LEVEL II SCOUR ANALYSIS FOR BRIDGE 42 (BRNETH00810042) on TOWN HIGHWAY 81, crossing the STEVENS RIVER, BARNET, VERMONT

Open-File Report 98-289

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

U.S. Department of the Interior
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By MICHELLE M. SERRA

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U.S. DEPARTMENT OF THE INTERIOR
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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 42 (BRNETH00810042) ON TOWN HIGHWAY 81, CROSSING THE STEVENS RIVER, BARNET, VERMONT

By **Michelle M. Serra**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRNETH00810042 on Town Highway 81 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 (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in northeastern Vermont. The 20.7-mi^2 drainage area is in a predominantly forested basin. In the vicinity of the study site, the surface cover is pasture on the left bank of the channel, upstream and downstream of the bridge. The right bank is predominantly shrub and brushland.

In the study area, Stevens River has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 36 ft and an average bank height of 2 ft. The channel bed material ranges from sand to boulders with a median grain size (D_{50}) of 55.0 mm (0.181 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 23, 1995, indicated that the reach was stable.

The Town Highway 81 crossing of the Stevens River is a 29-ft-long, one-lane bridge consisting of one 25-foot steel-beam span (Vermont Agency of Transportation, written communication, March 23, 1995). The opening length of the structure parallel to the bridge face is 22.3 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed in the center of the channel immediately downstream of the bridge during the Level I assessment. Scour protection measures at this site consisted of type-1 stone fill (less than 12 inches diameter) at the downstream right wingwall, type-2 stone fill (less than 36 inches diameter) at the upstream left and right wingwalls, the downstream left wingwall, and the right abutment, and type-3 stone fill (less than 48 inches diameter) at the left abutment. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 3.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.8 to 8.1 ft at the right abutment and from 10.1 to 11.0 ft at the left abutment. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 BRNETH00810042 ***Stream*** Stevens River

County Caledonia ***Road*** TH81 ***District*** 7

Description of Bridge

Bridge length 29 ***ft*** ***Bridge width*** 19.3 ***ft*** ***Max span length*** 25 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 8/23/95

Description of stone fill Type-2 stone fill protects the upstream left and right wingwalls, the right abutment, and the downstream left wingwall. Type-3 stone fill protects the left abutment and type-1 stone fill protects the downstream right wingwall.

Brief description of piers/abutments The abutments and wingwalls are concrete. There are no reports of undermining or exposed footings.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 15

There is a mild bend over the reach in the vicinity of this site, although overall, the channel is straight.

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*
	8/23/95	0	0
Level I	8/23/95	0	0
Level II			

Potential for debris There is a moderate potential for debris. There are a lot of trees and brush on the banks that could get caught in the stone fill under the bridge.

Describe any features near or at the bridge that may affect flow (include observation date) There is a bedrock outcrop under the right abutment and the stone fill along the left abutment protrudes into the channel as observed on 8/23/95.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley and has a narrow flood plain and moderately sloping valley sides.

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

Date of inspection 8/23/95

DS left: Steep channel bank to mildly sloped overbank

DS right: Moderate sloping channel bank to mildly sloped overbank

US left: Steep channel bank to moderately sloped overbank

US right: Steep channel bank

Description of the Channel

Average top width 36 ***ft*** ***Average depth*** 2 ***ft***

Predominant bed material Gravel ***Bank material*** Gravel

The stream is perennial and straight with non-alluvial channel boundaries and narrow point bars.

Vegetative co 8/23/95

Grass and brush

DS left: Small trees with some shrubs and brush

DS right: Grass and brush with a few trees

US left: Shrubs, brush, and small trees.

US right:

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

A pile of debris, mostly branches and leaves, was observed on 8/23/95 across the channel downstream of the bridge.

Describe any obstructions in channel and date of observation.

The stone fill on the right bank upstream also protrudes into the channel.

Hydrology

Drainage area 20.7 ***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 as of 8/23/95

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 Yes

About one third of the drainage area above this site is occupied by Harvey Lake.

Calculated Discharges

Q100 2,880 ***ft³/s*** ***Q500*** 4,000 ***ft³/s***

Method used to determine discharges The 100-year discharge is from a drainage area relationship [(20.7/23.0)exp0.67] with the 100-year discharge at the confluence of Peacham Hollow Brook with Stevens River from the Flood Insurance Study for the town of Barnet, VT (FEMA, May 1988). The confluence is downstream of this site and Stevens River has a drainage area of 23.0 square miles above the confluence. The 500-year discharge was inferred based on a range of values defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled square on top of the left abutment at the upstream end where it meets the wingwall (elev. 500.31 ft, arbitrary survey datum). RM2 is a chiseled "X" on top of the right abutment at the upstream end where it meets the wingwall (elev. 500.30 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	-32	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	42	2	Modelled Approach section (Templated from APTEM)
APTEM	49	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 0.050 to 0.055, and overbank "n" values ranged from 0.035 to 0.050.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. 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 0.0100 ft/ft, which was estimated from topographic map contour lines(U.S. Geological Survey, 1983).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.007 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.2 ***ft***
Average low steel elevation 498.5 ***ft***

100-year discharge 2,880 ***ft³/s***
Water-surface elevation in bridge opening 498.5 ***ft***
Road overtopping? Yes ***Discharge over road*** 774 ***ft³/s***
Area of flow in bridge opening 192 ***ft²***
Average velocity in bridge opening 11.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.7 ***ft/s***

Water-surface elevation at Approach section with bridge 502.0
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 4.4 ***ft***

500-year discharge 4,000 ***ft³/s***
Water-surface elevation in bridge opening 498.5 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,610 ***ft³/s***
Area of flow in bridge opening 192 ***ft²***
Average velocity in bridge opening 12.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.4 ***ft/s***

Water-surface elevation at Approach section with bridge 502.7
Water-surface elevation at Approach section without bridge 499.5
Amount of backwater caused by bridge 3.2 ***ft***

Incipient overtopping discharge 1,670 ***ft³/s***
Water-surface elevation in bridge opening 498.5 ***ft***
Area of flow in bridge opening 192 ***ft²***
Average velocity in bridge opening 8.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.8 ***ft/s***

Water-surface elevation at Approach section with bridge 500.2
Water-surface elevation at Approach section without bridge 495.4
Amount of backwater caused by bridge 4.8 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

At this site, the 100-year and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow. The 500-year discharge resulted in submerged 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 Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). The results are presented in appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions also are provided in appendix F.

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

Scour at the left abutment was computed by use of the HIRE equation (Richardson and Davis, 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 those defined for the Froehlich abutment-scour equation.

