LEVEL II SCOUR ANALYSIS FOR BRIDGE 36 (DUXBTH00040036) on TOWN HIGHWAY 4, crossing CROSSETT BROOK, DUXBURY, VERMONT

Open-File Report 97-661

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

U.S. Department of the Interior
U.S. Geological Survey

science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 36 (DUXBTH00040036) on TOWN HIGHWAY 4, crossing CROSSETT BROOK, DUXBURY, VERMONT

By EMILY C. WILD and JAMES R. DEGNAN

U.S. Geological Survey
Open-File Report 97-661

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
Mark Schaefer, Acting 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 36 (DUXBTH00040036) ON TOWN HIGHWAY 4, CROSSING CROSSETT BROOK, DUXBURY, VERMONT

By Emily C. Wild and James R. Degnan

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure DUXBTH00040036 on Town Highway 4 crossing the Crossett Brook, Duxbury, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in north-central Vermont. The 4.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover on the upstream left overbank is pasture. The upstream and downstream right overbanks are forested. The downstream left overbank is brushland, while the immediate banks have dense woody vegetation.

In the study area, the Crossett Brook has an incised, sinuous channel with a slope of approximately 0.006 ft/ft, an average channel top width of 55 ft and an average bank height of 9 ft. The channel bed material ranges from gravel to bedrock with a median grain size (D_{50}) of 51.6 mm (0.169 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 1, 1996, indicated that the reach was stable.

The Town Highway 4 crossing of the Crossett Brook is a 29-ft-long, two-lane bridge consisting of a 26-foot concrete slab span (Vermont Agency of Transportation, written communication, October 13, 1995). The opening length of the structure parallel to the bridge face is 26 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 35 degrees to the opening while the computed opening-skew-to-roadway is 5 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the upstream left wingwall and the right abutment during the Level I assessment. Scour countermeasures at the site includes type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream left and right wingwalls and the upstream left and right banks and road embankments. 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 0.0 to 1.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 6.4 to 8.3 ft. Right abutment scour ranged from 6.0 to 7.0 ft. The worst-case left and right abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Essex Junction, VT. Quadrangle, 1:24,000, 1948, photoinspected 1987

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 DUXBTH00040036 ***Stream*** Crossett Brook

County Washington ***Road*** TH4 ***District*** 6

Description of Bridge

Bridge length 29 ***ft*** ***Bridge width*** 22.7 ***ft*** ***Max span length*** 26 ***ft***

Alignment of bridge to road (on curve or straight) Straight on left side. On a curve, right.

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

Stone fill on abutment? No ***Date of inspection*** 7/01/96

Description of stone fill Type-2, around the upstream end of the upstream left and right wingwalls and along the upstream left and right banks and road embankments.

Brief description of piers/abutments Abutments and wingwalls are concrete. The right abutment footing is exposed 5 feet, and a scour depth of 1.5 feet.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 5

There is a moderate channel bend in the upstream reach. The scour hole has developed in the location where the bend impacts the upstream left 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	7/01/96	0	0
Level II	7/01/96	0	0

Potential for debris Moderate.

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

No features where observed on 7/01/96.

Description of the Geomorphic Setting

General topography The channel is located within a flat to slightly irregular flood plain with steep valley walls on both sides.

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

Date of inspection 7/01/96

DS left: Narrow flood plain.

DS right: Steep valley wall.

US left: Narrow flood plain.

US right: Steep valley wall.

Description of the Channel

Average top width 55 ft ***Average depth*** 9 ft

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

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

7/01/96

Vegetative co Brush with a few trees.

DS left: Trees and brush.

DS right: Pasture with some brush along the immediate bank.

US left: Trees with Town Highway 22 along the immediate bank.

US right: Y

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

The protection at the upstream ends of the left and right wingwalls was slumped into the channel during the July 1, 1996 site visit.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 4.9 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: -

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 1,200 ***ft³/s*** ***Q500*** 1,820 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(4.9/5.0)exp 0.67] with bridge number 7 in Duxbury. Bridge number 7 crosses the Crossett Brook downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 7 is 5.0 square miles. The values computed are within a range defined by several empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans 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. 500.42 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 497.78 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	-24	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPRO	50	2	Modelled Approach section (Templated from APTEM)
APTEM	59	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.050 to 0.055, and overbank "n" values ranged from 0.040 to 0.070.

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 0.0061 ft/ft which was calculated from thalweg slopes surveyed downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.019 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 approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.2 ***ft***
Average low steel elevation 496.8 ***ft***

100-year discharge 1,200 ***ft^3/s***
Water-surface elevation in bridge opening 491.6 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 129 ***ft^2***
Average velocity in bridge opening 9.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.5 ***ft/s***

Water-surface elevation at Approach section with bridge 492.6
Water-surface elevation at Approach section without bridge 492.2
Amount of backwater caused by bridge 0.4 ***ft***

500-year discharge 1,820 ***ft^3/s***
Water-surface elevation in bridge opening 492.2 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 144 ***ft^2***
Average velocity in bridge opening 12.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.9 ***ft/s***

Water-surface elevation at Approach section with bridge 494.8
Water-surface elevation at Approach section without bridge 493.0
Amount of backwater caused by bridge 1.8 ***ft***

Incipient overtopping discharge N/A ***ft^3/s***
Water-surface elevation in bridge opening - ***ft***
Area of flow in bridge opening - ***ft^2***
Average velocity in bridge opening - ***ft/s***
Maximum WSPRO tube velocity at bridge - ***ft/s***

