LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (SHARTH00040013) on TOWN HIGHWAY 4, crossing BROAD BROOK, SHARON, VERMONT

U.S. Geological Survey
Open-File Report 97-593

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (SHARTH00040013) on TOWN HIGHWAY 4, crossing BROAD BROOK, SHARON, VERMONT

By EMILY C. WILD and MATTHEW A. WEBER

U.S. Geological Survey
Open-File Report 97-593

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

Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

Copies of this report may be purchased from:

U.S. Geological Survey
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (SHARTH00040013) ON TOWN HIGHWAY 4, CROSSING BROAD BROOK, SHARON, VERMONT

By **Emily C. Wild and Matthew A. Weber**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SHARTH00040013 on Town Highway 4 crossing Broad Brook, Sharon, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in central Vermont. The 16.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is brushland on the downstream left overbank and row crops on the right overbank, while the immediate banks have dense woody vegetation. Upstream of the bridge, the overbanks are forested.

In the study area, Broad Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 69 ft and an average bank height of 5 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 112 mm (0.369 ft). The geomorphic assessment at the time of the Level I site visit on April 11, 1995 and Level II site visit on July 23, 1996, indicated that the reach was stable.

The Town Highway 4 crossing of Broad Brook is a 34-ft-long, two-lane bridge consisting of one 31-foot concrete tee beam span (Vermont Agency of Transportation, written communication, March 23, 1995). The opening length of the structure parallel to the bridge face is 30.1 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

A scour hole 2.0 ft deeper than the mean thalweg depth was observed along the upstream end of the right abutment. At the downstream end of the left abutment, a 1.0 foot scour hole was observed . Scour countermeasures at the site include type-2 stone fill (less than 3 feet diameter) at each road embankment. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.7 to 1.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 5.6 to 9.4 ft. The worst case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 19.0 to 19.8 ft. The worst-case right abutment scour occurred at the incipient-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

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

LEVEL II SUMMARY

Structure Number SHARTH00040013 ***Stream*** Broad Brook

County Windsor ***Road*** TH4 ***District*** 4

Description of Bridge

Bridge length 34 ***ft*** ***Bridge width*** 23.4 ***ft*** ***Max span length*** 31 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 4/11/95

Description of stone fill Scour countermeasures at the site include type-2 stone fill (less than 3 feet diameter) at each road embankment.

Abutments and wingwalls are concrete. There is a two foot deep scour hole in front of the upstream end of the right abutment. At the downstream end of the left abutment, there is a 1 foot deep scour hole.

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

There is a mild channel bend in the upstream reach. The scour hole has developed in the location where the bend impacts the upstream right wingwall.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	4/11/94	0	0
Level II	7/23/96	0	0

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

Describe any features near or at the bridge that may affect flow (include observation date)

Description of the Geomorphic Setting

General topography The channel is located within a moderately steep valley, with narrow, irregular flood plains.

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

Date of inspection 4/11/95

DS left: Narrow flood plain with moderately steep valley wall.

DS right: Narrow flood plain with steep valley wall.

US left: Narrow flood plain with moderately steep valley wall.

US right: Steep valley wall.

Description of the Channel

Average top width 69 ***ft*** ***Average depth*** 5 ***ft***

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

Sinuous but stable with alluvial channel boundaries and a narrow flood plain.

4/11/95

Vegetative co Brush.

DS left: Row crops with some brush.

DS right: Trees and brush.

US left: Trees.

US right:

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

None 4/11/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 16.6 ***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***:

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 3,270 ***ft³/s*** ***Q500*** 4,400 ***ft³/s***

The 100- and 500-year discharges are from the FHWA median curve of empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 499.58 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 499.52 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	-26	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	59	2	Modelled Approach section (Templated from APTEM)
APTEM	72	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 were 0.065, and overbank "n" values ranged from 0.060 to 0.080.

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 0.0236 ft/ft which was estimated from thalweg slopes surveyed downstream.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0415 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.6 *ft*
Average low steel elevation 497.1 *ft*

100-year discharge 3,270 *ft³/s*
Water-surface elevation in bridge opening 497.1 *ft*
Road overtopping? Y *Discharge over road* 247 *ft³/s*
Area of flow in bridge opening 265 *ft²*
Average velocity in bridge opening 11.2 *ft/s*
Maximum WSPRO tube velocity at bridge 13.7 *ft/s*

Water-surface elevation at Approach section with bridge 500.8
Water-surface elevation at Approach section without bridge 497.7
Amount of backwater caused by bridge 3.1 *ft*

500-year discharge 4,400 *ft³/s*
Water-surface elevation in bridge opening 497.1 *ft*
Road overtopping? Y *Discharge over road* 1,038 *ft³/s*
Area of flow in bridge opening 265 *ft²*
Average velocity in bridge opening 12.6 *ft/s*
Maximum WSPRO tube velocity at bridge 15.5 *ft/s*

Water-surface elevation at Approach section with bridge 501.8
Water-surface elevation at Approach section without bridge 498.6
Amount of backwater caused by bridge 3.2 *ft*

Incipient overtopping discharge 2,550 *ft³/s*
Water-surface elevation in bridge opening 497.1 *ft*
Area of flow in bridge opening 265 *ft²*
Average velocity in bridge opening 9.6 *ft/s*
Maximum WSPRO tube velocity at bridge 11.8 *ft/s*

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 497.0
Amount of backwater caused by bridge 2.3 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

At this site, the 100-year and incipient-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 others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Additional estimates of contraction scour also were computed by use of Laursen’s clear-water scour equation (Richardson and others, 1995, p. 32, equation 20, 20a) and the results are presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting alternative estimates for the depth of flow in the bridge at the downstream face in the Chang equation and Laursen’s clear-water equation. Contraction scour 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 others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.7	1.8	0.0
Depth to armoring	6.4 11.4	5.3	--
Left overbank	--	--	--
Right overbank	--	--	7.9 9.4

Local scour:			
Abutment scour	5.6	19.0	19.0
Left abutment	19.8–	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	2.4	3.2
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	2.2	2.4	3.2
Left abutment	2.2	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--		
Pier 2			