Scour Results

Contraction scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.4	3.7	0.0
Depth to armoring	26.3	20.4	N/A
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	11.0	11.0	10.1
Right abutment	7.4	8.1	6.8
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.1	3.1	1.0
Right abutment	2.1	3.1	1.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--
	--	--	--

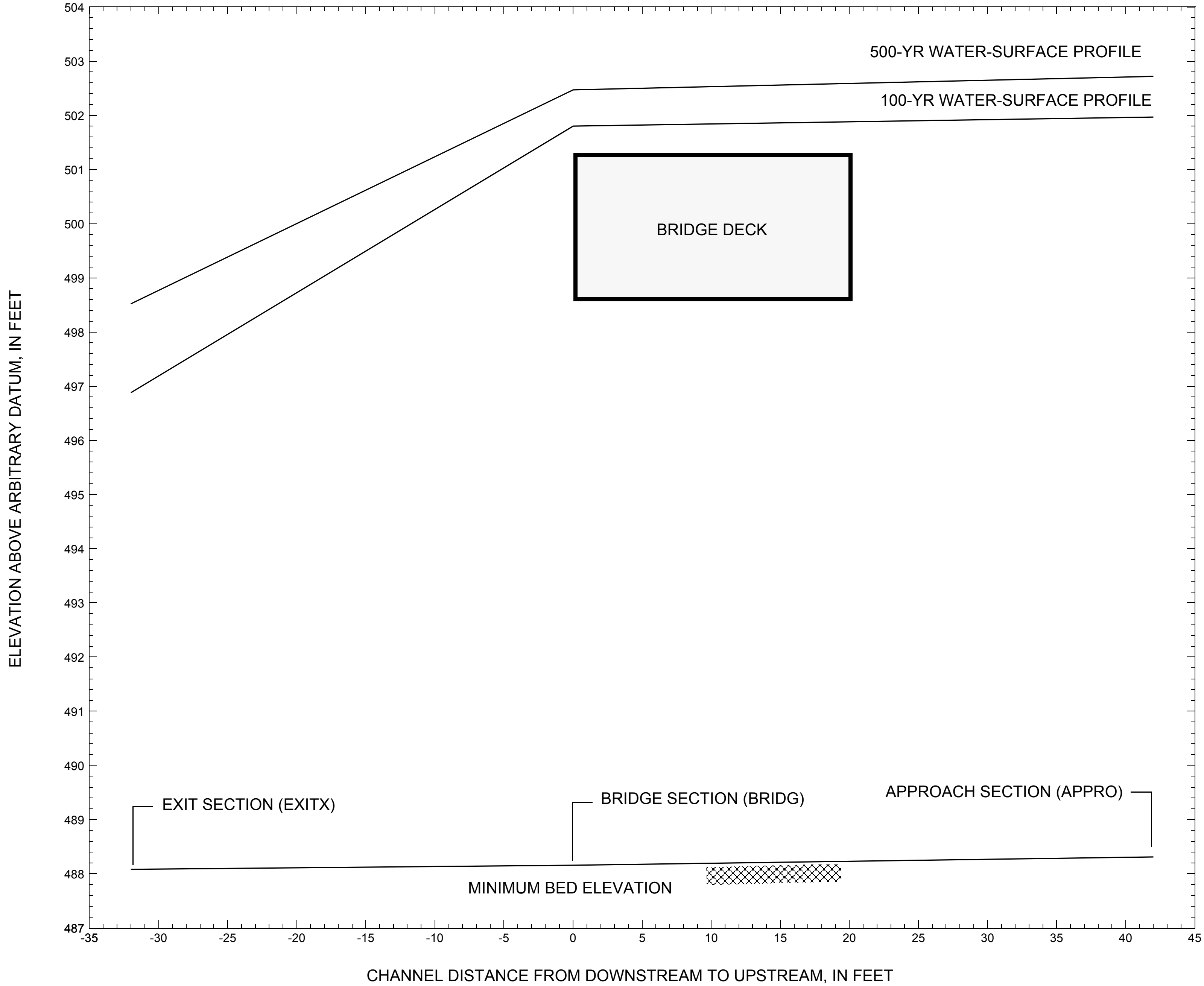

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure BRNETH00810042 on Town Highway 81, crossing the Stevens River, Barnet, Vermont.

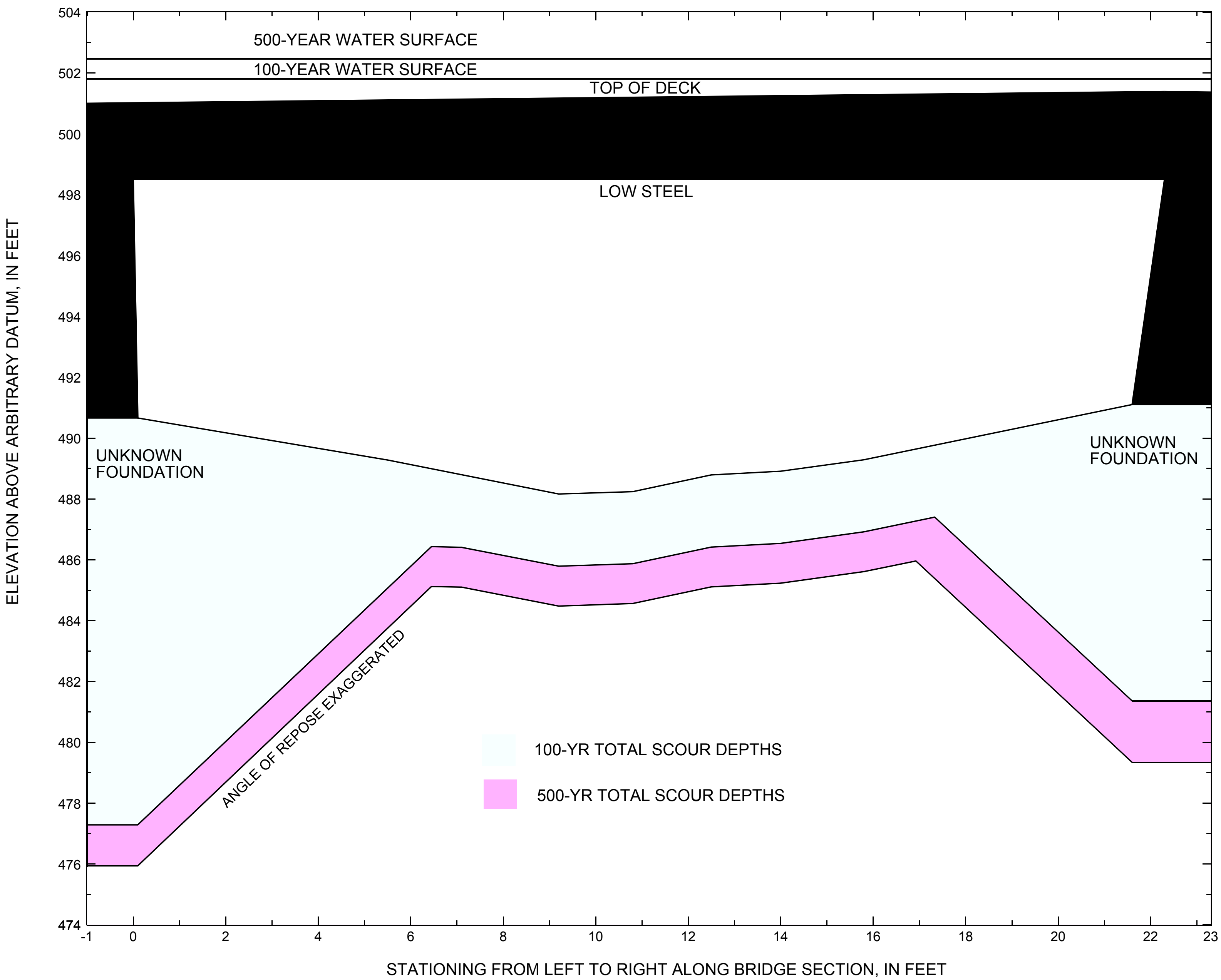

Figure 8. Scour elevations for the 100- and 500-year discharges at structure BRNETH00810042 on Town Highway 81, crossing the Stevens River, Barnet, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRNETH00810042 on Town Highway 81, crossing the Stevens River, Barnet, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 2,880 cubic-feet per second											
Left abutment	0.0	--	498.5	--	490.7	2.4	11.0	--	13.4	477.3	--
Right abutment	22.3	--	498.5	--	491.1	2.4	7.4	--	9.8	481.3	--

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 BRNETH00810042 on Town Highway 81, crossing the Stevens River, Barnet, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 4,000 cubic-feet per second											
Left abutment	0.0	--	498.5	--	490.7	3.7	11.0	--	14.7	476.0	--
Right abutment	22.3	--	498.5	--	491.1	3.7	8.1	--	11.8	479.3	--

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 by 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File brne042.wsp
T2        Hydraulic analysis for structure brneth00810042   Date: 21-JUL-97
T3        hydraulic analysis of bridge 42 in barnet over stevens river
*
J1         * *  0.0050
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2880.0   4000.0   1670.0
SK          0.0100   0.0100   0.0100
*
XS   EXITX    -32           0.
GR         -148.2, 503.15   -114.3, 500.94    -73.4, 499.21    -68.1, 499.64
GR          -45.7, 499.92    -38.2, 497.82    -23.2, 498.15    -12.4, 496.97
GR           -5.8, 492.58     -3.2, 490.95     -0.4, 490.15      0.0, 489.80
GR            2.2, 488.96      4.3, 488.95      4.5, 488.56      6.1, 488.43
GR            7.8, 488.10     10.3, 488.08     12.9, 488.40     15.5, 488.92
GR           17.9, 489.17     20.3, 488.70     22.4, 488.35     23.4, 488.79
GR           27.0, 489.42     31.2, 490.57     32.3, 493.98     36.2, 497.34
GR           44.5, 497.61     72.1, 498.08    123.5, 498.39    189.7, 501.56
GR          289.6, 509.81
*
N           0.035        0.055        0.50
SA                  -0.4         36.1
*
*
XS   FULLV      0  * * *   0.001
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.51      15.0
GR            0.0, 498.51      0.0, 490.66      5.5, 489.28      5.8, 488.81
GR            7.1, 488.78      9.2, 488.16     10.8, 488.24     12.5, 488.79
GR           14.0, 488.91     15.8, 489.29     21.6, 491.10     22.3, 498.51
GR            0.0, 498.51
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      31.3 * *     65.2      4.9
N           0.050
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      19.3     1
GR         -152.9, 502.72    -76.5, 500.14    -33.9, 500.44     -3.7, 500.83
GR            0.0, 501.02     24.2, 501.39     27.0, 501.33     71.3, 503.73
GR           77.5, 504.10
*
*
*
*           EXPECTED SRD =   42 AT ONE BR. LENGTH BUT COMPUTED SRD =   49
*
XT   APTEM     49           0.
GR           -180, 503.35   -158.3, 502.42   -145.6, 501.87   -121.3, 500.15
GR          -94.4, 499.24    -69.8, 498.88    -44.4, 497.16    -11.8, 494.76
GR           -4.6, 493.48      0.0, 491.50      1.9, 489.75      6.8, 489.44
GR            9.1, 489.05     11.5, 488.71     13.2, 488.36     14.3, 488.67
GR           18.1, 489.50     18.8, 489.83     21.3, 491.86     22.2, 493.65
GR           31.2, 499.66     57.1, 502.95     77.5, 504.10
*
AS   APPRO     42  * * *  0.007
GT
N           0.045        0.055        0.050
SA                  -4.6         31.2
*
```

```
HP 1 BRIDG  498.51 1 498.51
HP 2 BRIDG  498.51 * * 2120
*  Downstream bridge face
HP 1 BRIDG  497.34 1 497.34
HP 2 RDWAY  501.80 * *  774
HP 1 APPRO  501.97 1 501.97
HP 2 APPRO  501.97 * * 2880
*
HP 1 BRIDG  498.51 1 498.51
HP 2 BRIDG  498.51 * * 2393
HP 2 RDWAY  502.47 * * 1606
HP 1 APPRO  502.72 1 502.72
HP 2 APPRO  502.72 * * 4000
*
HP 1 BRIDG  498.51 1 498.51
HP 2 BRIDG  498.51 * * 1670
*  Downstream bridge face
HP 1 BRIDG  495.19 1 495.19
HP 1 APPRO  500.15 1 500.15
HP 2 APPRO  500.15 * * 1670
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File brne042.wsp
       Hydraulic analysis for structure brneth00810042   Date: 21-JUL-97
          *** RUN DATE & TIME: 01-07-98  15:12
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     192.   12558.    -1.    59.                          0.
   498.51          192.   12558.    -1.    59.  1.00     0.    22.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.51     0.0    22.3   192.5   12558.    2120.  11.01

X STA.         0.0         2.2         3.6         4.7         5.7         6.6
  A(I)             17.5        11.0         9.6         9.2         8.6
  V(I)             6.07        9.62       11.01       11.47       12.27

X STA.         6.6         7.5         8.4         9.2        10.0        10.7
  A(I)              8.4         8.0         8.1         7.8         7.8
  V(I)            12.55       13.32       13.14       13.62       13.68

X STA.        10.7        11.5        12.4        13.2        14.1        15.0
  A(I)              7.8         8.1         8.0         8.2         8.3
  V(I)            13.62       13.14       13.20       12.90       12.82

X STA.        15.0        16.0        17.0        18.2        19.6        22.3
  A(I)              8.9         9.0         9.8        11.0        17.5
  V(I)            11.97       11.80       10.87        9.61        6.06

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     167.   14215.    21.    35.                       2653.
   497.34          167.   14215.    21.    35.  1.00     0.    22.   2653.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.80  -125.7    35.7   161.2    6972.     774.   4.80

X STA.      -125.7       -96.9       -88.4       -82.6       -77.7       -73.6
  A(I)             14.0         9.4         7.9         7.5         6.7
  V(I)             2.77        4.11        4.87        5.14        5.74

X STA.       -73.6       -69.5       -65.3       -61.2       -56.9       -52.7
  A(I)              6.6         6.7         6.5         6.5         6.4
  V(I)             5.85        5.78        5.98        5.95        6.07

X STA.       -52.7       -48.3       -43.7       -39.0       -34.2       -29.0
  A(I)              6.6         6.6         6.7         6.6         6.9
  V(I)             5.91        5.85        5.80        5.88        5.61

X STA.       -29.0       -23.4       -17.2       -10.0        -1.6        35.7
  A(I)              7.1         7.4         7.9         8.3        19.0
  V(I)             5.47        5.23        4.91        4.68        2.04

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     516.   39871.   144.   145.                       5535.
             2     367.   43048.    36.    41.                       6679.
             3      22.     725.    19.    19.                        135.
   501.97          905.   83643.   199.   204.  1.16  -149.    50.  10169.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.97  -149.0    49.8   905.4   83643.    2880.   3.18

X STA.      -149.0       -91.9       -68.2       -51.8       -40.3       -31.2
  A(I)             94.4        70.9        62.3        54.7        50.1
  V(I)             1.53        2.03        2.31        2.63        2.87

X STA.       -31.2       -23.8       -17.4       -11.7        -6.8        -2.7
  A(I)             44.9        42.6        39.7        37.7        36.1
  V(I)             3.21        3.38        3.62        3.82        3.99

X STA.        -2.7         1.0         3.6         6.0         8.4        10.7
  A(I)             36.8        31.9        29.8        30.5        30.7
  V(I)             3.92        4.51        4.84        4.71        4.70

X STA.        10.7        13.0        15.4        18.1        22.1        49.8
  A(I)             30.3        32.1        34.2        44.8        70.8
  V(I)             4.75        4.49        4.21        3.22        2.03
```

```
      U.S. Geological Survey WSPRO Input File brne042.wsp
      Hydraulic analysis for structure brneth00810042   Date: 21-JUL-97
         *** RUN DATE & TIME: 01-07-98  15:12
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     192.  12558.    -1.    59.                            0.
 498.51          192.  12558.    -1.    59.  1.00     0.    22.       0.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.51     0.0    22.3   192.5   12558.    2393.  12.43

X STA.        0.0        2.2        3.6        4.7        5.7        6.6
  A(I)            17.5       11.0        9.6        9.2        8.6
  V(I)            6.86      10.86      12.43      12.95      13.85

X STA.        6.6        7.5        8.4        9.2       10.0       10.7
  A(I)             8.4        8.0        8.1        7.8        7.8
  V(I)           14.16      15.04      14.84      15.38      15.44

X STA.       10.7       11.5       12.4       13.2       14.1       15.0
  A(I)             7.8        8.1        8.0        8.2        8.3
  V(I)           15.38      14.83      14.90      14.56      14.47

X STA.       15.0       16.0       17.0       18.2       19.6       22.3
  A(I)             8.9        9.0        9.8       11.0       17.5
  V(I)           13.51      13.32      12.27      10.85       6.84

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

       WSEL     LEW     REW    AREA        K        Q    VEL
     502.47  -145.5    48.0   280.1   14953.    1606.   5.73

X STA.     -145.5     -107.0      -95.6      -87.7      -81.4      -75.9
  A(I)            25.0       17.0       14.3       13.1       12.4
  V(I)            3.21       4.71       5.61       6.15       6.48

X STA.      -75.9      -71.0      -65.9      -61.0      -55.9      -50.8
  A(I)            11.3       11.5       11.1       11.2       11.0
  V(I)            7.10       7.00       7.22       7.17       7.29

X STA.      -50.8      -45.6      -40.4      -35.0      -29.4      -23.5
  A(I)            11.1       10.9       11.2       11.3       11.3
  V(I)            7.25       7.38       7.17       7.13       7.08

X STA.      -23.5      -17.2      -10.4       -2.9       11.7       48.0
  A(I)            11.7       12.0       12.5       20.4       29.7
  V(I)            6.87       6.68       6.40       3.93       2.70

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     631.  51665.   162.   162.                         7068.
           2     394.  48418.    36.    41.                         7424.
           3      38.   1513.    24.    25.                          269.
 502.72         1063. 101596.   222.   228.  1.16  -166.    56.  12238.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

       WSEL     LEW     REW    AREA        K        Q    VEL
     502.72  -166.4    55.7  1063.2  101596.    4000.   3.76

X STA.     -166.4     -101.0      -78.6      -60.3      -47.4      -37.2
  A(I)           112.3       80.2       73.7       64.0       58.7
  V(I)            1.78       2.49       2.71       3.13       3.41

X STA.      -37.2      -29.0      -21.8      -15.6      -10.1       -5.3
  A(I)            52.9       50.5       46.3       44.1       41.4
  V(I)            3.78       3.96       4.32       4.53       4.83

X STA.       -5.3       -1.1        2.4        5.1        7.7       10.3
  A(I)            41.7       41.6       35.2       35.3       35.0
  V(I)            4.79       4.81       5.68       5.67       5.71

X STA.       10.3       12.8       15.4       18.4       23.0       55.7
  A(I)            36.0       36.7       40.1       51.7       85.8
  V(I)            5.56       5.45       4.99       3.87       2.33
```

```
       U.S. Geological Survey WSPRO Input File brne042.wsp
       Hydraulic analysis for structure brneth00810042   Date: 21-JUL-97
          *** RUN DATE & TIME: 01-07-98  15:12
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     192.   12558.    -1.    59.                          0.
  498.51          192.   12558.    -1.    59.  1.00     0.    22.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.51     0.0    22.3   192.5   12558.    1670.   8.68

X STA.        0.0         2.2         3.6         4.7         5.7         6.6
  A(I)            17.5        11.0         9.6         9.2         8.6
  V(I)            4.78        7.58        8.67        9.04        9.67

X STA.        6.6         7.5         8.4         9.2        10.0        10.7
  A(I)             8.4         8.0         8.1         7.8         7.8
  V(I)            9.88       10.49       10.35       10.73       10.77

X STA.       10.7        11.5        12.4        13.2        14.1        15.0
  A(I)             7.8         8.1         8.0         8.2         8.3
  V(I)           10.73       10.35       10.40       10.16       10.10

X STA.       15.0        16.0        17.0        18.2        19.6        22.3
  A(I)             8.9         9.0         9.8        11.0        17.5
  V(I)            9.43        9.29        8.56        7.57        4.77

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

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     121.    9102.    21.    30.                       1648.
  495.19          121.    9102.    21.    30.  1.00     0.    22.   1648.

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     279.   16416.   117.   118.                       2439.
            2     302.   31092.    36.    41.                       4983.
            3       1.      14.     4.     4.                          3.
  500.15          582.   47522.   157.   163.  1.22  -122.    35.   5755.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.15  -122.0    35.4   582.3   47522.    1670.   2.87

X STA.     -122.0       -52.4       -37.1       -27.0       -19.5       -13.4
  A(I)            74.8        46.2        40.1        34.4        31.1
  V(I)            1.12        1.81        2.08        2.42        2.69

X STA.      -13.4        -8.3        -4.2        -1.0         1.6         3.5
  A(I)            29.0        25.9        24.1        23.6        19.9
  V(I)            2.88        3.22        3.47        3.54        4.20

X STA.        3.5         5.3         7.1         8.8        10.5        12.2
  A(I)            19.0        19.2        19.2        19.2        19.6
  V(I)            4.39        4.34        4.35        4.36        4.25

X STA.       12.2        13.9        15.8        18.0        20.8        35.4
  A(I)            20.2        21.5        23.6        28.0        43.8
  V(I)            4.14        3.89        3.54        2.98        1.91
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File brne042.wsp
       Hydraulic analysis for structure brneth00810042   Date: 21-JUL-97
          *** RUN DATE & TIME: 01-07-98  15:12
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -12.     307.  1.37 *****  498.25  495.04   2880.  496.88
      -32. ******    36.   28780.  1.00 ***** *******    0.65    9.39

FULLV:FV      32.   -16.     328.  1.20  0.29  498.55 *******   2880.  497.34
        0.    32.    36.   31288.  1.00  0.00    0.00    0.61    8.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.95     497.59     497.41

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.84     504.05    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.84     504.05     497.41

APPRO:AS      42.   -51.     295.  1.70  0.50  499.28  497.41   2880.  497.59
       42.    42.    28.   22449.  1.15  0.25   -0.01    0.96    9.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   502.95       0.00     497.80     500.14

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   496.89     501.42     501.51     498.51

 ===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      32.     0.     192.  1.89 *****  500.40  496.24   2120.  498.51
        0. ******    22.   12558.  1.00 ***** *******    0.66   11.01

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.489  0.000  498.51 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    23.  0.03  0.18  502.13    0.00    774.  501.80

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    725.   136.  -126.    11.   1.7   1.1   5.6   4.8   1.4   3.1
   RT:     48.    25.    11.    36.   0.6   0.4   3.9   4.8   0.7   3.1

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

APPRO:AS      11.  -149.     906.  0.18  0.07  502.16  497.41   2880.  501.97
       42.    12.    50.   83713.  1.16  1.07    0.00    0.28    3.18

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

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -32.   -12.    36.   2880.   28780.     307.    9.39  496.88
   FULLV:FV       0.   -16.    36.   2880.   31288.     328.    8.77  497.34
   BRIDG:BR       0.     0.    22.   2120.   12558.     192.   11.01  498.51
   RDWAY:RG      10.*******   725.    774.*********       0.    1.00  501.80
   APPRO:AS      42.  -149.    50.   2880.   83713.     906.    3.18  501.97

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF     HO   VHD     EGL    WSEL
   EXITX:XS    495.04    0.65  488.08  509.81************  1.37  498.25  496.88
   FULLV:FV  ********    0.61  488.11  509.84  0.29  0.00  1.20  498.55  497.34
   BRIDG:BR    496.24    0.66  488.16  498.51************  1.89  500.40  498.51
   RDWAY:RG  ***************  500.14  504.10  0.03******  0.18  502.13  501.80
   APPRO:AS    497.41    0.28  488.31  504.05  0.07  1.07  0.18  502.16  501.97
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File brne042.wsp
        Hydraulic analysis for structure brneth00810042   Date: 21-JUL-97
           *** RUN DATE & TIME: 01-07-98  15:12
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -41.     448.  1.61 *****  500.13  496.42   4000.  498.52
      -32. ******   126.   39995.  1.30 ***** *******    1.10    8.93

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.92     499.11     496.46

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   498.02     509.84    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   498.02     509.84     496.46

FULLV:FV      32.   -43.     546.  1.28  0.28  500.40  496.46   4000.  499.12
        0.    32.   138.   46502.  1.53  0.00   -0.01    0.92    7.33
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.84     499.51     498.56

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   498.62     504.05    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   498.62     504.05     498.56

APPRO:AS      42.  -104.     490.  1.26  0.37  500.78  498.56   4000.  499.52
       42.    42.    31.   38841.  1.22  0.00    0.01    0.83    8.16
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   499.12     498.51

            <<<<<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      32.     0.     192.  2.40 *****  500.91  496.83   2393.  498.51
        0. ******    22.   12558.  1.00 ***** *******    0.75   12.43

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.51 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      10.    23.  0.04  0.26  502.94    0.00   1606.  502.47

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1434.   156.  -146.    11.   2.3   1.6   6.7   5.7   2.1   3.1
   RT:    172.    37.    11.    48.   1.3   0.8   5.3   5.5   1.3   3.1

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

APPRO:AS      11.  -166.    1063.  0.26  0.11  502.98  498.56   4000.  502.72
       42.    14.    56.  101613.  1.16  1.07    0.00    0.33    3.76

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

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -32.   -41.   126.   4000.   39995.     448.    8.93  498.52
   FULLV:FV       0.   -43.   138.   4000.   46502.     546.    7.33  499.12
   BRIDG:BR       0.     0.    22.   2393.   12558.     192.   12.43  498.51
   RDWAY:RG      10.******* 1434.   1606.*****************    1.00  502.47
   APPRO:AS      42.  -166.    56.   4000.  101613.    1063.    3.76  502.72

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    496.42    1.10  488.08  509.81************  1.61  500.13  498.52
   FULLV:FV    496.46    0.92  488.11  509.84  0.28  0.00  1.28  500.40  499.12
   BRIDG:BR    496.83    0.75  488.16  498.51************  2.40  500.91  498.51
   RDWAY:RG  ***************  500.14  504.10  0.04******  0.26  502.94  502.47
   APPRO:AS    498.56    0.33  488.31  504.05  0.11  1.07  0.26  502.98  502.72
```

```
       U.S. Geological Survey WSPRO Input File brne042.wsp
       Hydraulic analysis for structure brneth00810042   Date: 21-JUL-97
          *** RUN DATE & TIME: 01-07-98  15:12
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******    -9.     211.  0.97 *****  495.73  493.25   1670.  494.76
      -32. ******    33.   16690.  1.00 ***** *******    0.62    7.91

FULLV:FV      32.   -10.     228.  0.83  0.29  496.02 *******   1670.  495.19
        0.    32.    34.   18701.  1.00  0.00    0.00    0.56    7.32
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     1.10     495.15     495.36

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.69     504.05    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.69     504.05     495.36

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   495.36     504.05     495.36

APPRO:AS      42.   -21.     156.  1.91 *****  497.26  495.36   1670.  495.36
       42.    42.    25.   10742.  1.07 ***** *******    1.05   10.68
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.24     498.87     498.97     498.51

 ===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      32.     0.     192.  1.17 *****  499.68  495.24   1668.  498.51
        0. ******    22.   12558.  1.00 ***** *******    0.52    8.67

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.439  0.000  498.51 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      11.  -122.     583.  0.16  0.05  500.31  495.36   1670.  500.15
       42.    11.    35.   47604.  1.22  1.03    0.00    0.29    2.86

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   500.13

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL   WSEL
   EXITX:XS     -32.    -9.    33.   1670.   16690.     211.    7.91  494.76
   FULLV:FV       0.   -10.    34.   1670.   18701.     228.    7.32  495.19
   BRIDG:BR       0.     0.    22.   1668.   12558.     192.    8.67  498.51
   RDWAY:RG      10.**************      0.        0.       0.    1.00********
   APPRO:AS      42.  -122.    35.   1670.   47604.     583.    2.86  500.15

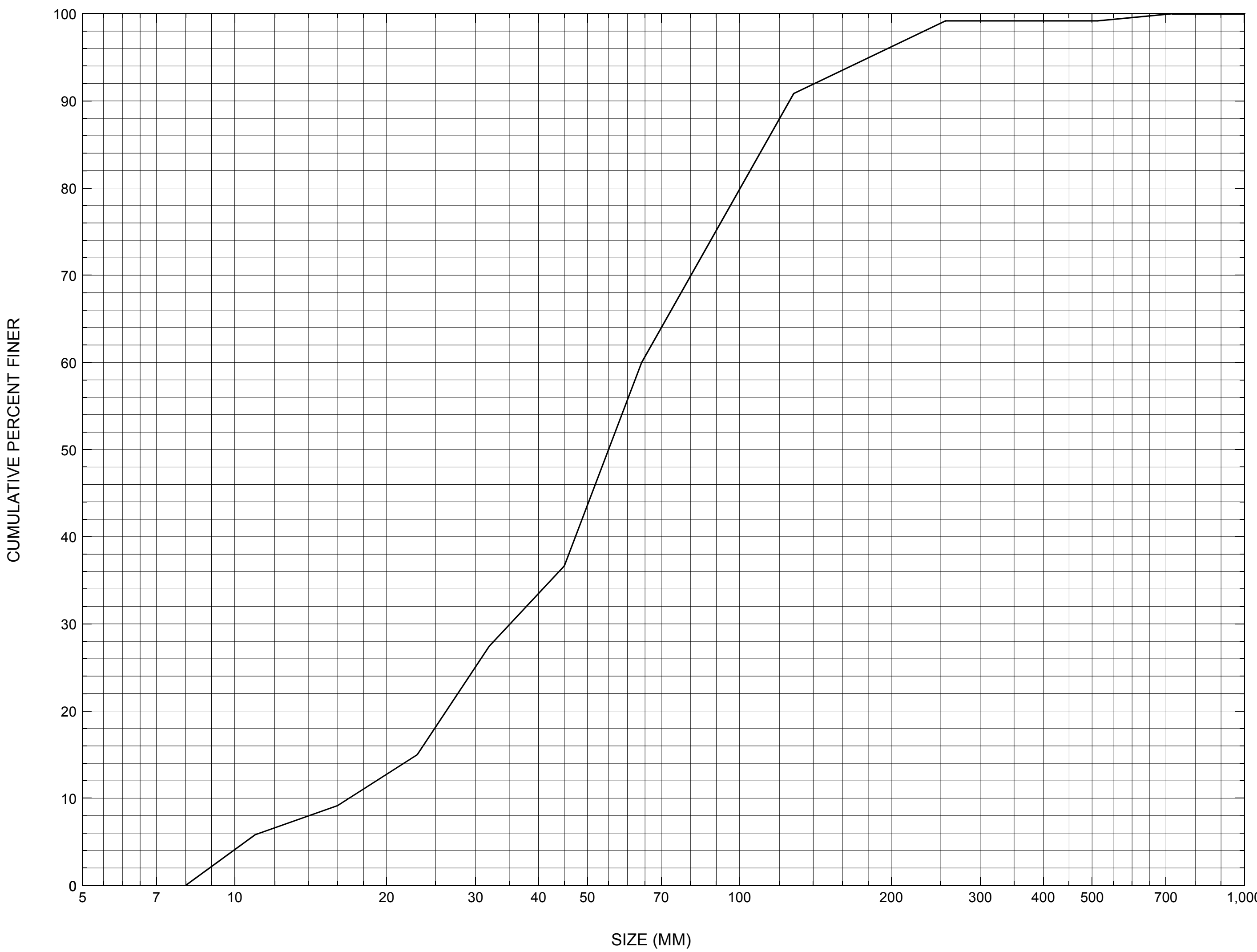
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  **********************

          *** RUN DATE & TIME: 01-07-98  15:12
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.25    0.62  488.08  509.81************  0.97  495.73  494.76
   FULLV:FV  ********    0.56  488.11  509.84  0.29  0.00  0.83  496.02  495.19
   BRIDG:BR    495.24    0.52  488.16  498.51************  1.17  499.68  498.51
   RDWAY:RG  ****************  500.14  504.10************  0.16  500.28********
   APPRO:AS    495.36    0.29  488.31  504.05  0.05  1.03  0.16  500.31  500.15
  ER
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BRNETH00810042 in Barnet, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BRNETH00810042

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 23 / 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 TH081

Vicinity *(I - 9)* 0.04 MI TO JCT W CL2 TH1

Topographic Map Barnet

Hydrologic Unit Code: 01080103

Latitude *(I - 16; nnnn.n)* 44187

Longitude *(i - 17; nnnnn.n)* 72082

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030100420301

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

Maximum span length *(I - 48; nnnn)* 0025

Year built *(I - 27; YYYY)* 1926

Structure length *(I - 49; nnnnnn)* 000029

Average daily traffic, ADT *(I - 29; nnnnnn)* 000150

Deck Width *(I - 52; nn.n)* 193

Year of ADT *(I - 30; YY)* 93

Channel & Protection *(I - 61; n)* 6

Opening skew to Roadway *(I - 34; nn)* 15

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

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

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*) 023.8

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

Vertical clearance from streambed (*nnn.n ft*) 007.8

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

Waterway of full opening (*nnn.n ft*^{2}) 185.9

Comments:

The structural inspection report of 9/6/94 indicates the structure is a steel stringer type bridge with a concrete deck and asphalt roadway surface. The abutment walls and wingwalls are concrete. The right abutment and its wingwalls have widespread cracking and leaking reported through the cracks. Additionally, there are areas of spalling and displacement in the wall of about 4 inches. The left abutment and its wingwalls reportedly have some areas of cracking with leaking, and a large spall and break on the downstream wingwall. This abutment evidently is sealed or doweled into bedrock, which outcrops at the base of the wall. There is some stone fill along the front face of the left abutment. **(Continued, page 34)**

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area (*mi*^{2}): -

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft*^{3}*/ sec*): -

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

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

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

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

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

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

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

Comments:

The channel bed consists of gravel, cobbles, and boulders under the bridge. The type of foundation recorded for this bridge is a spread footing. According to the report, even though the base of the left abutment is on bedrock, the footings are noted as not visible. Furthermore, undermining and settling are reported as not apparent. The report indicates some channel scour is evident just downstream. Debris accumulation and point bar development are noted as not evident.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **20.67** mi^2 Lake/pond/swamp area **1.31** mi^2

Watershed storage *(ST)* **6.3** %

Bridge site elevation **886** ft Headwater elevation **2369** ft

Main channel length **6.13** mi

10% channel length elevation **899** ft 85% channel length elevation **1529** ft

Main channel slope *(S)* **136.81** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:
NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness ______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS

Cross-sectional Data

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

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

Comments: **This cross section is the upstream face. The low chord elevation is from the survey log done for this report on 8/23/95. The low chord to bed length data are from the sketch attached to a bridge inspection report dated 9/6/94. The sketch was done on 7/1/92.**

Station	0	7.5	11.8	15.5	23.9	-	-	-	-	-	-
Feature	LAB				RAB	-	-	-	-	-	-
Low chord elevation	498.5	498.5	498.5	498.5	498.5	-	-	-	-	-	-
Bed elevation	491.2	489.6	488.1	489.5	491.4	-	-	-	-	-	-
Low chord to bed	7.3	8.9	10.4	9.0	7.1	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments:

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 2/26/96
Computerized by: RB Date: 2/26/96
Reviewd by: MS Date: 1/12/98