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year and 500-year discharges was computed by use of the live-bed contraction scour equation (Richardson and others, 1995, p. 30, equation 17). At this site, the 100-year and 500-year discharges resulted in free surface flow. 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) and the results are presented in Appendix F.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	0.0	1.7	--
Clear-water scour	0.1 1.9	--	5.7
Depth to armoring	27.3	--	--
Left overbank	--	--	--
Right overbank	--	--	6.4
Local scour:			
Abutment scour	8.3	--	6.0
Left abutment	7.0–	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	1.7
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	2.3	--	1.7
Left abutment	2.3	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	
Pier 2			

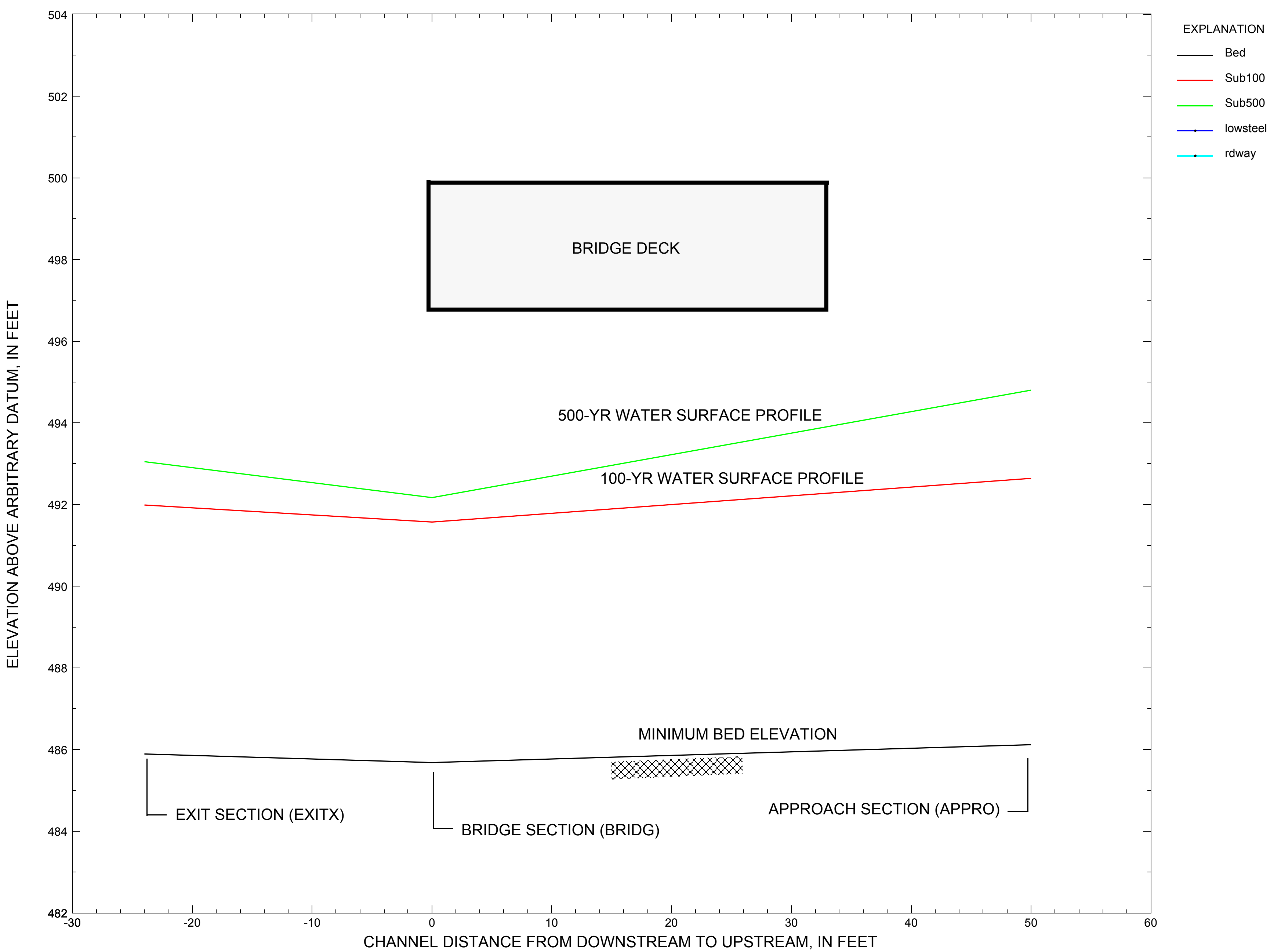


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure DUXBTH00040036 on Town Highway 4, crossing Crossett Brook, Duxbury, Vermont.

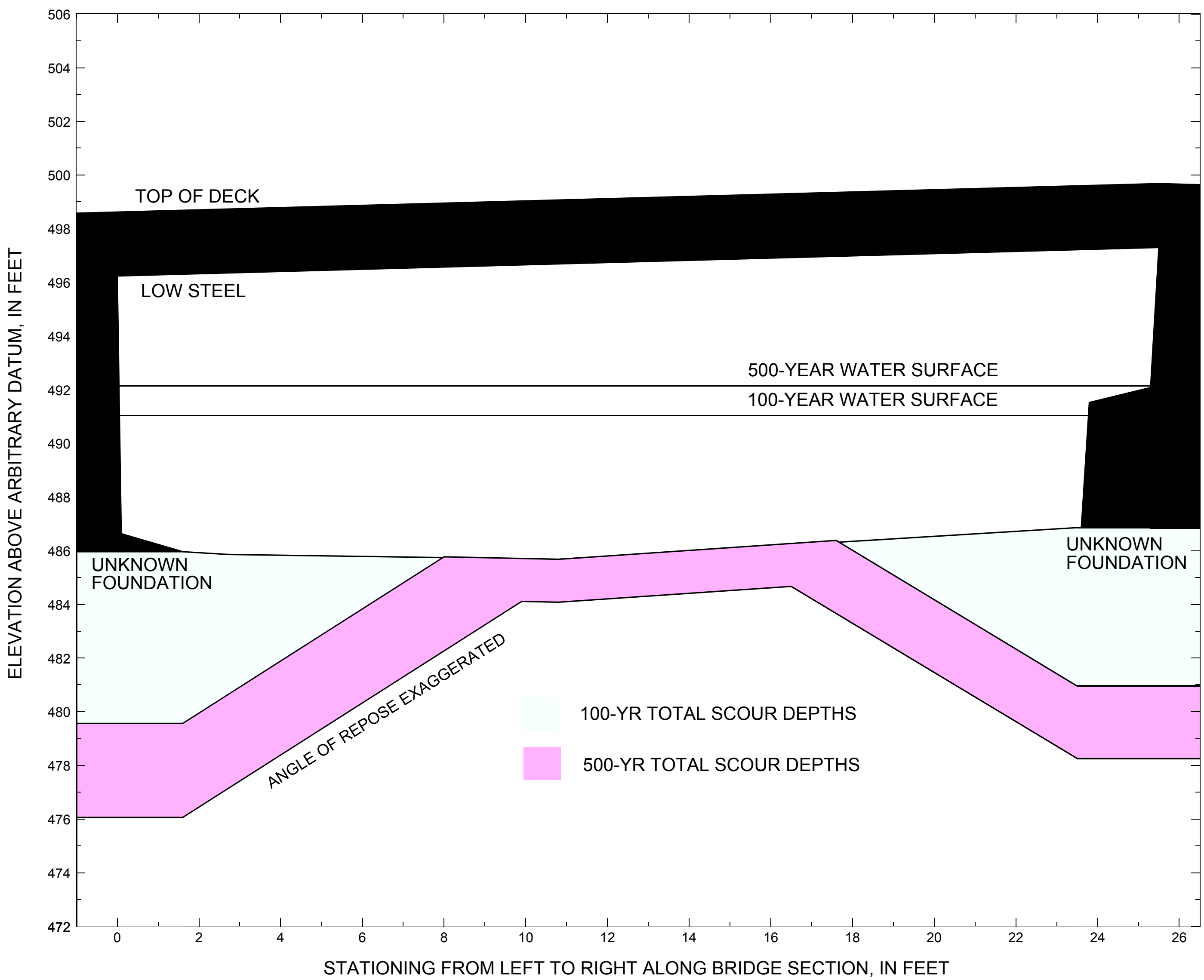


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure DUXBTH00040036 on Town Highway 4, crossing Crossett Brook, Duxbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure DUXBTH00040036 on Town Highway 4, crossing Crossett Brook, Duxbury, 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 1,200 cubic-feet per second											
Left abutment	0.0	--	496.2	--	486.0	0.0	6.4	--	6.4	479.6	--
Right abutment	25.5	--	497.3	--	486.8	0.0	6.0	--	6.0	480.8	--

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 DUXBTH00040036 on Town Highway 4, crossing Crossett Brook, Duxbury, 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 1,820 cubic-feet per second											
Left abutment	0.0	--	496.2	--	486.0	1.7	8.3	--	10.0	476.0	--
Right abutment	25.5	--	497.3	--	486.8	1.7	7.0	--	8.7	478.1	--

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, 1948, Waterbury, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1980, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File duxb036.wsp
T2        Hydraulic analysis for structure DUXBTH00040036   Date: 15-MAY-97
T3        Town Highway 4, Crossett Brook, Duxbury, Vermont         ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1200.0   1820.0
SK          0.0061   0.0061
*
XS   EXITX    -24           0.
GR         -242.4, 502.09    -94.5, 494.70    -19.7, 491.63      0.0, 488.93
GR            7.8, 487.84     10.4, 486.70     15.0, 486.21     19.6, 486.34
GR           27.9, 485.89     28.9, 485.98     30.0, 486.81     35.0, 486.86
GR           36.5, 489.55     44.9, 499.31     61.7, 500.94     90.4, 502.13
GR          100.9, 506.30
*
N           0.070        0.050        0.065
SA               -19.7          44.9
*
*
XS   FULLV      0  * * *
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.77      5.0
GR            0.0, 496.24      0.1, 486.63      0.1, 486.20      1.3, 486.10
GR            1.6, 485.96      2.7, 485.86      5.6, 485.84     10.8, 485.68
GR           18.3, 486.45     23.5, 486.79     23.6, 486.86     23.8, 491.52
GR           25.3, 492.08     25.5, 497.30      0.0, 496.24
*
*         BRTYPE  BRWDTH          WWANGL   WWWID
CD           1      33.3 * *       65.9     6.6
N           0.050
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     12      22.7     2
GR         -302.1, 508.56   -225.9, 505.57    -80.6, 497.95     -0.2, 498.62
GR            0.0, 499.40     25.6, 500.39     25.7, 499.68     37.7, 500.17
GR           87.4, 501.98
*
*
*
XT   APTEM     59           0.
GR         -302.1, 508.56   -225.9, 505.57    -80.6, 497.95
GR          -59.2, 497.85     -6.7, 497.61     -2.9, 496.76      0.0, 488.71
GR            2.9, 487.17      3.9, 486.73     10.4, 486.29     12.7, 486.52
GR           17.4, 487.05     27.0, 491.30     29.1, 494.07     37.9, 495.98
GR           49.4, 496.83     62.0, 496.65     74.1, 503.45
*
AS   APPRO     50 * * * 0.019
GT
N           0.040        0.055        0.060
SA                 -6.7          37.9
*
HP 1 BRIDG 491.57 1 491.57
HP 2 BRIDG 491.57 * * 1200
HP 1 APPRO 492.64 1 492.64
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File duxb036.wsp
        Hydraulic analysis for structure DUXBTH00040036   Date: 15-MAY-97
        Town Highway 4, Crossett Brook, Duxbury, Vermont         ECW
           *** RUN DATE & TIME: 07-29-97  16:15

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      129      9383     24     34                          1701
   491.57           129      9383     24     34  1.00      0     24      1701


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       491.57     0.0    23.9   128.8    9383.    1200.   9.32

X STA.        0.0        2.3        3.6        4.7        5.7        6.7
  A(I)            12.1        7.2        6.4        5.9        5.7
  V(I)            4.95       8.34       9.42      10.17      10.44

X STA.        6.7        7.7        8.6        9.5       10.4       11.3
  A(I)             5.5        5.4        5.3        5.2        5.2
  V(I)           10.99      11.07      11.39      11.47      11.46

X STA.       11.3       12.2       13.1       14.1       15.1       16.2
  A(I)             5.3        5.3        5.4        5.6        5.5
  V(I)           11.41      11.24      11.09      10.74      10.88

X STA.       16.2       17.3       18.5       19.8       21.3       23.9
  A(I)             5.9        6.0        6.7        7.3       11.7
  V(I)           10.15       9.92       8.96       8.18       5.11

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      143      9937     30     35                          1779
   492.64           143      9937     30     35  1.00      0     28      1779


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.64    -1.5    28.1   142.8    9937.    1200.   8.40

X STA.       -1.5        2.0        3.5        4.6        5.7        6.7
  A(I)            12.5        8.0        7.0        6.5        6.2
  V(I)            4.79       7.53       8.61       9.21       9.67

X STA.        6.7        7.6        8.5        9.4       10.3       11.2
  A(I)             6.0        5.8        5.8        5.8        5.8
  V(I)            9.94      10.36      10.39      10.42      10.42

X STA.       11.2       12.1       13.1       14.0       15.0       16.1
  A(I)             5.8        5.9        6.0        6.2        6.4
  V(I)           10.37      10.20      10.05       9.73       9.41

X STA.       16.1       17.2       18.5       20.1       22.3       28.1
  A(I)             6.6        6.9        7.8        9.2       12.8
  V(I)            9.11       8.66       7.65       6.52       4.70
```

```
     U.S. Geological Survey WSPRO Input File duxb036.wsp
     Hydraulic analysis for structure DUXBTH00040036   Date: 15-MAY-97
     Town Highway 4, Crossett Brook, Duxbury, Vermont         ECW
        *** RUN DATE & TIME: 07-29-97  16:15

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      144     10788     25     36                         1946
492.17           144     10788     25     36  1.00      0     25     1946


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

      WSEL     LEW     REW    AREA        K        Q    VEL
    492.17     0.0    25.3   143.6   10788.    1820.  12.68

X STA.        0.0        2.3        3.6        4.7        5.7        6.7
  A(I)           13.7        7.9        7.2        6.4        6.1
  V(I)           6.65      11.51      12.67      14.11      14.82

X STA.        6.7        7.7        8.6        9.5       10.4       11.3
  A(I)            6.1        5.7        5.8        5.8        5.8
  V(I)          14.91      15.88      15.68      15.80      15.77

X STA.       11.3       12.2       13.1       14.1       15.1       16.1
  A(I)            5.8        5.8        5.9        6.1        6.1
  V(I)          15.82      15.56      15.32      14.80      14.96

X STA.       16.1       17.2       18.4       19.7       21.2       25.3
  A(I)            6.5        6.9        7.2        8.7       13.9
  V(I)          13.93      13.20      12.56      10.50       6.53

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          2      211     16549     36     43                         2918
494.80           211     16549     36     43  1.00     -1     33     2918


 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

      WSEL     LEW     REW    AREA        K        Q    VEL
    494.80    -2.3    33.3   211.0   16549.    1820.   8.63

X STA.       -2.3        1.8        3.3        4.5        5.6        6.7
  A(I)           19.0       11.6       10.0        9.1        8.9
  V(I)           4.78       7.87       9.12      10.01      10.23

X STA.        6.7        7.7        8.6        9.6       10.6       11.5
  A(I)            8.6        8.1        8.3        8.2        8.2
  V(I)          10.53      11.17      11.00      11.05      11.10

X STA.       11.5       12.5       13.5       14.5       15.6       16.7
  A(I)            8.3        8.4        8.6        8.9        9.2
  V(I)          11.02      10.81      10.62      10.24       9.87

