; nn)* 19

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

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*) 031.2

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

Vertical clearance from streambed (*nnn.n ft*) 020.0

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

Waterway of full opening (*nnn.n ft*^{2}) 650.0

Comments:

The structural inspection report of 9/6/94 indicates the structure is a concrete slab type bridge. The abutment walls and wingwalls are concrete. The right abutment has three full-height vertical cracks reported and some other small cracks. Likewise, the left abutment wall has two full-height vertical cracks and some fine cracks noted elsewhere. All of the wingwalls have some randomly distributed cracks. The report indicates a large amount of stone fill is protecting the channel edges and the abutment walls. There is a small, older dam reported across the channel just below the upstream edge of the deck. The streambed is noted to consist of gravel and cobbles, with some boulders. **(Continued, page 33)**

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: 39.6

Terrain character: -

Stream character & type: -

Streambed material: Gravel and cobbles with some boulders

Discharge Data *(cfs)*: $Q_{2.33}$ 1000 Q_{10} 2350 Q_{25} 3400

Q_{50} 4200 Q_{100} 5000 Q_{500} -

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

Estimated Discharge *(cfs)*: - Velocity at Q 25 *(ft/s)*: 15.4

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*)	718.9	722.8	725.4	727.1	728.7
Velocity (*ft / sec*)	-	-	15.4	-	-

Long term stream bed changes: -

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

There is minor debris accumulation noted in the channel. The footings are reported as not visible at the surface, and undermining and settling are not apparent. The above hydrologic information is printed on the plans.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **41.48** mi^2

Lake/pond/swamp area **1.33** mi^2

Watershed storage *(ST)* **3.5** %

Bridge site elevation **709** ft

Headwater elevation **2513** ft

Main channel length **8.99** mi

10% channel length elevation **722** ft

85% channel length elevation **1509** ft

Main channel slope *(S)* **116.72** 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)*: **02** / **1986**

Project Number **BRZ 1447(11)** Minimum channel bed elevation: **713.0**

Low superstructure elevation: USLAB **733.17** DSLAB **732.57** USRAB **733.77** DSRAB **733.06**

Benchmark location description:

There is no specific benchmark shown on the plans but several points are given with elevations. One is on the top of the concrete curb lining the upstream side of the deck at the left bank end where the curb comes to a point immediately above the extreme upstream left corner of the concrete slab deck, elevation 736.54. Another is at the same point but on the upstream right corner of the deck, elevation 737.14

Reference Point (*MSL, Arbitrary, Other*): **MSL** Datum (*NAD27, NAD83, Other*): **NGVD1929**

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

If 1: Footing Thickness **3.0** Footing bottom elevation: **709.0**

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

If 3: Footing bottom elevation: **-**

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

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

Briefly describe material at foundation bottom elevation or around piles:

-

Comments:

There are no channel cross sections on the plans. The plans show as built dimensions. The streambed elevation at the time of construction was about 1.0 foot above the top of both abutment footings at its lowest elevation.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 2/27/96
Computerized by: RB Date: 2/27/96
Reviewd by: MAL Date: 9/18/97

Structure Number BRNETH00070045

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. Hammond Date *(MM/DD/YY)* 8 / 22 / 1995
2. Highway District Number 7 Mile marker 0
   County Caledonia (005) Town Barnet (02875)
   Waterway *(I - 6)* Stevens River Road Name -
   Route Number TH 7 Hydrologic Unit Code: 01080103
3. Descriptive comments:

The site is located 0.01 miles from the junction with Town Highway 1.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 4 RBDS 6/4 Overall 6
*(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 1 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 37 *(feet)* Span length 34 *(feet)* Bridge width 25.4 *(feet)*

Road approach to bridge:

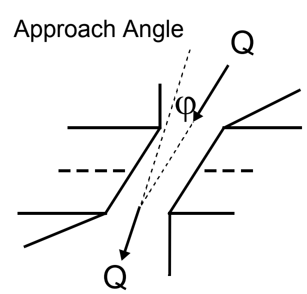
8. LB 0 RB 2 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 2.2:1 US right 2.1:1

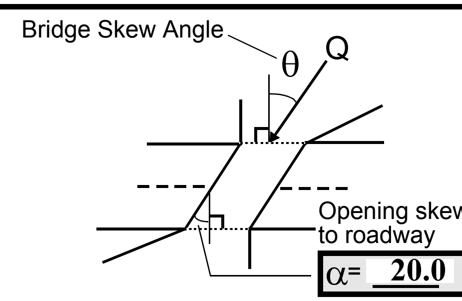
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	1	1	0	-
RBUS	1	1	0	-
RBDS	1	1	0	-
LBDS	1	1	0	-

*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: 5 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 60 feet US *(US, UB, DS)* to 100 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: **4**

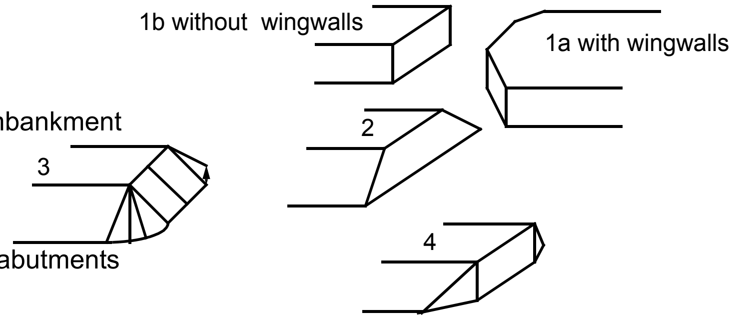
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. The bridge dimension values are from the VTAOT files. The measured bridge length is 37 feet, bridge span is 33 feet, and bridge width is 25.5 (outside deck).