Structure Number BRNETH00810042

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. BOEHMLER Date *(MM/DD/YY)* 8 / 23 / 1995
2. Highway District Number 07 Mile marker 0000
County CALEDONIA (005) Town BARNET (02875)
Waterway *(I - 6)* STEVENS RIVER Road Name -
Route Number TH081 Hydrologic Unit Code: 01080103
3. Descriptive comments:
This bridge is located about 200 feet east of the intersection of Town Highway 81 with Town Highway 1.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 5 LBDS 4 RBDS 5 Overall 4
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 1 UB 1 DS 1 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 29 *(feet)* Span length 25 *(feet)* Bridge width 19.3 *(feet)*

Road approach to bridge:

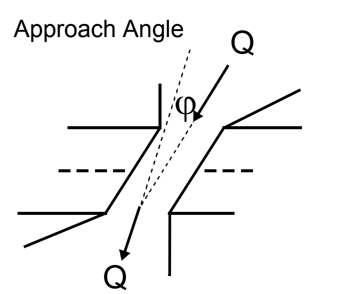
8. LB 0 RB 2 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

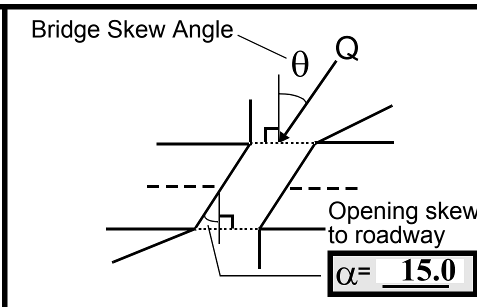
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	2	1
LBDS	0	-	0	0

*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: 15



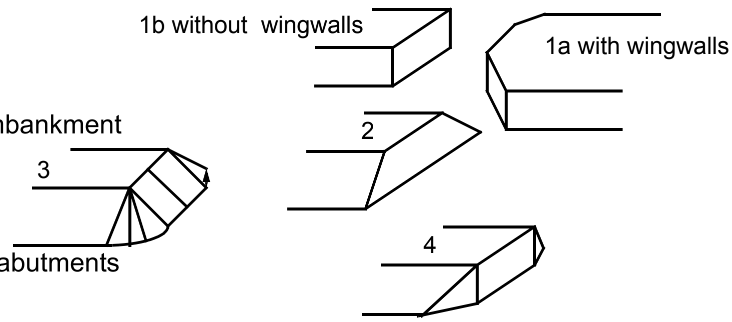


17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 25 feet US *(US, UB, DS)* to 5 feet US
Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 35 feet DS *(US, UB, DS)* to 75 feet DS

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

18. Bridge Type: **1a**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

4. Surface cover on the US left bank consists of a lawn around a church. A bit DS and behind the church is a shed. On the DS left bank there is a lawn and a house. The US and DS right banks have weeds, shrubs, and small trees. TH81 bisects the US right bank coverage. Beyond 2 bridge lengths on the US right bank is forest. The DS right bank has older trees only along the immediate side of the channel. Overflow will occur over the left bank road approach before topping the bridge deck.
7. These values are from VTAOT files. The measured bridge length, span length, and bridge width are 27 ft, 25 ft, and 19.3 ft, respectively.

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
28.0	1.5			2.5	1	1	324	324	2	1

23. Bank width **5.0** 24. Channel width **30.0** 25. Thalweg depth **21.5** 29. Bed Material **325**

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.):

The right bank protection extends from 65 feet US to the US face of the bridge. The left bank protection extends from 20 feet US to the US bridge face. The left bank side is eroding moderately and is cut as indicated. The cutting process is not due to a meander bend but due to the US channel constriction by stone fill on the right bank. The left bank side is freshly eroded.

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: **55** 42. Cut bank extent: **70** feet **US** (US, UB) to **25** feet **US** (US, UB, DS)

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

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

Cutting is due to channel widening.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **43**

47. Scour dimensions: Length **18** Width **6** Depth : **1** Position **40** %LB to **100** %RB

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

Scouring of bed is occurring US where stone fill on the right bank begins to influence flow by constricting the channel. Currently the deepest pools in the channel elsewhere are no more than 0.5 feet deep.

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
2.0		1.0		2	7	7	-

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

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

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

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

352

The channel under the bridge is constricted by bedrock on the DS half of the right side where the rock juts out 10 feet from the right abutment wall and is about 4.5 feet higher than the adjacent stream bed near mid-channel. The channel is further constricted by stone fill on the left abutment, which also sits 4.5 feet high from the lowest channel spot adjacent to the stone fill, and up to 5 feet toward the channel from the left abutment wall.

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

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

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

70. Debris and Ice Comments:

2

The banks are fairly stable but have a lot of trees, shrubs, and brush on them. The channel does not bend much under the bridge but debris may get lodged on bedrock or stone fill.

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**	**0**	**0**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**0**	**21.5**

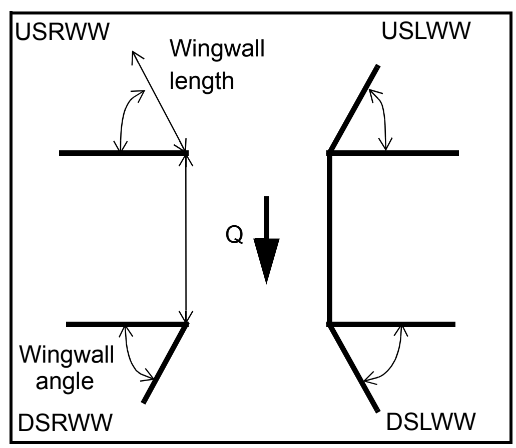
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1-* Concrete; *2-* Stone masonry or drywall; *3-* steel or metal; *4-* wood

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

0
0
1
-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**21.5**	
USRWW:	**Y**		**1**		**0**	**1.0**	
DSLWW:	**0**		**0**		**Y**	**21.0**	
DSRWW:	**1**		**0**		**0**	**20.5**	



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**	**0**	**Y**	**0**	**1**	**1**	**1**	**1**
Condition	**Y**	**0**	**1**	**0**	**1**	**1**	**1**	**1**
Extent	**1**	**0**	**0**	**2**	**2**	**3**	**2**	**-**

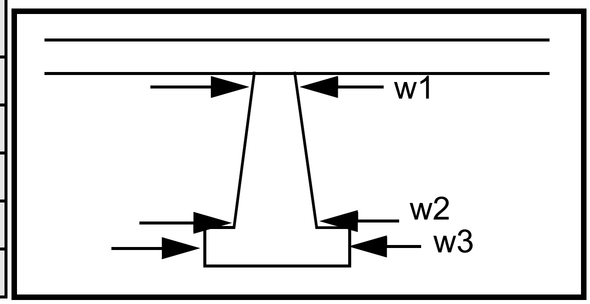
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**75.0**	**11.5**	**55.0**
Pier 2				**12.0**	**40.0**	**13.5**
Pier 3			-	**55.0**	**14.5**	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e pro-**	**US**	**sur-**	**is cov-**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**tec-**	**half**	**face.**	**ered**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**tion**	**wher**	**The**	**by**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**on**	**e the**	**pro-**	**sand**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**the**	**bed-**	**tec-**	**and**	*Y- yes; N- no*
91. Attack ∠ (BF)	**right**	**rock**	**tion**	**fine**	
92. Pushed	**abut**	**is**	**on**	**grav**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**ment**	**not**	**the**	**el**	
95. Cross-members	**is**	**visi-**	**DS**	**from**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**only**	**ble**	**right**	**the**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**on**	**on**	**wing**	**chan**	
98. Exposure depth	**the**	**the**	**wall**	**nel.**	

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

The US right wingwall protection is visible more toward the stream edge but back by the wall is covered with sand and fine gravel like the DS right wingwall.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: -____

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

-
-
-
-

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

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

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

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

Is channel scour present? _____ *(Y or if N type ctrl-n cs)* Mid-scour distance: 1______

Scour dimensions: Length 2_____ Width 324____ Depth: 342___ Positioned 1___ %LB to 1___ %RB

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

342
0
0
-

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

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

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

Confluence comments (eg. confluence name):

on the right bank from 30 feet DS to about 65 feet DS. There are a few scattered boulders in the channel as well.

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

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: BRNETH00810042 Town: Barnet
Road Number: TH81 County: Caledonia
Stream: Stevens River

Initials MS Date: 08/22/97 Checked:EMB

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	2880	4000	1670
Main Channel Area, ft2	367	394	302
Left overbank area, ft2	516	631	279
Right overbank area, ft2	22	38	1
Top width main channel, ft	36	36	36
Top width L overbank, ft	144	162	117
Top width R overbank, ft	19	24	4
D50 of channel, ft	0.181	0.181	0.181
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.2	10.9	8.4
y1, average depth, LOB, ft	3.6	3.9	2.4
y1, average depth, ROB, ft	1.2	1.6	0.3
Total conveyance, approach	83643	101596	47522
Conveyance, main channel	43048	48418	31092
Conveyance, LOB	39871	51665	16416
Conveyance, ROB	725	1513	14
Percent discrepancy, conveyance	-0.0012	0.0000	0.0000
Qm, discharge, MC, cfs	1482.2	1906.3	1092.6
Ql, discharge, LOB, cfs	1372.8	2034.1	576.9
Qr, discharge, ROB, cfs	25.0	59.6	0.5
Vm, mean velocity MC, ft/s	4.0	4.8	3.6
Vl, mean velocity, LOB, ft/s	2.7	3.2	2.1
Vr, mean velocity, ROB, ft/s	1.1	1.6	0.5
Vc-m, crit. velocity, MC, ft/s	9.3	9.4	9.0
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	2880	4000	1670
(Q) discharge thru bridge, cfs	2120	2393	1670
Main channel conveyance	12558	12558	12558
Total conveyance	12558	12558	12558
Q2, bridge MC discharge,cfs	2120	2393	1670
Main channel area, ft2	192	192	192
Main channel width (normal), ft	21.5	21.5	21.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.5	21.5	21.5
y_bridge (avg. depth at br.), ft	8.93	8.93	8.93
Dm, median (1.25*D50), ft	0.22625	0.22625	0.22625
y2, depth in contraction,ft	9.68	10.74	7.89
ys, scour depth (y2-ybridge), ft	0.75	1.81	-1.04

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	2120	2393	1670
Main channel area (DS), ft2	167	192	123
Main channel width (normal), ft	21.5	21.5	21.5
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	21.5	21.5	21.5
D90, ft	0.4122	0.4122	0.4122
D95, ft	0.5906	0.5906	0.5906
Dc, critical grain size, ft	0.5497	0.5037	0.7059
Pc, Decimal percent coarser than Dc	0.059	0.069	0.029
Depth to armoring, ft	26.30	20.39	N/A

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	2880	4000	1670
Q, thru bridge MC, cfs	2120	2393	1670
Vc, critical velocity, ft/s	9.34	9.45	9.04
Va, velocity MC approach, ft/s	4.04	4.84	3.62
Main channel width (normal), ft	21.5	21.5	21.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.5	21.5	21.5
qbr, unit discharge, ft2/s	98.6	111.3	77.7
Area of full opening, ft2	192.0	192.0	192.0
Hb, depth of full opening, ft	8.93	8.93	8.93
Fr, Froude number, bridge MC	0.66	0.75	0.52
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	167	N/A	121
**Hb, depth at downstream face, ft	7.77	N/A	5.63
**Fr, Froude number at DS face	0.80	ERR	1.03
**Cf, for downstream face (<=1.0)	1.00	N/A	1.00
Elevation of Low Steel, ft	498.51	498.51	498.51
Elevation of Bed, ft	489.58	489.58	489.58
Elevation of Approach, ft	501.97	502.72	500.15
Friction loss, approach, ft	0.07	0.11	0.05
Elevation of WS immediately US, ft	501.90	502.61	500.10
ya, depth immediately US, ft	12.32	13.03	10.52
Mean elevation of deck, ft	501.2	501.2	501.2
w, depth of overflow, ft (>=0)	0.70	1.41	0.00
Cc, vert contrac correction (<=1.0)	0.93	0.93	0.96
**Cc, for downstream face (<=1.0)	0.894135	ERR	0.96
Ys, scour w/Chang equation, ft	**2.37**	**3.68**	**0.02**
Ys, scour w/Umbrell equation, ft	-1.02	0.02	-2.26

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

**Ys, scour w/Chang equation, ft	4.04	N/A	3.23
**Ys, scour w/Umbrell equation, ft	0.14	N/A	1.05

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	9.68	10.74	7.89
WSEL at downstream face, ft	497.34	--	495.19
Depth at downstream face, ft	7.77	N/A	5.72
Ys, depth of scour (Laursen), ft	1.92	N/A	2.17

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	2880	4000	1670	2880	4000	1670
a', abut.length blocking flow, ft	149.4	166.8	122.4	27.9	33.8	13.5
Ae, area of blocked flow ft2	421.11	449.68	318.31	66.21	77.13	40.5
Qe, discharge blocked abut.,cfs	--	--	712.96	--	--	77.21
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.77	3.34	2.24	2.07	2.52	1.91
ya, depth of f/p flow, ft	2.82	2.69	2.60	2.37	2.27	3.00
--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	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.251	0.291	0.245	0.225	0.261	0.194
ys, scour depth, ft	15.51	16.89	13.57	**7.37**	**8.08**	**6.83**

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)	149.4	166.8	122.4	27.9	33.8	13.5
y1 (depth f/p flow, ft)	2.82	2.69	2.60	2.37	2.27	3.00
a'/y1	53.03	61.95	47.07	11.79	14.87	4.50
Skew correction (p. 49, fig. 16)	1.03	1.03	1.03	0.95	0.95	0.95
Froude no. f/p flow	0.25	0.29	0.24	0.23	0.26	0.19
Ys w/ corr. factor K1/0.55:						
vertical	13.41	13.46	12.28	ERR	ERR	ERR
vertical w/ ww's	**11.00**	**11.04**	**10.07**	ERR	ERR	ERR
spill-through	7.38	7.40	6.75	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	0.66	0.75	0.52	0.66	0.75	0.52
y, depth of flow in bridge, ft	7.77	8.93	5.63	7.77	8.93	5.63
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.09	3.11	0.96	2.09	3.11	0.96
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR