LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (MAIDTH00070004) on TOWN HIGHWAY 7, crossing CUTLER MILL BROOK, MAIDSTONE, VERMONT

Open-File Report 97-760

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (MAIDTH00070004) on TOWN HIGHWAY 7, crossing CUTLER MILL BROOK, MAIDSTONE, VERMONT

By LORA K. STRIKER AND LAURA MEDALIE

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Pembroke, New Hampshire

1997

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

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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	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 4 (MAIDTH00070004) ON TOWN HIGHWAY 7, CROSSING CUTLER MILL BROOK, MAIDSTONE, VERMONT

By **Lora K. Striker and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MAIDTH00070004 on Town Highway 7 crossing the Cutler Mill Brook, Maidstone, 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 White Mountain section of the New England physiographic province in northeastern Vermont. The 18.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly shrub and brushland.

In the study area, the Cutler Mill Brook has a non-incised, meandering channel with local braiding and a slope of approximately 0.004 ft/ft, an average channel top width of 43 ft and an average bank height of 2 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 27.6 mm (0.091 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 19, 1995, indicated that the reach was laterally unstable due to large meanders in the channel.

The Town Highway 7 crossing of the Cutler Mill Brook is a 25-ft-long, one-lane bridge consisting of one 22-foot concrete span (Vermont Agency of Transportation, written communication, August 5, 1994). The opening length of the structure parallel to the bridge face is 21.7 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 20 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

A scour hole 2.0 ft deeper than the mean thalweg depth was observed along the left abutment during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along both banks upstream, along the entire base length of the upstream left wingwall, and along the upstream end of the upstream right wingwall. 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) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 2.2 to 4.2 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 5.7 to 12.4 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 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.

Groveton, VT. Quadrangle, 1:24,000, 1988

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 MAIDTH00070004 ***Stream*** Cutler Mill Brook

County Essex ***Road*** TH 7 ***District*** 7

Description of Bridge

Bridge length 25 ***ft*** ***Bridge width*** 22 ***ft*** ***Max span length*** 20 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 07/19/95

Description of stone fill Type-2, along the entire base length of the upstream left wingwall and at the upstream end of the upstream right wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a two foot deep scour hole along the left abutment.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 20

There is a large channel bend in the upstream reach. A scour hole has developed where the flow impacts the left abutment.

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	07/19/95	0	0
Level II	07/19/95	0	0

Potential for debris Low.

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

Heavy vegetation 10 to 15 ft in height along the banks upstream is noted as an obstruction to flow, 07/19/95.

Description of the Geomorphic Setting

General topography The channel is located within a narrow flood plain with a steep valley wall on the right.

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

Date of inspection 07/19/95

DS left: Moderately sloping channel bank to a narrow flood plain

DS right: Steep channel bank to a narrow flood plain

US left: Steep channel bank to a narrow flood plain

US right: Moderately sloped channel bank to a narrow flood plain

Description of the Channel

Average top width 43 ***ft*** ***Average depth*** 2 ***ft***

Predominant bed material Sand/ Gravel ***Bank material*** Sand

Meandering and laterally unstable with alluvial channel boundaries and a narrow flood plain.

07/19/95

Vegetative co

Brush and a few small trees

DS left: Brush and a few small trees

DS right: Brush and a few small trees to a pasture overbank

US left: Brush to a pasture overbank

US right:

Do banks appear stable? N

There is a large bend in the upstream reach and an additional bend that impacts the left abutment.

date of observation.

None, 07/19/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 18.1 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/White Mountain	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 1,800 ***ft³/s*** ***Q500*** 3,090 ***ft³/s***

The 100-year discharge is from flood frequency estimates available from the VTAOT database which were extended graphically to the 500-year discharge. 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) VTAOT

Datum tie between USGS survey and VTAOT plans USGS and VTAOT datums are tied by survey points on the top of the upstream wing walls.

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. 502.81 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 502.60 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-26	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APPRO	39	1	Approach section

[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 0.050, and overbank "n" values ranged from 0.055 to 0.095.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0038 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1988).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 502.7 ***ft***
Average low steel elevation 501.0 ***ft***

100-year discharge 1,800 ***ft³/s***
Water-surface elevation in bridge opening 501.0 ***ft***
Road overtopping? Y ***Discharge over road*** 357 ***ft³/s***
Area of flow in bridge opening 165 ***ft²***
Average velocity in bridge opening 8.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.4 ***ft/s***

Water-surface elevation at Approach section with bridge 502.9
Water-surface elevation at Approach section without bridge 500.3
Amount of backwater caused by bridge 2.6 ***ft***

500-year discharge 3,090 ***ft³/s***
Water-surface elevation in bridge opening 501.2 ***ft***
Road overtopping? Y ***Discharge over road*** 1,320 ***ft³/s***
Area of flow in bridge opening 166 ***ft²***
Average velocity in bridge opening 10.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.2 ***ft/s***

Water-surface elevation at Approach section with bridge 503.8
Water-surface elevation at Approach section without bridge 501.2
Amount of backwater caused by bridge 2.6 ***ft***

Incipient overtopping discharge 1,270 ***ft³/s***
Water-surface elevation in bridge opening 498.7 ***ft***
Area of flow in bridge opening 117 ***ft²***
Average velocity in bridge opening 10.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.7 ***ft/s***

Water-surface elevation at Approach section with bridge 501.1
Water-surface elevation at Approach section without bridge 499.8
Amount of backwater caused by bridge 1.3 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100-year discharge resulted in unsubmerged orifice flow while the 500-year discharge resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146).

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

Scour at the abutments was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE 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	--	--	--
Clear-water scour	2.6	4.2	2.2
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	7.8	8.6	6.3
Right abutment	9.5	12.4	5.7
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	2.0	2.1	2.2
Right abutment	2.0	2.1	2.2
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

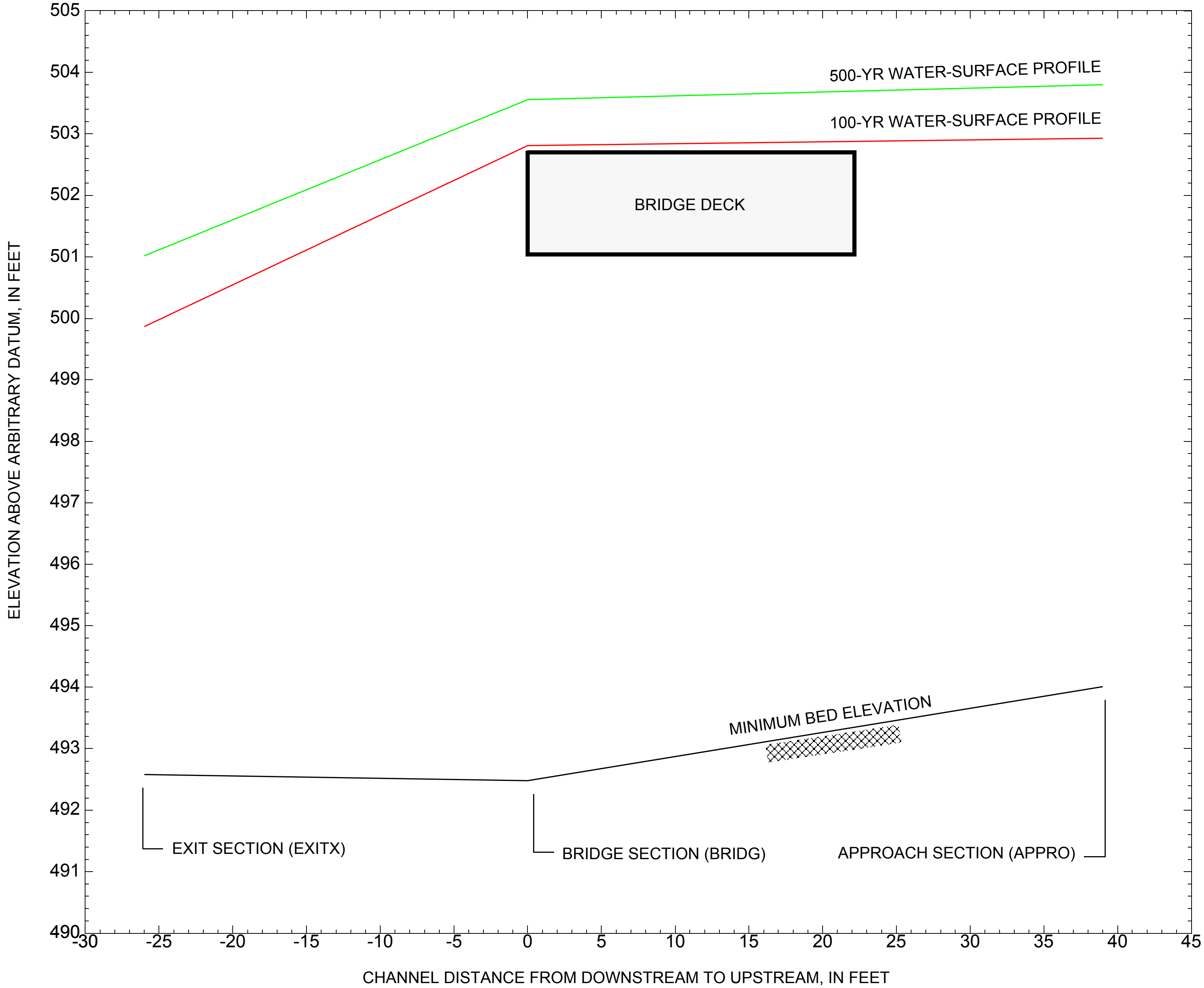

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure MAIDTH00070004 on Town Highway 7, crossing Cutler Mill Brook, Maidstone, Vermont.

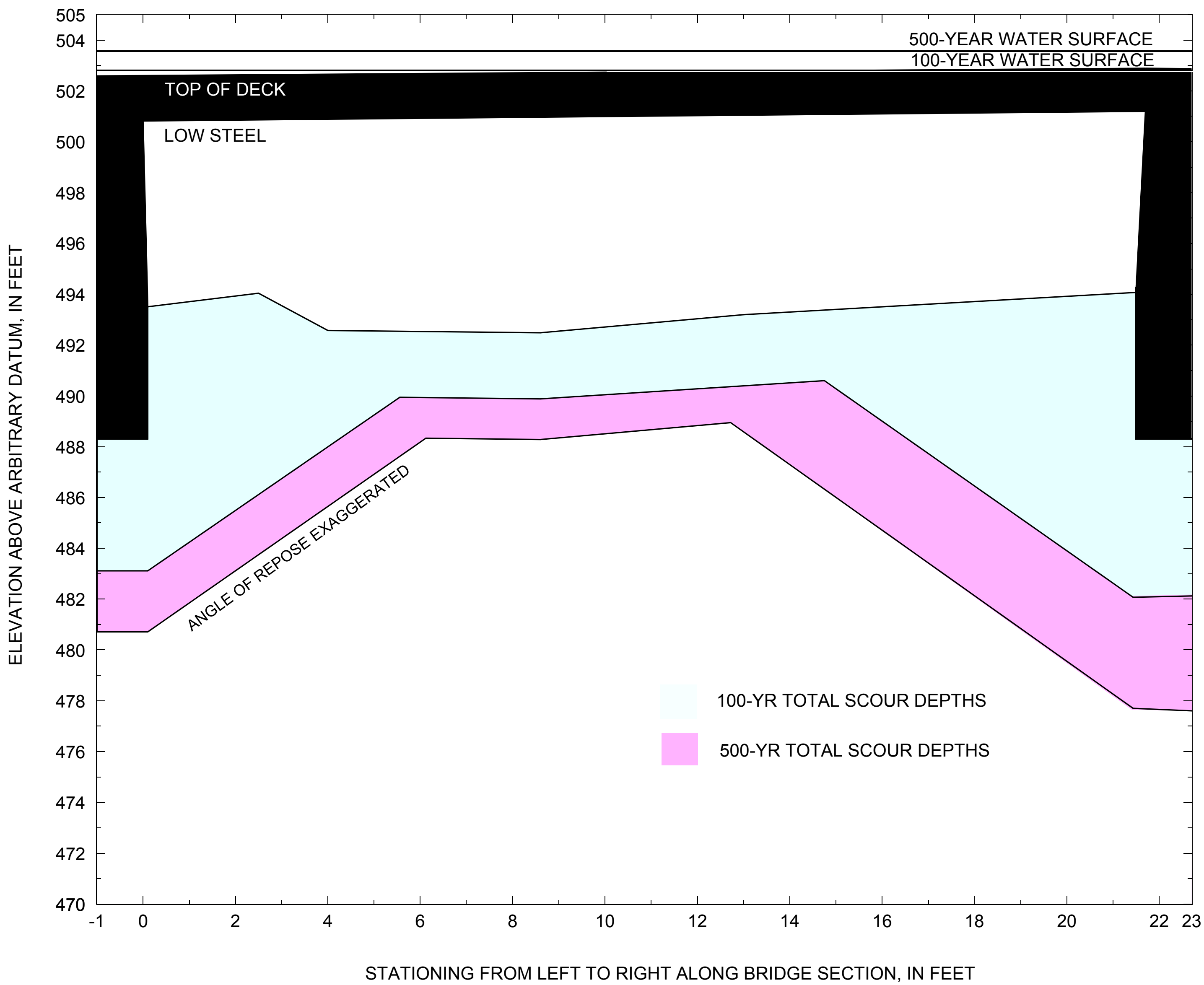

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure MAIDTH00070004 on Town Highway 7, crossing Cutler Mill Brook, Maidstone, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MAIDTH00070004 on Town Highway 7, crossing Cutler Mill Brook, Maidstone, 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-yr. discharge is 1,800 cubic-feet per second											
Left abutment	0.0	500.8	500.8	488.3	493.5	2.6	7.8	--	10.4	483.1	-5.2
Right abutment	21.7	501.2	501.2	488.3	494.3	2.6	9.5	--	12.1	482.2	-6.1

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure MAIDTH00070004 on Town Highway 7, crossing Cutler Mill Brook, Maidstone, 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-yr. discharge is 3,090 cubic-feet per second											
Left abutment	0.0	500.8	500.8	488.3	493.5	4.2	8.6	--	12.8	480.7	-7.6
Right abutment	21.7	501.2	501.2	488.3	494.3	4.2	12.4	--	16.6	477.7	-10.6

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File maid004.wsp
T2        Hydraulic analysis for structure MAIDTH00070004   Date: 30-JUL-97
T3        TH 7 crossing Cutler Mill Brook 0.2 Miles to Jct with TH 4,    LKS
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1800.0   3090.0   1270.0
SK          0.0038   0.0038   0.0038
*
XS   EXITX    -26           0.
GR         -245.0, 506.58   -203.6, 501.95   -165.8, 498.97    -17.9, 498.68
GR          -10.2, 497.21     -6.6, 495.80      0.0, 494.07      5.1, 493.09
GR            9.6, 492.58     13.1, 493.03     22.3, 493.99     29.6, 494.90
GR           31.0, 495.24     31.6, 497.27     34.3, 498.03     46.1, 498.24
GR           85.6, 497.86    118.0, 497.43    177.3, 504.38    313.1, 515.80
*
N           0.095        0.050        0.090
SA                 -17.9         34.3
*
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    501.01       0.0
GR            0.0, 500.82      0.0, 497.13      0.1, 493.51      2.5, 494.04
GR            4.0, 492.57      8.6, 492.48     13.0, 493.20     21.4, 494.27
GR           21.5, 497.19     21.7, 501.20      0.0, 500.82
*
*        BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD            4      22.4      4.1    502.7     43.0
N           0.035
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      20.0     2
GR         -311.2, 507.59   -170.2, 502.07    -72.9, 502.05      0.0, 502.60
GR           21.7, 502.89     39.6, 503.41     78.6, 504.16    143.8, 505.88
GR          287.7, 516.93    359.3, 521.48
*
*
*
AS   APPRO     39           0.
GR         -251.1, 504.93   -195.4, 501.56    -89.7, 498.92    -18.1, 498.48
GR            0.0, 498.24      6.5, 497.22     10.1, 494.37     16.3, 494.01
GR           20.8, 494.66     26.1, 496.65     29.5, 497.25     34.6, 500.05
GR           69.8, 499.21    149.7, 500.23    189.7, 507.32    213.5, 518.53
GR          290.2, 517.52
*
N           0.055        0.045        0.065
SA                   0.0         34.6
*
HP 1 BRIDG   501.01 1 501.01
HP 2 BRIDG   501.01 * * 1464
HP 1 BRIDG   500.00 1 500.00
HP 2 RDWAY   502.81 * *  357
HP 1 APPRO   502.93 1 502.93
HP 2 APPRO   502.93 * * 1800
*
HP 1 BRIDG   501.15 1 501.15
HP 2 BRIDG   501.15 * * 1732
HP 2 RDWAY   503.56 * * 1319
HP 1 APPRO   503.80 1 503.80
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
         U.S. Geological Survey WSPRO Input File maid004.wsp
        Hydraulic analysis for structure MAIDTH00070004   Date: 30-JUL-97
        TH 7 crossing Cutler Mill Brook 0.2 Miles to Jct with TH 4,    LKS
           *** RUN DATE & TIME: 07-30-97  12:49

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.01     0.0    21.7   165.4   16299.    1464.   8.85
 X STA.        0.0        2.4        3.9        5.0        6.0        7.1
  A(I)            16.6       11.4        9.3        8.7        8.5
  V(I)            4.41       6.44       7.83       8.42       8.64

 X STA.        7.1        8.0        9.0        9.9       10.9       11.7
  A(I)             8.2        8.2        8.0        7.8        6.1
  V(I)            8.94       8.97       9.15       9.41      11.91

 X STA.       11.7       12.4       13.2       13.9       14.7       15.5
  A(I)             6.0        5.9        5.9        6.0        6.2
  V(I)           12.17      12.36      12.38      12.13      11.86

 X STA.       15.5       16.4       17.3       18.3       19.5       21.7
  A(I)             6.3        6.6        7.3        8.2       14.2
  V(I)           11.58      11.08      10.04       8.95       5.14

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      145     16059     22     34                          2121
   500.00           145     16059     22     34  1.00      0     22     2121

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.81  -189.1    15.7   117.0    1358.     357.   3.05
 X STA.     -189.1     -168.7     -160.7     -153.3     -145.9     -138.8
  A(I)             8.1        5.9        5.5        5.5        5.3
  V(I)            2.19       3.04       3.25       3.23       3.34

 X STA.     -138.8     -131.5     -124.5     -117.4     -110.3     -103.3
  A(I)             5.4        5.3        5.3        5.3        5.3
  V(I)            3.32       3.38       3.34       3.38       3.37

 X STA.     -103.3      -96.3      -89.3      -82.2      -75.2      -67.8
  A(I)             5.3        5.3        5.4        5.3        5.5
  V(I)            3.38       3.37       3.33       3.35       3.26

 X STA.      -67.8      -59.7      -49.6      -37.2      -18.7       15.7
  A(I)             5.7        6.3        6.7        7.8        6.9
  V(I)            3.16       2.85       2.68       2.29       2.59

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      39.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      685     39838    218    218                          6896
             2      233     26388     35     37                          3433
             3      393     18795    130    131                          3875
   502.93          1312     85021    383    386  1.44   -217    165    11463

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      39.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.93  -218.0   164.9  1311.7   85021.    1800.   1.37

 X STA.     -218.0     -144.7     -115.4      -94.6      -77.4      -61.3
  A(I)           117.0       88.0       75.3       69.1       66.9
  V(I)            0.77       1.02       1.19       1.30       1.34

 X STA.      -61.3      -46.1      -31.6      -17.7       -4.7        5.4
  A(I)            63.9       62.7       61.3       59.2       49.7
  V(I)            1.41       1.44       1.47       1.52       1.81

 X STA.        5.4       11.0       14.6       18.2       22.2       28.1
  A(I)            39.1       32.0       31.8       33.2       39.1
  V(I)            2.30       2.81       2.83       2.71       2.30

 X STA.       28.1       47.2       70.6       93.2      120.1      164.9
  A(I)            68.1       81.0       80.7       87.3      106.2
  V(I)            1.32       1.11       1.12       1.03       0.85
```

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        U.S. Geological Survey WSPRO Input File maid004.wsp
        Hydraulic analysis for structure MAIDTH00070004   Date: 30-JUL-97
        TH 7 crossing Cutler Mill Brook 0.2 Miles to Jct with TH 4,    LKS
           *** RUN DATE & TIME: 07-30-97  12:49
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      166     14795      3     55                          7210
   501.15           166     14795      3     55  1.00      0     22      7210

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.15     0.0    21.7   166.4   14795.    1732.  10.41

  X STA.         0.0         2.2         3.6         4.6         5.6         6.5
    A(I)              15.3         9.9         8.8         7.8         7.7
    V(I)              5.65        8.73        9.86       11.11       11.31

  X STA.         6.5         7.3         8.2         9.0         9.9        10.7
    A(I)               7.3         7.2         7.1         7.2         7.1
    V(I)             11.83       12.01       12.19       12.05       12.24

  X STA.        10.7        11.6        12.5        13.4        14.4        15.4
    A(I)               7.2         7.1         7.3         7.3         7.4
    V(I)             12.05       12.24       11.88       11.91       11.65

  X STA.        15.4        16.4        17.4        18.5        19.6        21.7
    A(I)               7.6         7.7         8.0         8.2        13.2
    V(I)             11.38       11.21       10.87       10.52        6.55

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

         WSEL     LEW     REW    AREA        K        Q    VEL
       503.56  -208.3    47.4   289.9    5675.    1319.   4.55

  X STA.      -208.3      -173.3      -162.4      -152.2      -142.4      -132.6
    A(I)              23.9        16.1        15.2        14.7        14.6
    V(I)              2.76        4.09        4.34        4.47        4.53

  X STA.      -132.6      -123.1      -113.8      -104.4       -95.1       -85.8
    A(I)              14.3        14.0        14.1        14.0        14.0
    V(I)              4.62        4.71        4.67        4.72        4.71

  X STA.       -85.8       -76.5       -67.3       -57.2       -46.3       -33.9
    A(I)              14.0        13.9        14.4        14.8        15.6
    V(I)              4.72        4.76        4.59        4.45        4.22

  X STA.       -33.9       -19.7       -10.2        -0.2        12.0        47.4
    A(I)              16.5        10.1        10.0        10.8        15.0
    V(I)              4.00        6.51        6.58        6.12        4.39

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      39.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      881     58047    232    233                          9739
             2      263     32310     35     37                          4119
             3      509     28160    135    136                          5599
   503.80          1653    118517    402    405  1.35   -231    170     16341

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      39.

         WSEL     LEW     REW    AREA        K        Q    VEL
       503.80  -232.4   169.8  1653.3  118517.    3090.   1.87

  X STA.      -232.4      -157.3      -127.4      -105.2       -86.7       -70.1
    A(I)             144.9       106.5        93.8        87.0        82.4
    V(I)              1.07        1.45        1.65        1.78        1.87

  X STA.       -70.1       -54.3       -38.9       -24.5       -10.6         2.1
    A(I)              79.7        79.3        75.4        74.2        70.0
    V(I)              1.94        1.95        2.05        2.08        2.21

  X STA.         2.1         9.8        14.3        18.5        23.4        30.8
    A(I)              53.4        42.5        40.9        44.0        52.0
    V(I)              2.90        3.63        3.78        3.51        2.97

  X STA.        30.8        54.1        76.1        98.8       124.6       169.8
    A(I)              96.3        97.7        98.9       104.8       129.5
    V(I)              1.60        1.58        1.56        1.47        1.19
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        U.S. Geological Survey WSPRO Input File maid004.wsp
        Hydraulic analysis for structure MAIDTH00070004   Date: 30-JUL-97
        TH 7 crossing Cutler Mill Brook 0.2 Miles to Jct with TH 4,    LKS
           *** RUN DATE & TIME: 07-30-97  12:49
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      117     11903     22     32                         1549
   498.73           117     11903     22     32  1.00      0     22     1549

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.73     0.0    21.6   117.1   11903.    1270.  10.84

X STA.        0.0        2.3        3.7        4.7        5.6        6.4
  A(I)            11.4        7.2        6.1        5.3        5.1
  V(I)            5.59       8.79      10.46      11.92      12.52

X STA.        6.4        7.2        7.9        8.7        9.4       10.2
  A(I)             4.9        4.7        4.7        4.7        4.6
  V(I)           12.87      13.40      13.59      13.42      13.69

X STA.       10.2       11.0       11.8       12.7       13.6       14.5
  A(I)             4.7        4.9        4.8        4.9        5.1
  V(I)           13.62      13.09      13.20      12.86      12.47

X STA.       14.5       15.5       16.6       17.8       19.1       21.6
  A(I)             5.3        5.5        5.9        6.6       10.8
  V(I)           12.09      11.52      10.75       9.66       5.88

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      39.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      311     12342    176    176                         2351
             2      169     15400     35     37                         2114
             3      161      4470    120    120                         1054
   501.07           641     32212    330    333  1.86   -175    154     3716

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      39.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.07  -175.8   154.4   640.5   32212.    1270.   1.98

X STA.     -175.8     -102.8      -81.5      -64.1      -48.3      -33.5
  A(I)            66.5       43.9       39.1       37.3       36.3
  V(I)            0.96       1.44       1.62       1.70       1.75

X STA.      -33.5      -19.9       -7.6        2.7        8.3       11.0
  A(I)            34.4       32.6       29.4       21.6       16.9
  V(I)            1.85       1.95       2.16       2.94       3.75

X STA.       11.0       13.2       15.2       17.3       19.5       21.9
  A(I)            14.6       14.4       14.4       14.7       15.7
  V(I)            4.36       4.42       4.41       4.32       4.04

X STA.       21.9       25.3       30.6       65.6       96.2      154.4
  A(I)            17.9       21.8       51.4       52.3       65.2
  V(I)            3.55       2.91       1.23       1.21       0.97
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        U.S. Geological Survey WSPRO Input File maid004.wsp
        Hydraulic analysis for structure MAIDTH00070004   Date: 30-JUL-97
        TH 7 crossing Cutler Mill Brook 0.2 Miles to Jct with TH 4,    LKS
           *** RUN DATE & TIME: 07-30-97  12:49

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******   -176      610  0.32 *****  500.19  498.55    1800  499.87
       -25 ******    139    29186  2.40 ***** *******    0.58    2.95

FULLV:FV       26   -178      652  0.29  0.09  500.29 *******    1800  500.00
         0     26    140    31276  2.42  0.00    0.00    0.53    2.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.92     499.50     500.26
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   499.50     518.53    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   499.50     518.53     500.26
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   500.26     518.53     500.26

APPRO:AS       39   -142      388  0.68 *****  500.93  500.26    1800  500.26
        39     39    150    18166  2.02 ***** *******    1.01    4.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   503.29       0.00     499.32     502.05
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   504.16         1.      1799.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
BRIDG:BR       26      0      165  1.22 *****  502.23  498.53    1464  501.01
         0 ******     22    16299  1.00 ***** *******    0.57    8.85

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.461  0.000  501.01 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    19.  0.01  0.04  502.96    0.01    357.  502.81

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    356.   199.  -189.    10.   0.8   0.6   3.6   3.1   0.7   2.8
   RT:      1.     5.    10.    16.   0.1   0.0   1.7   5.9   0.2   2.6

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

APPRO:AS       17   -217     1310  0.04  0.05  502.97  500.26    1800  502.93
        39     25    165    84889  1.44  0.00    0.01    0.16    1.37

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -26.  -177.   139.   1800.   29186.     610.    2.95  499.87
   FULLV:FV       0.  -179.   140.   1800.   31276.     652.    2.76  500.00
   BRIDG:BR       0.     0.    22.   1464.   16299.     165.    8.85  501.01
   RDWAY:RG      11.*******   356.    357.*********       0.    2.00  502.81
   APPRO:AS      39.  -218.   165.   1800.   84889.    1310.    1.37  502.93

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    498.55    0.58  492.58  515.80************  0.32  500.19  499.87
   FULLV:FV  ********    0.53  492.58  515.80  0.09  0.00  0.29  500.29  500.00
   BRIDG:BR    498.53    0.57  492.48  501.20************  1.22  502.23  501.01
   RDWAY:RG  ****************  502.05  521.48  0.01******  0.04  502.96  502.81
   APPRO:AS    500.26    0.16  494.01  518.53  0.05  0.00  0.04  502.97  502.93
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        U.S. Geological Survey WSPRO Input File maid004.wsp
        Hydraulic analysis for structure MAIDTH00070004   Date: 30-JUL-97
        TH 7 crossing Cutler Mill Brook 0.2 Miles to Jct with TH 4,    LKS
           *** RUN DATE & TIME: 07-30-97  12:49

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******   -191      987  0.36 *****  501.38  499.80    3090  501.02
       -25 ******    149    50120  2.38 ***** *******    0.50    3.13

FULLV:FV       26   -192     1032  0.33  0.09  501.48 *******    3090  501.15
         0     26    150    52923  2.37  0.00    0.01    0.47    2.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.67

APPRO:AS       39   -181      693  0.56  0.20  501.79 *******    3090  501.23
        39     39    155    35540  1.81  0.12    0.00    0.74    4.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   501.15     501.01

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

BRIDG:BR       26      0      166  1.69 *****  502.83  499.16    1732  501.15
         0 ******     22    14803  1.00 ***** *******    0.66   10.41

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****    6.  0.800  0.000  501.01 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    19.  0.01  0.07  503.86   -0.01   1319.  503.56

           Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:  1253.   219.  -208.    11.   1.5   1.2   5.5   4.6   1.5   3.0
   RT:    67.    36.    11.    47.   0.8   0.4   3.7   4.2   0.7   2.9

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

APPRO:AS       17   -231     1652  0.07  0.09  503.87  500.91    3090  503.80
        39     28    170   118394  1.35  0.00   -0.01    0.19    1.87

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -26.  -192.   149.   3090.   50120.     987.    3.13  501.02
   FULLV:FV      0.  -193.   150.   3090.   52923.    1032.    2.99  501.15
   BRIDG:BR      0.     0.    22.   1732.   14803.     166.   10.41  501.15
   RDWAY:RG      11.*******  1253.   1319.*****************    2.00  503.56
   APPRO:AS      39.  -232.   170.   3090.  118394.    1652.    1.87  503.80

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    499.80    0.50  492.58  515.80************  0.36  501.38  501.02
   FULLV:FV  ********    0.47  492.58  515.80  0.09  0.00  0.33  501.48  501.15
   BRIDG:BR    499.16    0.66  492.48  501.20************  1.69  502.83  501.15
   RDWAY:RG  ****************  502.05  521.48  0.01******  0.07  503.86  503.56
   APPRO:AS    500.91    0.19  494.01  518.53  0.09  0.00  0.07  503.87  503.80
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WSPRO OUTPUT FILE (continued)

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       U.S. Geological Survey WSPRO Input File maid004.wsp
       Hydraulic analysis for structure MAIDTH00070004   Date: 30-JUL-97
       TH 7 crossing Cutler Mill Brook 0.2 Miles to Jct with TH 4,    LKS
          *** RUN DATE & TIME: 07-30-97  12:49

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******   -168      416  0.30 *****  499.55  497.19    1270  499.24
      -25 ******    133    20590  2.10 ***** *******    0.66    3.05

FULLV:FV       26   -170      458  0.26  0.09  499.64 *******    1270  499.38
        0     26    135    22304  2.21  0.00    0.01    0.59    2.77
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   498.88     518.53    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   498.88     518.53     499.80
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
           ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                WSBEG,WSEND,CRWS =   499.80     518.53     499.80

APPRO:AS       39   -124      267  0.66 *****  500.47  499.80    1270  499.80
       39     39    116    12836  1.88 ***** *******    1.07    4.76
        <<<<<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       26      0      117  2.04  0.17  500.77  498.06    1270  498.73
        0     26     22    11899  1.11  1.05    0.00    0.87   10.84

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  0.948 ******  501.01 ****** ****** ******

    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       17   -175      642  0.11  0.10  501.19  499.80    1270  501.07
       39     23    154    32305  1.85  0.33    0.02    0.34    1.98

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.910  0.595   12936.     3.    25.   501.04

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

  FIRST USER DEFINED TABLE.

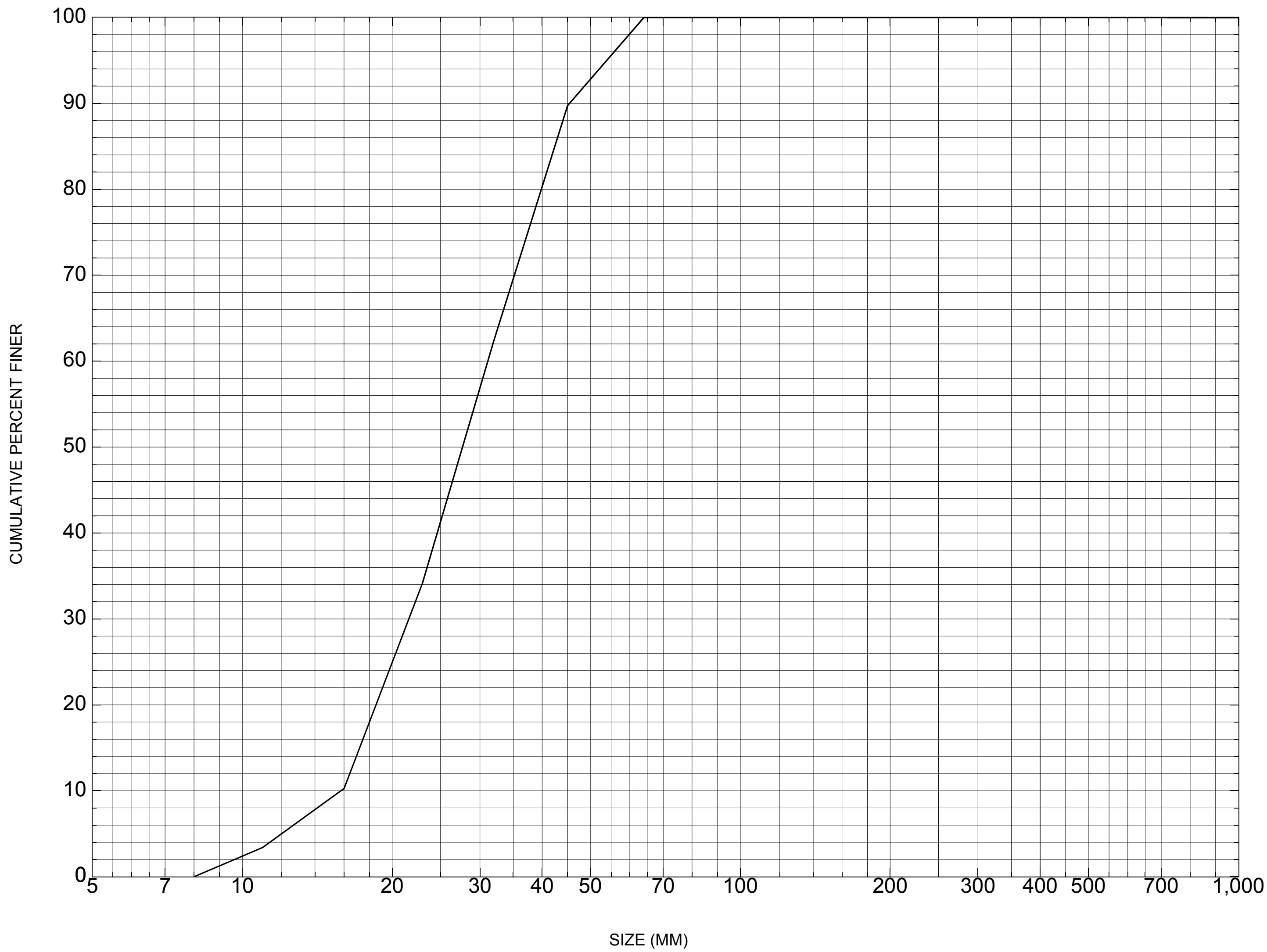
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -26.  -169.   133.   1270.   20590.     416.    3.05  499.24
   FULLV:FV       0.  -171.   135.   1270.   22304.     458.    2.77  499.38
   BRIDG:BR       0.     0.    22.   1270.   11899.     117.   10.84  498.73
   RDWAY:RG      11.**************       0.******************    2.00********
   APPRO:AS      39.  -176.   154.   1270.   32305.     642.    1.98  501.07

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    497.19    0.66  492.58  515.80************  0.30  499.55  499.24
   FULLV:FV  ********    0.59  492.58  515.80  0.09  0.00  0.26  499.64  499.38
   BRIDG:BR    498.06    0.87  492.48  501.20  0.17  1.05  2.04  500.77  498.73
   RDWAY:RG ****************  502.05  521.48**********************************
   APPRO:AS    499.80    0.34  494.01  518.53  0.10  0.33  0.11  501.19  501.07
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure MAIDTH00070004, in Maidstone, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MAIDTH00070004

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 05 / 94

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 009

Town *(FIPS place code; I - 4; nnnnn)* 42475

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

Waterway *(I - 6)* CUTLER MILL BROOK

Road Name *(I - 7)*: -

Route Number TH007

Vicinity *(I - 9)* 0.2 MI JCT TH 7 + TH 4

Topographic Map Groveton, NH

Hydrologic Unit Code: 01080101

Latitude *(I - 16; nnnn.n)* 44355

Longitude *(i - 17; nnnnn.n)* 71357

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10051500040515

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

Maximum span length *(I - 48; nnnn)* 0022

Year built *(I - 27; YYYY)* 1975

Structure length *(I - 49; nnnnnn)* 000025

Average daily traffic, ADT *(I - 29; nnnnnn)* 000010

Deck Width *(I - 52; nn.n)* 200

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

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

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

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*) -

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

Vertical clearance from streambed (*nnn.n ft*) 006.8

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

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

Comments:

The structural inspection report of 9/1/92 indicates the structure is a concrete slab type bridge. Minor cracks are reported in both abutment walls with no apparent settlement. The footing is not exposed and there is no channel scour or embankment erosion noted. Further, point bars and debris accumulation are reported as minor. The deepest part of the channel is noted along the left abutment. Stone fill is reported as not present on the abutments.

Bridge Hydrologic Data

Is there hydrologic data available? **N** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **18.3**

Terrain character:

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} **850** Q_{25} **1050**

Q_{50} **1400** Q_{100} **1800** Q_{500} -

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

Estimated Discharge *(cfs)*: - Velocity at Q **25** *(ft/s)*: **10.2**

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: **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*)	-	**5.5**	**6.5**	**8.1**	**8.9**
Velocity (*ft / sec*)	-	-	**10.2**	-	-

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*): **Y** *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): **1.2** Town: **Maidstone** Year Built: **1968**

Highway No. : **TH 4** Structure No. : **5** Structure Type: **302**

Clear span (*ft*): - Clear Height (*ft*): **6.6** Full Waterway (*ft²*): -

Upstream distance (*miles*): 1.7 Town: Maidstone Year Built: 1985

Highway No. : TH 5 Structure No. : 6 Structure Type: 101

Clear span (*ft*): 20.8 Clear Height (*ft*): 20.7 Full Waterway (ft^2): -

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 18.11 mi^2 Lake/pond/swamp area 0.4 mi^2

Watershed storage *(ST)* 2.2 %

Bridge site elevation 870 ft Headwater elevation 2520 ft

Main channel length 11.55 mi

10% channel length elevation 980 ft 85% channel length elevation 1720 ft

Main channel slope *(S)* 85.43 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? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 10 / 1974

Project Number TH 3515 Minimum channel bed elevation: 491.5

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

Benchmark location description:

BM#1, spike in pole, 25 feet from left bank on TH7 and 15' off the right side of the roadway, elevation 500.00. BM#2, 8 inch cherry tree, 130 feet from right bank on TH 7 and 15 feet of the left side of the road.

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

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

If 1: Footing Thickness 2.0 Footing bottom elevation: 488.25

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:

There is no foundation material information available.

Comments:

Plans indicate a right abutment footing bottom elevation of 488.25 feet while that for the left abutment is 488.00 feet. Hydraulic data entered above is from structural report and bridge plans. An updated copy of elevation bridge drawing has all elevations exactly one foot lower than the elevation values entered above.

***Other elevation points are at the top of upstream wingwalls 502.58 left and 502.83 right.**

Cross-sectional Data

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

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

Comments: **Channel cross section surveyed 75 feet from the downstream bridge face. The channel base line CBL(0) runs along the left bank parallel to the stream 26 feet from the left abutment; nearly parallel to the abutment wall.**

Station	-20	-10	0	10	13	18	25	35	53	65	69
Feature	HLB		CBL	TLB	LEW			TD		REW	TRB
Low chord elevation											
Bed elevation	497.5	498.0	498.3	497.8	495.0	492.1	489.2	487.0	491.6	495.0	498.0
Low chord-bed											

Station	79										
Feature	HRB										
Low chord elevation											
Bed elevation	498.7										VTA
Low chord-bed											OT

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

Comments: **section surveyed 25 feet from the downstream bridge face.**

Station	-13	0	15	19	20	43	50	60	64	67	
Feature	HLB	CBL	TLB	LEW			TD		REW	TRB	
Low chord elevation											
Bed elevation	497.9	496.1	497.4	495.0	493.3	488.1	487.0	490.5	495.0	498.0	
Low chord-bed											

Station											
Feature											
Low chord elevation											
Bed elevation											
Low chord-bed											

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 03/05/96

Computerized by: EW Date: 03/05/96

Reviewd by: LKS Date: 08/12/97

Structure Number MAIDTH0007004

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 07 / 19 / 1995

2. Highway District Number 07 Mile marker -

County Essex (009) Town Maidstone (42475)

Waterway *(I - 6)* Cutler Mill Brook Road Name -

Route Number TH007 Hydrologic Unit Code: 01080101

3. Descriptive comments:

The bridge is located 0.2 miles from the junction of Town Highway 7 and Town Highway 4.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 5 LBDS 5 RBDS 5 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 1 UB 1 DS 1 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 25 *(feet)* Span length 22 *(feet)* Bridge width 20 *(feet)*

Road approach to bridge:

8. LB 0 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 2.7:1 US right 5.6:1

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

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

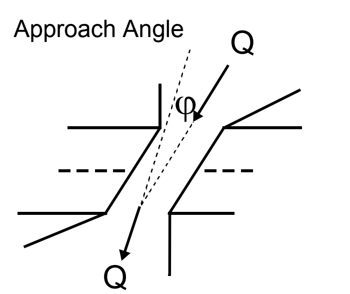
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

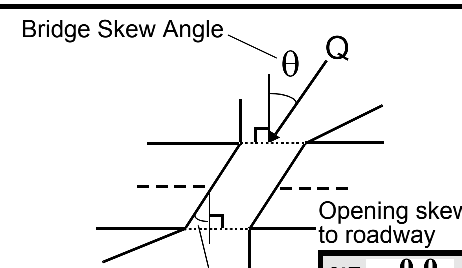
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 20 16. Bridge skew: 20





α= 0.0

17. Channel impact zone 1: Exist? Y *(Y or N)*

Where? LB *(LB, RB)* Severity 1

Range? 0 feet US *(US, UB, DS)* to 25 feet US

Channel impact zone 2: Exist? Y *(Y or N)*

Where? LB *(LB, RB)* Severity 0

Range? 17 feet DS *(US, UB, DS)* to 42 feet DS

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

18. Bridge Type: **4**

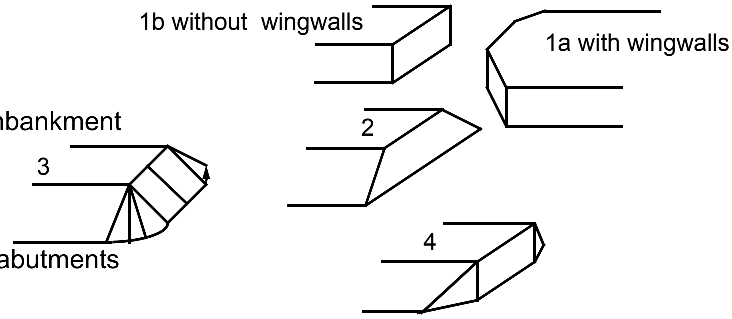
1a- Vertical abutments with wingwalls

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 pasture on the LBUS after 30 feet width of brush. There are some trees on the right bank downstream and the right bank upstream.
#7: Bridge dimensions measured values: bridge length= 25 feet; span length= 21.7 feet; bridge width= 21.6 feet
#8: Water will flow over bridge deck first, then road on both sides. Refer to roadway survey log for clarification.

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
18.0	**1.0**			**3.0**	**4**	**3**	**2135**	**2345**	**1**	**1**

23. Bank width **10.0** 24. Channel width **30.0** 25. Thalweg depth **34.5** 29. Bed Material **324**

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

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

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

#26: Although vegetation is brush, it is considered an obstruction to flow since it is 10-15 feet tall and has significant root mass.
#28: The bank erosion is very slight.
#30: There are some large boulders along the LB placed as protection.

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

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

37. Material: **-**

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

There are no point bars upstream at this site.

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

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

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

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

There are no cut-banks upstream at this site.

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.):

There is no channel scour upstream at this site.

Scour begins 5 feet US and extends DS, refer to DS assessment.

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

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

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

54. Confluence comments (eg. confluence name):

There are no major confluences upstream at this site.

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
23.0		3.0		2	7	7	-

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

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

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

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

324

#63: The bed material grades from sand at the right abutment to gravel and cobble at the left abutment.

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 rated as moderate since the span width is 1/2 the average bank width.

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		20	90	0	1	2	-	90.0
RABUT	1	0	90			0	0	21.5

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

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

-

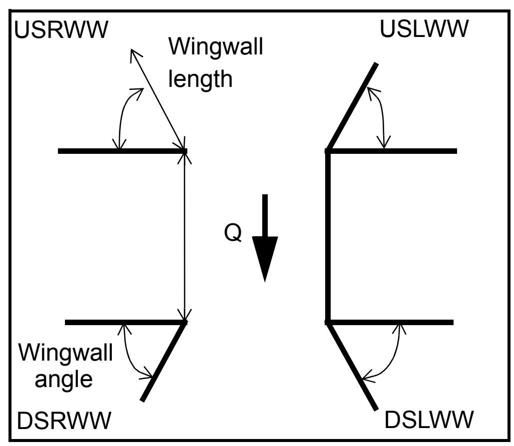
-

1

#74-75: At LABUT, the bed is as deep as 5 feet, which is 2 feet deeper than average US and DS thalweg.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						21.5	
USRWW:	Y		1		0	4.5	
DSLWW:	-		-		Y	22.5	
DSRWW:	1		0		-	22.5	



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

82. **Bank / Bridge Protection**:

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

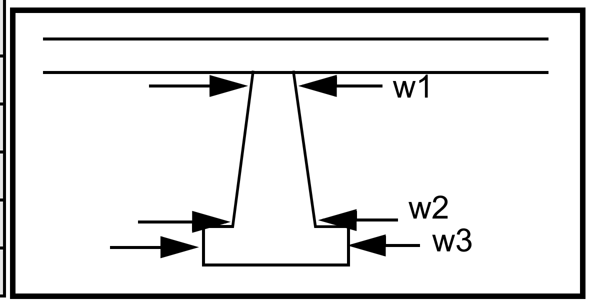
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
0
-
-

Piers:

84. Are there piers? **#82** *(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				**45.0**	**12.0**	**40.0**
Pier 2				**11.5**	**45.0**	**11.5**
Pier 3			**-**	**45.0**	**11.5**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

There are no piers.

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):

3
3
2

106. Point/Side bar present? **2** (Y or N. if N type ctrl-n pb) Mid-bar distance: **1** Mid-bar width: **1**

Point bar extent: **234** feet **0** (US, UB, DS) to **0** feet **-** (US, UB, DS) positioned **-** %LB to **Th** %RB

Material: **e**

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

bed material grades from sand along RB to gravel and cobble at LB.
There is a minor inflow at 42 feet DS along LB. The confluence is 2 feet across and 1-2 feet high.

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

Cut bank extent: _____ 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.):

N

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

Scour dimensions: Length **e is** Width **no** Depth: **dro** Positioned **p** %LB to **stru** %RB

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

cture.

A beaver dam exists about 400 feet DS. The dam is 40 ft wide and has created a flooded area to the right of

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

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

Confluence 2: Distance **ut** Enters on **100** (LB or RB) Type **feet** (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

in diameter.

F. Geomorphic Channel Assessment

107. Stage of reach evolution **Y**

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)*:

70
12
55
DS
140
DS
60
100
23
Bar grades into area with permanent vegetation.

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: MAIDTH000070004 Town: MAIDSTONE
Road Number: TH 7 County: ESSEX
Stream: CUTLER MILL BROOK

Initials LKS Date: 08/07/97 Checked: MAI

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16VP

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1800	3090	1270
Main Channel Area, ft2	233	263	169
Left overbank area, ft2	685	881	311
Right overbank area, ft2	393	509	161
Top width main channel, ft	35	35	35
Top width L overbank, ft	218	232	176
Top width R overbank, ft	130	135	120
D50 of channel, ft	0.091	0.091	0.091
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.7	7.5	4.8
y1, average depth, LOB, ft	3.1	3.8	1.8
y1, average depth, ROB, ft	3.0	3.8	1.3
Total conveyance, approach	85021	118517	32212
Conveyance, main channel	26388	32310	15400
Conveyance, LOB	39838	58047	12342
Conveyance, ROB	18795	28160	4470
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	558.7	842.4	607.2
Ql, discharge, LOB, cfs	843.4	1513.4	486.6
Qr, discharge, ROB, cfs	397.9	734.2	176.2
Vm, mean velocity MC, ft/s	2.4	3.2	3.6
Vl, mean velocity, LOB, ft/s	1.2	1.7	1.6
Vr, mean velocity, ROB, ft/s	1.0	1.4	1.1
Vc-m, crit. velocity, MC, ft/s	6.9	7.1	6.6
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

```
y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)    Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)
```

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1800	3090	1270
(Q) discharge thru bridge, cfs	1464	1732	1270
Main channel conveyance	16299	14795	11903
Total conveyance	16299	14795	11903
Q2, bridge MC discharge,cfs	1464	1732	1270
Main channel area, ft2	165	166	117
Main channel width (normal), ft	21.7	21.7	21.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.7	21.7	21.6
y_bridge (avg. depth at br.), ft	7.62	7.67	5.42
Dm, median (1.25*D50), ft	0.11375	0.11375	0.11375
y2, depth in contraction,ft	8.51	9.83	7.57
ys, scour depth (y2-ybridge), ft	0.89	2.16	**2.15**

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	1464	1732	1270
Main channel area (DS), ft2	145	166.4	117
Main channel width (normal), ft	21.7	21.7	21.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	21.7	21.7	21.6
D90, ft	0.1489	0.1489	0.1489
D95, ft	0.1768	0.1768	0.1768
Dc, critical grain size, ft	0.2587	0.2633	0.3199
Pc, Decimal percent coarser than Dc	0.000	0.000	0.000
Depth to armoring, ft	**N/A**	**N/A**	**N/A**

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1800	3090	1270
Q, thru bridge MC, cfs	1464	1732	1270
Vc, critical velocity, ft/s	6.92	7.06	6.56
Va, velocity MC approach, ft/s	2.40	3.20	3.59
Main channel width (normal), ft	21.7	21.7	21.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.7	21.7	21.6
qbr, unit discharge, ft2/s	67.5	79.8	58.8
Area of full opening, ft2	165.4	166.4	117.0
Hb, depth of full opening, ft	7.62	7.67	5.42
Fr, Froude number, bridge MC	0.57	0.66	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	145	N/A	N/A
**Hb, depth at downstream face, ft	6.68	N/A	N/A
**Fr, Froude number at DS face	0.69	ERR	ERR
**Cf, for downstream face (<=1.0)	1.00	N/A	N/A
Elevation of Low Steel, ft	501.01	501.01	0
Elevation of Bed, ft	493.39	493.34	-5.42
Elevation of Approach, ft	502.93	503.8	0
Friction loss, approach, ft	0.05	0.09	0
Elevation of WS immediately US, ft	502.88	503.71	0.00
ya, depth immediately US, ft	9.49	10.37	5.42
Mean elevation of deck, ft	502.7	502.7	0
w, depth of overflow, ft (>=0)	0.18	1.01	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.95	1.00
**Cc, for downstream face (<=1.0)	0.915524	ERR	ERR
Ys, scour w/Chang equation, ft	**2.64**	**4.22**	N/A
Ys, scour w/Umbrell equation, ft	-2.16	-1.00	N/A

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

**Ys, scour w/Chang equation, ft	3.97	N/A	N/A

**Ys, scour w/Umbrell equation, ft	-1.22	N/A	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	8.51	9.83	7.57
WSEL at downstream face, ft	500.00	--	--
Depth at downstream face, ft	6.68	N/A	N/A
Ys, depth of scour (Laursen), ft	1.83	N/A	N/A

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1800	3090	1270	1800	3090	1270
a', abut.length blocking flow, ft	218	232.4	175.8	143.2	148.1	132.8
Ae, area of blocked flow ft2	572.58	617.25	311.79	466.55	583.58	210.56
Qe, discharge blocked abut.,cfs	--	--	491.35	551.25	--	325.44
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.24	1.72	1.58	1.18	1.65	1.55
ya, depth of f/p flow, ft	2.63	2.66	1.77	3.26	3.94	1.59
--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	0.123	0.156	0.209	0.115	0.145	0.216
ys, scour depth, ft	11.73	13.54	10.93	11.52	14.68	9.37

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)	218	232.4	175.8	143.2	148.1	132.8
y1 (depth f/p flow, ft)	2.63	2.66	1.77	3.26	3.94	1.59
a’/y1	83.00	87.50	99.12	43.95	37.58	83.76
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.12	0.16	0.21	0.12	0.15	0.22
Ys w/ corr. factor K1/0.55:						
vertical	9.57	10.46	7.69	11.62	15.15	6.96
vertical w/ ww’s	**7.84**	**8.58**	**6.30**	**9.53**	**12.43**	**5.71**
spill-through	5.26	5.75	4.23	6.39	8.33	3.83

Abutment riprap Sizing

Isbash Relationship

D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)

(Richardson and others, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.69	0.66	0.87	0.69	0.66	0.87
y, depth of flow in bridge, ft	6.68	7.67	5.42	6.68	7.67	5.42
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.97**	**2.07**	ERR	**1.97**	**2.07**	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	**2.18**	ERR	ERR	**2.18**