X STA.       16.7       18.0       19.4       21.2       23.6       33.3
  A(I)           10.0       10.4       11.8       13.5       21.9
  V(I)           9.10       8.71       7.71       6.77       4.16
```

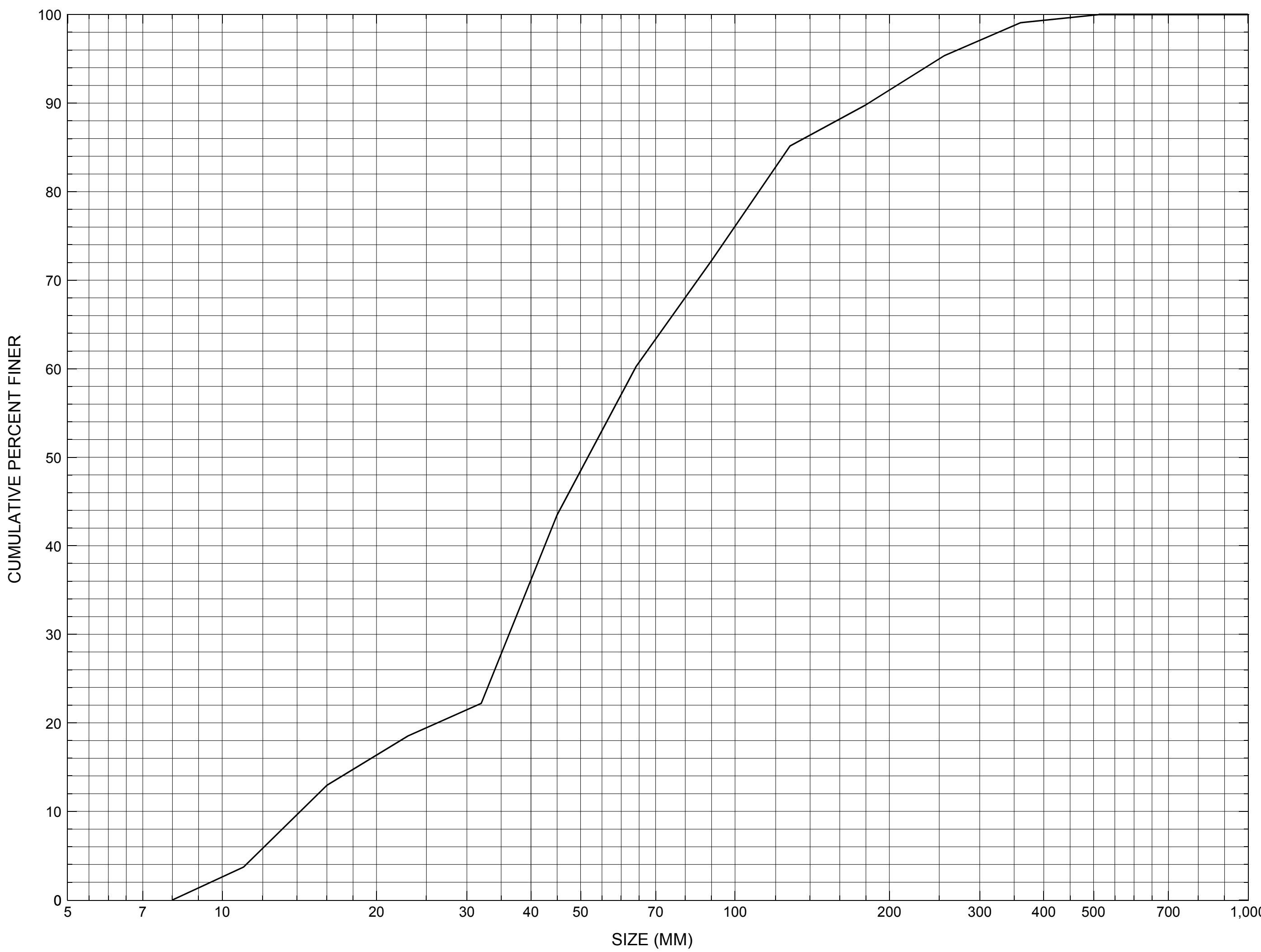
WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File duxb036.wsp
       Hydraulic analysis for structure DUXBTH00040036   Date: 15-MAY-97
       Town Highway 4, Crossett Brook, Duxbury, Vermont         ECW
          *** RUN DATE & TIME: 07-29-97  16:15

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

EXITX:XS   ******    -27      222  0.46 *****  492.44  490.25    1200  491.99
       -23 ******     39    15355  1.01 ***** *******    0.53    5.40

FULLV:FV       24    -32      235  0.42  0.14  492.59 *******    1200  492.17
         0     24     39    16632  1.03  0.00    0.01    0.50    5.10
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.52

APPRO:AS       50      0      130  1.32  0.50  493.53 *******    1200  492.21
        50     50     28     8670  1.00  0.45   -0.01    0.77    9.23
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

           <<<<<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       24      0      129  1.35  0.24  492.92  490.43    1200  491.57
         0     24     24     9387  1.00  0.24    0.01    0.71    9.31

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.77 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<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       17      0      143  1.10  0.26  493.74  491.44    1200  492.64
        50     17     28     9923  1.00  0.55   -0.02    0.68    8.41

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.133  0.000   10833.     0.    24.   492.24

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


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL   WSEL
   EXITX:XS     -24.   -28.    39.   1200.   15355.     222.    5.40  491.99
   FULLV:FV       0.   -33.    39.   1200.   16632.     235.    5.10  492.17
   BRIDG:BR       0.     0.    24.   1200.    9387.     129.    9.31  491.57
   RDWAY:RG      12.**************      0.******************    2.00********
   APPRO:AS      50.    -1.    28.   1200.    9923.     143.    8.41  492.64

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       0.    24.   10833.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    490.25    0.53  485.89  506.30************  0.46  492.44  491.99
   FULLV:FV  ********    0.50  485.89  506.30  0.14  0.00  0.42  492.59  492.17
   BRIDG:BR    490.43    0.71  485.68  497.30  0.24  0.24  1.35  492.92  491.57
   RDWAY:RG  ****************  497.95  508.56**********************************
   APPRO:AS    491.44    0.68  486.12  508.39  0.26  0.55  1.10  493.74  492.64
```

```
        U.S. Geological Survey WSPRO Input File duxb036.wsp
        Hydraulic analysis for structure DUXBTH00040036   Date: 15-MAY-97
        Town Highway 4, Crossett Brook, Duxbury, Vermont        ECW
           *** RUN DATE & TIME: 07-29-97  16:15

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

EXITX:XS   ******    -53      307  0.61 *****  493.66  491.24    1820  493.05
       -23 ******     40    23296  1.12 ***** *******    0.61    5.92

FULLV:FV       24    -58      327  0.55  0.14  493.80 *******    1820  493.25
         0     24     40    25088  1.15  0.00    0.01    0.58    5.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.92     493.03     492.72

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.75     508.39    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.75     508.39     492.72

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.44

APPRO:AS       50     -1      155  2.15  0.59  495.19  492.72    1820  493.04
        50     50     28    11159  1.00  0.80    0.00    0.91   11.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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       24      0      143  2.50  0.32  494.67  491.88    1820  492.17
         0     24     25    10779  1.00  0.71    0.02    0.94   12.69

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.77 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<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       17     -1      211  1.16  0.31  495.96  492.72    1820  494.80
        50     17     33    16557  1.00  0.96   -0.01    0.62    8.62

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.158  0.000   19124.     0.    25.   494.47

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


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -24.   -54.    40.   1820.   23296.     307.    5.92  493.05
   FULLV:FV       0.   -59.    40.   1820.   25088.     327.    5.56  493.25
   BRIDG:BR       0.     0.    25.   1820.   10779.     143.   12.69  492.17
   RDWAY:RG      12.**************      0.*****************     2.00********
   APPRO:AS      50.    -2.    33.   1820.   16557.     211.    8.62  494.80

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       0.    25.   19124.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    491.24    0.61  485.89  506.30************  0.61  493.66  493.05
   FULLV:FV  ********    0.58  485.89  506.30  0.14  0.00  0.55  493.80  493.25
   BRIDG:BR    491.88    0.94  485.68  497.30  0.32  0.71  2.50  494.67  492.17
   RDWAY:RG ****************  497.95  508.56**********************************
   APPRO:AS    492.72    0.62  486.12  508.39  0.31  0.96  1.16  495.96  494.80
  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 DUXBTH00040036, in Duxbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number DUXBTH00040036

General Location Descriptive

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

Date *(MM/DD/YY)* 10 / 13 / 95

Highway District Number *(I - 2; nn)* 06

County *(FIPS county code; I - 3; nnn)* 023

Town *(FIPS place code; I - 4; nnnnn)* 18550

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

Waterway *(I - 6)* CROSSETT BROOK

Road Name *(I - 7)*: -

Route Number C3004

Vicinity *(I - 9)* 0.07 MI TO JCT W C3 TH22

Topographic Map Waterbury

Hydrologic Unit Code: 2010003

Latitude *(I - 16; nnnn.n)* 44192

Longitude *(i - 17; nnnnn.n)* 72459

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10120600361206

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

Maximum span length *(I - 48; nnnn)* 0026

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

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000200

Deck Width *(I - 52; nn.n)* 227

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

Channel & Protection *(I - 61; n)* 4

Opening skew to Roadway *(I - 34; nn)* 18

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

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

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

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 25.67

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

Vertical clearance from streambed (*nnn.n ft*) 10.28

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

Waterway of full opening (*nnn.n ft*^{2}) 263.8

Comments:

According to the structural inspection report dated 5/12/94, the deck is gravel and the guard rail needs to be replaced. The abutments are concrete. The RABUT rests on bedrock. Both abutments have verticle and horizontal cracks and random cracking with leakage in the stems and footings. The wingwalls have cracks with leakage, most are on the LABUT. There is some settlement at the LABUT. The LABUT tips toward the stream; it is out of plum approximately 1.5 inches in 4 feet. The streambed material is bedrock and boulders. Streamflow is skewed towards the LABUT. Some rip-rap is placed at US wingwalls. Some aggradation noted both US and DS, though minor at US side.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -
-

Streambed material: -

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft*^{2}): -

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 4.88 mi^2 Lake and pond area 0 mi^2
Watershed storage *(ST)* 0 %
Bridge site elevation 570 ft Headwater elevation 2640 ft
Main channel length 4.13 mi
10% channel length elevation 630 ft 85% channel length elevation 1840 ft
Main channel slope *(S)* 390.64 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:

-

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

Foundation Type: - (*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? - *If no, type ctrl-n bi* Number of borings taken: -

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

Briefly describe material at foundation bottom elevation or around piles:

-

Comments:

-

Cross-sectional Data

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

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

Comments: **The low cord elevations and the bed elevations are from the FEMA cross sections.**

Station	**270**	**270.1**	**276**	**280**	**286**	**290**	**296**	**296.1**	-	-	-
Feature	**LB**							**RB**	-	-	-
Low cord elevation	**594.0**	**592.4**	**592.6**	**592.8**	**593.0**	**593.2**	**593.5**	**595.1**	-	-	-
Bed elevation	**594.0**	**582.5**	**582.7**	**582.7**	**582.6**	**582.4**	**582.6**	**595.1**	-	-	-
Low cord to bed length	**0**	**9.9**	**9.9**	**10.1**	**10.4**	**10.8**	**10.9**	**0**	-	-	-

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: 10/2/96
Computerized by: EW Date: 10/2/96
Reviewd by: EW Date: 6/30/97

Structure Number DUXBTH00040036

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 07 / 01 / 1996

2. Highway District Number 06 Mile marker 000000

County WSAHINGTON (023) Town DUXBURY (18550)

Waterway *(I - 6)* CROSSETT BROOK Road Name -

Route Number TH004 Hydrologic Unit Code: 2010003

3. Descriptive comments:

The bridge deck and abutments are concrete. The site is located 0.07 miles from junction with Town Highway 22.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 6 LBDS 5 RBDS 6 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 29 *(feet)* Span length 26 *(feet)* Bridge width 22.7 *(feet)*

Road approach to bridge:

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

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

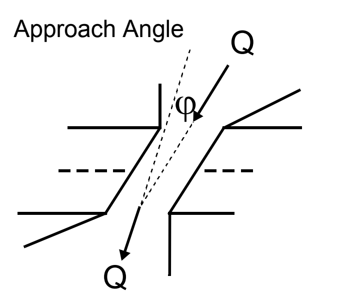
10. Embankment slope (*run / rise in feet / foot*):
US left 1.9:1 US right 1.9:1

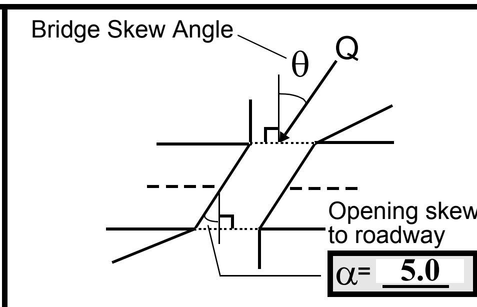
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	2	3	2
RBUS	2	1	0	-
RBDS	0	-	2	2
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 15 16. Bridge skew: 35





α= 5.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 3
Range? 64 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? 0 feet US *(US, UB, DS)* to 0 feet DS

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

18. Bridge Type: **1a**

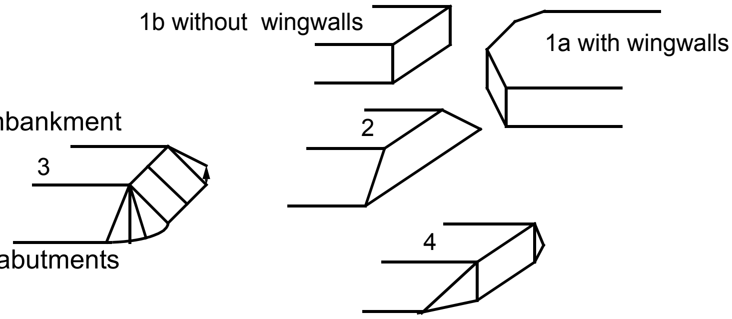
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#4: There is a house on the downstream right bank and on the upstream left bank beyond mowed grass lawn.

#13: The downstream right bank has a road wash gully that comes down at the downstream end of the downstream right wingwall.

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
34.5	**10.5**			**9.0**	**1**	**3**	**453**	**453**	**2**	**1**

23. Bank width **35.0** 24. Channel width **25.0** 25. Thalweg depth **45.0** 29. Bed Material **543**

30 .Bank protection type: LB **2** RB **2** 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.):

Right bank protection extends from 55 feet upstream to 0 feet upstream.

Left bank protection extends from 42 feet upstream to 30 feet upstream (the upstream end of the upstream left wingwall).

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **45** 35. Mid-bar width: **6**

36. Point bar extent: **80** feet **US** (US, UB) to **25** feet **US** (US, UB, DS) positioned **30** %LB to **100** %RB

37. Material: **453**

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

This right bank point bar has grass growing along its entire length.

This is a channel bar at the upstream section.

39. Is a cut-bank present? **Y** (Y or if N type ctrl-n cb) 40. Where? **LB** (LB or RB)

41. Mid-bank distance: **55** 42. Cut bank extent: **70** feet **US** (US, UB) to **42** feet **US** (US, UB, DS)

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

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

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **14**

47. Scour dimensions: Length **30** Width **6** Depth : **1.5** Position **0** %LB to **50** %RB

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

Scour depth assumes 0.5 feet thalweg.

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

A culvert, 2 feet in diameter, enters the right bank at 60 feet upstream.

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
15.0		**1.0**		**2**	**7**	**7**	**-**

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

436

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? 2___ *(Y or N)* Ice Blockage Potential N____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

Capture efficiency is moderate because of the narrow span between the abutments.

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		-	90	2	5	0	0.2	90.0
RABUT	1	35	90			2	2	25.0

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.):

1.5
0.5
1

The right bank footing has been eroded along its entire length at the bedrock contact.

The left abutment concrete has been eroded on the upstream end at the footing contact.

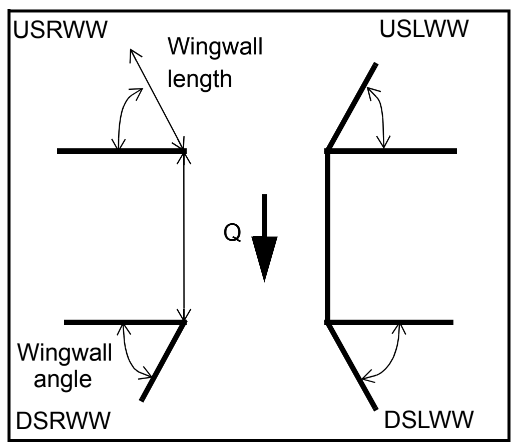
The right abutment scour depth is based on a thalweg of 0.5 feet.

There is a gravel bar along the downstream half of the left abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						25.0	
USRWW:	Y		1		5	1.0	
DSLWW:	1.5		1		Y	26.5	
DSRWW:	1		0		-	25.0	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	0.5	2	2	-	-
Condition	Y	-	1	5.5	2	2	-	-
Extent	1	-	2	2	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

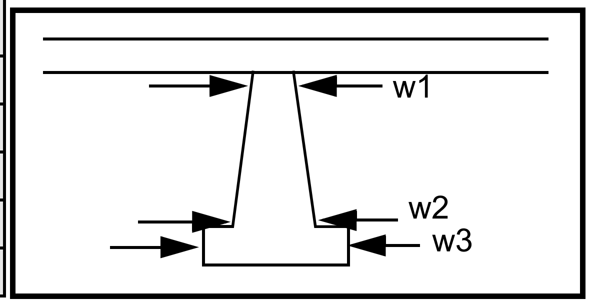
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
0
-
-

Piers:

84. Are there piers? _____ *(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				**20.0**	**16.0**	**105.0**
Pier 2	**8.5**			**50.0**	**14.5**	**35.0**
Pier 3		-	-	**18.5**	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

Bank width (BF) - _____ Channel width - _____ Thalweg depth (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.):

3
3
453
453
1
1
453
0
0
-
-

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

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

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

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

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

Material: **OP**

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

STRUCTURE

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

Cut bank extent: **0 DS** feet **10** *(US, UB, DS)* to **0** feet **UB** *(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.):

DS
0
35
342

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

Scour dimensions: Length **anot** Width **her** Depth: **poin** Positioned **t** %LB to **bar** %RB

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

along the right bank from 66 feet downstream to 114 feet downstream. The mid-bank distance is 97 feet downstream where it is 6 feet wide. The bar is vegetated with grass and comprised of cobbles, boulders and gravel.

Are there major confluences? **N** *(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):

NO CUT BANKS

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

Y
10
30
6
2.5
80
100

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: DUXBTH00040036 Town: DUXBURY
Road Number: TH 4 County: WASHINGTON
Stream: CROSSETT BROOK

Initials ECW Date: 6/11/97 Checked: RHF

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	1200	1820	0
Main Channel Area, ft2	143	211	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	30	36	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.169	0.169	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	4.8	5.9	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	9937	16549	0
Conveyance, main channel	9937	16549	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1200.0	1820.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	8.4	8.6	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	8.0	8.3	N/A
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	1	1	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	1200	1820	N/A

Main channel area (DS), ft2	129	144	0
Main channel width (normal), ft	23.8	25.2	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	23.8	25.2	0.0
D90, ft	0.5975	0.5975	0.5975
D95, ft	0.8204	0.8204	0.0000
Dc, critical grain size, ft	0.3939	0.7110	ERR
Pc, Decimal percent coarser than Dc	0.172	0.073	0.000
Depth to armoring, ft	5.70	27.25	ERR

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	1200	1820	0	1200	1820	0
Total conveyance	9937	16549	0	9383	10788	0
Main channel conveyance	9937	16549	0	9383	10788	0
Main channel discharge	1200	1820	ERR	1200	1820	ERR
Area - main channel, ft2	143	211	0	129	144	0
(W1) channel width, ft	30	36	0	23.8	25.2	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	30	36	0	23.8	25.2	0
D50, ft	0.169	0.169	0			
w, fall velocity, ft/s (p. 32)	3.37	3.37	0			
y, ave. depth flow, ft	4.77	5.86	N/A	5.42	5.71	ERR
S1, slope EGL	0.0188	0.0278	0			
P, wetted perimeter, MC, ft	35	43	0			
R, hydraulic Radius, ft	4.086	4.907	ERR			
V*, shear velocity, ft/s	1.573	2.096	N/A			
V*/w	0.467	0.622	ERR			
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	0.59	0.64	0			
y2,depth in contraction, ft	5.46	7.36	ERR			
ys, scour depth, ft (y2-y_bridge)	0.04	1.65	N/A			

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units

ys=y2-y_bridge

(Richardson and others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1200	1820	0
(Q) discharge thru bridge, cfs	1200	1820	0
Main channel conveyance	9383	10788	0
Total conveyance	9383	10788	0
Q2, bridge MC discharge,cfs	1200	1820	ERR

Main channel area, ft2	129	144	0
Main channel width (normal), ft	23.8	25.2	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	23.8	25.2	0
y_bridge (avg. depth at br.), ft	5.42	5.71	ERR
Dm, median (1.25*D50), ft	0.21125	0.21125	0
y2, depth in contraction,ft	5.56	7.56	ERR
ys, scour depth (y2-ybridge), ft	0.14	1.85	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	1200	1820	0	1200	1820	0
a’, abut.length blocking flow, ft	1.6	2.4	0	4.2	8	0
Ae, area of blocked flow ft2	5.7	11.1	0	9.3	18.1	0
Qe, discharge blocked abut.,cfs	27.4	53.3	0	43.5	75.1	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.81	4.80	ERR	4.68	4.15	ERR
ya, depth of f/p flow, ft	3.56	4.63	ERR	2.21	2.26	ERR
--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	85	85	85	95	95	95
K2	0.99	0.99	0.99	1.01	1.01	1.01
Fr, froude number f/p flow	0.449	0.393	ERR	0.554	0.486	ERR
ys, scour depth, ft	6.42	8.27	N/A	6.03	6.96	N/A

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)	1.6	2.4	0	4.2	8	0
y1 (depth f/p flow, ft)	3.56	4.63	ERR	2.21	2.26	ERR
a’/y1	0.45	0.52	ERR	1.90	3.54	ERR
Skew correction (p. 49, fig. 16)	0.98	0.98	0.98	1.01	1.01	1.01
Froude no. f/p flow	0.45	0.39	N/A	0.55	0.49	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww’s	ERR	ERR	ERR	ERR	ERR	ERR

spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.71	0.94	0	0.71	0.94	0
y, depth of flow in bridge, ft	5.41	5.70	0.00	5.41	5.70	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.69	ERR	0.00	1.69	ERR	0.00
Fr>0.8 (vertical abut.)	ERR	2.34	ERR	ERR	2.34	ERR