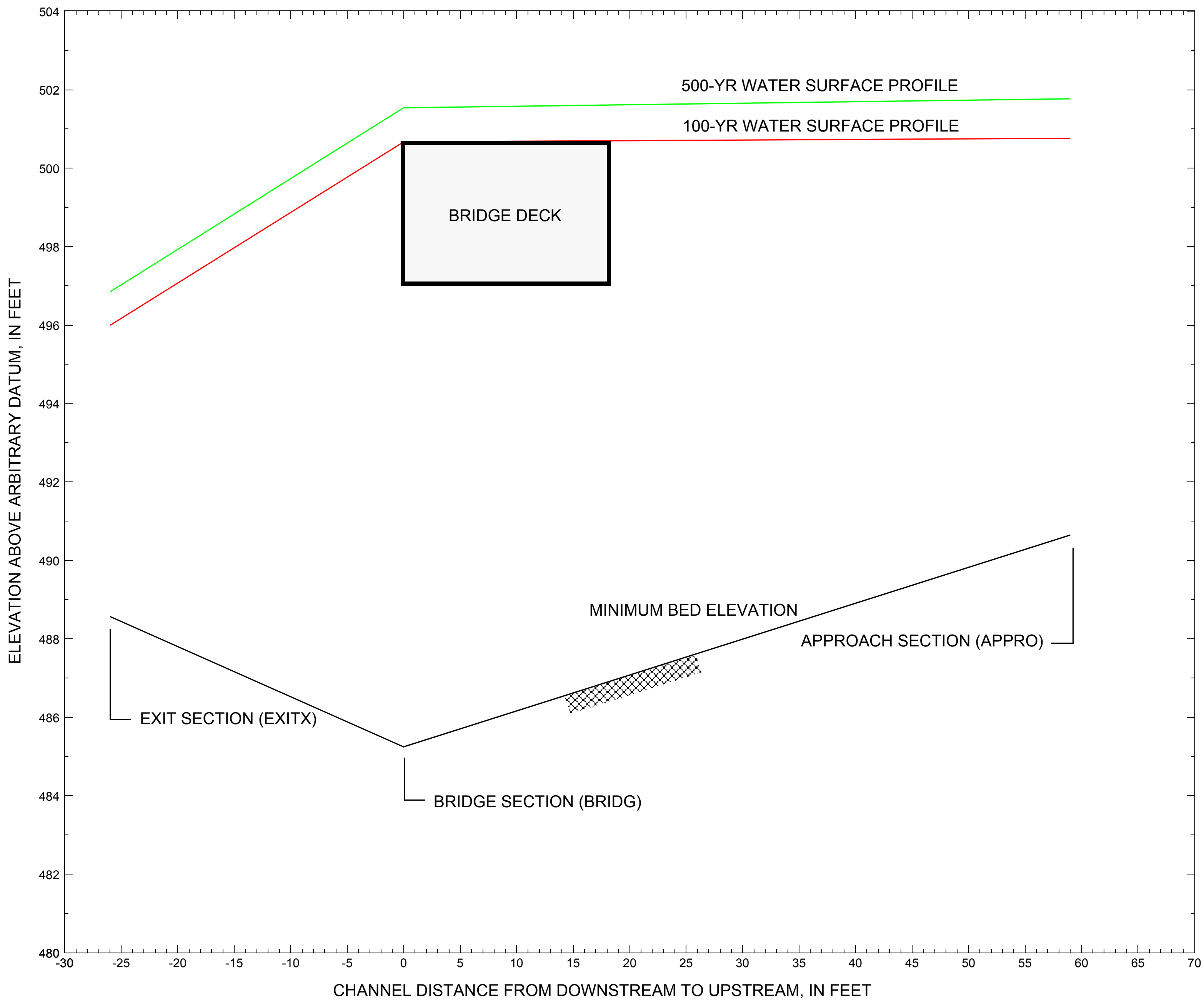


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure SHARTH00040013 on Town Highway 4, crossing Broad Brook, Sharon, Vermont.

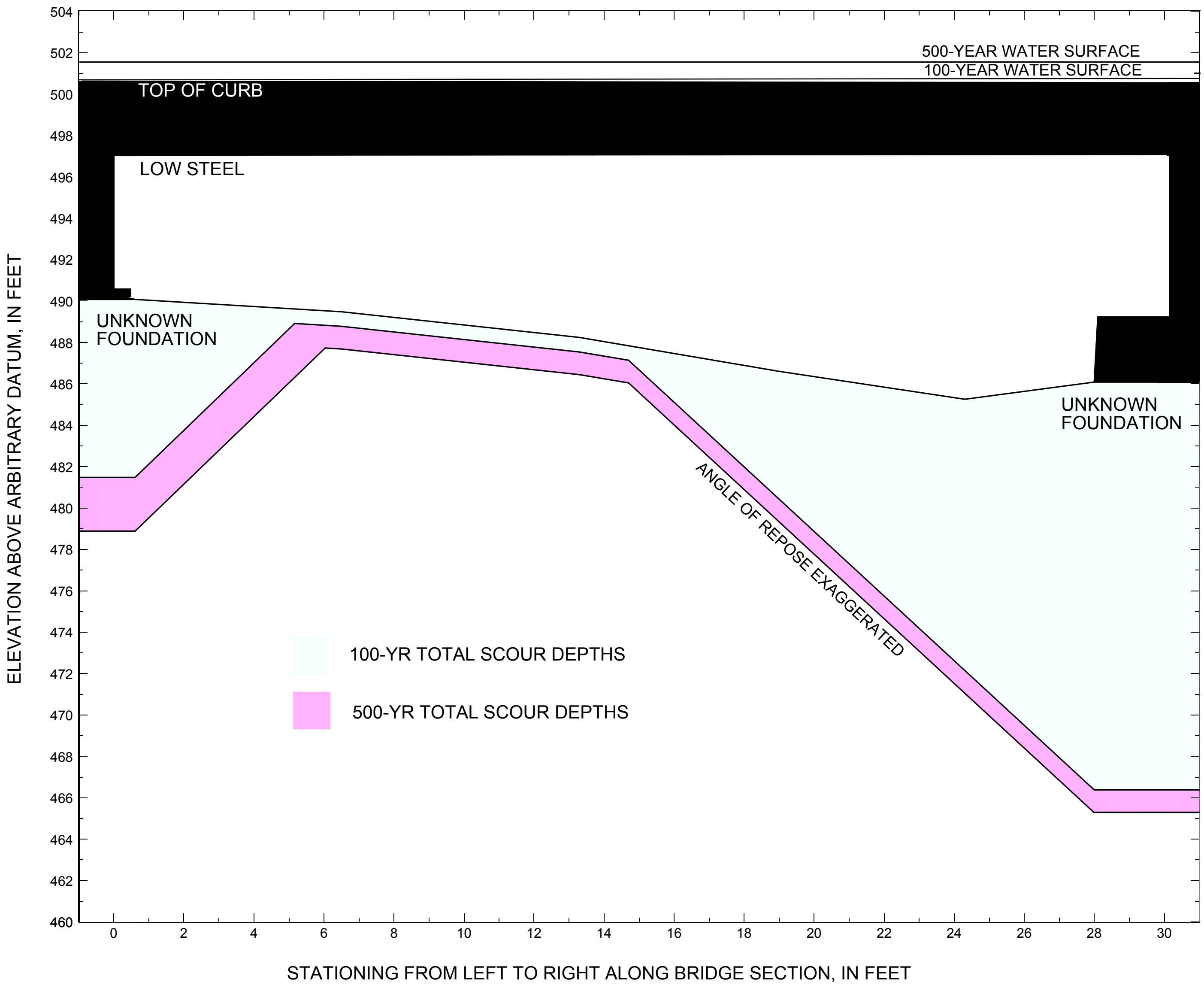


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure SHARTH00040013 on Town Highway 4, crossing Broad Brook, Sharon, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SHARTH00040013 on Town Highway 4, crossing Broad Brook, Sharon, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 3,270 cubic-feet per second											
Left abutment	0.0	--	497.1	--	490.1	0.7	7.9	--	8.6	481.5	--
Right abutment	30.1	--	497.1	--	486.1	0.7	19.0	--	19.7	466.4	--

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 SHARTH00040013 on Town Highway 4, crossing Broad Brook, Sharon, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 4,400 cubic-feet per second											
Left abutment	0.0	--	497.1	--	490.1	1.8	9.4	--	11.2	478.9	--
Right abutment	30.1	--	497.1	--	486.1	1.8	19.0	--	20.8	465.3	--

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.

