LEVEL II SCOUR ANALYSIS FOR BRIDGE 41 (BRNETH00990041) on TOWN HIGHWAY 99, crossing the STEVENS RIVER, BARNET, VERMONT

Open-File Report 98-540

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 41 (BRNETH00990041) on TOWN HIGHWAY 99, crossing the STEVENS RIVER,

BARNET, VERMONT

By ROBERT H. FLYNN AND MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1998

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 41 (BRNETH00990041) ON TOWN HIGHWAY 99, CROSSING THE STEVENS RIVER, BARNET, VERMONT

By **Robert H. Flynn and Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRNETH00990041 on Town Highway 99 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 45.5-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is trees, shrubs and brush.

In the study area, the Stevens River has an incised, sinuous channel with a slope of approximately 0.0038 ft/ft, an average channel top width of 49 ft and an average bank height of 4 ft. The channel bed material is predominantly cobbles with a median grain size (D_{50}) of 59.2 mm (0.194 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 99 crossing of the Stevens River is a 37-ft-long, two-lane bridge consisting of one 34-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 31 ft. The bridge is supported on the right by a vertical, concrete abutment and wingwalls and on the left by a “laid-up” and grouted stone abutment and wingwalls with a concrete cap. A stone retaining wall extends upstream from the left abutment. A concrete block retaining wall extends upstream from the right abutment. The channel is skewed approximately 30 degrees to the opening and the computed opening-skew-to-roadway is 30 degrees.

The scour protection measures at the site included retaining walls along the upstream left and right banks and along the upstream end of the upstream left wingwall. Type-2 stone fill (less than 36 inches diameter) was found along the upstream end of the upstream right wingwall and along the downstream right bank. 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 2.0 to 4.4 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 5.7 to 15.0 ft. The worst-case abutment scour occurred along the left abutment at the incipient roadway-overtopping discharge and the right abutment 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. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 BRNETH00990041 ***Stream*** Stevens River

County Caledonia ***Road*** TH 99 ***District*** 7

Description of Bridge

Bridge length 37 ***ft*** ***Bridge width*** 21.9 ***ft*** ***Max span length*** 34 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/22/95

Description of stone fill Type-2 (less than 36 inches diameter) along the upstream end of the upstream right wingwall and a retaining wall at the upstream end of the upstream left wingwall.

Abutments and wingwalls are concrete on the right and grouted stone with a concrete cap on the left.

Yes

30 Yes

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

is a moderate channel bend in the upstream reach. The flow impacts the upstream right wingwall.

8/22/94

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***
	0	0	8/22/
Level I	94	0	0
Level II			

Potential for debris Low. There is no tree debris in the channel near the bridge location and the upstream channel is laterally stable with no upstream cut-banks.

Describe any features near or at the bridge that may affect flow (include observation date) There is the potential for backwater from the Connecticut River, which is approximately 2,500 feet downstream of the bridge.

Description of the Geomorphic Setting

General topography The channel is located within an irregular flood plain in a moderate relief valley setting.

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

Date of inspection 8/22/95

DS left: Steep channel bank to a wide overbank area.

DS right: Steep channel bank to a narrow overbank and steep valley wall.

US left: Steep channel bank to steep valley wall.

US right: Steep channel bank to steep valley wall.

Description of the Channel

Average top width 49 *ft* ***Average depth*** 4 *ft*

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

Sinuous but stable with non-alluvial channel boundaries.

8/22/95

Vegetative co Shrubs, brush and trees.

DS left: Trees and brush.

DS right: Trees and brush.

US left: Trees and brush.

US right: Yes

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

None noted, 8/22/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 45.5 ***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:*** There are a some houses on the upstream and downstream left overbank area in the vicinity of the bridge, but the drainage area is rural.

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 5,200 ***ft³/s*** ***Q500*** 9,000 ***ft³/s***

The 100- and 500-year discharges are the discharge values for the Stevens River at its confluence with the Connecticut River as determined in the Flood Insurance Study of Barnet (FEMA, 1988). The values used were within a range defined by flood frequency curves developed from several empirical methods (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 None. To obtain the North American Vertical Datum of 1988, subtract 437.35 ft from the USGS survey datum.

Description of reference marks used to determine USGS datum. RM1 is a U.S. Coast and Geodetic Survey disk (S55, 1978) on top of the downstream end of the left wingwall (elev. 897.74 ft, arbitrary survey datum). RM2 is a chiseled "X" on top of the upstream curb at the end of the bridge rail curbing (elev. 900.94 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	-30	1	Exit section as surveyed in conjunction with FEMA FIS data.
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section as surveyed in conjunction with FEMA FIS data.
APPRO	53	1	Modelled Approach section as surveyed in conjunction with FEMA FIS data.

[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. The channel "n" value for the reach was 0.045, and overbank "n" values ranged from 0.035 to 0.045.

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 0.0038 ft/ft, which was determined from the thalweg points surveyed downstream.

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

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 900.4 ***ft***
Average low steel elevation 898.1 ***ft***

100-year discharge 5,200 ***ft^3/s***
Water-surface elevation in bridge opening 898.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 2,220 ***ft^3/s***
Area of flow in bridge opening 259 ***ft^2***
Average velocity in bridge opening 11.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.3 ***ft/s***

Water-surface elevation at Approach section with bridge 901.9
Water-surface elevation at Approach section without bridge 901.2
Amount of backwater caused by bridge 0.7 ***ft***

500-year discharge 9,000 ***ft^3/s***
Water-surface elevation in bridge opening 898.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 5,610 ***ft^3/s***
Area of flow in bridge opening 259 ***ft^2***
Average velocity in bridge opening 13.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.8 ***/s***

Water-surface elevation at Approach section with bridge 903.3
Water-surface elevation at Approach section without bridge 902.5
Amount of backwater caused by bridge 0.8 ***ft***

Incipient overtopping discharge 3,470 ***ft^3/s***
Water-surface elevation in bridge opening 896.4 ***ft***
Area of flow in bridge opening 215 ***ft^2***
Average velocity in bridge opening 16.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 20.4 ***ft/s***

Water-surface elevation at Approach section with bridge 899.5
Water-surface elevation at Approach section without bridge 897.3
Amount of backwater caused by bridge 2.2 ***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 analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p. 30, equation 17). At this site, the 100-year discharge resulted in unsubmerged orifice flow and 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 for this discharge 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). Furthermore, for the 100-year discharge, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these alternative computations are provided in appendix F.

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

Scour Results

Contraction scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	2.0
Clear-water scour	2.9	4.4	--
Depth to armoring	8.1 12.3	N/A	--
Left overbank	--	--	--
Right overbank	--	--	5.7 5.7
Local scour:			
Abutment scour	11.5	13.9	15.0
Left abutment	8.7	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	2.8	3.8
Pier 3			

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	3.4	2.8	3.8
Left abutment	3.4	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--		
Pier 2			

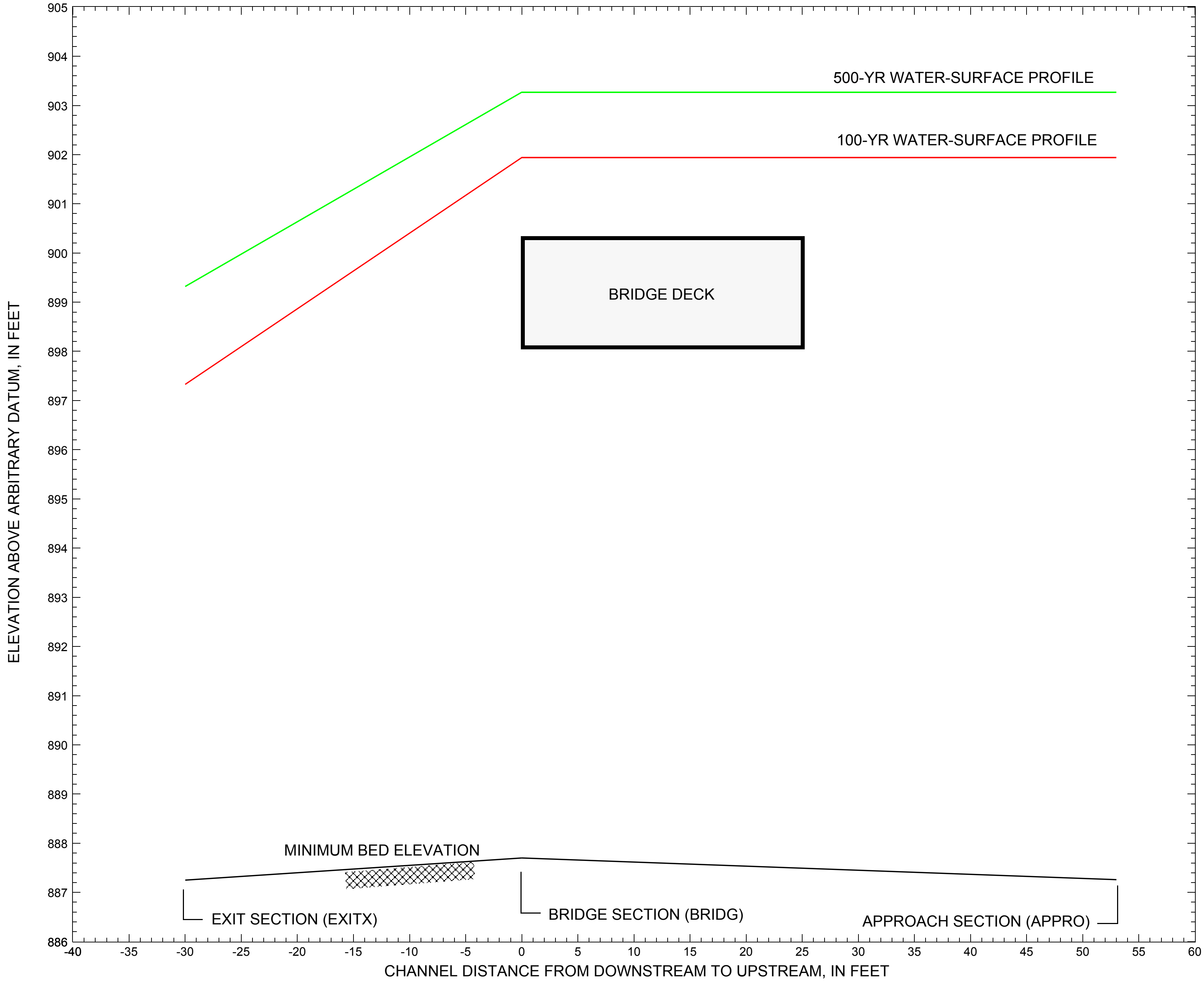

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure BRNETH00990041 on Town Highway 99, crossing the Stevens River, Barnet, Vermont.

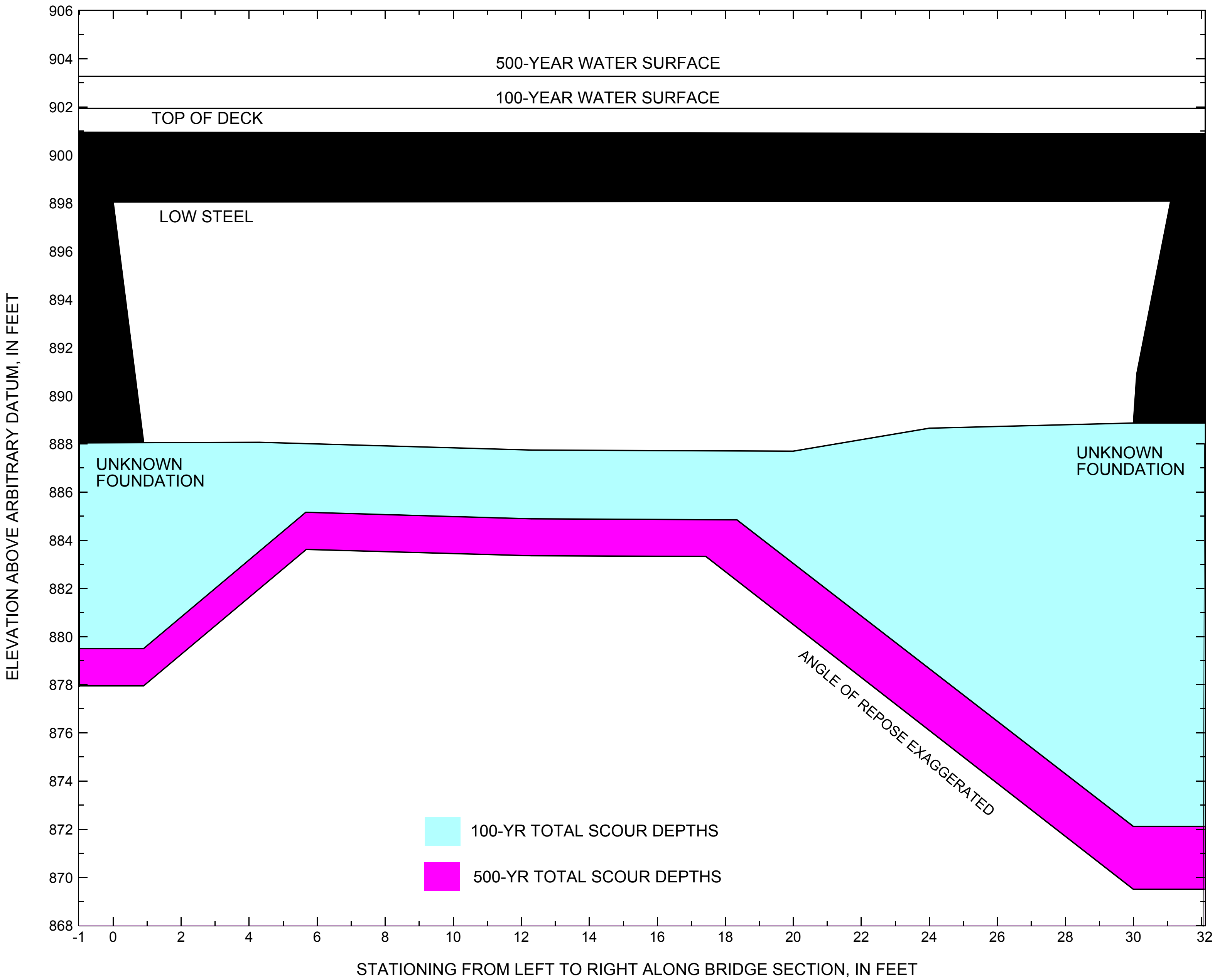

Figure 8. Scour elevations for the 100- and 500-year discharges at structure BRNETH00990041 on Town Highway 99, crossing the Stevens River, Barnet, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRNETH00990041 on Town Highway 99, 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 5,200 cubic-feet per second											
Left abutment	0.0	-	898.0	-	888.0	2.9	5.7	--	8.6	879.4	-
Right abutment	31.1	-	898.1	-	888.9	2.9	13.9	--	16.8	872.1	-

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure BRNETH00990041 on Town Highway 99, 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 9,000 cubic-feet per second											
Left abutment	0.0	-	898.0	-	888.0	4.4	5.7	--	10.1	877.9	-
Right abutment	31.1	-	898.1	-	888.9	4.4	15.0	--	19.4	869.5	-

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158.

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

Federal Emergency Management Agency, 1988, Flood Insurance Study, Town of Barnet, Caledonia County, Vermont: Washington, D.C., May 1988.

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

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 brne041.wsp
T2        Hydraulic analysis for structure BRNETH00990041   Date: 16-SEP-97
T3        Bridge #41 on TH99 crossing the Stevens River in Barnet, Vt.   RHF
*
J1        * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5200.0   9000.0   3470.0
SK          0.0038   0.0038   0.0038
*
XS   EXITX    -30           0.
GR         -258.4, 909.47   -187.1, 902.71   -171.4, 899.03   -157.6, 900.38
GR         -133.2, 899.02    -28.6, 893.80     -9.6, 892.36      0.0, 888.65
GR           11.4, 888.16     23.1, 888.08     32.0, 887.25     37.8, 888.48
GR           45.1, 891.35     49.3, 894.18     78.3, 894.96    106.1, 896.80
GR          150.0, 900.70    165.0, 903.70    165.0, 910.00
*
N           0.040        0.045        0.045
SA                -9.6         49.3
*
XS   FULLV      0  * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    898.07      30.0
GR            0.0, 898.05      0.9, 888.04      4.3, 888.07
GR           12.3, 887.75     20.0, 887.70     24.0, 888.65     30.0, 888.87
GR           30.1, 890.90     31.1, 898.09      0.0, 898.05
*
*         BRTYPE  BRWDTH
CD           1     25.5
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      21.9     1
GR         -308.2, 911.03   -258.5, 910.37   -158.9, 903.21    -78.7, 900.59
GR            0.0, 900.35      0.2, 900.95     26.1, 900.89     26.3, 900.36
GR          150.0, 900.70    165.0, 903.70    165.0, 910.00
*
AS   APPRO     53           0.
GR         -253.4, 911.65   -211.8, 907.78   -172.5, 904.28   -101.5, 901.03
GR          -13.6, 900.53     -5.1, 898.69     -0.2, 893.49     -0.1, 888.92
GR            0.0, 888.38      2.0, 887.58      5.1, 887.26      9.0, 887.26
GR           11.9, 888.46     14.4, 888.01     17.6, 888.82     22.7, 891.65
GR           25.3, 893.61     26.1, 898.82     51.8, 898.15
GR          150.0, 900.70    165.0, 903.70    165.0, 910.00
*
N           0.040        0.045        0.035
SA                -13.6         26.1
*
HP 1 BRIDG  898.07 1 898.07
HP 2 BRIDG  898.07 * * 2978
HP 1 BRIDG  897.53 1 897.53
HP 2 RDWAY  901.94 * * 2219
HP 1 APPRO  901.94 1 901.94
HP 2 APPRO  901.94 * * 5200
*
HP 1 BRIDG  898.09 1 898.09
HP 2 BRIDG  898.09 * * 3416
HP 2 RDWAY  903.27 * * 5605
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File brne041.wsp
       Hydraulic analysis for structure BRNETH00990041   Date: 16-SEP-97
       Bridge #41 on TH99 crossing the Stevens River in Barnet, Vt.   RHF

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      259     23244     13     58                         6450
  898.07           259     23244     13     58  1.00      0     31     6450

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      898.07     0.0    31.1   259.1   23244.    2978.  11.49

X STA.         0.0         3.5         5.4         7.1         8.7        10.2
  A(I)             26.4        16.3        14.9        14.1        13.3
  V(I)             5.64        9.13       10.00       10.55       11.21

X STA.        10.2        11.7        13.1        14.5        15.8        16.9
  A(I)             13.0        12.8        12.7        11.8         9.5
  V(I)            11.46       11.67       11.70       12.64       15.73

X STA.        16.9        17.9        19.0        20.0        21.0        22.2
  A(I)              9.4         9.4         9.2         9.4         9.6
  V(I)            15.91       15.90       16.27       15.87       15.46

X STA.        22.2        23.4        24.6        26.0        27.6        31.1
  A(I)             10.0        10.4        11.3        12.8        23.0
  V(I)            14.91       14.33       13.20       11.60        6.47


   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      245     25604     27     44                         4194
  897.53           245     25604     27     44  1.00      0     31     4194


   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.
        WSEL     LEW     REW    AREA        K        Q    VEL
      901.94  -120.0   156.2   348.8   14078.    2219.   6.36

X STA.      -120.0       -80.3       -67.4       -55.2       -44.3       -33.9
  A(I)             25.8        17.5        17.0        15.7        15.3
  V(I)             4.29        6.32        6.52        7.05        7.25

X STA.       -33.9       -24.0       -14.3        -4.7        12.0        29.7
  A(I)             14.9        14.8        15.0        19.5        20.2
  V(I)             7.44        7.52        7.38        5.69        5.49

X STA.        29.7        40.1        50.8        61.4        72.9        84.5
  A(I)             16.2        16.4        16.0        16.9        16.6
  V(I)             6.87        6.78        6.94        6.58        6.69

X STA.        84.5        96.8       109.6       122.7       136.4       156.2
  A(I)             17.3        17.5        17.4        17.8        20.9
  V(I)             6.42        6.33        6.37        6.22        5.30


   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      111      4217    108    108                          639
            2      388     48133     40     53                         6881
            3      340     27386    130    130                         3114
  901.94           839     79736    278    292  1.28   -120    156     7300

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
        WSEL     LEW     REW    AREA        K        Q    VEL
      901.94  -121.4   156.2   838.5   79736.    5200.   6.20

X STA.      -121.4       -18.1         1.0         3.5         5.5         7.3
  A(I)            104.7        71.4        35.0        29.3        27.3
  V(I)             2.48        3.64        7.42        8.89        9.53

X STA.         7.3         9.1        10.9        12.7        14.5        16.3
  A(I)             25.7        25.7        24.7        24.7        24.5
  V(I)            10.13       10.11       10.51       10.51       10.59

X STA.        16.3        18.2        20.6        23.7        37.7        49.3
  A(I)             25.7        28.5        33.1        56.5        41.4
  V(I)            10.13        9.13        7.85        4.60        6.28

X STA.        49.3        60.7        73.8        89.8       111.4       156.2
  A(I)             42.3        44.1        48.4        54.3        71.1
  V(I)             6.15        5.89        5.37        4.78        3.66
```

```
         U.S. Geological Survey WSPRO Input File brne041.wsp
         Hydraulic analysis for structure BRNETH00990041   Date: 16-SEP-97
         Bridge #41 on TH99 crossing the Stevens River in Barnet, Vt.   RHF

     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      259     20242      0     72                            0
    898.09           259     20242      0     72  1.00      0     31        0

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA         K        Q    VEL
        898.09     0.0    31.1   259.2   20242.    3416.  13.18

 X STA.        0.0        3.1        4.8        6.3        7.7        9.0
   A(I)            23.3       14.6       12.6       12.1       11.6
   V(I)            7.34      11.68      13.53      14.09      14.76

 X STA.        9.0       10.3       11.5       12.7       13.9       15.2
   A(I)            11.3       11.2       10.9       10.8       10.8
   V(I)           15.12      15.24      15.68      15.84      15.82

 X STA.       15.2       16.4       17.6       18.8       20.0       21.3
   A(I)            10.9       10.9       11.0       10.9       11.5
   V(I)           15.74      15.73      15.53      15.64      14.84

 X STA.       21.3       22.7       24.2       25.8       27.6       31.1
   A(I)            11.9       12.3       12.8       14.9       23.0
   V(I)           14.37      13.91      13.33      11.42       7.43


     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.
          WSEL     LEW     REW    AREA         K        Q    VEL
        903.27  -159.7   162.9   747.6   45596.    5605.   7.50

 X STA.     -159.7      -98.7      -80.8      -67.1      -54.2      -42.0
   A(I)            62.9       41.6       36.7       35.2       33.9
   V(I)            4.46       6.74       7.63       7.95       8.27

 X STA.      -42.0      -30.5      -19.2       -8.3        5.5       22.0
   A(I)            32.3       32.1       31.5       36.8       39.0
   V(I)            8.67       8.73       8.89       7.62       7.19

 X STA.       22.0       35.3       47.1       59.3       71.8       84.4
   A(I)            36.4       33.7       34.7       34.8       35.1
   V(I)            7.70       8.32       8.08       8.05       7.99

 X STA.       84.4       97.4      110.9      124.5      138.6      162.9
   A(I)            35.4       36.5       36.2       37.0       45.9
   V(I)            7.92       7.68       7.74       7.57       6.11


     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      274     16179    137    137                         2196
              2      441     59541     40     53                         8332
              3      517     53347    137    137                         5705
    903.27          1231    129068    313    327  1.21   -149    163    12611

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
          WSEL     LEW     REW    AREA         K        Q    VEL
        903.27  -150.4   162.9  1231.5  129068.    9000.   7.31

 X STA.     -150.4      -70.2      -31.7       -2.6        2.9        5.6
   A(I)           127.7       97.4       94.3       68.2       41.9
   V(I)            3.52       4.62       4.77       6.60      10.73

 X STA.        5.6        8.0       10.4       12.9       15.3       17.9
   A(I)            39.4       38.0       37.0       36.9       38.2
   V(I)           11.42      11.86      12.17      12.19      11.79

 X STA.       17.9       21.0       29.5       41.1       52.1       63.0
   A(I)            41.4       69.3       54.5       54.6       54.3
   V(I)           10.87       6.49       8.26       8.25       8.29

 X STA.       63.0       75.1       88.9      105.3      125.5      162.9
   A(I)            56.3       60.1       64.6       70.0       87.3
   V(I)            7.99       7.48       6.96       6.43       5.15
```

```
     U.S. Geological Survey WSPRO Input File brne041.wsp
     Hydraulic analysis for structure BRNETH00990041   Date: 16-SEP-97
     Bridge #41 on TH99 crossing the Stevens River in Barnet, Vt.   RHF

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      215    21381     27     41                         3470
 896.42          215    21381     27     41  1.00      0     31     3470


 VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL     LEW     REW    AREA        K        Q    VEL
    896.42     0.1    30.9   215.1   21381.    3470.  16.13

X STA.        0.1        3.5        5.2        6.7        8.0        9.3
  A(I)            21.9       12.1       10.7        9.9        9.4
  V(I)            7.92      14.29      16.16      17.47      18.42

X STA.        9.3       10.6       11.7       12.9       14.0       15.1
  A(I)             9.1        8.8        8.6        8.5        8.5
  V(I)           19.02      19.61      20.18      20.39      20.37

X STA.       15.1       16.3       17.4       18.6       19.7       20.9
  A(I)             8.5        8.5        8.6        8.6        9.1
  V(I)           20.35      20.33      20.07      20.21      19.07

X STA.       20.9       22.2       23.7       25.3       27.2       30.9
  A(I)             9.6       10.2       10.7       12.5       20.9
  V(I)           18.04      16.98      16.28      13.86       8.28


 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
          2      293    32182     35     49                         4821
          3       15      304     44     44                           49
 899.49          308    32486     79     93  1.07     -8     70     3329

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
      WSEL     LEW     REW    AREA        K        Q    VEL

    899.49    -8.8    70.3   307.9   32486.    3470.  11.27

X STA.       -8.8        1.4        2.9        4.2        5.4        6.5
  A(I)            35.5       18.6       15.9       13.9       13.1
  V(I)            4.89       9.35      10.91      12.48      13.21

X STA.        6.5        7.4        8.4        9.4       10.4       11.4
  A(I)            12.2       11.9       11.5       11.8       11.4
  V(I)           14.25      14.53      15.15      14.67      15.20

X STA.       11.4       12.4       13.4       14.4       15.4       16.5
  A(I)            11.5       11.3       11.4       11.5       12.0
  V(I)           15.03      15.37      15.25      15.06      14.42

X STA.       16.5       17.6       18.9       20.5       22.4       70.3
  A(I)            12.2       13.4       14.5       16.6       37.6
  V(I)           14.25      12.95      11.93      10.46       4.61
```

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        U.S. Geological Survey WSPRO Input File brne041.wsp
        Hydraulic analysis for structure BRNETH00990041   Date: 16-SEP-97
        Bridge #41 on TH99 crossing the Stevens River in Barnet, Vt.   RHF

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

EXITX:XS   ******    -98      817  0.85 *****  898.18  895.77    5200  897.33
       -29 ******    112    84324  1.34 ***** *******    0.66    6.37

FULLV:FV       30   -102      860  0.77  0.11  898.30 *******    5200  897.53
         0     30    114    89570  1.35  0.00    0.01    0.62    6.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   897.03     911.65    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   897.03     911.65     901.22
 ===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 =   901.22     911.65     901.22

APPRO:AS       53   -105      645  1.32 *****  902.53  901.22    5200  901.22
        53     53    153    59547  1.30 ***** *******    1.03    8.07
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   905.26       0.00     898.05     900.35
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                 WS,QBO,QRD =   903.73         0.      5200.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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       30      0      259  2.05 *****  900.12  895.63    2978  898.07
         0 ******     31    23244  1.00 ***** *******    0.70   11.49

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.491  0.000  898.07 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    31.  0.13  0.77  902.58    0.00   2219.  901.94

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1018.   135.  -120.    15.   1.6   1.2   6.2   6.4   1.8   3.1
   RT:   1201.   141.    15.   156.   1.6   1.3   6.4   6.3   2.0   3.1

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

APPRO:AS       28   -120      839  0.77  0.30  902.71  901.22    5200  901.94
        53     33    156    79810  1.28  0.00    0.00    0.71    6.20

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -30.   -99.   112.   5200.   84324.     817.    6.37  897.33
   FULLV:FV       0.  -103.   114.   5200.   89570.     860.    6.05  897.53
   BRIDG:BR       0.     0.    31.   2978.   23244.     259.   11.49  898.07
   RDWAY:RG      13.******* 1018.   2219.******************    1.00  901.94
   APPRO:AS      53.  -121.   156.   5200.   79810.     839.    6.20  901.94

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    895.77    0.66  887.25  910.00************  0.85  898.18  897.33
   FULLV:FV  ********    0.62  887.25  910.00  0.11  0.00  0.77  898.30  897.53
   BRIDG:BR    895.63    0.70  887.70  898.09************  2.05  900.12  898.07
   RDWAY:RG  ****************  900.35  911.03  0.13******  0.77  902.58  901.94
   APPRO:AS    901.22    0.71  887.26  911.65  0.30  0.00  0.77  902.71  901.94
```

```
        U.S. Geological Survey WSPRO Input File brne041.wsp
        Hydraulic analysis for structure BRNETH00990041   Date: 16-SEP-97
        Bridge #41 on TH99 crossing the Stevens River in Barnet, Vt.   RHF

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

EXITX:XS   ******   -172     1299  1.01 *****  900.32  897.77    9000  899.32
       -29 ******    134   145894  1.35 ***** *******    0.65    6.93

FULLV:FV       30   -173     1357  0.92  0.11  900.45 *******    9000  899.52
         0     30    137   153417  1.35  0.00    0.02    0.62    6.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   899.02     911.65    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   899.02     911.65     902.51
 ===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 =   902.51     911.65     902.51

APPRO:AS       53   -133     1000  1.57 *****  904.08  902.51    9000  902.51
        53     53    159    98838  1.25 ***** *******    0.96    9.00
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   899.52     898.07

            <<<<<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       30      0      259  2.70 *****  900.79  896.34    3416  898.09
         0 ******     31    20242  1.00 ***** *******    0.80   13.18

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  898.07 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    31.  0.15  1.01  904.12    0.00   5605.  903.27

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   2735.   174.  -159.    15.   2.9   2.1   8.0   7.5   2.9   3.1
   RT:   2871.   148.    15.   163.   2.9   2.6   8.5   7.5   3.4   3.1

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

APPRO:AS       28   -149     1230  1.01  0.53  904.27  902.51    9000  903.27
        53     36    163   128864  1.21  0.00    0.00    0.72    7.32

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -30.  -173.   134.   9000.  145894.    1299.    6.93  899.32
   FULLV:FV       0.  -174.   137.   9000.  153417.    1357.    6.63  899.52
   BRIDG:BR       0.     0.    31.   3416.   20242.     259.   13.18  898.09
   RDWAY:RG      13.******* 2735.   5605.******************    1.00  903.27
   APPRO:AS      53.  -150.   163.   9000.  128864.    1230.    7.32  903.27

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    897.77    0.65  887.25  910.00************  1.01  900.32  899.32
   FULLV:FV  ********    0.62  887.25  910.00  0.11  0.00  0.92  900.45  899.52
   BRIDG:BR    896.34    0.80  887.70  898.09************  2.70  900.79  898.09
   RDWAY:RG  ****************  900.35  911.03  0.15******  1.01  904.12  903.27
   APPRO:AS    902.51    0.72  887.26  911.65  0.53  0.00  1.01  904.27  903.27
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File brne041.wsp
       Hydraulic analysis for structure BRNETH00990041   Date: 16-SEP-97
       Bridge #41 on TH99 crossing the Stevens River in Barnet, Vt.   RHF

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

EXITX:XS   ******    -72      570  0.74 *****  896.77  893.95    3470  896.04
       -29 ******     95    56242  1.28 ***** *******    0.66    6.08

FULLV:FV       30    -76      603  0.67  0.11  896.89 *******    3470  896.23
         0     30     97    59854  1.30  0.00    0.01    0.62    5.75
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   895.73     911.65    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   895.73     911.65     897.25
 ===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 =   897.25     911.65     897.25

APPRO:AS       53     -3      223  3.76 *****  901.02  897.25    3470  897.25
        53     53     26    22761  1.00 ***** *******    1.00   15.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   896.42     899.00     899.48     898.07
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   900.73      2697.       316.
 ===270 REJECTED FLOW CLASS 2 (5) SOLUTION.
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    3470.      896.42

            <<<<<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       30      0      215  4.05 *****  900.47  896.42    3470  896.42
         0     30     31    21385  1.00 ***** *******    1.00   16.13

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  898.07 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<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       28     -8      308  2.12  0.48  901.61  897.25    3470  899.49
        53     28     70    32486  1.07  0.67    0.01    1.04   11.27

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.000   34065.    -4.    26.   899.13

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -30.   -73.    95.   3470.   56242.     570.    6.08  896.04
   FULLV:FV       0.   -77.    97.   3470.   59854.     603.    5.75  896.23
   BRIDG:BR       0.     0.    31.   3470.   21385.     215.   16.13  896.42
   RDWAY:RG      13.**************      0.       0.       0.    1.00********
   APPRO:AS      53.    -9.    70.   3470.   32486.     308.   11.27  899.49

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -4.    26.   34065.

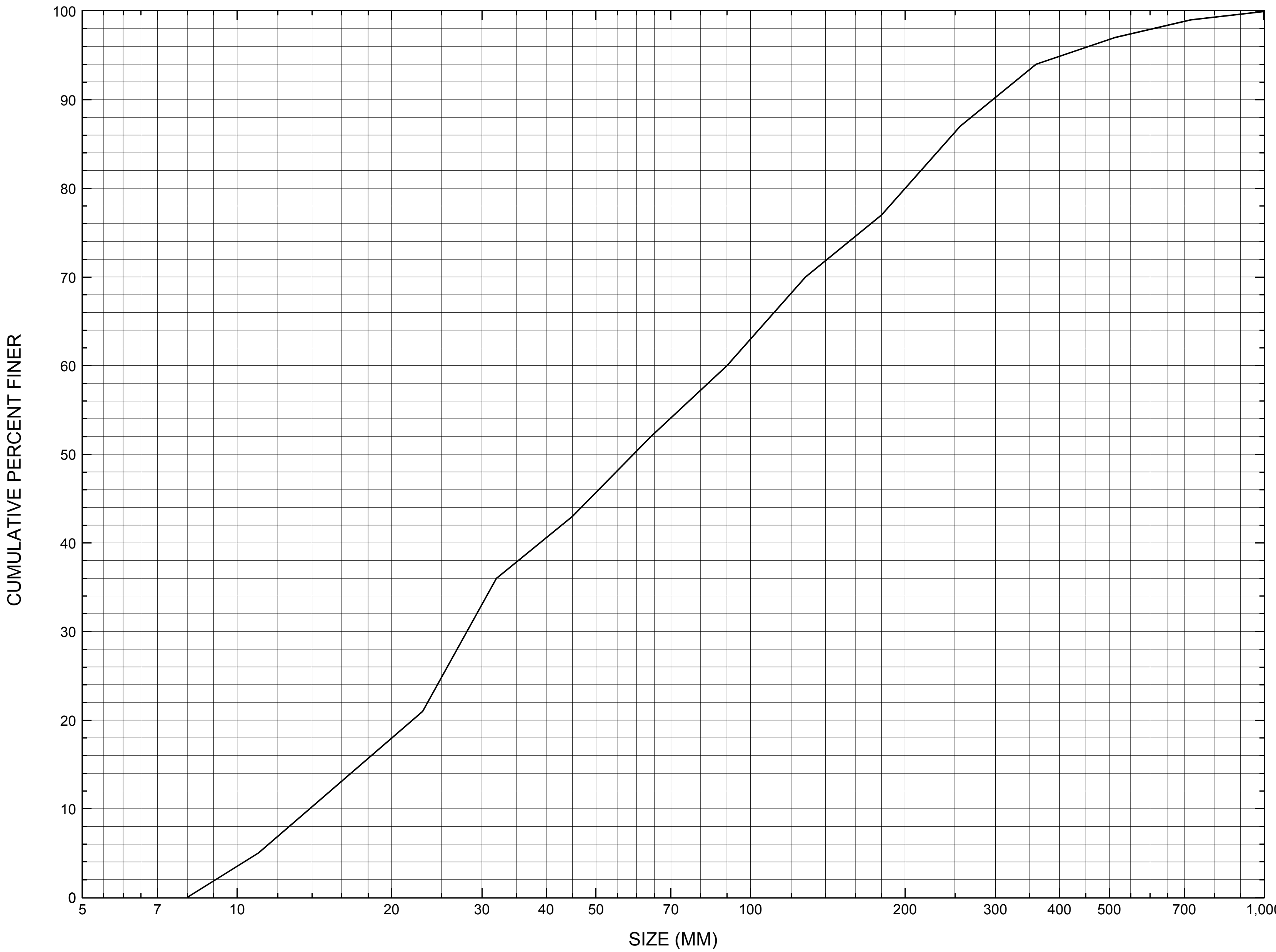

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    893.95    0.66  887.25  910.00************  0.74  896.77  896.04
   FULLV:FV  ********    0.62  887.25  910.00  0.11  0.00  0.67  896.89  896.23
   BRIDG:BR    896.42    1.00  887.70  898.09************  4.05  900.47  896.42
   RDWAY:RG ****************  900.35  911.03************  1.14  901.67********
   APPRO:AS    897.25    1.04  887.26  911.65  0.48  0.67  2.12  901.61  899.49
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BRNETH00990041, in Barnet, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BRNETH00990041

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 TH099

Vicinity *(I - 9)* 0.04 MI TO JCT W TH100

Topographic Map Barnet

Hydrologic Unit Code: 01080103

Latitude *(I - 16; nnnn.n)* 44177

Longitude *(i - 17; nnnnn.n)* 72030

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030100410301

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

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

Year built *(I - 27; YYYY)* 1944

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000125

Deck Width *(I - 52; nn.n)* 219

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

Channel & Protection *(I - 61; n)* 5

Opening skew to Roadway *(I - 34; nn)* 25

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 025.8

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

Vertical clearance from streambed (*nnn.n ft*) 010.3

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

Waterway of full opening (*nnn.n* ft^2) 266.0

Comments:

The structural inspection report of 9/8/94 indicates the structure is a steel stringer type bridge with a concrete deck and an asphalt roadway surface. The right abutment wall and its wingwalls are concrete. The right abutment wall has a large settlement crack reported which tapers from 2 inches wide to a fine line with a large spall at the base of the wall. There also is evidence of displacement along the crack. The wingwalls are oriented nearly parallel with the stream and have areas of scaling and some large spalls noted. There is a large concrete subfooting, which was poured along the base of the right abutment and wingwalls. The left abutment and its wingwalls are constructed of large “laid-up” **(Continued, page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} - Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

and grouted stone blocks, which make up about one half of the height. The remaining portion of the wall is a concrete cap, through which there is a full-height crack. The crack also extends downward into the grouted stone portion of the wall and shows signs of displacement along the crack. There is a stone retaining wall which extends upstream from the left abutment. There are large blocks of riprap placed along the concrete block wall at the right abutment. A bedrock outcrop is reported along the edge of the channel upstream. There is a large gravel bar just downstream.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **45.53** mi^2 Lake/pond/swamp area **1.33** mi^2

Watershed storage *(ST)* **3.1** %

Bridge site elevation **472** ft Headwater elevation **2513** ft

Main channel length **12.37** mi

10% channel length elevation **623** ft 85% channel length elevation **1398** ft

Main channel slope *(S)* **83.53** 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? 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 to bed	-	-	-	-	-	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: **NO CROSS SECTION INFORMATION**

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: CG Date: 02/26/96
Computerized by: CG Date: 02/26/96
Reviewd by: RF Date: 01/26/98

Structure Number BRNETH00990041

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. Ivanoff Date *(MM/DD/YY)* 08 / 22 / 1995
2. Highway District Number 07 Mile marker 0
County Caledonia (005) Town Barnet (02875)
Waterway *(I - 6)* Stevens River Road Name -
Route Number TH 099 Hydrologic Unit Code: 01080103
3. Descriptive comments:
This bridge is located 0.04 miles from the junction with Town Highway 100.

B. Bridge Deck Observations

4. Surface cover... LBUS 2 RBUS 5 LBDS 5 RBDS 6 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 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 37 *(feet)* Span length 34 *(feet)* Bridge width 21.9 *(feet)*

Road approach to bridge:

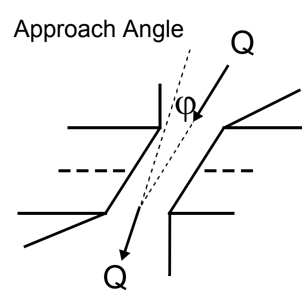
8. LB 2 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left - US right -

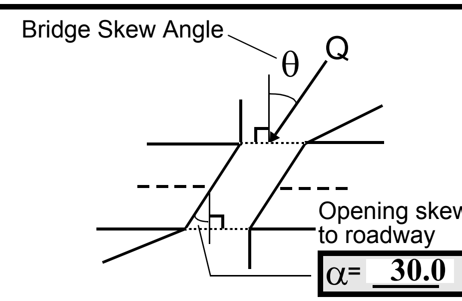
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	5	1	0	0
LBDS	5	1	0	0

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

Channel approach to bridge (BF):

15. Angle of approach: 10 16. Bridge skew: 30





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 0
Range? 60 feet US *(US, UB, DS)* to 90 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: **1a**

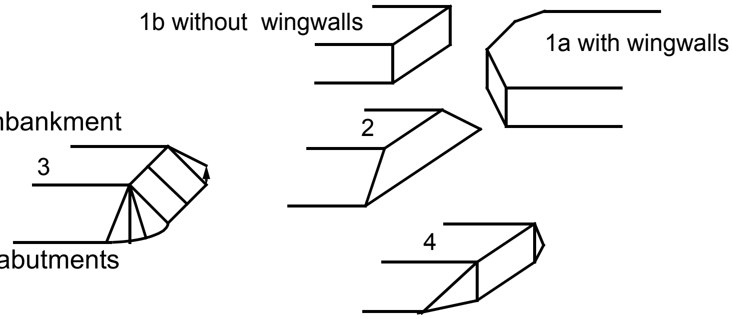
1a- Vertical abutments with wingwalls

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.)

7. The values are from the VTAOT database. During the site visit, the bridge length measured was 36.5 feet, measured span length was 31 feet and measured width was 21.7 feet

11. The right and left downstream approaches are protected by a laid up stone wall extending parallel to the road from the ends of the wingwalls.

18. Modelled as bridge type 1b due to an average wingwall angle of approximately 90 degrees.

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
23.5	**5.0**			**3.0**	**2**	**2**	**7**	**76**	**1**	**0**

23. Bank width **85.0** 24. Channel width **30.0** 25. Thalweg depth **39.5** 29. Bed Material **453**

30 .Bank protection type: LB **5** RB **53** 31. Bank protection condition: LB **2** RB **1**

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

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

27. Both banks are protected by stone walls. The right bank has a newer concrete block wall extending 57 feet upstream from the upstream right wingwall.
A two foot diameter culvert enters the right bank 18 feet from the upstream bridge face and six feet above the streambed in the block wall.
30. As stated above, the right bank is protected by a concrete block wall for 57 feet then bedrock continues upstream with large stones at the base.
The left bank has a laid up stone wall with small chinks missing and some stones protruding from the wall and a leaning of the top of the wall towards the channel. It extends 130 feet 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? __N__ *(Y or if N type ctrl-n cb)* 40. Where? __-__ *(LB or RB)*

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

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

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

NO CUT BANKS
There is a break in the left bank laid-up stone wall from 130 feet to 160 feet upstream.

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):

There are no major confluences, but a two feet diameter culvert enters the right bank 13 feet from the bridge face and 6 feet above the stream bed. Water was flowing in the culvert during the survey.

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
17.5		1.5		2	7	7	-

58. Bank width (BF) __-__ 59. Channel width __-__ 60. Thalweg depth __90.0__ 63. Bed Material __-__

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

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

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

453

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 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

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	2,1	0	90			2	2	27.0

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

0.4

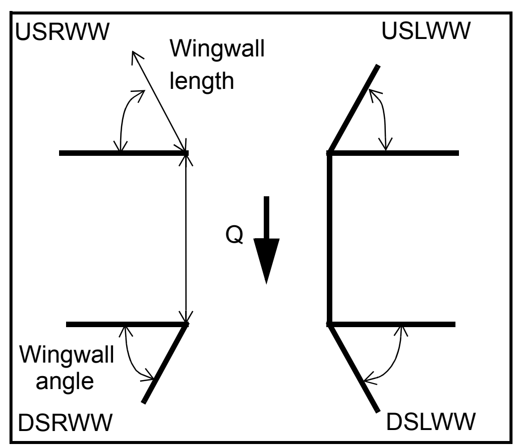
1

77. The left abutment has a lower laid-up and grouted stone wall with concrete above to the bridge deck.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						27.0	
USRWW:	Y		2,1		0	1.0	
DSLWW:	0		0		Y	25.5	
DSRWW:	1		0		0	25.5	

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	2	1	-	-
Condition	Y	0	1	0.5	2	2	-	-
Extent	2,1	0	2	5	2	0	0	-

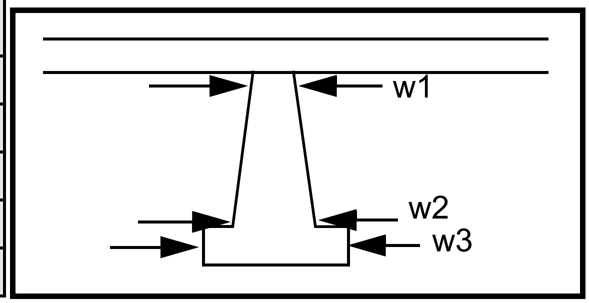
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **80.** *(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				**65.0**	**10.5**	**120.0**
Pier 2			**6.0**	**70.5**	**110.0**	**60.0**
Pier 3		**-**	**-**	**10.0**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**the**	**con-**	**N**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**mate**	**abut**	**crete**	**-**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**rial**	**ment**	**cap.**	**-**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**of**	**wall**		**-**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**the**	**with**		**-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**wing**	**laid-**		**-**	
92. Pushed	**walls**	**up**		**-**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**is a**	**grou**		**-**	
95. Cross-members	**con-**	**ted**		**-**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**tinu-**	**stone**		**-**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**ation**	**s and**		**-**	
98. Exposure depth	**of**	**a**		**-**	

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
-	-			-	-	-	-	-	-	-

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: **NO** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

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

PIERS

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

Point bar extent: ______ feet **2** *(US, UB, DS)* to **3** feet **324** *(US, UB, DS)* positioned **341** %LB to **1** %RB

Material: **2**

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

435
0
2
-

Is a cut-bank present? **1** *(Y or if N type ctrl-n cb)* Where? **The** *(LB or RB)* Mid-bank distance: **righ**

Cut bank extent: **t** feet **ba** *(US, UB, DS)* to **nk** feet **has** *(US, UB, DS)*

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

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

me stone fill along the bank extending 80 feet from the bridge.
The left bank has some stone fill along the bank from 45 feet to 90 feet from the bridge. The cut bank is just upstream of the protection between the end of the left wingwall and the protection.

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

Scour dimensions: Length ______ Width ______ Depth: _____ Positioned ____ %LB to ____ %RB

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

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

Confluence 1: Distance **NO** Enters on **DR** *(LB or RB)* Type **OP** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

RE

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

N

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: BRNETH00990041 Town: Barnet, Vt.
Road Number: TH99 County: Caledonia
Stream: Stevens River

Initials RHF Date: 12/30/97 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	5200	9000	3470
Main Channel Area, ft2	388	441	293
Left overbank area, ft2	111	274	0
Right overbank area, ft2	340	517	15
Top width main channel, ft	40	40	35
Top width L overbank, ft	108	137	0
Top width R overbank, ft	130	137	44
D50 of channel, ft	0.19416	0.19416	0.19416
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.7	11.0	8.4
y1, average depth, LOB, ft	1.0	2.0	ERR
y1, average depth, ROB, ft	2.6	3.8	0.3
Total conveyance, approach	79736	129068	32486
Conveyance, main channel	48133	59541	32182
Conveyance, LOB	4217	16179	0
Conveyance, ROB	27386	53347	304
Percent discrepancy, conveyance	0.0000	0.0008	0.0000
Qm, discharge, MC, cfs	3139.0	4151.8	3437.5
Ql, discharge, LOB, cfs	275.0	1128.2	0.0
Qr, discharge, ROB, cfs	1786.0	3719.9	32.5
Vm, mean velocity MC, ft/s	8.1	9.4	11.7
Vl, mean velocity, LOB, ft/s	2.5	4.1	ERR
Vr, mean velocity, ROB, ft/s	5.3	7.2	2.2
Vc-m, crit. velocity, MC, ft/s	9.5	9.7	9.2
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	1
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]

Depth to Armoring=3*(1/Pc-1)

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2978	3416	3470
Main channel area (DS), ft2	245	259	215

Main channel width (normal), ft	26.9	26.9	26.7
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	26.9	26.9	26.7
D90, ft	0.9720	0.9720	0.9720
D95, ft	1.3282	1.3282	1.3282
Dc, critical grain size, ft	0.6633	0.7630	1.2326
Pc, Decimal percent coarser than Dc	0.197	0.157	0.056
Depth to armoring, ft	8.11	12.27	N/A

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and others, 1995, p. 30, eq. 17 and 18)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	5200	9000	3470	2978	3416	3470
Total conveyance	79736	129068	32486	23244	20242	21381
Main channel conveyance	48133	59541	32182	23244	20242	21381
Main channel discharge	3139	4152	3438	2978	3416	3470
Area - main channel, ft2	388	441	293	259	259	215
(W1) channel width, ft	40	40	35	26.9	26.9	26.7
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	40	40	35	26.9	26.9	26.7
D50, ft	0.19416	0.19416	0.19416			
w, fall velocity, ft/s (p. 32)	3.60501	3.60501	3.60501			
y, ave. depth flow, ft	9.70	11.03	8.37	9.63	9.63	8.05
S1, slope EGL	0.0696	0.0564	0.0779			
P, wetted perimeter, MC, ft	53	53	49			
R, hydraulic Radius, ft	7.321	8.321	5.980			
V*, shear velocity, ft/s	4.051	3.887	3.873			
V*/w	1.124	1.078	1.074			

Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)

k1	0.64	0.64	0.64
y2,depth in contraction, ft	11.95	12.02	10.04
ys, scour depth, ft (y2-y_bridge)	2.32	2.40	**1.98**

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	5200	9000	3470
(Q) discharge thru bridge, cfs	2978	3416	3470
Main channel conveyance	23244	20242	21381
Total conveyance	23244	20242	21381
Q2, bridge MC discharge,cfs	2978	3416	3470
Main channel area, ft2	259	259	215
Main channel width (normal), ft	26.9	26.9	26.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	26.9	26.9	26.7
y_bridge (avg. depth at br.), ft	9.63	9.63	8.05
Dm, median (1.25*D50), ft	0.2427	0.2427	0.2427

y2, depth in contraction,ft	10.48	11.79	12.03
ys, scour depth (y2-ybridge), ft	0.85	2.16	3.97

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)

	5	6	1
	Q100	Q500	OtherQ
Q, total, cfs	5200	9000	3470
Q, thru bridge MC, cfs	2978	3416	3470
Vc, critical velocity, ft/s	9.48	9.68	9.25
Va, velocity MC approach, ft/s	8.09	9.41	11.73
Main channel width (normal), ft	26.9	26.9	26.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	26.9	26.9	26.7
qbr, unit discharge, ft2/s	110.7	127.0	130.0
Area of full opening, ft2	259.0	259.0	215.0
Hb, depth of full opening, ft	9.63	9.63	8.05
Fr, Froude number, bridge MC	0.7	0.8	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	245	N/A	N/A
**Hb, depth at downstream face, ft	9.11	N/A	N/A
**Fr, Froude number at DS face	0.71	ERR	ERR
**Cf, for downstream face (<=1.0)	1.00	N/A	N/A
Elevation of Low Steel, ft	898.07	898.07	0
Elevation of Bed, ft	888.44	888.44	-8.05
Elevation of Approach, ft	901.94	903.27	0
Friction loss, approach, ft	0.3	0.53	0
Elevation of WS immediately US, ft	901.64	902.74	0.00
ya, depth immediately US, ft	13.20	14.30	8.05
Mean elevation of deck, ft	900.92	900.92	0
w, depth of overflow, ft (>=0)	0.72	1.82	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.94	1.00
**Cc, for downstream face (<=1.0)	0.920344	0.79	ERR
Ys, scour w/Chang equation, ft	**2.86**	**4.39**	N/A
Ys, scour w/Umbrell equation, ft	3.15	4.64	N/A

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

**Ys, scour w/Chang equation, ft	3.58	N/A	N/A

**Ys, scour w/Umbrell equation, ft	3.67	N/A	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	10.48	N/A	N/A
WSEL at downstream face, ft	897.53	--	--
Depth at downstream face, ft	9.11	N/A	N/A
Ys, depth of scour (Laursen), ft	1.37	N/A	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	5200	9000	3470	5200	9000	3470
a', abut.length blocking flow, ft	123.5	152.5	11	127.2	133.9	41.4
Ae, area of blocked flow ft2	50.01	49.35	45.42	165.89	164.99	32.5
Qe, discharge blocked abut.,cfs	__	__	266.03	__	__	149.96
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.31	4.59	5.86	5.11	7.17	4.61
ya, depth of f/p flow, ft	0.40	0.32	4.13	1.30	1.23	0.79
--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	60	60	60	120	120	120
K2	0.95	0.95	0.95	1.04	1.04	1.04
Fr, froude number f/p flow	0.469	0.514	0.508	0.554	0.650	0.918
ys, scour depth, ft	**5.68**	**5.70**	**11.48**	**13.90**	**14.98**	**8.71**

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)	123.5	152.5	11	127.2	133.9	41.4
y1 (depth f/p flow, ft)	0.40	0.32	4.13	1.30	1.23	0.79
a'/y1	304.98	471.25	2.66	97.53	108.67	52.74
Skew correction (p. 49, fig. 16)	0.90	0.90	0.90	1.07	1.07	1.07
Froude no. f/p flow	0.47	0.51	0.51	0.55	0.65	0.92
Ys w/ corr. factor K1/0.55:						
vertical	2.06	1.70	ERR	8.33	8.29	5.92
vertical w/ ww's	1.69	1.39	ERR	6.83	6.80	4.86
spill-through	1.14	0.94	ERR	4.58	4.56	3.26

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	0.71	0.8	1	0.71	0.8	1
y, depth of flow in bridge, ft	9.11	9.63	8.06	9.11	9.63	8.06
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.84	3.81	ERR	2.84	3.81	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	3.37	ERR	ERR	3.37