4. The right bank upstream is a combination of woods and town highway 1.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
50.0	**5.5**			**21.0**	**2**	**3**	**54**	**54**	**0**	**1**

23. Bank width **30.0** 24. Channel width **25.0** 25. Thalweg depth **81.5** 29. Bed Material **453**

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.):

30. The right bank protection extends 80 feet US from the bridge.
The left bank protection extends 70 feet US from the bridge.

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? **RB** *(LB or RB)*

41. Mid-bank distance: **85** 42. Cut bank extent: **70** feet **US** *(US, UB)* to **100** feet **US** *(US, UB, DS)*

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

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

-

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. Minor confluence on the left bank at 120 feet, 1 foot diameter culvert road drain. The culvert was dripping at the time of the visit.

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
28.5		1.0		2	7	7	0

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

543

There was a boulder riffle at the upstream face under the bridge.

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

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

There was minor accumulation of small debris caught in boulders and trees leaning over the upstream channel.

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	10	90			2	0	30.5

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

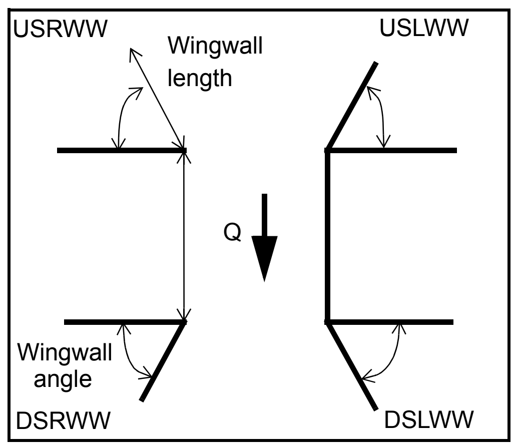
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

-
-
1
-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						30.5	
USRWW:	Y		1		0	1.5	
DSLWW:	-		-		Y	32.5	
DSRWW:	1		0		-	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	-	0	Y	-	1	1	1	1
Condition	Y	-	1	-	1	1	1	1
Extent	1	-	0	2	2	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

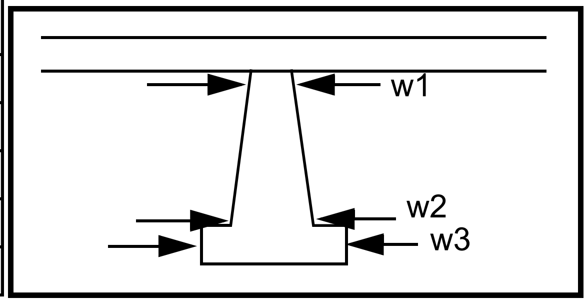
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
2
1
1
2
1
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				50.0	20.5	40.0
Pier 2				30.0	25.0	29.5
Pier 3			-	50.0	22.5	-
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 - Thalweg depth - Bed Material _____

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

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

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

1
2
5
5
0
0
453
2
2
1
1
The left and right bank protection extends 75 feet downstream of the bridge.
There is 0% vegetation cover from the bridge to about 100 feet downstream on both banks, then 100% vegeta-

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

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

105. Drop structure comments (eg. downstream scour depth):
cover beyond that.

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 **N** %LB to **-** %RB

Material: **NO**

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

DROP 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. Local scour exists from 68 feet to 85 feet DS, maximum scour is 1 foot. The scour is due in part to large boulders along the left bank upstream of the scour.

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

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: BRNETH00070045 Town: Barnet
Road Number: TH 7 County: Caledonia
Stream: Stevens

