LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (WNDSTH00070023) on TOWN HIGHWAY 7, crossing MILL BROOK, WINDSOR, VERMONT

Open-File Report 98-079

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

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

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By RONDA L. BURNS

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Pembroke, New Hampshire

1998

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (WNDSTH00070023) ON TOWN HIGHWAY 7, CROSSING MILL BROOK, WINDSOR, VERMONT

By **Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WNDSTH00070023 on Town Highway 7 crossing Mill Brook, Windsor, 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 (Federal Highway Administration, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in east-central Vermont. The 37.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, Mill Brook has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 79 ft and an average bank height of 12 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 64.6 mm (0.212 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 29, 1996, indicated that the reach was laterally unstable. There are cut-banks upstream and downstream of the bridge.

The Town Highway 7 crossing of Mill Brook is a 54-ft-long, two-lane bridge consisting of one 51-foot steel-beam span (Vermont Agency of Transportation, written communication, March 23, 1995). The opening length of the structure parallel to the bridge face is 48.7 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 zero degrees.

Channel scour 1.0 ft deeper than the mean thalweg depth was observed along the downstream right side of the channel during the Level I assessment. Also, the footings of the left and right abutments and left wingwalls are exposed and the upstream end of the left abutment footing is undermined. The only scour protection measure at the site was type-3 stone fill (less than 48 inches diameter) along the upstream and downstream right bank and wingwalls. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. 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 3.0 to 3.9 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 11.0 to 14.3 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 WNDSTH00070023 ***Stream*** Mill Brook

County Windsor ***Road*** TH 7 ***District*** 4

Description of Bridge

Bridge length 54 ***ft*** ***Bridge width*** 19.7 ***ft*** ***Max span length*** 51 ***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*** 7/29/96

Description of stone fill No stone fill on the abutments. The only protection at this site was type-3, along the entire base length of the upstream and downstream right wingwalls.

Abutments and wingwalls are concrete. The footings of the left and right abutments and left

Brief description of piers/abutments upstream and downstream wingwalls are exposed and the upstream end of the left abutment footing is undermined.

Yes

Is bridge skewed to flood flow according to - ***survey?*** ***Angle*** 10 No

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

7/29/96

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	0	0	7/29/
Level II	96	0	0

Moderate. There is some debris caught on the upstream banks.

None as of 7/29/96.

Potential for debris

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 low relief valley with a steep valley wall on the right.

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

Date of inspection 7/29/96

DS left: Steep channel bank to a moderately sloped overbank

DS right: Steep valley wall

US left: Steep channel bank to a moderately sloped overbank

US right: Steep valley wall

Description of the Channel

Average top width 79 *ft* ***Average depth*** 12 *ft*

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

Straight but laterally unstable with semi-alluvial channel boundaries.

7/29/96

Vegetative co Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right:

No

Do banks appear stable? There are cut-banks upstream and downstream of the bridge. ***If not, describe location and type of instability and date of observation.***

The assessment of 7/29/96 noted low flow conditions are influenced by a mid-channel bar in the upstream reach which causes the flow to impact the upstream left bank.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 37.9 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 5,470 ***ft³/s*** ***Q500*** 7,580 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(37.9/42.0)exp 0.67] with the drainage area above the confluence of Mill Brook with the Connecticut River. This drainage area is 42.0 square miles and has flood frequency estimates available from the Flood Insurance Study for the town of Windsor (Federal Emergency Management Agency, 1988). The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

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. 499.75 ft, arbitrary survey datum). RM2 is the painted corner on the downstream left end of the bridge curb (elev. 500.62 ft, arbitrary survey datum). RM3 is a chiseled X on top of the upstream left wingwall, 1.5 ft from the end of the left abutment (elev. 499.73 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	-54	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APPRO	70	2	Modelled Approach section (Templated from APTEM)
APTEM	78	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 0.035 to 0.060, and overbank "n" values ranged from 0.070 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 0.0102 ft/ft, which was estimated from surveyed thalweg points.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0080 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

For the 100-year and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.5 *ft*
Average low steel elevation 496.8 *ft*

100-year discharge 5,470 *ft³/s*
Water-surface elevation in bridge opening 490.6 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 354 *ft²*
Average velocity in bridge opening 15.5 *ft/s*
Maximum WSPRO tube velocity at bridge 19.0 *ft/s*

Water-surface elevation at Approach section with bridge 493.6
Water-surface elevation at Approach section without bridge 492.3
Amount of backwater caused by bridge 1.3 *ft*

500-year discharge 7,580 *ft³/s*
Water-surface elevation in bridge opening 492.4 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 441 *ft²*
Average velocity in bridge opening 17.2 *ft/s*
Maximum WSPRO tube velocity at bridge 21.5 */s*

Water-surface elevation at Approach section with bridge 496.1
Water-surface elevation at Approach section without bridge 494.1
Amount of backwater caused by bridge 2.0 *ft*

Incipient overtopping discharge - *ft³/s*
Water-surface elevation in bridge opening - *ft*
Area of flow in bridge opening - *ft²*
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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year and 500-year discharges was computed by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p. 30, equation 17). Variables for the Laursen clear-water contraction scour equation include the discharge through the bridge, the width of the channel at the bridge, and the median grain size of the channel bed material.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	3.0	3.9	--
Clear-water scour	--	--	--
Depth to armoring	N/A	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	11.0	12.8	--
Right abutment	12.5	14.3	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	3.6	4.2	--
Right abutment	3.6	4.2	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

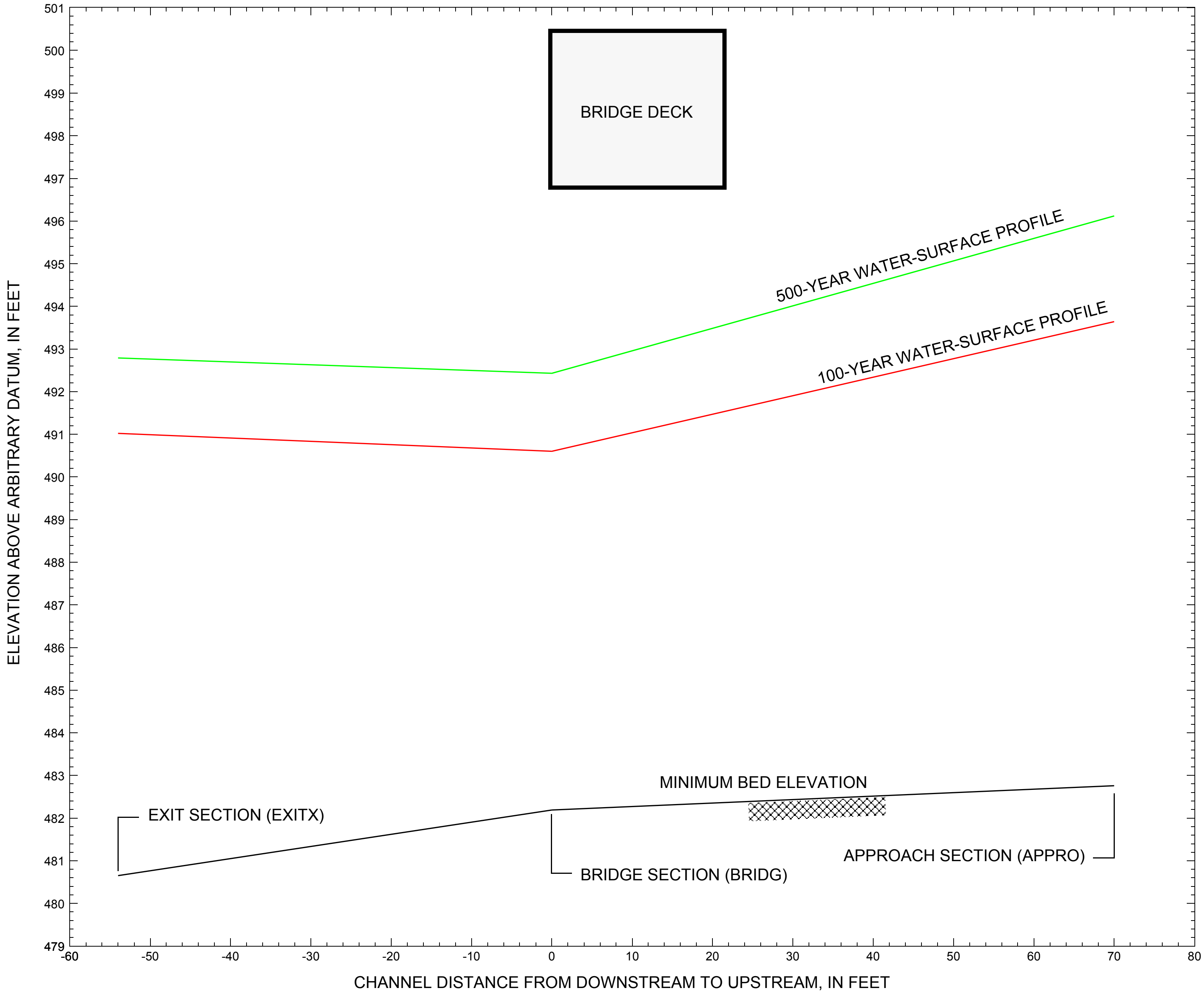

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure WNDSTH00070023 on Town Highway 7, crossing Mill Brook, Windsor, Vermont.

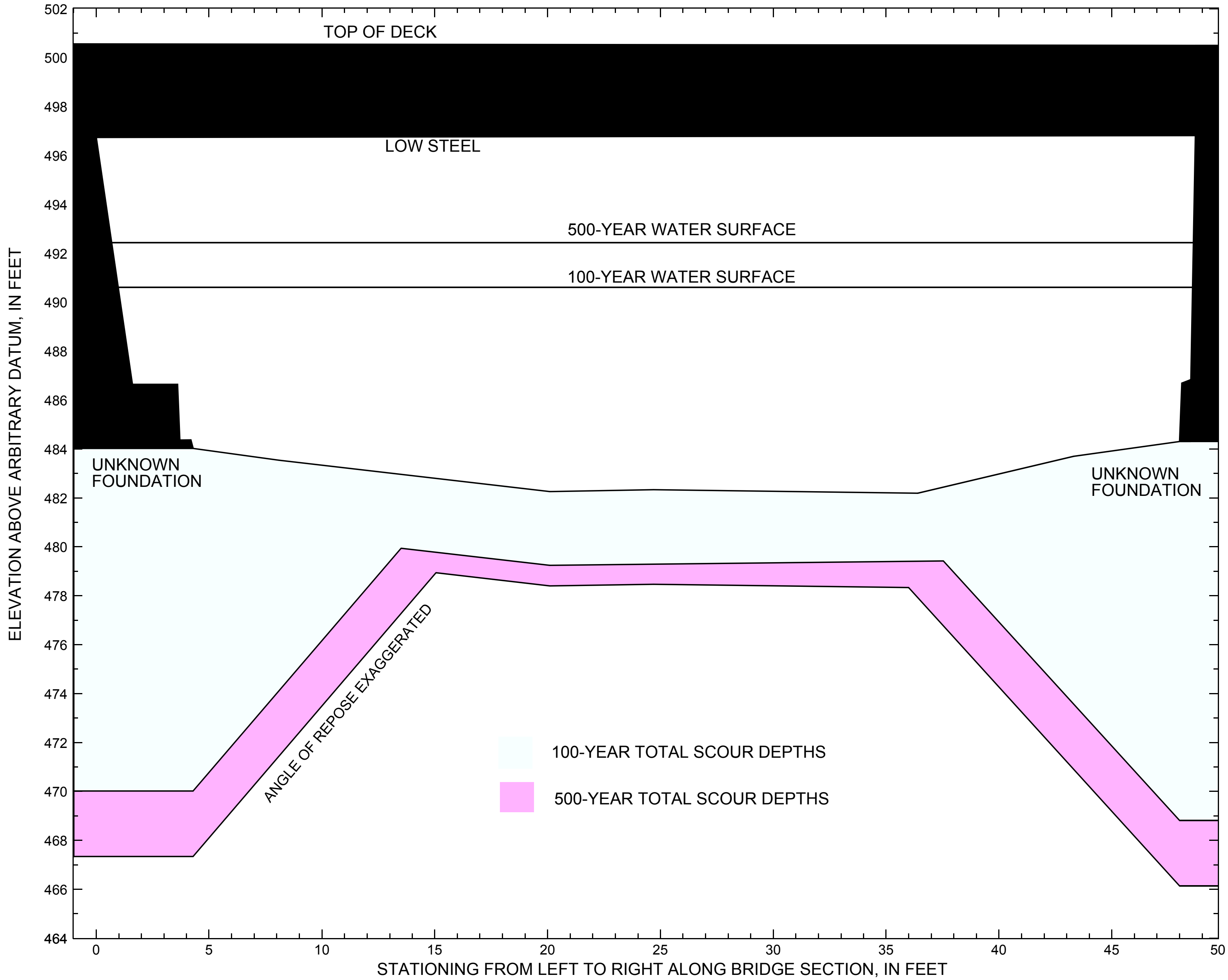

Figure 8. Scour elevations for the 100- and 500-year discharges at structure WNDSTH00070023 on Town Highway 7, crossing Mill Brook, Windsor, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WNDSTH00070023 on Town Highway 7, crossing Mill Brook, Windsor, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 5,470 cubic-feet per second											
Left abutment	0.0	--	496.7	--	484.0	3.0	11.0	--	14.0	470.0	--
Right abutment	48.7	--	496.8	--	484.3	3.0	12.5	--	15.5	468.8	--

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 WNDSTH00070023 on Town Highway 7, crossing Mill Brook, Windsor, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 7,580 cubic-feet per second											
Left abutment	0.0	--	496.7	--	484.0	3.9	12.8	--	16.7	467.3	--
Right abutment	48.7	--	496.8	--	484.3	3.9	14.3	--	18.2	466.1	--

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

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U.S. Geological Survey, 1984, Mt. Ascutney, Vermont 7.5 x 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File wnds023.wsp
T2        Hydraulic analysis for structure WNDSTH00070023   Date: 02-JAN-98
T3        TH 7 CROSSING MILL BROOK IN WINDSOR, VT                          RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5470.0   7580.0
SK          0.0102   0.0102
*
XS   EXITX    -54           0.
GR         -185.0, 506.34   -125.6, 495.74    -71.8, 494.70     -7.3, 492.46
GR            0.0, 486.90      7.5, 483.60      8.9, 482.85     21.3, 482.57
GR           26.7, 482.24     33.3, 481.85     37.0, 480.65     43.4, 480.83
GR           51.4, 483.54     58.6, 485.69     64.0, 490.85     76.2, 499.51
GR           94.1, 500.35    109.9, 499.66    137.0, 512.05
*
N           0.070        0.050
SA                  -7.3
*
XS   FULLV      0  * * *   0.0064
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.77       0.0
GR            0.0, 496.73      0.0, 496.41      1.6, 486.64      3.6, 486.64
GR            3.7, 484.36      4.2, 484.37      4.3, 484.02      8.1, 483.54
GR           20.1, 482.26     24.7, 482.33     36.4, 482.19     43.3, 483.70
GR           48.1, 484.30     48.1, 486.69     48.5, 486.83     48.6, 496.50
GR           48.7, 496.81      0.0, 496.73
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      28.8 * *     47.2      7.0
N           0.035
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      19.7     2
GR         -330.7, 522.51   -239.0, 511.18   -159.6, 504.67    -67.6, 501.51
GR           -2.5, 500.14     -2.1, 500.59      0.0, 500.56     50.1, 500.50
GR           51.3, 500.49     51.7, 500.06     78.2, 500.47     91.3, 499.60
GR          106.5, 512.16    113.8, 515.48
*
XT   APTEM     78           0.
GR         -206.7, 513.48   -143.9, 502.92     -8.9, 497.70      0.0, 491.51
GR            1.3, 485.22      3.2, 484.40      7.9, 483.48     16.1, 482.82
GR           23.8, 483.41     42.8, 483.75     49.4, 484.46
GR           54.1, 485.86     56.2, 490.95     66.0, 497.33     90.4, 499.16
GR           99.8, 498.51    114.4, 511.39    126.2, 515.74
*            31.9, 484.58
*
AS   APPRO     70  * * *  0.0080
GT
N           0.080        0.060
SA                  -8.9
*
HP 1 BRIDG  490.60 1 490.60
HP 2 BRIDG  490.60 * * 5470
HP 1 APPRO  493.64 1 493.64
HP 2 APPRO  493.64 * * 5470
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File wnds023.wsp
        Hydraulic analysis for structure WNDSTH00070023   Date: 02-JAN-98
        TH 7 CROSSING MILL BROOK IN WINDSOR, VT                    RLB
           *** RUN DATE & TIME: 01-07-98  16:36

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     354.  49218.    48.    60.                          5471.
   490.60          354.  49218.    48.    60.  1.00     1.    49.   5471.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       490.60     1.0    48.5   353.7   49218.    5470.  15.47

X STA.         1.0        8.9       11.0       13.0       15.0       16.9
  A(I)            44.7       15.3       15.6       14.9       15.0
  V(I)            6.11      17.83      17.57      18.35      18.28

X STA.        16.9       18.7       20.5       22.2       24.0       25.8
  A(I)            14.6       14.7       14.5       14.8       14.8
  V(I)           18.72      18.66      18.86      18.48      18.52

X STA.        25.8       27.6       29.3       31.1       32.8       34.6
  A(I)            14.8       14.8       14.5       14.8       14.4
  V(I)           18.50      18.45      18.84      18.50      19.01

X STA.        34.6       36.3       38.1       40.0       42.0       48.5
  A(I)            14.5       14.6       15.3       15.1       42.1
  V(I)           18.87      18.68      17.93      18.17       6.49

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      70.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     554.  52582.    64.    74.                          9282.
   493.64          554.  52582.    64.    74.  1.00    -3.    60.   9282.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      70.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.64    -3.2    60.4   554.1   52582.    5470.   9.87

X STA.        -3.2        7.5        9.7       11.9       14.0       16.1
  A(I)            68.9       22.8       22.7       22.7       22.6
  V(I)            3.97      11.98      12.03      12.03      12.09

X STA.        16.1       18.2       20.3       22.5       24.8       27.1
  A(I)            22.2       23.0       23.2       23.1       23.7
  V(I)           12.29      11.89      11.77      11.86      11.56

X STA.        27.1       29.4       31.6       33.9       36.2       38.5
  A(I)            23.2       23.1       23.3       23.0       23.4
  V(I)           11.77      11.82      11.73      11.87      11.69

X STA.        38.5       40.9       43.2       45.6       48.1       60.4
  A(I)            23.2       23.2       23.3       24.2       69.0
  V(I)           11.81      11.79      11.73      11.28       3.96
```

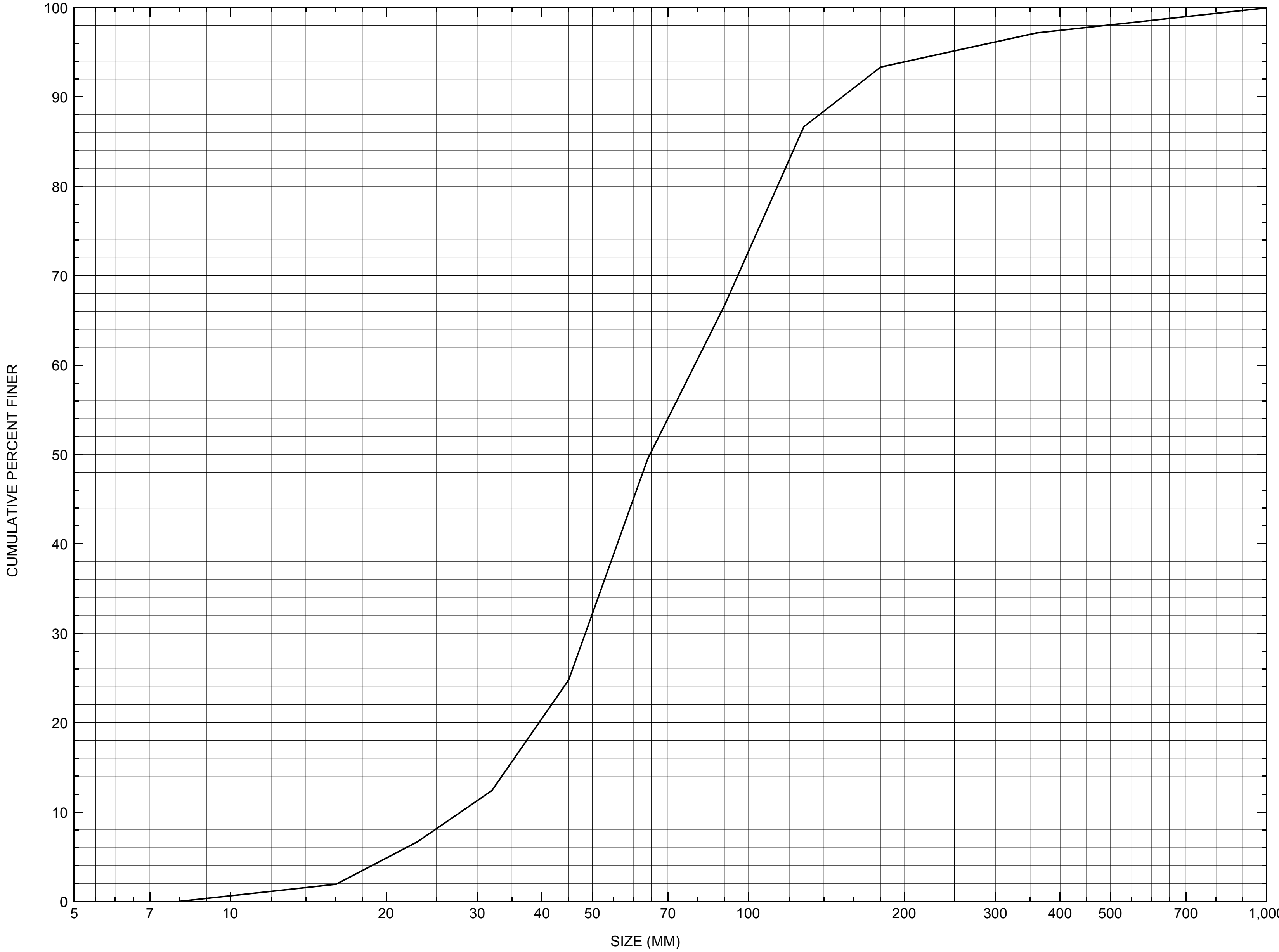
```
        U.S. Geological Survey WSPRO Input File wnds023.wsp
        Hydraulic analysis for structure WNDSTH00070023   Date: 02-JAN-98
        TH 7 CROSSING MILL BROOK IN WINDSOR, VT                      RLB
           *** RUN DATE & TIME: 01-07-98  16:36

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     441.  68333.    48.    64.                         7594.
   492.43          441.  68333.    48.    64.  1.00     1.    49.   7594.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.43     0.7    48.6   441.1   68333.    7580.  17.19

X STA.         0.7        8.8       10.8       12.8       14.8       16.6
  A(I)            58.7       18.4       18.7       18.4       18.0
  V(I)            6.45      20.58      20.25      20.59      21.08

X STA.        16.6       18.4       20.2       22.0       23.7       25.5
  A(I)            18.0       17.9       17.8       18.2       18.1
  V(I)           21.11      21.12      21.31      20.87      20.91

X STA.        25.5       27.3       29.1       30.9       32.6       34.4
  A(I)            18.1       18.2       17.8       18.1       17.6
  V(I)           20.92      20.87      21.32      20.95      21.53

X STA.        34.4       36.1       37.9       39.8       41.8       48.6
  A(I)            17.7       18.0       18.4       18.9       56.1
  V(I)           21.38      21.02      20.64      20.08       6.76

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      70.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     721.  75611.    71.    83.                        13039.
   496.12          721.  75611.    71.    83.  1.00    -7.    64.  13039.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      70.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.12    -6.7    64.2   720.9   75611.    7580.  10.51

X STA.        -6.7        7.4        9.6       11.8       14.0       16.2
  A(I)            99.0       27.9       28.8       28.8       28.5
  V(I)            3.83      13.58      13.15      13.18      13.29

X STA.        16.2       18.3       20.5       22.8       25.1       27.4
  A(I)            28.6       28.9       29.3       29.2       30.0
  V(I)           13.25      13.11      12.94      12.99      12.65

X STA.        27.4       29.8       32.1       34.4       36.7       39.1
  A(I)            29.7       29.6       28.8       29.1       29.6
  V(I)           12.78      12.82      13.17      13.00      12.80

X STA.        39.1       41.4       43.8       46.2       48.7       64.2
  A(I)            29.3       29.4       29.5       29.7       97.2
  V(I)           12.92      12.91      12.84      12.74       3.90
```

```
        U.S. Geological Survey WSPRO Input File wnds023.wsp
        Hydraulic analysis for structure WNDSTH00070023   Date: 02-JAN-98
        TH 7 CROSSING MILL BROOK IN WINDSOR, VT                     RLB
           *** RUN DATE & TIME: 01-07-98  16:36

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

EXITX:XS   ******    -5.      508.  1.81 *****  492.83  489.33   5470.  491.02
      -54. ******    64.   54136.  1.00 ***** *******    0.70   10.77

FULLV:FV      54.    -6.      530.  1.66  0.52  493.34 *******   5470.  491.68
        0.    54.    65.   57527.  1.00  0.00   -0.01    0.66   10.33
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      70.    -1.      473.  2.08  0.86  494.41 *******   5470.  492.33
       70.    70.    58.   42219.  1.00  0.21    0.00    0.72   11.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                 SECID "BRIDG"     Q,CRWS =    5470.     490.60

            <<<<<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      54.     1.      354.  3.72 *****  494.32  490.60   5470.  490.60
        0.    54.    49.   49200.  1.00 ***** *******    1.00   15.47

     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      11.        <<<<<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      41.    -3.      554.  1.51  0.48  495.16  490.59   5470.  493.64
       70.    42.    60.   52602.  1.00  0.36    0.01    0.59    9.87

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.199  0.000   55807.    2.    50.   493.10

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -54.    -5.    64.   5470.   54136.     508.   10.77  491.02
   FULLV:FV       0.    -6.    65.   5470.   57527.     530.   10.33  491.68
   BRIDG:BR       0.     1.    49.   5470.   49200.     354.   15.47  490.60
   RDWAY:RG      11.**************      0.*****************     2.00********
   APPRO:AS      70.    -3.    60.   5470.   52602.     554.    9.87  493.64

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    50.   55807.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    489.33    0.70  480.65  512.05************  1.81  492.83  491.02
   FULLV:FV  ********    0.66  481.00  512.40  0.52  0.00  1.66  493.34  491.68
   BRIDG:BR    490.60    1.00  482.19  496.81************  3.72  494.32  490.60
   RDWAY:RG ****************  499.60  522.51**********************************
   APPRO:AS    490.59    0.59  482.76  515.68  0.48  0.36  1.51  495.16  493.64
```

```
        U.S. Geological Survey WSPRO Input File wnds023.wsp
        Hydraulic analysis for structure WNDSTH00070023   Date: 02-JAN-98
        TH 7 CROSSING MILL BROOK IN WINDSOR, VT                      RLB
           *** RUN DATE & TIME: 01-07-98  16:36

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

EXITX:XS   ******   -17.     636.  2.22 *****  495.00  490.89   7580.  492.79
      -54. ******    67.   75016.  1.00 ***** *******    0.76   11.91

FULLV:FV      54.   -26.     666.  2.05  0.52  495.52 *******   7580.  493.47
        0.    54.    67.   79663.  1.02  0.00   -0.01    0.76   11.38
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      70.    -4.     581.  2.64  0.90  496.71 *******   7580.  494.07
       70.    70.    61.   56210.  1.00  0.30    0.00    0.77   13.04
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =     7580.     492.43

            <<<<<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      54.     1.     441.  4.59 *****  497.02  492.43   7580.  492.43
        0.    54.    49.   68365.  1.00 ***** *******    1.00   17.18

     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      11.        <<<<<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      41.    -7.     721.  1.72  0.47  497.84  492.35   7580.  496.12
       70.    42.    64.   75641.  1.00  0.35    0.01    0.58   10.51

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.259  0.000   80905.     2.    50.   495.62

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS      -54.   -17.    67.   7580.   75016.     636.   11.91  492.79
   FULLV:FV        0.   -26.    67.   7580.   79663.     666.   11.38  493.47
   BRIDG:BR        0.     1.    49.   7580.   68365.     441.   17.18  492.43
   RDWAY:RG       11.**************       0.*****************     2.00********
   APPRO:AS       70.    -7.    64.   7580.   75641.     721.   10.51  496.12

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    50.   80905.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS     490.89    0.76  480.65  512.05************  2.22  495.00  492.79
   FULLV:FV   ********    0.76  481.00  512.40  0.52  0.00  2.05  495.52  493.47
   BRIDG:BR     492.43    1.00  482.19  496.81************  4.59  497.02  492.43
   RDWAY:RG   ****************  499.60  522.51**********************************
   APPRO:AS     492.35    0.58  482.76  515.68  0.47  0.35  1.72  497.84  496.12
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WNDSTH00070023, in Windsor, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WNDSTH00070023

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)* 84925

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

Waterway *(I - 6)* MILL BROOK

Road Name *(I - 7):* -

Route Number TH007

Vicinity *(I - 9)* @ JCT W CL3 TH6

Topographic Map Mt. Ascutney

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 43281

Longitude *(i - 17; nnnnn.n)* 72257

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10142300231423

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

Maximum span length *(I - 48; nnnn)* 0051

Year built *(I - 27; YYYY)* 1947

Structure length *(I - 49; nnnnnn)* 000054

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

Deck Width *(I - 52; nn.n)* 197

Year of ADT *(I - 30; YY)* 91

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

Opening skew to Roadway *(I - 34; nn)* 00

Waterway adequacy *(I - 71; n)* 7

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 013.8

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

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

Comments:

The structural inspection report of 9/11/93 indicates the structure is a single span, steel stringer bridge with a concrete deck and an asphalt roadway surface. The abutments are concrete. The right abutment concrete is noted as clean. The left abutment concrete is reported as having a fairly large area of delamination concrete. A crack also may be seen in the bridge seat above. Along the bottom of the left abutment the report mentions a large concrete subfooting, which has been slightly undermined at its upstream end. The footing on the right abutment is exposed as well, with some minor spalling at the end. The report mentions that bank erosion and debris accumulation near this site are not evident. **(Continued, page 31)**

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:

The waterway proceeds straight through the crossing. The streambed material consists of mainly stone and gravel. Some stone fill at the upstream end of the left abutment is recommended in the report.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **37.86** mi^2 Lake/pond/swamp area **0.03** mi^2

Watershed storage *(ST)* **0.08** %

Bridge site elevation **591** ft Headwater elevation **3093** ft

Main channel length **14.27** mi

10% channel length elevation **689** ft 85% channel length elevation **1300** ft

Main channel slope *(S)* **57.09** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **10/17/96**
Computerized by: **EW** Date: **10/17/96**
Reviewd by: **RB** Date: **1/21/98**

Structure Number **WNDSTH00070023**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. BURNS** Date *(MM/DD/YY)* **07** / **29** / 19**96**

2. Highway District Number **04** Mile marker **000000**
County **WINDSOR (027)** Town **WINDSOR (84925)**
Waterway *(I - 6)* **MILL BROOK** Road Name **-**
Route Number **TH007** Hydrologic Unit Code: **01080104**

3. Descriptive comments:
This bridge is located at the junction with CL3 TH6.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **6** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **2** UB **2** DS **1** *(**1**- pool; **2**- riffle)*

6. Bridge structure type **1** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length **54** *(feet)* Span length **51** *(feet)* Bridge width **19.7** *(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)*

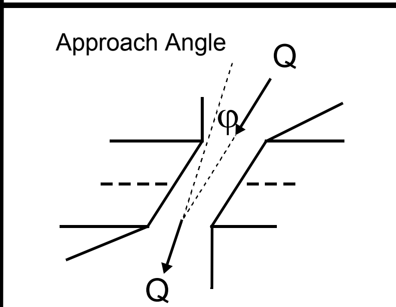
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

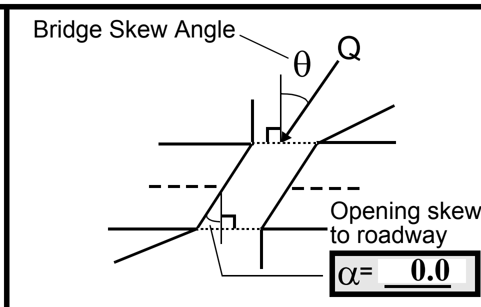
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	0	-	2	1
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	1

*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? **LB** *(LB, RB)* Severity **2**
Range? **130** feet **US** *(US, UB, DS)* to **80** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **0**
Range? **70** feet **DS** *(US, UB, DS)* to **100** feet **DS**

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

18. Bridge Type: **1a**

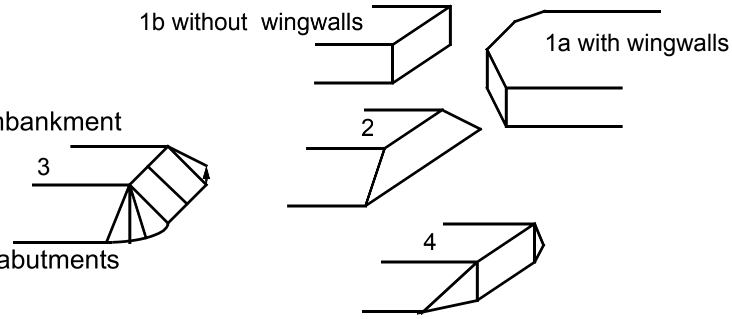
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#4: Surface cover on the right bank upstream and downstream is forest, but there is also a gravel road that runs parallel to the stream.

#7: Values are from the VTAOT files. Measured bridge length = 53.7 feet; bridge span = 50.5 feet; and bridge width = 19.9 feet.

#11: There is a gully along the road embankment on the upstream left bank.

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
56.0	**12.5**			**13.0**	**4**	**3**	**542**	**542**	**2**	**0**

23. Bank width **50.0** 24. Channel width **35.0** 25. Thalweg depth **75.0** 29. Bed Material **453**

30 .Bank protection type: LB **0** RB **3** 31. Bank protection condition: LB **-** RB **1**

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

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

The left bank is moderately eroded from the bridge to two bridge lengths US.

The right bank is protected by stone fill from 74 feet upstream to the upstream bridge face. The fill also acts as the road embankment protection for TH6.

33. Point/Side bar present? Y (*Y or N. if N type ctrl-n pb*) 34. Mid-bar distance: 105 35. Mid-bar width: 22

36. Point bar extent: 160 feet US (*US, UB*) to 54 feet US (*US, UB, DS*) positioned 30 %LB to 60 %RB

37. Material: 432

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

This is a mid-bar that is vegetated with short grass along the right side.

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: 104 42. Cut bank extent: 124 feet US (*US, UB*) to 90 feet US (*US, UB, DS*)

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

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

Most of the flow is pushed left by the mid-bar. A large tree has fallen where the bank has been cut.

Another cut-bank exists on the left bank from 64 feet upstream to 7 feet upstream at the USLWW. The bank is eroded with many exposed roots.

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

47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB

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

NO CHANNEL SCOUR

49. Are there major confluences? N (*Y or if N type ctrl-n mc*) 50. How many? -

51. Confluence 1: Distance - 52. Enters on - (*LB or RB*) 53. Type - (***1**- perennial; **2**- ephemeral*)

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

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
48.0		1.5		2	7	7	-

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

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

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

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

5432

The bed material is mostly sand along the abutments.

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

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

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

70. Debris and Ice Comments:

1

-

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		-	90	2	3	0	4.25	90.0
RABUT	1	10	90			2	2	48.5

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

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

0

3

1

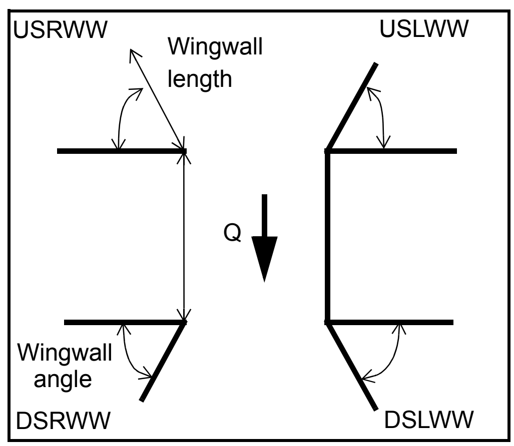
The left abutment is undermined 0.5 feet at the upstream corner where it joins the wingwall. There is a subfooting on the left abutment that starts at the upstream end and widens at the downstream end. The subfooting is 1.5 feet thick and the footing is 2 feet thick.

On the right abutment, there is a narrow footing that is exposed 3 feet in the center of the abutment wall, and then the banks angle up to the protection on both upstream and downstream ends.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						48.5	
USRWW:	Y		1		3	1.5	
DSLWW:	0		4		Y	19.0	
DSRWW:	1		0		-	23.5	

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	-	-	1	-	-
Extent	1	2.25	0	0	3	0	0	-

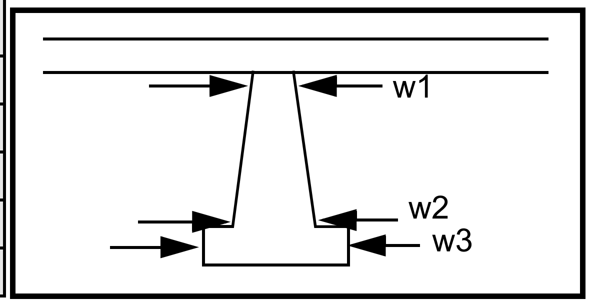
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
3
1
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				50.0	11.0	45.0
Pier 2				10.0	60.0	10.5
Pier 3		7.5	-	25.0	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	RWW	bank	sed	feet at	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	and	pro-	foot-	the	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	DSR	tec-	ings.	cor-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	WW	tion.	The	ner	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	pro-	The	USL	with	*Y- yes; N- no*
91. Attack ∠ (BF)	tec-	USL	WW	the	
92. Pushed	tion	WW	is	LAB	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	is	and	also	UT.	
95. Cross-members	same	DSL	unde	Ther	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	as	WW	rmin	e is	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	the	have	ed	no	
98. Exposure depth	right	expo	0.5	sub-	

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

footing here and the footing is 3.5 feet thick. At the downstream end, only the top of the subfooting is visible and the footing is 2.25 feet thick for the DSLWW.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -

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

-
-
-
-

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

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

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

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

Is channel scour present? _____ (Y or if N type ctrl-n cs) Mid-scour distance: 3

Scour dimensions: Length 3 Width 234 Depth: 234 Positioned 0 %LB to 0 %RB

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

432
0
3
-

Are there major confluences? 1 (Y or if N type ctrl-n mc) How many? The

Confluence 1: Distance bed Enters on mat (LB or RB) Type erial (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance is Enters on mos (LB or RB) Type tly (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

sand along the banks.

F. Geomorphic Channel Assessment

107. Stage of reach evolution Ba

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)*:

nk protection on the right bank extends from the downstream bridge face to 49 feet downstream.

109. **G. Plan View Sketch** - N

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: WNDSTH00070023		Town:	WINDSOR
Road Number: TH 7		County:	WINDSOR
Stream: MILL BROOK			

Initials RLB Date: 1/7/98 Checked: LKS

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 Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	5470	7580	0
Main Channel Area, ft2	554	721	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	64	71	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.212	0.212	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.7	10.2	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	52582	75611	0
Conveyance, main channel	52582	75611	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	5470.0	7580.0	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	9.9	10.5	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	9.6	9.8	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
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Live-Bed Contraction Scour

Laursen’s Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and Davis, 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	5470	7580	0	5470	7580	0
Total conveyance	52582	75611	0	49218	68333	0
Main channel conveyance	52582	75611	0	49218	68333	0
Main channel discharge	5470	7580	ERR	5470	7580	ERR
Area - main channel, ft2	554	721	0	354	441	0
(W1) channel width, ft	64	71	0	47.5	47.9	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	64	71	0	47.5	47.9	0
D50, ft	0.212	0.212	0.212			
w, fall velocity, ft/s (p. 32)	3.77	3.77	0			
y, ave. depth flow, ft	8.66	10.15	N/A	7.45	9.21	ERR
S1, slope EGL	0.0153	0.017	0			
P, wetted perimeter, MC, ft	74	83	0			
R, hydraulic Radius, ft	7.486	8.687	ERR			
V*, shear velocity, ft/s	1.920	2.181	N/A			
V*/w	0.509	0.578	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	0.64	0.64	0			
y2,depth in contraction, ft	10.48	13.06	ERR			
ys, scour depth, ft (y2-y_bridge)	3.02	3.86	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	5470	7580	N/A
Main channel area (DS), ft2	354	441	0
Main channel width (normal), ft	47.5	47.9	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	47.5	47.9	0.0
D90, ft	0.4980	0.4980	0.0000
D95, ft	0.8037	0.8037	0.0000
Dc, critical grain size, ft	0.8881	1.0149	ERR
Pc, Decimal percent coarser than Dc	0.045	0.037	0.000

Depth to armoring, ft	N/A	N/A	ERR

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 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	5470	7580	0	5470	7580	0
a', abut.length blocking flow, ft	4.2	7.4	0	11.9	15.6	0
Ae, area of blocked flow ft2	27.04	51.96	0	66.76	98.39	0
Qe, discharge blocked abut.,cfs	107.36	198.91	0	264.61	394.16	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.97	3.83	ERR	3.96	4.01	ERR
ya, depth of f/p flow, ft	6.44	7.02	ERR	5.61	6.31	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	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.276	0.255	ERR	0.295	0.281	ERR
ys, scour depth, ft	10.98	12.82	N/A	12.46	14.30	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	4.2	7.4	0	11.9	15.6	0
y1 (depth f/p flow, ft)	6.44	7.02	ERR	5.61	6.31	ERR
a'/y1	0.65	1.05	ERR	2.12	2.47	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.28	0.25	N/A	0.29	0.28	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 Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	0	1	1	0
y, depth of flow in bridge, ft	8.66	10.15	0.00	8.66	10.15	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	3.62	4.24	ERR	3.62	4.24	ERR