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. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1981, Sharon, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File shar013.wsp
T2        Hydraulic analysis for structure SHARTH00040013   Date: 15-APR-97
T3        TOWN HIGHWAY 4, BROAD BROOK, SHARON, VERMONT     ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3270.0   4400.0  2550.0
SK          0.0236   0.0236  0.0236
*
XS   EXITX    -26
GR         -163.3, 504.63   -152.2, 499.77   -112.1, 497.98    -65.7, 497.36
GR          -52.5, 499.42    -32.1, 496.74      0.0, 495.18      9.6, 490.12
GR           17.3, 488.95     22.6, 488.57     28.0, 489.20     33.8, 488.87
GR           38.1, 489.33     40.8, 490.25     51.7, 492.53     71.6, 495.44
GR           85.1, 498.08    106.5, 498.01    119.7, 509.24
*
N           0.065        0.065        0.060
SA                   0.0         71.6
*
*
XS   FULLV      0  * * *   0.00
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.07      15.0
GR            0.0, 497.05      0.0, 490.32      0.6, 490.08      6.5, 489.48
GR           13.3, 488.24     19.0, 486.60     24.3, 485.25     28.0, 486.08
GR           28.1, 489.33     29.7, 489.37     29.8, 490.04     30.1, 497.09
GR            0.0, 497.05
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      43.0 * *     43.2     13.5
N           0.065
**
*             SRD    EMBWID   IPAVE
XR   RDWAY     15      23.4     1
GR         -316.6, 510.74   -222.0, 505.29   -110.1, 501.37    -55.1, 500.62
GR           -1.7, 500.02     -1.4, 500.55      0.0, 500.62     29.9, 500.54
GR           31.3, 500.56     32.0, 499.92     55.4, 499.15     85.7, 509.27
*
*
XT   APTEM     72
GR         -297.4, 510.74   -234.9, 506.73   -163.2, 501.11   -111.3, 499.59
GR          -42.3, 498.01    -14.5, 497.89     -0.8, 495.42      0.0, 493.85
GR           18.0, 492.40     25.9, 491.71     34.3, 491.85     39.0, 491.30
GR           45.9, 491.19     49.4, 492.79     51.4, 496.14     57.4, 503.05
*
AS   APPRO     59 * * * 0.0415
GT
N           0.080        0.065
SA                 -14.5
*
HP 1 BRIDG 497.09 1 497.09
HP 2 BRIDG 497.09 * * 2960
HP 1 BRIDG 496.96 1 496.96
HP 2 RDWAY 500.67 * * 247
HP 1 APPRO 500.76 1 500.76
HP 2 APPRO 500.76 * * 3270
*
HP 1 BRIDG 497.09 1 497.09
HP 2 BRIDG 497.09 * * 3349
HP 2 RDWAY 501.54 * * 1038
HP 1 APPRO 501.77 1 501.77
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
         U.S. Geological Survey WSPRO Input File shar013.wsp
         Hydraulic analysis for structure SHARTH00040013   Date: 15-APR-97
         TOWN HIGHWAY 4, BROAD BROOK, SHARON, VERMONT     ECW
            *** RUN DATE & TIME: 04-24-97  16:53
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      265     13955      0     76                     12530726
    497.09           265     13955      0     76  1.00      0     30 12530726

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        497.09     0.0    30.1   265.0   13955.    2960.  11.17

 X STA.         0.0        3.3        5.3        7.3        9.0       10.6
   A(I)            22.2       14.9       14.1       13.2       12.9
   V(I)            6.67       9.96      10.53      11.23      11.48

 X STA.        10.6       12.1       13.6       14.9       16.2       17.3
   A(I)            12.5       12.0       11.7       11.5       11.2
   V(I)           11.88      12.33      12.69      12.82      13.16

 X STA.        17.3       18.5       19.6       20.6       21.6       22.6
   A(I)            11.0       11.0       10.8       10.8       11.0
   V(I)           13.45      13.46      13.70      13.69      13.46

 X STA.        22.6       23.6       24.7       25.8       27.1       30.1
   A(I)            11.2       11.7       12.6       14.2       24.7
   V(I)           13.21      12.68      11.77      10.45       5.99


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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      262     18910     29     47                         4457
    496.96           262     18910     29     47  1.00      0     30     4457


     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      15.
          WSEL     LEW     REW    AREA        K        Q    VEL
        500.67   -58.8    60.0    52.2     715.     247.   4.73

 X STA.       -58.8      -29.3      -20.1      -13.9       -8.9       -4.6
   A(I)             5.1        3.6        3.0        2.7        2.6
   V(I)            2.41       3.45       4.16       4.53       4.84

 X STA.        -4.6       37.6       40.4       42.6       44.5       46.1
   A(I)             9.9        2.7        2.3        2.2        1.9
   V(I)            1.24       4.51       5.31       5.74       6.39

 X STA.        46.1       47.6       48.9       50.1       51.2       52.3
   A(I)             1.8        1.7        1.6        1.5        1.4
   V(I)            6.75       7.38       7.64       8.08       8.54

 X STA.        52.3       53.3       54.2       55.2       56.3       60.0
   A(I)             1.4        1.4        1.4        1.5        2.3
   V(I)            8.56       8.87       8.63       8.08       5.48

      CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      59.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      315      9576    151    151                         2582
              2      542     45914     70     76                         8535
    500.76           857     55491    221    227  1.45   -165     56     7932


     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
          WSEL     LEW     REW    AREA        K        Q    VEL
        500.76  -165.6    55.9   857.1   55491.    3270.   3.82

 X STA.      -165.6      -76.0      -46.9      -24.1       -7.5        0.5
   A(I)           124.1       82.8       75.5       61.0       44.3
   V(I)            1.32       1.97       2.17       2.68       3.69

 X STA.         0.5        4.9        8.9       12.6       16.1       19.4
   A(I)            33.9       31.7       30.7       30.2       29.3
   V(I)            4.82       5.17       5.32       5.41       5.58

 X STA.        19.4       22.5       25.5       28.4       31.4       34.3
   A(I)            28.6       28.5       27.7       28.1       28.2
   V(I)            5.73       5.74       5.90       5.82       5.79