Initials MAI Date: 08/22/97 Checked: LKS

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	5080	8790	7680
Main Channel Area, ft2	758	1382	1101
Left overbank area, ft2	702	1960	1371
Right overbank area, ft2	0	87	0
Top width main channel, ft	64	82	78
Top width L overbank, ft	120	183	156
Top width R overbank, ft	0	52	0
D50 of channel, ft	0.3437	0.3437	0.3437
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	11.8	16.9	14.1
y1, average depth, LOB, ft	5.9	10.7	8.8
y1, average depth, ROB, ft	ERR	1.7	ERR
Total conveyance, approach	126851	373673	245703
Conveyance, main channel	85467	198336	140097
Conveyance, LOB	41384	172573	105606
Conveyance, ROB	0	2764	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	3422.7	4665.5	4379.0
Ql, discharge, LOB, cfs	1657.3	4059.5	3301.0
Qr, discharge, ROB, cfs	0.0	65.0	0.0
Vm, mean velocity MC, ft/s	4.5	3.4	4.0
Vl, mean velocity, LOB, ft/s	2.4	2.1	2.4
Vr, mean velocity, ROB, ft/s	ERR	0.7	ERR
Vc-m, crit. velocity, MC, ft/s	11.9	12.6	12.2
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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	5080	8790	7680
(Q) discharge thru bridge, cfs	5080	7878	7680
Main channel conveyance	36426	77805	53299
Total conveyance	36426	77805	53299
Q2, bridge MC discharge,cfs	5080	7878	7680
Main channel area, ft2	291	617	383
Main channel width (normal), ft	30.5	30.7	30.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.5	30.7	30.6
y_bridge (avg. depth at br.), ft	9.53	20.10	12.53
Dm, median (1.25*D50), ft	0.429625	0.429625	0.429625
y2, depth in contraction,ft	12.64	18.30	17.96
ys, scour depth (y2-ybridge), ft	**3.11**	-1.80	**5.43**

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	5080	8790	7680
Q, thru bridge MC, cfs	5080	7878	7680
Vc, critical velocity, ft/s	11.86	12.57	12.21
Va, velocity MC approach, ft/s	4.52	3.38	3.98
Main channel width (normal), ft	30.5	30.7	30.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.5	30.7	30.6
qbr, unit discharge, ft2/s	166.6	256.6	251.0
Area of full opening, ft2	290.6	617.2	383.3
Hb, depth of full opening, ft	9.53	20.10	12.53
Fr, Froude number, bridge MC	0	0.52	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	461	N/A
**Hb, depth at downstream face, ft	N/A	15.02	N/A
**Fr, Froude number at DS face	ERR	0.78	ERR

**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	733.46	0
Elevation of Bed, ft	-9.53	713.36	-12.53
Elevation of Approach, ft	0	737.08	0
Friction loss, approach, ft	0	0.09	0
Elevation of WS immediately US, ft	0.00	736.99	0.00
ya, depth immediately US, ft	9.53	23.63	12.53
Mean elevation of deck, ft	0	735.52	0
w, depth of overflow, ft (>=0)	0.00	1.47	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.98	1.00
**Cc, for downstream face (<=1.0)	ERR	0.898398	ERR
Ys, scour w/Chang equation, ft	N/A	**0.80**	N/A
Ys, scour w/Umbrell equation, ft	N/A	-8.77	N/A

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

**Ys, scour w/Chang equation, ft	N/A	7.70	N/A
**Ys, scour w/Umbrell equation, ft	ERR	-3.68	ERR

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

y2, from Laursen's equation, ft	12.64	18.30	17.96
WSEL at downstream face, ft	--	728.38	--
Depth at downstream face, ft	N/A	15.02	N/A
Ys, depth of scour (Laursen), ft	N/A	3.29	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	5080	7878	7680
Main channel area (DS), ft2	290.6	461	383.3
Main channel width (normal), ft	30.5	30.7	30.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	30.5	30.7	30.6
D90, ft	0.7947	0.7947	0.7947
D95, ft	1.0512	1.0512	1.0512
Dc, critical grain size, ft	1.2398	0.9952	1.4639
Pc, Decimal percent coarser than Dc	0.026	0.060	0.012
Depth to armoring, ft	**N/A**	**47.19**	**N/A**

Abutment Scour

Froehlich's Abutment Scour

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

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

	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	5080	8790	7680	5080	8790	7680
a', abut.length blocking flow, ft	130.9	193.9	167.7	22.1	91.8	35.9

Ae, area of blocked flow ft2	841.64	2046.25	1565.72	149.59	473.76	287.78
Qe, discharge blocked abut.,cfs	2294.19	--	4160	424.87	--	720.66

(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)

Ve, (Qe/Ae), ft/s	2.73	2.25	2.66	2.84	2.05	2.50
ya, depth of f/p flow, ft	6.43	10.55	9.34	6.77	5.16	8.02

--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)

K1	0.82	0.82	0.82	0.82	0.82	0.82

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

theta	70	70	70	110	110	110
K2	0.97	0.97	0.97	1.03	1.03	1.03
Fr, froude number f/p flow	0.189	0.118	0.153	0.192	0.153	0.156
ys, scour depth, ft	**21.77**	**28.60**	**27.88**	**14.64**	**15.98**	**17.41**

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)	130.9	193.9	167.7	22.1	91.8	35.9
y1 (depth f/p flow, ft)	6.43	10.55	9.34	6.77	5.16	8.02
a'/y1	20.36	18.37	17.96	3.26	17.79	4.48
Skew correction (p. 49, fig. 16)	0.93	0.93	0.93	1.04	1.04	1.04
Froude no. f/p flow	0.19	0.12	0.15	0.19	0.15	0.16
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	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1.04	0.78	1.06	1.04	0.78	1.06
y, depth of flow in bridge, ft	9.53	15.02	12.53	9.53	15.02	12.53
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	**5.65**	ERR	ERR	**5.65**	ERR
Fr>0.8 (vertical abut.)	**4.03**	ERR	**5.33**	**4.03**	ERR	**5.33**