 X STA.        34.3       37.3       40.2       43.2       46.5       55.9
   A(I)            28.3       29.1       29.9       33.0       52.1
   V(I)            5.78       5.61       5.47       4.95       3.14
```

```
        U.S. Geological Survey WSPRO Input File shar013.wsp
        Hydraulic analysis for structure SHARTH00040013   Date: 15-APR-97
        TOWN HIGHWAY 4, BROAD BROOK, SHARON, VERMONT     ECW
           *** RUN DATE & TIME: 04-24-97  16:53
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      265     13955      0     76                     12530726
   497.09           265     13955      0     76  1.00      0     30 12530726

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       497.09     0.0    30.1   265.0   13955.    3349.  12.64

X STA.         0.0        3.3        5.3        7.3        9.0       10.6
  A(I)            22.2       14.9       14.1       13.2       12.9
  V(I)            7.55      11.27      11.92      12.70      12.99

X STA.        10.6       12.1       13.6       14.9       16.2       17.3
  A(I)            12.5       12.0       11.7       11.5       11.2
  V(I)           13.44      13.95      14.36      14.51      14.89

X STA.        17.3       18.5       19.6       20.6       21.6       22.6
  A(I)            11.0       11.0       10.8       10.8       11.0
  V(I)           15.22      15.23      15.50      15.49      15.23

X STA.        22.6       23.6       24.7       25.8       27.1       30.1
  A(I)            11.2       11.7       12.6       14.2       24.7
  V(I)           14.95      14.34      13.32      11.82       6.78


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      15.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.54  -115.0    62.6   183.7    4433.    1038.   5.65

X STA.      -115.0      -69.4      -54.2      -42.6      -33.3      -25.3
  A(I)            18.6       12.6       11.5       10.4        9.6
  V(I)            2.79       4.12       4.50       4.99       5.42

X STA.       -25.3      -18.2      -11.9       -6.2        0.3       11.8
  A(I)             9.2        8.7        8.2        8.7       10.8
  V(I)            5.65       5.99       6.30       6.00       4.82

X STA.        11.8       23.1       33.1       37.2       40.9       44.2
  A(I)            10.9       10.8        7.2        6.7        6.5
  V(I)            4.75       4.81       7.21       7.70       8.02

X STA.        44.2       47.1       50.0       52.6       55.3       62.6
  A(I)             6.1        6.1        5.9        6.4        8.8
  V(I)            8.45       8.46       8.75       8.14       5.93

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      59.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      474     17920    164    164                         4576
             2      614     55801     71     78                        10215
   501.77          1088     73721    235    242  1.44   -178     57    11065

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.77  -178.5    56.8  1087.7   73721.    4400.   4.05

X STA.      -178.5     -102.8      -71.4      -49.0      -29.9      -12.5
  A(I)           134.9      102.8       87.0       82.0       76.4
  V(I)            1.63       2.14       2.53       2.68       2.88

X STA.       -12.5       -3.2        2.9        7.4       11.5       15.4
  A(I)            52.7       47.0       39.8       38.0       36.9
  V(I)            4.17       4.68       5.53       5.79       5.96

X STA.        15.4       19.1       22.5       25.8       29.2       32.5
  A(I)            36.0       34.9       34.9       35.3       35.2
  V(I)            6.10       6.30       6.30       6.24       6.26

X STA.        32.5       35.9       39.2       42.6       46.3       56.8
  A(I)            35.3       36.3       37.6       40.1       64.4
  V(I)            6.23       6.06       5.85       5.49       3.42
```

```
        U.S. Geological Survey WSPRO Input File shar013.wsp
        Hydraulic analysis for structure SHARTH00040013   Date: 15-APR-97
        TOWN HIGHWAY 4, BROAD BROOK, SHARON, VERMONT      ECW
           *** RUN DATE & TIME: 04-24-97  16:53
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      265     13955      0     76                     12530726
   497.09           265     13955      0     76  1.00      0     30 12530726

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       497.09     0.0    30.1   265.0   13955.    2550.   9.62

X STA.         0.0        3.3        5.3        7.3        9.0       10.6
  A(I)            22.2       14.9       14.1       13.2       12.9
  V(I)            5.75       8.58       9.07       9.67       9.89

X STA.        10.6       12.1       13.6       14.9       16.2       17.3
  A(I)            12.5       12.0       11.7       11.5       11.2
  V(I)           10.23      10.62      10.94      11.05      11.33

X STA.        17.3       18.5       19.6       20.6       21.6       22.6
  A(I)            11.0       11.0       10.8       10.8       11.0
  V(I)           11.59      11.60      11.80      11.79      11.60

X STA.        22.6       23.6       24.7       25.8       27.1       30.1
  A(I)            11.2       11.7       12.6       14.2       24.7
  V(I)           11.38      10.92      10.14       9.00       5.16

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      239     16633     29     45                         3893
   496.18           239     16633     29     45  1.00      0     30     3893


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      59.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      128      2714    106    106                          801
             2      442     33265     69     74                         6347
   499.33           571     35980    175    181  1.32   -120     55     5074


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.33  -120.8    54.6   570.7   35980.    2550.   4.47

X STA.      -120.8      -32.5       -6.5        1.3        5.5        9.2
  A(I)            93.5       56.8       34.3       26.3       24.5
  V(I)            1.36       2.25       3.72       4.85       5.21

X STA.         9.2       12.5       15.7       18.6       21.4       24.0
  A(I)            23.2       22.5       21.8       21.4       20.7
  V(I)            5.49       5.66       5.86       5.96       6.16

X STA.        24.0       26.6       29.1       31.6       34.1       36.6
  A(I)            20.7       20.1       20.6       20.3       20.0
  V(I)            6.17       6.34       6.20       6.28       6.39

X STA.        36.6       39.1       41.4       44.0       46.8       54.6
  A(I)            20.8       20.4       22.2       23.7       37.2
  V(I)            6.14       6.25       5.74       5.39       3.43
```

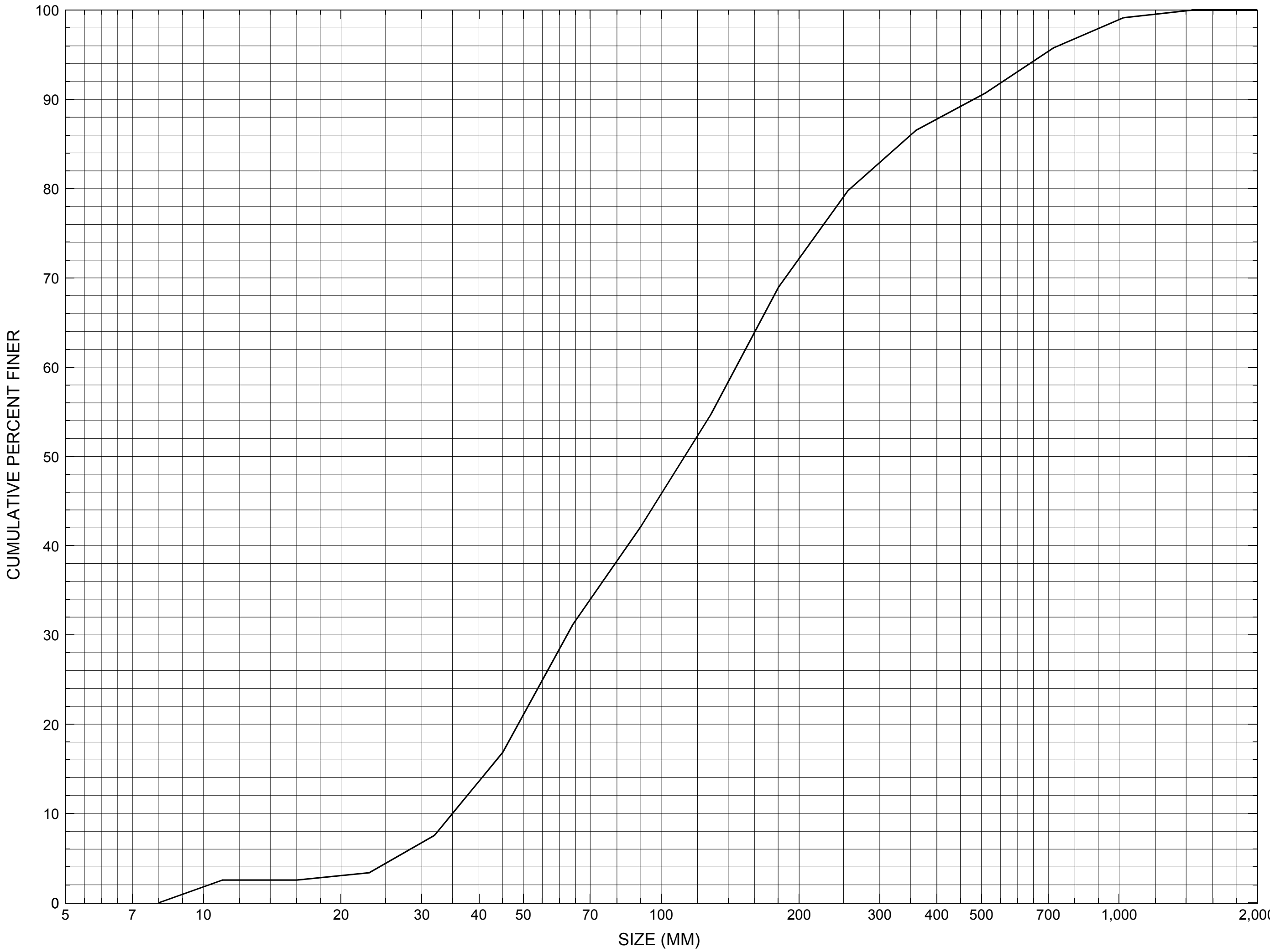
```
        U.S. Geological Survey WSPRO Input File shar013.wsp
        Hydraulic analysis for structure SHARTH00040013   Date: 15-APR-97
        TOWN HIGHWAY 4, BROAD BROOK, SHARON, VERMONT      ECW
           *** RUN DATE & TIME: 04-24-97  16:53

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

EXITX:XS   ******    -16      344  1.45 *****  497.45  495.32    3270  496.00
       -25 ******     74    21282  1.03 ***** *******    0.88    9.51

FULLV:FV       26    -33      442  0.94  0.44  497.89 *******    3270  496.96
         0     26     79    29693  1.10  0.00    0.00    0.69    7.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.97     497.69     496.91

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.46     510.20    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.46     510.20     496.91

APPRO:AS       59    -51      338  1.52  1.02  499.20  496.91    3270  497.69
        59     59     53    20863  1.04  0.29    0.00    0.97    9.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   501.26       0.00     495.29     499.15

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.60     500.18     500.48     497.07

 ===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       26      0      265  1.94 *****  499.03  494.81    2960  497.09
         0 ******     30    13955  1.00 ***** *******    0.66   11.17

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.488  0.000  497.07 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.    36.  0.12  0.33  500.97   -0.02    247.  500.67

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     97.    72.   -55.    17.   0.6   0.3   3.5   4.9   0.6   3.1
   RT:    150.    43.    17.    60.   1.5   0.7   5.0   4.7   1.0   3.3

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


APPRO:AS       16   -165      858  0.33  0.28  501.09  496.91    3270  500.76
        59     22     56    55539  1.45  1.88   -0.02    0.41    3.81

       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     -26.   -17.    74.   3270.   21282.     344.    9.51  496.00
   FULLV:FV       0.   -34.    79.   3270.   29693.     442.    7.39  496.96
   BRIDG:BR       0.     0.    30.   2960.   13955.     265.   11.17  497.09
   RDWAY:RG      15.*******    97.    247.       0.*********    1.00  500.67
   APPRO:AS      59.  -166.    56.   3270.   55539.     858.    3.81  500.76
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO  VHD     EGL    WSEL
   EXITX:XS     495.32    0.88  488.57  509.24************  1.45  497.45  496.00
   FULLV:FV   ********    0.69  488.57  509.24  0.44  0.00  0.94  497.89  496.96
   BRIDG:BR     494.81    0.66  485.25  497.09************  1.94  499.03  497.09
   RDWAY:RG   ****************  499.15  510.74  0.12******  0.33  500.97  500.67
   APPRO:AS     496.91    0.41  490.65  510.20  0.28  1.88  0.33  501.09  500.76
```

```
       U.S. Geological Survey WSPRO Input File shar013.wsp
       Hydraulic analysis for structure SHARTH00040013   Date: 15-APR-97
       TOWN HIGHWAY 4, BROAD BROOK, SHARON, VERMONT     ECW
          *** RUN DATE & TIME: 04-24-97  16:53

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

EXITX:XS   ******    -32      430  1.78 *****  498.63  496.41    4400  496.85
      -25 ******     79    28628  1.10 ***** *******    0.96   10.23

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
           FNTEST,FR#,WSEL,CRWS =  0.80    0.82     497.95     496.41

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   496.35     509.24    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   496.35     509.24     496.41

FULLV:FV       26   -108      574  1.12  0.44  499.07  496.41    4400  497.94
         0     26     84    40034  1.23  0.00    0.00    0.82    7.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
           FNTEST,FR#,WSEL,CRWS =  0.80    1.06     498.62     498.30

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   497.44     510.20    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   497.44     510.20     498.30

APPRO:AS       59    -92      457  1.75  1.00  500.37  498.30    4400  498.63
        59     59     54    28674  1.21  0.31    0.00    1.06    9.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                     WS3N,LSEL =   497.94     497.07

            <<<<<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       26      0      265  2.48 *****  499.57  495.40    3349  497.09
         0 ******     30    13955  1.00 ***** *******    0.75   12.64

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.07 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.    36.  0.13  0.37  502.01    0.00   1038.  501.54

           Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    633.   132.  -115.    17.   1.5   0.9   5.4   5.6   1.3   3.1
   RT:    404.    45.    17.    63.   2.4   1.5   6.6   5.8   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       16   -178     1089  0.37  0.32  502.14  498.30    4400  501.77
        59     22     57    73811  1.44  1.88    0.00    0.40    4.04

       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     -26.   -33.    79.   4400.   28628.     430.   10.23  496.85
   FULLV:FV       0.  -109.    84.   4400.   40034.     574.    7.66  497.94
   BRIDG:BR       0.     0.    30.   3349.   13955.     265.   12.64  497.09
   RDWAY:RG      15.*******   633.   1038.******************    1.00  501.54
   APPRO:AS      59.  -179.    57.   4400.   73811.    1089.    4.04  501.77

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    496.41    0.96  488.57  509.24************  1.78  498.63  496.85
   FULLV:FV    496.41    0.82  488.57  509.24  0.44  0.00  1.12  499.07  497.94
   BRIDG:BR    495.40    0.75  485.25  497.09************  2.48  499.57  497.09
   RDWAY:RG  ***************  499.15  510.74  0.13******  0.37  502.01  501.54
   APPRO:AS    498.30    0.40  490.65  510.20  0.32  1.88  0.37  502.14  501.77
```

```
       U.S. Geological Survey WSPRO Input File shar013.wsp
       Hydraulic analysis for structure SHARTH00040013   Date: 15-APR-97
       TOWN HIGHWAY 4, BROAD BROOK, SHARON, VERMONT     ECW
          *** RUN DATE & TIME: 04-24-97  16:53

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

EXITX:XS   ******     -2      289  1.21 *****  496.56  494.54    2550  495.35
       -25 ******     71    16590  1.00 ***** *******    0.79    8.81

FULLV:FV       26    -20      360  0.81  0.45  496.99 *******    2550  496.18
         0     26     75    22708  1.05  0.00   -0.01    0.66    7.08
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       59    -11      282  1.27  1.03  498.24 *******    2550  496.97
        59     59     53    16482  1.00  0.23   -0.01    0.77    9.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.17     498.38     498.73     497.07

 ===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       26      0      265  1.40 *****  498.49  494.09    2511  497.09
         0 ******     30    13955  1.00 ***** *******    0.56    9.48

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.454  0.000  497.07 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS       16   -120      570  0.41  0.29  499.74  496.13    2550  499.33
        59     22     55    35944  1.32  1.47   -0.02    0.50    4.47

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.15
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL   WSEL
   EXITX:XS     -26.    -3.    71.   2550.   16590.     289.    8.81  495.35
   FULLV:FV       0.   -21.    75.   2550.   22708.     360.    7.08  496.18
   BRIDG:BR       0.     0.    30.   2511.   13955.     265.    9.48  497.09
   RDWAY:RG      15.**************      0.       0.       0.    1.00********
   APPRO:AS      59.  -121.    55.   2550.   35944.     570.    4.47  499.33

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    494.54    0.79  488.57  509.24************  1.21  496.56  495.35
   FULLV:FV  ********    0.66  488.57  509.24  0.45  0.00  0.81  496.99  496.18
   BRIDG:BR    494.09    0.56  485.25  497.09************  1.40  498.49  497.09
   RDWAY:RG  ****************  499.15  510.74************  0.41  499.56********
   APPRO:AS    496.13    0.50  490.65  510.20  0.29  1.47  0.41  499.74  499.33

  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 SHARTH00040013, in Sharon, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SHARTH00040013

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)* 04

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 63775

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

Waterway *(I - 6)* BROAD BROOK

Road Name *(I - 7):* -

Route Number TH004

Vicinity *(I - 9)* 0.2 MI JCT TH 4 + TH 35

Topographic Map Sharon

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43468

Longitude *(i - 17; nnnnn.n)* 72291

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10141700131417

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

Maximum span length *(I - 48; nnnn)* 0031

Year built *(I - 27; YYYY)* 1929

Structure length *(I - 49; nnnnnn)* 000034

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

Deck Width *(I - 52; nn.n)* 234

Year of ADT *(I - 30; YY)* 90

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

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

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

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

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

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 008.0

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

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

Comments:

The structural inspection report of 6/22/94 indicates the structure is a concrete T-beam type bridge. The abutment walls are concrete and have vertical shrinkage cracks reported. Overall, the report notes they are in "like-new" condition. Both abutment footings are exposed. At the upstream end of the right abutment, the top of the footing is about 2.5 feet above the adjacent streambed level. At the downstream end of the right abutment and for the entire length of the left abutment the top of the footing is roughly flush with the adjacent streambed level. The bottom of the left abutment is reported as having a large boulder cast into the concrete wall / footing near the centerline of the roadway. The wingwalls **(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:

reportedly are concrete with very minor stains. The waterway is noted as making a moderate bend into the crossing. The streambed consists of stone and gravel with several randomly distributed boulders. There is bedrock noted, which outcrops upstream. Just upstream from the end of the right abutment there is a large boulder, which extends out to mid-channel. Just downstream of the boulder is a localized area of channel scour reported but there is no undermining of the footing. There is a 15 inch diameter tree stem noted as wedged up against the upstream end of the right abutment and extending to mid-channel near the center line of the bridge, which may trap additional debris and create further hydraulic problems.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **16.61** mi^2 Lake and pond area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **490** ft Headwater elevation **1958** ft

Main channel length **8.46** mi

10% channel length elevation **590** ft 85% channel length elevation **1280** ft

Main channel slope *(S)* **108.75** 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 cord elevations are from the survey log done for this report on 7/23/96. The low cord to bed length data is from the sketch attached to a bridge inspection report dated 6/22/94.**

Station	0	1.7	15	21.5	27.5	30	-	-	-	-	-
Feature	LAB					RAB	-	-	-	-	-
Low cord elevation	497.0	497.0	497.0	497.1	497.1	497.1	-	-	-	-	-
Bed elevation	489.3	489.2	488.1	486.5	486.9	489.5	-	-	-	-	-
Low cord to bed length	7.7	7.8	8.9	10.6	10.2	7.6	-	-	-	-	-

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

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

Comments:

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 3/24/97
Computerized by: EW Date: 3/25/97
Reviewd by: EW Date: 5/8/97

Structure Number SHARTH00040013

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. Weber Date *(MM/DD/YY)* 04 / 11 / 1995
2. Highway District Number 04 Mile marker 000000
   County Windsor (027) Town Sharon (63775)
   Waterway *(I - 6)* Broad Brook Road Name -
   Route Number TH004 Hydrologic Unit Code: 01080105
3. Descriptive comments:

Bridge is located 0.2 miles from the junction between Town Highway 4 and Town Highway 35. "Downer" and "1929" lettering on the upstream concrete bridge rail.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 5 RBDS 3 Overall 5
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 1 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 34 *(feet)* Span length 31 *(feet)* Bridge width 23.4 *(feet)*

Road approach to bridge:

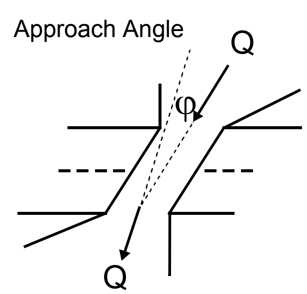
8. LB 0 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
    US left -- US right --

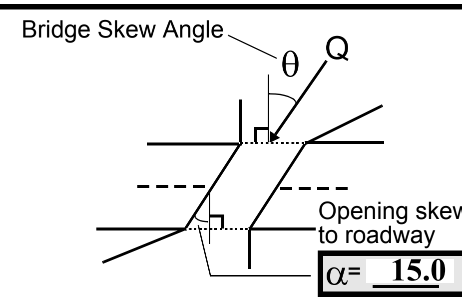
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	4	3
RBUS	2	1	0	-
RBDS	2	1	0	-
LBDS	2	1	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 5 16. Bridge skew: 10



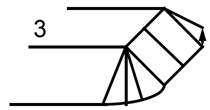


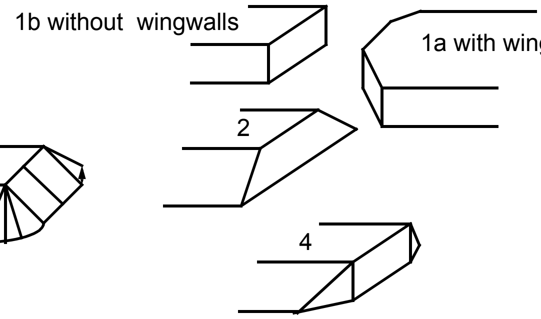
17. Channel impact zone 1: Exist? Y *(Y or N)*
    Where? RB *(LB, RB)* Severity 3
    Range? 15 feet US *(US, UB, DS)* to 0 feet US
    Channel impact zone 2: Exist? Y *(Y or N)*
    Where? RB *(LB, RB)* Severity 2
    Range? 100 feet US *(US, UB, DS)* to 50 feet US

*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 perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.





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

4: The downstream left bank is a soil road with trees and shrubs beyond, as well as along the immediate bank. On the downstream right bank, there are shrubs on the immediate bank, but the overbank is harvested row crops. The overall surface cover observed from the bridge deck is forest.

7: Values are from VTAOT database. Measured values during site visit: bridge length = 33 feet and bridge width = 23 feet.

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
59	**5.5**			**3.5**	**4**	**4**	**4532**	**4532**	**1**	**3**

23. Bank width **10.0** 24. Channel width **60.0** 25. Thalweg depth **66.0** 29. Bed Material **3452**

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

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

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

29: Bed and bank material is gravel, cobble, boulder and sand. There is more sand on the left bank than the right bank.

A seep enters the left bank at 20 feet upstream.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 130 35. Mid-bar width: 31
36. Point bar extent: 250 feet US (US, UB) to 20 feet US (US, UB, DS) positioned 0 %LB to 50 %RB
37. Material: 2345
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
There are some small trees growing on the point bar. The point bar material is gravel, cobbles and boulders underneath the layer of sand.

39. Is a cut-bank present? Y (Y or if N type ctrl-n cb) 40. Where? RB (LB or RB)
41. Mid-bank distance: 75 42. Cut bank extent: 250 feet US (US, UB) to 30 feet US (US, UB, DS)
43. Bank damage: 1 (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)
44. Cut bank comments (eg. additional cut banks, protection condition, etc.):
Between 140 feet and 90 feet upstream, the cut-bank is less severe due to boulder bank material. Roots are undercut, and some trees lean towards the stream.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 3 UB
47. Scour dimensions: Length 45 Width 25 Depth : 3 Position 0 %LB to 100 %RB
48. Scour comments (eg. additional scour areas, local scouring process, etc.):
Upstream section of scour is deepest. Scour hole extends from 2 feet upstream to 20 feet downstream.

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
32.0		1.5		2	7	7	-

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

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

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

64. Comments (bank material variation, minor inflows, protection extent, etc.):
4523

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

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

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

70. Debris and Ice Comments:

1

At the present time, there are logs caught under the bridge.

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		5	90	2	2	1	2	90.0
RABUT	1	0	90			2	3	-

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.):

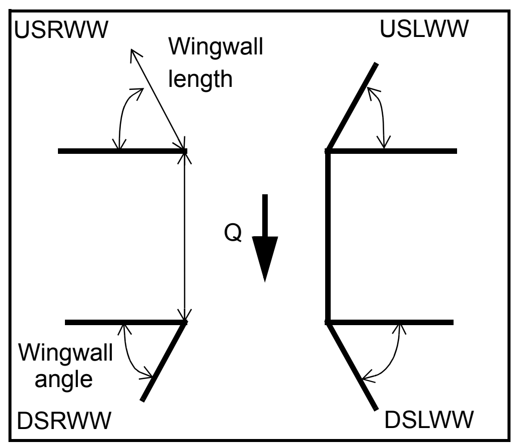
2
3
1

The left abutment footing is exposed 2 feet at the downstream end; it is even with the channel bed at the upstream end. The downstream end of the right abutment footing is exposed 3 feet, undermined less than one foot and can be penetrated 2 feet. The upstream end of the right abutment footing is even with the channel bed.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						-	
USRWW:	Y		1		0	3.5	
DSLWW:	-		-		Y	29.5	
DSRWW:	1		0		-	30.5	

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

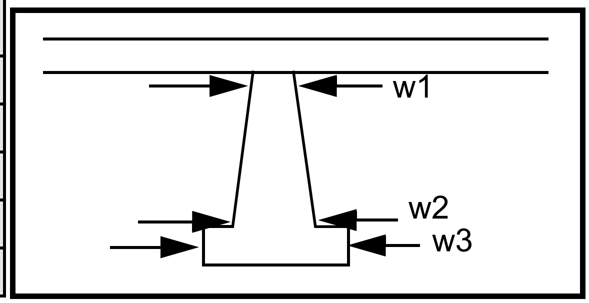
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
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				35.0	18.0	50.0
Pier 2				19.5	55.0	11.5
Pier 3			-	20.0	12.5	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	At the	the	the	0.5	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	upst	foot-	dow	feet.	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	ream	ing is	nstre		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	end	expo	am		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	of	sed 2	right		*Y- yes; N- no*
91. Attack ∠ (BF)	the	feet.	wing		
92. Pushed	dow	At	wall,		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	nstre	the	the		
95. Cross-members	am	upst	foot-		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	left	ream	ing is		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	wing	end	expo		
98. Exposure depth	wall,	of	sed	N	

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 (Amb) -   Thalweg depth (Amb) -   Bed Material -

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

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

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

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

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

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

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

Point bar extent: _-_ feet _NO_ (US, UB, DS) to _PIE_ feet _RS_ (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? ____ (Y or if N type ctrl-n cb) Where? ____ (LB or RB) Mid-bank distance: _2_

Cut bank extent: _1_ feet _324_ (US, UB, DS) to _5_ feet _234_ (US, UB, DS)

Bank damage: _5_ (1- eroded and/or creep; 2- slip failure; 3- block failure)

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

2
0
3425
0

Is channel scour present? _0_ (Y or if N type ctrl-n cs) Mid-scour distance: _-_

Scour dimensions: Length _-_ Width _Flu-_ Depth: _vial_ Positioned _ero_ %LB to _sio_ %RB

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

n on the left bank is light near the bridge and moderate where the cut-bank exists.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

1- Constructed
2- Stable
3- Aggraded
4- Degraded
5- Laterally unstable
6- Vertically and laterally unstable

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

N

-

NO DROP STRUCTURE

N

-

-

-

-

109. G. Plan View Sketch

point bar (pb)	debris	flow (Q)	stone wall
cut-bank (cb)	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: SHARTH00040013   Town: SHARON
Road Number: TH4   County: WINDSOR
Stream: BROAD BROOK

Initials ECW   Date: 5/7/97   Checked: MAI

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	3270	4400	2550
Main Channel Area, ft2	542	614	442
Left overbank area, ft2	315	474	128
Right overbank area, ft2	0	0	0
Top width main channel, ft	70	71	69
Top width L overbank, ft	151	164	106
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.369	0.369	0.369
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.7	8.6	6.4
y1, average depth, LOB, ft	2.1	2.9	1.2
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	55491	73721	35980
Conveyance, main channel	45914	55801	33265
Conveyance, LOB	9576	17920	2714
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0018	0.0000	0.0028
Qm, discharge, MC, cfs	2705.6	3330.5	2357.6
Ql, discharge, LOB, cfs	564.3	1069.5	192.3
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	5.0	5.4	5.3
Vl, mean velocity, LOB, ft/s	1.8	2.3	1.5
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	11.3	11.5	11.0
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

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	3270	4400	2550
(Q) discharge thru bridge, cfs	2960	3349	2550
Main channel conveyance	13955	13955	13955
Total conveyance	13955	13955	13955
Q2, bridge MC discharge,cfs	2960	3349	2550
Main channel area, ft2	265	265	265
Main channel width (normal), ft	29.1	29.1	29.1
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.1	29.1	29.1
y_bridge (avg. depth at br.), ft	9.11	9.11	9.11
Dm, median (1.25*D50), ft	0.46125	0.46125	0.46125
y2, depth in contraction,ft	8.11	9.02	7.14
ys, scour depth (y2-ybridge), ft	-0.99	-0.09	-1.97

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)
```

	Q100	Q500	OtherQ
Q, total, cfs	3270	4400	2550
Q, thru bridge MC, cfs	2960	3349	2550
Vc, critical velocity, ft/s	11.31	11.52	10.96
Va, velocity MC approach, ft/s	4.99	5.42	5.33
Main channel width (normal), ft	29.1	29.1	29.1
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.1	29.1	29.1
qbr, unit discharge, ft2/s	101.7	115.1	87.6
Area of full opening, ft2	265.0	265.0	265.0
Hb, depth of full opening, ft	9.11	9.11	9.11
Fr, Froude number, bridge MC	0.66	0.75	0.56
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	262	N/A	239
**Hb, depth at downstream face, ft	9.00	N/A	8.21
**Fr, Froude number at DS face	0.66	ERR	0.66
**Cf, for downstream face (<=1.0)	1.00	N/A	1.00
Elevation of Low Steel, ft	497.07	497.07	497.07
Elevation of Bed, ft	487.96	487.96	487.96
Elevation of Approach, ft	500.76	501.77	499.33
Friction loss, approach, ft	0.28	0.32	0.29
Elevation of WS immediately US, ft	500.48	501.45	499.04
ya, depth immediately US, ft	12.52	13.49	11.08
Mean elevation of deck, ft	500.58	500.58	500.58
w, depth of overflow, ft (>=0)	0.00	0.87	0.00
Cc, vert contrac correction (<=1.0)	0.92	0.92	0.95
**Cc, for downstream face (<=1.0)	0.916224	ERR	0.924716
Ys, scour w/Chang equation, ft	0.68	1.79	-0.71
Ys, scour w/Umbrell equation, ft	-0.68	-0.04	-1.20

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

**Ys, scour w/Chang equation, ft	0.81	N/A	0.44

**Ys, scour w/Umbrell equation, ft	-0.58	N/A	-0.31

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	8.11	9.02	7.14
WSEL at downstream face, ft	496.96	--	496.18
Depth at downstream face, ft	9.00	N/A	8.21
Ys, depth of scour (Laursen), ft	-0.89	N/A	-1.07

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	2960	3349	2550
Main channel area (DS), ft2	262	265	239
Main channel width (normal), ft	29.1	29.1	29.1
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	29.1	29.1	29.1
D90, ft	1.5766	1.5766	1.5766
D95, ft	2.2381	2.2381	2.2381
Dc, critical grain size, ft	0.7144	0.8891	0.6656
Pc, Decimal percent coarser than Dc	0.252	0.190	0.274
Depth to armoring, ft	6.36	11.37	5.29

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	3270	4400	2550	3270	4400	2550
a', abut.length blocking flow, ft	166.1	179	121.3	26.3	27.2	25
Ae, area of blocked flow ft2	369.62	467.21	181.1	193.5	194.7	181.1
Qe, discharge blocked abut.,cfs	--	--	369.4	--	--	994.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.11	2.58	2.04	4.96	5.29	5.49
ya, depth of f/p flow, ft	2.23	2.61	1.49	7.36	7.16	7.24
--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	75	75	75	105	105	105
K2	0.98	0.98	0.98	1.02	1.02	1.02
Fr, froude number f/p flow	0.243	0.256	0.294	0.304	0.311	0.360
ys, scour depth, ft	13.13	15.34	10.02	19.04	18.99	19.81

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)	166.1	179	121.3	26.3	27.2	25
y1 (depth f/p flow, ft)	2.23	2.61	1.49	7.36	7.16	7.24
a'/y1	74.64	68.58	81.25	3.57	3.80	3.45
Skew correction (p. 49, fig. 16)	0.95	0.95	0.95	1.03	1.03	1.03
Froude no. f/p flow	0.24	0.26	0.29	0.30	0.31	0.36
Ys w/ corr. factor K1/0.55:						
vertical	9.64	11.50	6.89	ERR	ERR	ERR
vertical w/ ww's	7.90	9.43	5.65	ERR	ERR	ERR
spill-through	5.30	6.33	3.79	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)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.66	0.75	0.66	0.66	0.75	0.66
y, depth of flow in bridge, ft	9.00	9.11	8.21	9.00	9.11	8.21
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.42	3.17	2.21	2.42	3.17	2.21
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	2.11	2.76	1.93	2.11	2.76	1.93
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR