LEVEL II SCOUR ANALYSIS FOR BRIDGE 5 (MAIDTH00040005) on TOWN HIGHWAY 4, crossing CUTLER MILL BROOK, MAIDSTONE, VERMONT

Open-File Report 98-194

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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LEVEL II SCOUR ANALYSIS FOR BRIDGE 5 (MAIDTH00040005) on TOWN HIGHWAY 4, crossing CUTLER MILL BROOK

MAIDSTONE, VERMONT

by LORA K. STRIKER AND JAMES R. DEGNAN

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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Box 25286
Denver, CO 80225-0286

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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 5 (MAIDTH00040005) ON TOWN HIGHWAY 4, CROSSING CUTLER MILL BROOK, MAIDSTONE, VERMONT

By **Lora K. Striker and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MAIDTH00040005 on Town Highway 4 crossing 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 (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the White Mountain section of the New England physiographic province in north-eastern Vermont. The 14.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forested along the left bank upstream and right bank downstream, while the right bank upstream is pasture and the left bank downstream is shrub and brushland.

In the study area, Cutler Mill Brook has an incised, straight channel with a slope of approximately 0.02 ft/ft, an average channel top width of 59 ft and an average bank height of 5 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 54.9 mm (0.180 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 12, 1995, indicated that the reach was stable.

The Town Highway 4 crossing of Cutler Mill Brook is a 41-ft-long, one-lane bridge consisting of one 38-foot steel-beam span (Vermont Agency of Transportation, written communication, August 5, 1994). The opening length of the structure parallel to the bridge face is 34.9 ft. The bridge is supported by vertical, concrete abutments. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed in mid-channel underneath the bridge during the Level I assessment. The scour protection measure at the site was type-1 stone fill (less than 12 inches diameter) along the left bank upstream and along the base length of the left and right abutments. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 1.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 5.8 to 7.6 ft for the left abutment and from 7.9 to 8.8 ft for the right abutment. 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.

Groveton, NH-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 MAIDTH00040005 ***Stream*** Cutler Mill Brook

County Essex ***Road*** TH 4 ***District*** 7

Description of Bridge

Bridge length 41 ***ft*** ***Bridge width*** 20.7 ***ft*** ***Max span length*** 38 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** Sloping; near vertical

Stone fill on abutment? Yes ***Date of inspection*** 07/12/95

Description of stone fill Type-1, along the entire base length of the left and right abutments.

Abutments are concrete.

Brief description of piers/abutments

Yes

Is bridge skewed to flood flow according to None. ***survey?*** 10 ***Angle*** No

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

07/12/95

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 95	0 0	07/12/ 0
Level II			

Potential for debris Debris potential is low, despite the dense vegetation on the upstream banks. The capture efficiency is moderate due to the low clearance.

None.

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 moderate relief valley with a narrow flood plain.

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

Date of inspection 07/12/95

DS left: Moderately sloping channel bank and overbank

DS right: Moderately sloping channel bank to narrow flood plain

US left: Irregular channel bank to narrow flood plain

US right: Steep channel bank

Description of the Channel

Average top width 59 ***ft*** ***Average depth*** 5 ***ft***

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

The stream is straight and stable with semi-alluvial channel boundaries and narrow point bars.

Vegetative co[ver] 07/12/95

Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right:

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

None.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 14.9 ***mi***^{2}

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 -- ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 1,500 ***ft***^{3}***/s*** ***Q500*** 2,100 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database (written communication, May 1995) for this site. 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). Each curve was extended graphically to the 500-year event.

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 US end of the left abutment (elev. 495.14 ft, arbitrary survey datum). RM2 is a chiseled X on top of the DS end of the right abutment (elev. 495.02 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	-40	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPRO	61	1	Approach section as surveyed.

[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 0.040 to 0.075, and overbank "n" values ranged from 0.065 to 0.090.

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 0.0152 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 499.9 ***ft***
Average low steel elevation 497.3 ***ft***

100-year discharge 1,500 ***ft^3/s***
Water-surface elevation in bridge opening 497.5 ***ft***
Road overtopping? No ***Discharge over road*** 0 ***ft^3/s***
Area of flow in bridge opening 198 ***ft^2***
Average velocity in bridge opening 7.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.6 ***ft/s***

Water-surface elevation at Approach section with bridge 498.9
Water-surface elevation at Approach section without bridge 496.1
Amount of backwater caused by bridge 2.8 ***ft***

500-year discharge 2,100 ***ft^3/s***
Water-surface elevation in bridge opening 497.5 ***ft***
Road overtopping? Yes ***Discharge over road*** 261 ***ft^3/s***
Area of flow in bridge opening 198 ***ft^2***
Average velocity in bridge opening 9.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.8 ***/s***

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 496.6
Amount of backwater caused by bridge 3.5 ***ft***

Incipient overtopping discharge 1,590 ***ft^3/s***
Water-surface elevation in bridge opening 497.5 ***ft***
Area of flow in bridge opening 198 ***ft^2***
Average velocity in bridge opening 8.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.2 ***ft/s***

Water-surface elevation at Approach section with bridge 499.2
Water-surface elevation at Approach section without bridge 496.2
Amount of backwater caused by bridge 3.0 ***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.

At this site, all of the modelled discharges resulted in unsubmerged 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 all discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour was also computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, eq. 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144) and is 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.

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

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	1.1	0.1
Depth to armoring	18.6	23.6	22.0
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	5.8	7.6	6.3
Right abutment	7.9	8.8	8.1
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge (D50 in feet)	Incipient overtopping discharge
Abutments:			
Left abutment	1.6	1.9	1.7
Right abutment	1.6	1.9	1.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

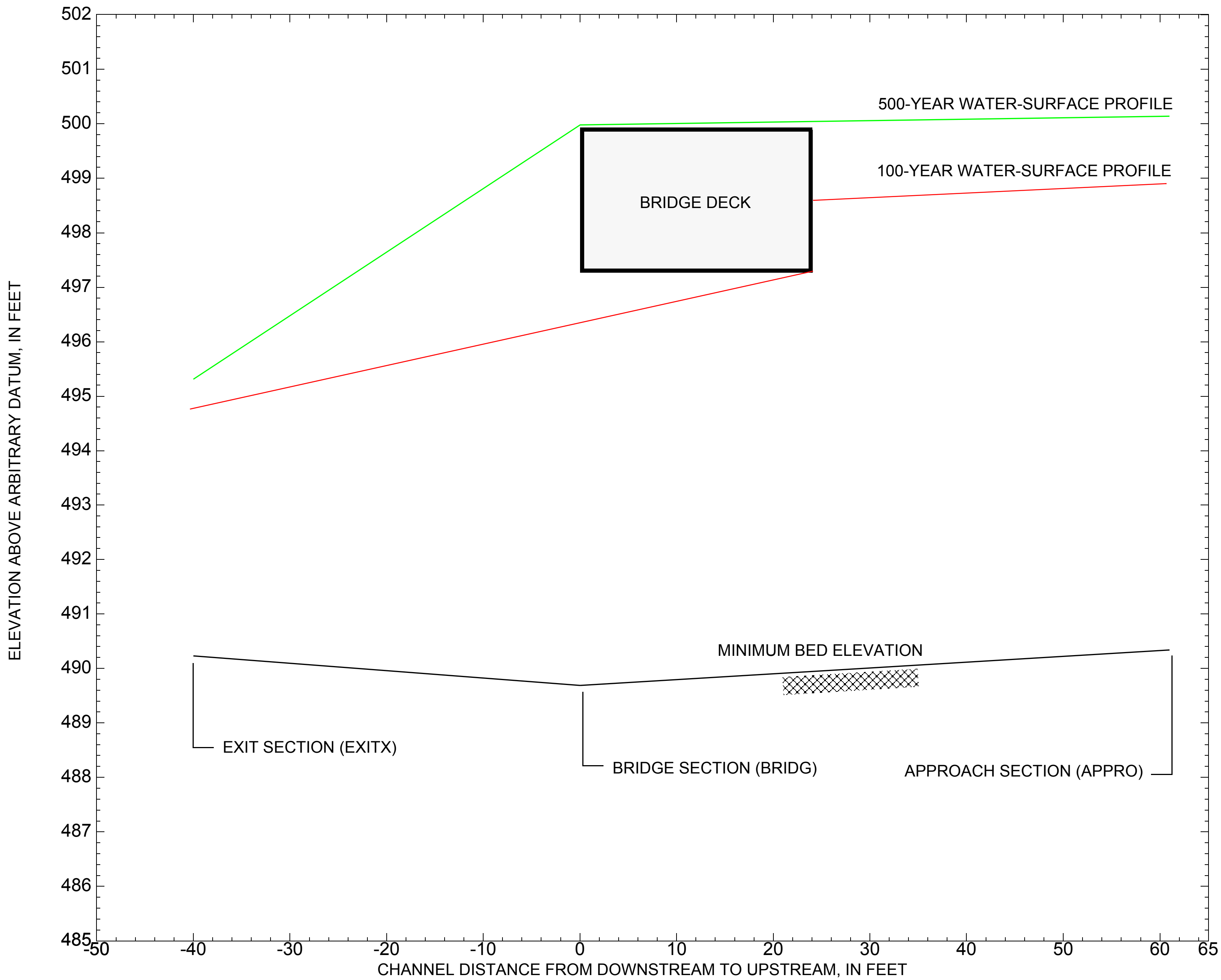

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure MAIDTH00040005 on Town Highway 4, crossing Cutler Mill Brook, Maidstone, Vermont.

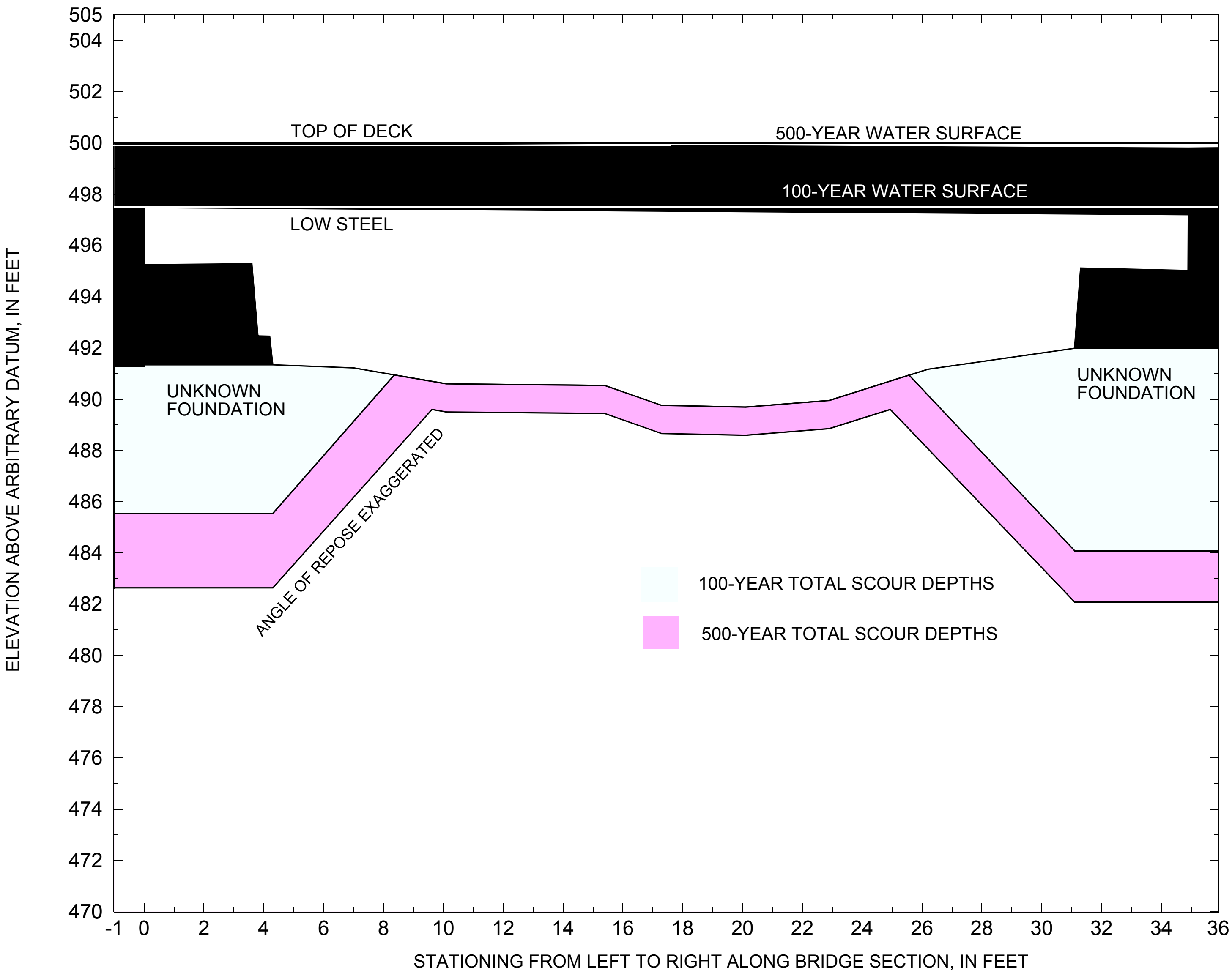

Figure 8. Scour elevations for the 100- and 500-year discharges at structure MAIDTH00040005 on Town Highway 4, crossing Cutler Mill Brook, Maidstone, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MAIDTH00040005 on Town Highway 4, 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-year discharge is 1,500 cubic-feet per second											
Left abutment	0.0	--	497.5	--	491.3	0.0	5.8	--	5.8	485.5	--
Right abutment	34.9	--	497.2	--	492.0	0.0	7.9	--	7.9	484.1	--

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 MAIDTH00040005 on Town Highway 4, 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-year discharge is 2,100 cubic-feet per second											
Left abutment	0.0	--	497.5	--	491.3	1.1	7.6	--	8.7	482.6	--
Right abutment	34.9	--	497.2	--	492.0	1.1	8.8	--	9.9	482.1	--

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 maid005.wsp
T2        Hydraulic analysis for structure MAIDTH004005     Date: 03-SEP-97
T3        The bridge 5 over Cutler Mill Brook, LKS
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1500.0   2100.0  1590.0
SK          0.0152   0.0152  0.0152
*
XS   EXITX    -40           0.
GR         -155.2, 505.74   -135.1, 502.55   -106.6, 500.37    -87.4, 496.78
GR          -75.6, 497.19    -55.6, 495.55    -46.0, 495.37    -19.8, 493.76
GR           -5.4, 493.02      0.0, 493.94      6.4, 492.52     10.2, 491.04
GR           11.8, 490.23     18.3, 490.33     24.8, 490.84     30.8, 490.53
GR           32.4, 491.02     35.3, 491.55     40.2, 493.83     50.4, 493.99
GR          99.6, 493.24     131.2, 492.67    151.7, 499.10    191.8, 498.84
GR          224.0, 500.72
*
N           0.090        0.050        0.090
SA                   0.0        40.2
*
XS   FULLV     0 * * * 0.0000
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    497.34       0.0
GR            0.0, 497.48      0.1, 495.25      3.6, 495.29      3.8, 492.47
GR            4.2, 492.46      4.3, 491.34      7.0, 491.22     10.1, 490.60
GR           15.4, 490.54     17.3, 489.76     20.1, 489.69     22.9, 489.95
GR           26.2, 491.17     31.1, 491.99     31.3, 495.12     34.8, 495.02
GR           34.9, 497.20      0.0, 497.48
*
*        BRTYPE  BRWDTH
CD          1      23.9
N           0.040
*
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     12      20.7     2
GR         -277.7, 507.64   -222.7, 503.39   -169.1, 502.07   -125.7, 501.07
GR          -83.9, 498.86    -43.7, 499.56      0.0, 499.99     34.9, 499.80
GR           98.1, 499.63    124.6, 500.90
*
*
AS   APPRO     61           0.
GR         -288.0, 506.89   -170.7, 499.85    -95.6, 498.40    -65.1, 498.57
GR          -50.4, 498.53    -30.2, 498.01    -16.5, 496.61    -12.3, 493.81
GR            6.9, 493.08     10.0, 492.76     11.9, 491.27     14.8, 490.47
GR           17.6, 490.56     24.4, 490.34     27.8, 490.43     29.5, 491.24
GR           33.4, 492.76     36.1, 493.36     40.5, 497.55     47.0, 502.05
GR           60.5, 502.94
*
N           0.065        0.075
SA                 -30.2
*
HP 1 BRIDG   497.48 1 497.48
HP 2 BRIDG   497.48 * * 1500
HP 1 BRIDG   495.57 1 495.57
HP 1 APPRO   498.90 1 498.90
HP 2 APPRO   498.90 * * 1500
*
HP 1 BRIDG   497.48 1 497.48
HP 2 BRIDG   497.48 * * 1838
HP 1 BRIDG   496.14 1 496.14
HP 2 RDWAY   499.98 * *  261
HP 1 APPRO   500.14 1 500.14
HP 2 APPRO   500.14 * * 2100
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File maid005.wsp
        Hydraulic analysis for structure MAIDTH00040005     Date: 03-SEP-97
        The bridge 5 over Cutler Mill Brook, LKS
           *** RUN DATE & TIME: 02-02-98  11:50
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     198.  13389.     0.    81.                            0.
   497.48          198.  13389.     0.    81.  1.00     0.    35.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.48     0.0    34.9   198.2   13389.    1500.   7.57

X STA.         0.0        6.7        8.0        9.3       10.5       11.7
  A(I)            25.5        8.6        8.3        8.3        8.1
  V(I)            2.94       8.76       9.07       9.04       9.31

X STA.        11.7       12.9       14.1       15.3       16.5       17.6
  A(I)             8.1        8.2        8.3        8.1        8.1
  V(I)            9.25       9.14       9.02       9.21       9.23

X STA.        17.6       18.6       19.7       20.7       21.7       22.8
  A(I)             8.0        8.0        7.8        7.8        7.9
  V(I)            9.38       9.36       9.59       9.56       9.51

X STA.        22.8       23.9       25.2       26.5       28.1       34.9
  A(I)             8.0        8.4        8.5        9.0       25.1
  V(I)            9.36       8.94       8.79       8.37       2.99

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     137.  11043.    35.    43.                         1536.
   495.57          137.  11043.    35.    43.  1.00     0.    35.   1536.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      61.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      37.    464.    91.    91.                          134.
             2     380.  21878.    73.    77.                         4925.
   498.90          417.  22343.   164.   168.  1.13  -121.    42.   3543.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      61.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.90  -121.5    42.5   416.7   22343.    1500.   3.60

X STA.      -121.5       -9.1       -5.5       -2.1        1.2        4.3
  A(I)            90.9       19.0       18.1       18.3       17.6
  V(I)            0.83       3.94       4.15       4.09       4.27

X STA.         4.3        7.4       10.2       12.6       14.4       15.9
  A(I)            17.8       17.2       17.2       14.4       12.5
  V(I)            4.21       4.35       4.37       5.20       6.02

X STA.        15.9       17.5       19.4       21.2       23.0       24.8
  A(I)            13.8       15.7       15.6       15.2       15.2
  V(I)            5.42       4.78       4.82       4.93       4.92

X STA.        24.8       26.6       28.4       30.4       32.9       42.5
  A(I)            15.0       15.3       15.8       16.8       35.4
  V(I)            5.01       4.91       4.74       4.47       2.12
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File maid005.wsp
        Hydraulic analysis for structure MAIDTH00040005     Date: 03-SEP-97
        The bridge 5 over Cutler Mill Brook, LKS
           *** RUN DATE & TIME: 02-02-98  11:50
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     198.   13389.     0.    81.                           0.
   497.48          198.   13389.     0.    81.  1.00     0.    35.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.48     0.0    34.9   198.2   13389.    1838.   9.27

X STA.         0.0         6.7         8.0         9.3        10.5        11.7
  A(I)             25.5         8.6         8.3         8.3         8.1
  V(I)             3.60       10.74       11.11       11.08       11.41

X STA.        11.7        12.9        14.1        15.3        16.5        17.6
  A(I)              8.1         8.2         8.3         8.1         8.1
  V(I)            11.33       11.20       11.06       11.29       11.31

X STA.        17.6        18.6        19.7        20.7        21.7        22.8
  A(I)              8.0         8.0         7.8         7.8         7.9
  V(I)            11.50       11.47       11.75       11.71       11.65

X STA.        22.8        23.9        25.2        26.5        28.1        34.9
  A(I)              8.0         8.4         8.5         9.0        25.1
  V(I)            11.47       10.95       10.78       10.26        3.66

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     156.   13600.    35.    44.                        1881.
   496.14          156.   13600.    35.    44.  1.00     0.    35.   1881.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      12.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.98  -105.1   105.4    72.8     679.     261.   3.59

X STA.      -105.1       -91.8       -88.6       -85.9       -83.7       -81.4
  A(I)              4.7         2.5         2.5         2.4         2.5
  V(I)             2.80        5.15        5.15        5.40        5.31

X STA.       -81.4       -79.1       -76.5       -73.7       -70.7       -68.9
  A(I)              2.5         2.6         2.7         2.7         1.6
  V(I)             5.28        4.93        4.89        4.79        8.35

X STA.       -68.9       -67.9       -65.0       -61.8       -58.0       -53.5
  A(I)              0.9         2.4         2.5         2.6         2.8
  V(I)            14.71        5.54        5.26        4.94        4.65

X STA.       -53.5       -47.4        50.9        71.8        87.0       105.4
  A(I)              3.3        16.8         5.2         4.6         5.0
  V(I)             3.95        0.78        2.49        2.86        2.61

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      61.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     189.    5141.   145.   145.                        1219.
             2     471.   30742.    74.    79.                        6720.
   500.14          659.   35883.   220.   224.  1.27  -176.    44.   5753.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      61.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.14  -175.5    44.2   659.4   35883.    2100.   3.18

X STA.      -175.5       -90.2       -55.4       -19.0       -10.7        -6.6
  A(I)             86.2        56.6        76.0        39.7        26.4
  V(I)             1.22        1.86        1.38        2.65        3.97

X STA.        -6.6        -2.7         1.0         4.6         8.1        11.1
  A(I)             25.6        24.8        25.2        24.7        22.4
  V(I)             4.10        4.23        4.17        4.25        4.68

X STA.        11.1        13.5        16.0        18.3        20.6        22.8
  A(I)             21.7        23.3        22.0        22.1        21.7
  V(I)             4.83        4.50        4.76        4.76        4.83

X STA.        22.8        25.0        27.2        29.6        32.5        44.2
  A(I)             21.8        21.5        22.4        23.5        51.7
  V(I)             4.81        4.88        4.69        4.46        2.03
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File maid005.wsp
       Hydraulic analysis for structure MAIDTH00040005     Date: 03-SEP-97
       The bridge 5 over Cutler Mill Brook, LKS
          *** RUN DATE & TIME: 02-02-98  11:50
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     198.  13389.     0.    81.                           0.
   497.48          198.  13389.     0.    81.  1.00     0.    35.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.48     0.0    34.9   198.2   13389.    1590.   8.02

X STA.         0.0        6.7        8.0        9.3       10.5       11.7
  A(I)            25.5        8.6        8.3        8.3        8.1
  V(I)            3.11       9.29       9.61       9.59       9.87

X STA.        11.7       12.9       14.1       15.3       16.5       17.6
  A(I)             8.1        8.2        8.3        8.1        8.1
  V(I)            9.80       9.69       9.56       9.76       9.78

X STA.        17.6       18.6       19.7       20.7       21.7       22.8
  A(I)             8.0        8.0        7.8        7.8        7.9
  V(I)            9.94       9.92      10.16      10.13      10.08

X STA.        22.8       23.9       25.2       26.5       28.1       34.9
  A(I)             8.0        8.4        8.5        9.0       25.1
  V(I)            9.92       9.47       9.32       8.88       3.17

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     140.  11435.    35.    43.                        1589.
   495.66          140.  11435.    35.    43.  1.00     0.    35.   1589.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      61.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      61.    990.   104.   104.                         268.
             2     398.  23565.    73.    77.                        5271.
   499.15          459.  24555.   177.   182.  1.18  -134.    43.   3860.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      61.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.15  -134.4    42.8   459.3   24555.    1590.   3.46

X STA.      -134.4      -11.4       -7.7       -4.2       -0.8        2.4
  A(I)           107.8       20.4       19.4       19.4       18.9
  V(I)            0.74       3.91       4.09       4.09       4.20

X STA.         2.4        5.6        8.7       11.5       13.6       15.1
  A(I)            19.0       18.7       18.9       16.7       13.4
  V(I)            4.19       4.26       4.21       4.76       5.94

X STA.        15.1       16.9       18.8       20.8       22.7       24.5
  A(I)            15.0       17.0       16.8       16.4       16.1
  V(I)            5.29       4.69       4.73       4.84       4.95

X STA.        24.5       26.3       28.2       30.3       32.9       42.8
  A(I)            16.1       16.0       17.2       18.2       38.0
  V(I)            4.93       4.98       4.63       4.37       2.09
```

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        U.S. Geological Survey WSPRO Input File maid005.wsp
        Hydraulic analysis for structure MAIDTH00040005     Date: 03-SEP-97
        The bridge 5 over Cutler Mill Brook, LKS
           *** RUN DATE & TIME: 02-02-98  11:50

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

EXITX:XS   ******   -36.     303.  0.78 *****  495.56  494.72   1500.  494.78
      -40. ******   138.   12161.  2.03 ***** *******    0.94    4.95

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.61

FULLV:FV      40.   -56.     446.  0.36  0.38  495.92 *******   1500.  495.57
        0.    40.   140.   19615.  2.03  0.00   -0.01    0.56    3.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.45

APPRO:AS      61.   -16.     196.  0.91  0.79  496.97 *******   1500.  496.07
       61.    61.    39.    8844.  1.00  0.28   -0.02    0.71    7.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.51     497.56     498.05     497.34

 ===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      40.     0.     198.  0.89 *****  498.37  495.51   1501.  497.48
        0. ******    35.   13389.  1.00 ***** *******    0.56    7.57

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.453  0.000  497.34 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      37.  -121.     416.  0.23  0.29  499.13  495.28   1500.  498.90
       61.    38.    42.   22321.  1.13  0.46    0.00    0.42    3.60

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.72

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -40.   -36.   138.   1500.   12161.     303.    4.95  494.78
   FULLV:FV       0.   -56.   140.   1500.   19615.     446.    3.36  495.57
   BRIDG:BR       0.     0.    35.   1501.   13389.     198.    7.57  497.48
   RDWAY:RG      12.**************      0.       0.       0.    2.00********
   APPRO:AS      61.  -121.    42.   1500.   22321.     416.    3.60  498.90

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    494.72    0.94  490.23  505.74************  0.78  495.56  494.78
   FULLV:FV  ********    0.56  490.23  505.74  0.38  0.00  0.36  495.92  495.57
   BRIDG:BR    495.51    0.56  489.69  497.48************  0.89  498.37  497.48
   RDWAY:RG  ****************  498.86  507.64************  0.23  498.94********
   APPRO:AS    495.28    0.42  490.34  506.89  0.29  0.46  0.23  499.13  498.90
```

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        U.S. Geological Survey WSPRO Input File maid005.wsp
        Hydraulic analysis for structure MAIDTH00040005     Date: 03-SEP-97
        The bridge 5 over Cutler Mill Brook, LKS
           *** RUN DATE & TIME: 02-02-98  11:50

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

EXITX:XS   ******   -45.     397.  0.87 *****  496.18  495.19   2100.  495.31
      -40. ******   140.   17023.  2.01 ***** *******    0.90    5.29

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.56

FULLV:FV      40.   -63.     562.  0.43  0.39  496.57 *******   2100.  496.14
        0.    40.   142.   26501.  1.97  0.00    0.00    0.56    3.74
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
           FNTEST,FR#,WSEL,CRWS =  0.80    0.81     496.62     496.05
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   495.64     506.89    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   495.64     506.89     496.05
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.42

APPRO:AS      61.   -17.     227.  1.33  0.92  497.95  496.05   2100.  496.62
       61.    61.    40.   11014.  1.00  0.45    0.00    0.81    9.25
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   499.45       0.00     496.48     498.86
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   496.46     498.98     499.39     497.34
 ===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      40.     0.     198.  1.34 *****  498.82  496.08   1838.  497.48
        0. ******    35.   13389.  1.00 ***** *******    0.69    9.28

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.492  0.000  497.34 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.    40.  0.14  0.20  500.20    0.00    261.  499.98

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    190.   119.  -105.    18.   1.1   0.4   3.6   3.6   0.7   3.0
   RT:     71.    88.    18.   105.   0.3   0.2   2.7   3.6   0.5   2.7

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS      37.  -175.     659.  0.20  0.31  500.34  496.05   2100.  500.14
       61.    38.    44.   35853.  1.27  0.45    0.00    0.37    3.19

       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     -40.   -45.   140.   2100.   17023.     397.    5.29  495.31
   FULLV:FV       0.   -63.   142.   2100.   26501.     562.    3.74  496.14
   BRIDG:BR       0.     0.    35.   1838.   13389.     198.    9.28  497.48
   RDWAY:RG      12.*******   190.    261.*********       0.    2.00  499.98
   APPRO:AS      61.  -175.    44.   2100.   35853.     659.    3.19  500.14

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    495.19    0.90  490.23  505.74************  0.87  496.18  495.31
   FULLV:FV  ********    0.56  490.23  505.74  0.39  0.00  0.43  496.57  496.14
   BRIDG:BR    496.08    0.69  489.69  497.48************  1.34  498.82  497.48
   RDWAY:RG  ***************  498.86  507.64  0.14******  0.20  500.20  499.98
   APPRO:AS    496.05    0.37  490.34  506.89  0.31  0.45  0.20  500.34  500.14
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       U.S. Geological Survey WSPRO Input File maid005.wsp
       Hydraulic analysis for structure MAIDTH00040005     Date: 03-SEP-97
       The bridge 5 over Cutler Mill Brook, LKS
          *** RUN DATE & TIME: 02-02-98  11:50

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

EXITX:XS   ******   -38.     318.  0.79 *****  495.66  494.79   1590.  494.87
      -40. ******   138.   12892.  2.03 ***** *******    0.94    5.00

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.60

FULLV:FV      40.   -57.     464.  0.37  0.38  496.03 *******   1590.  495.66
        0.    40.   141.   20622.  2.02  0.00   -0.02    0.56    3.43
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.45

APPRO:AS      61.   -16.     201.  0.97  0.81  497.13 *******   1590.  496.16
       61.    61.    39.    9187.  1.00  0.30   -0.01    0.73    7.90
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.66     497.78     498.26     497.34

 ===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      40.     0.     198.  1.00 *****  498.48  495.66   1587.  497.48
        0. ******    35.   13389.  1.00 ***** *******    0.59    8.01

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.467  0.000  497.34 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      37.  -134.     459.  0.22  0.30  499.37  495.40   1590.  499.15
       61.    38.    43.   24548.  1.18  0.46    0.00    0.41    3.46

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.98

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -40.   -38.   138.   1590.   12892.     318.    5.00  494.87
   FULLV:FV       0.   -57.   141.   1590.   20622.     464.    3.43  495.66
   BRIDG:BR       0.     0.    35.   1587.   13389.     198.    8.01  497.48
   RDWAY:RG      12.**************      0.       0.       0.    2.00********
   APPRO:AS      61.  -134.    43.   1590.   24548.     459.    3.46  499.15

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    494.79    0.94  490.23  505.74************  0.79  495.66  494.87
   FULLV:FV   ********   0.56  490.23  505.74  0.38  0.00  0.37  496.03  495.66
   BRIDG:BR    495.66    0.59  489.69  497.48************  1.00  498.48  497.48
   RDWAY:RG  ****************  498.86  507.64************  0.22  499.20********
   APPRO:AS    495.40    0.41  490.34  506.89  0.30  0.46  0.22  499.37  499.15
```
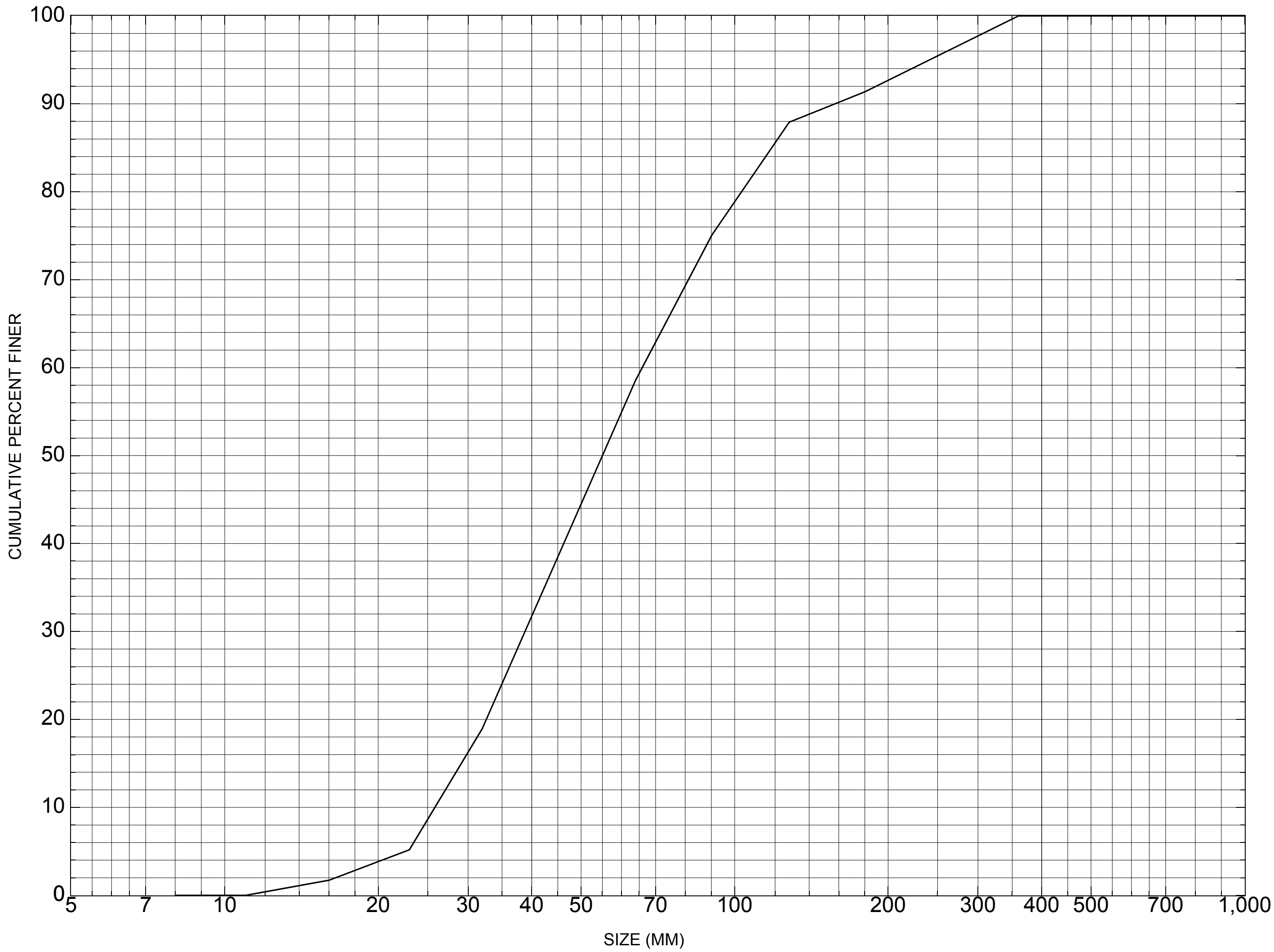

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure MAIDTH00040005, in Maidstone, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MAIDTH00040005

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 TH004

Vicinity *(I - 9)* 0.5 MI JCT TH 4 + TH 5

Topographic Map Groveton, NH

Hydrologic Unit Code: 01080101

Latitude *(I - 16; nnnn.n)* 44363

Longitude *(i - 17; nnnnn.n)* 71356

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10051500050515

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

Maximum span length *(I - 48; nnnn)* 0038

Year built *(I - 27; YYYY)* 1968

Structure length *(I - 49; nnnnnn)* 000041

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 207

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

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

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*) 006.6

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 steel stringer bridge with a concrete deck. The footings are reported exposed on both sides but no undermining or settlement has occurred. Some minor concrete spalling is noted on the abutments. The inspection report indicates 2.0 ft of possible channel scour underneath the bridge. Point bars and debris accumulation problems at the site are reported as minor. Stone fill coverage is noted as fair.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

Q_{50} - Q_{100} - Q_{500} -

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

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

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: 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} (*ft^3/ 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 (*ft^2*): -

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 14.92 mi^2

Lake/pond/swamp area 0.35 mi^2

Watershed storage *(ST)* 1.8 %

Bridge site elevation 980 ft

Headwater elevation 2520 ft

Main channel length 10.24 mi

10% channel length elevation 1050 ft

85% channel length elevation 1780 ft

Main channel slope *(S)* 71.28 ft / mi

Watershed Precipitation Data

Average site precipitation - in

Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:

-

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

Is boring information available? 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:

There are no bridge plans available.

Cross-sectional Data

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

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

Comments: **There is no cross-section information available.**

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: **There is no cross-section information available.**

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: 03/05/96
Computerized by: EW Date: 03/05/96
Reviewd by: LKS Date: 02/18/97

Structure Number MAIDTH00040005

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 07 / 12 / 1995
2. Highway District Number 07 Mile marker -
County Essex (009) Town Maidstone (42475)
Waterway *(I - 6)* Cutler Mill Brook Road Name -
Route Number TH04 Hydrologic Unit Code: 01080101
3. Descriptive comments:
The bridge is located 0.5 miles from the intersection of TH 5 and TH 4.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 4 LBDS 5 RBDS 6 Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 1 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 41 *(feet)* Span length 38 *(feet)* Bridge width 20.7 *(feet)*

Road approach to bridge:

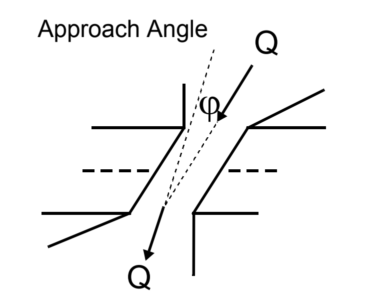
8. LB 0 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

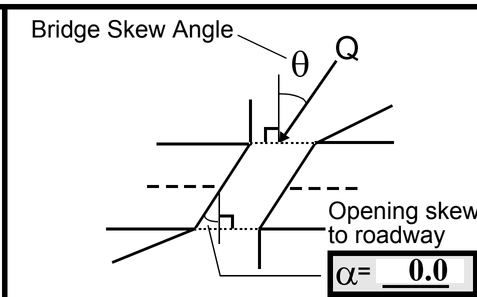
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	2	1
RBUS	2	1	2	1
RBDS	0	-	0	-
LBDS	0	-	2	1

*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: 10 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 5 feet US *(US, UB, DS)* to 25 feet US
Channel impact zone 2: Exist? N *(Y or N)*
Where? - *(LB, RB)* Severity -
Range? - feet - *(US, UB, DS)* to - feet -

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

18. Bridge Type: **1b**

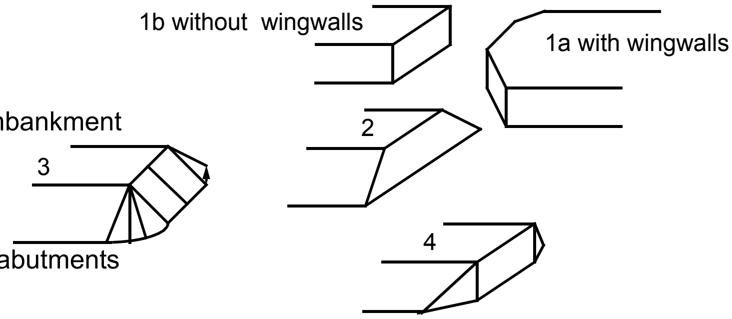
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

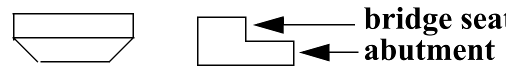
3- Spill through abutments

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: The upstream right overbank consists of cottages and lawn
#7: Bridge dimension values are from the VTAOT files. Field measured values include: bridge length- 40 ft and span length- 35 ft.
#11: Protection consists of natural boulders.
#13: There is evidence of US erosion from gullies running parallel to road. The eroded material has been deposited in the bed of the stream.
#18: The bridge type includes an abutment with a set back bridge seat: front view side view



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
61.0	6.5			11.0	4	4	245	453	2	1

23. Bank width **10.0** 24. Channel width **30.0** 25. Thalweg depth **77.0** 29. Bed Material **4523**

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

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

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

#32/33: The bank protection on the LB is stone fill which extends from the abutment to 20 ft US. US of the protection, the bank is undercut. Thick grass and brush on the banks help to minimize erosion.

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? **Y** (Y or if N type ctrl-n cb) 40. Where? **LB** (LB or RB)

41. Mid-bank distance: **37** 42. Cut bank extent: **20** feet **US** (US, UB) to **50** feet **US** (US, UB, DS)

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

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

The cut-bank starts US of the LB protection.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **0**

47. Scour dimensions: Length **34** Width **11** Depth : **1.5** Position **35** %LB to **70** %RB

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

For further details refer to #79.

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)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
18.0		**0.5**		**2**	**7**	**7**	**-**

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

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

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

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

453

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

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

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

70. Debris and Ice Comments:

1

#68: The debris potential at this site is low although there is heavy vegetation along the banks upstream. The capture efficiency is moderate due to the low bridge deck.

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	2	-	1	90.0
RABUT	1	10	90			2	0	35.0

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

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

-

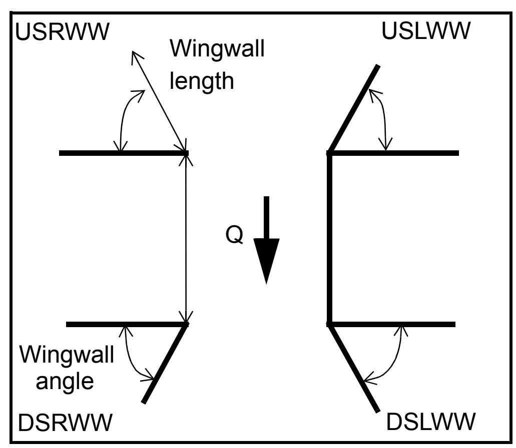
-

1

A scour hole exists under the bridge. The scour depth is 1.5 ft below the thalweg depth. The scour hole is 34 ft long and 11 ft wide and extends from 14 ft US to the DS bridge face.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						35.0	
USRWW:	N		-		-	1.5	
DSLWW:	-		-		N	24.0	
DSRWW:	-		-		-	24.0	



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

82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	1	1	-

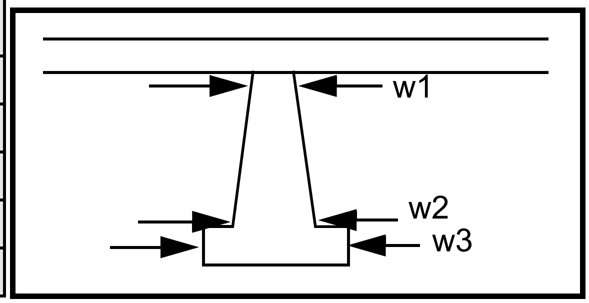
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? Th (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	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	ere is	area	pre-		LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	pro-	on	vent		1- Solid pier, 2- column, 3- bent
88. Material	tec-	both	fur-		1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	tion	bank	ther		1- Round; 2- Square; 3- Pointed
90. Inclined?	in	s.	ero-		Y- yes; N- no
91. Attack ∠ (BF)	the	The	sion		
92. Pushed	upst	pro-	of		LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	ream	tec-	the		
95. Cross-members	road	tion	emb		0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	emb	was	ank-	N	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	ank-	place	ment	-	
98. Exposure depth	ment	d to	.	-	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

103. Drop: - feet 104. Structure material: - *(**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: Ther

Point bar extent: e are feet no (US, UB, DS) to piers 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? _____ (Y or if N type ctrl-n cb) Where? _____ (LB or RB) Mid-bank distance: 3

Cut bank extent: 4 feet 342 (US, UB, DS) to 342 feet 1 (US, UB, DS)

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

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

4352

0

0

-

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

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

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

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

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

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

Confluence comments (eg. confluence name):

re is no drop structure at this site.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N

-
-
-
-
-
-
-
-
-

109. G. Plan View Sketch

T

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: MAIDTH00040005            Town:    MAIDSTONE
Road Number:      TH 4                      County:  ESSEX
Stream:           CUTLER MILL BROOK

Initials LKS      Date:    12/19/97 Checked: EMB

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

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

Approach Section
Characteristic                      100 yr   500 yr   other Q

  Total discharge, cfs              1500     2100     1590
  Main Channel Area, ft2            380      471      398
  Left overbank area, ft2           37       189      61
  Right overbank area, ft2          0        0        0
  Top width main channel, ft        73       74       73
  Top width L overbank, ft          91       145      104
  Top width R overbank, ft          0        0        0
  D50 of channel, ft                0.1802   0.1802   0.1802
  D50 left overbank, ft             --       --       --
  D50 right overbank, ft            --       --       --

y1, average depth, MC, ft             5.2      6.4      5.5
y1, average depth, LOB, ft            0.4      1.3      0.6
y1, average depth, ROB, ft          ERR      ERR      ERR

  Total conveyance, approach        22343    35883    24555
  Conveyance, main channel          21878    30742    23565
  Conveyance, LOB                   464      5141     990
  Conveyance, ROB                   0        0        0
  Percent discrepancy, conveyance   0.0045   0.0000   0.0000
  Qm, discharge, MC, cfs            1468.8   1799.1   1525.9
  Ql, discharge, LOB, cfs           31.2     300.9    64.1
  Qr, discharge, ROB, cfs           0.0      0.0      0.0

Vm, mean velocity MC, ft/s          3.9      3.8      3.8
Vl, mean velocity, LOB, ft/s        0.8      1.6      1.1
Vr, mean velocity, ROB, ft/s        ERR      ERR      ERR
Vc-m, crit. velocity, MC, ft/s        8.3      8.6      8.4
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	1500	2100	1590
(Q) discharge thru bridge, cfs	1500	1838	1590
Main channel conveyance	13389	13389	13389
Total conveyance	13389	13389	13389
Q2, bridge MC discharge,cfs	1500	1838	1590
Main channel area, ft2	198	198	198
Main channel width (normal), ft	34.9	34.9	34.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.9	34.9	34.9
y_bridge (avg. depth at br.), ft	5.68	5.68	5.68
Dm, median (1.25*D50), ft	0.22525	0.22525	0.22525
y2, depth in contraction,ft	4.76	5.66	5.00
ys, scour depth (y2-ybridge), ft	-0.92	-0.01	-0.68

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	1500	1838	1590
Main channel area (DS), ft2	137	156	140
Main channel width (normal), ft	34.9	34.9	34.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	34.9	34.9	34.9
D90, ft	0.5153	0.5153	0.5153
D95, ft	0.7939	0.7939	0.7939
Dc, critical grain size, ft	0.5884	0.6440	0.6271
Pc, Decimal percent coarser than Dc	0.087	0.076	0.079
Depth to armoring, ft	**18.64**	**23.62**	**21.99**

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	1500	2100	1590
Q, thru bridge MC, cfs	1500	1838	1590
Vc, critical velocity, ft/s	8.34	8.62	8.40
Va, velocity MC approach, ft/s	3.87	3.82	3.83
Main channel width (normal), ft	34.9	34.9	34.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.9	34.9	34.9
qbr, unit discharge, ft2/s	43.0	52.7	45.6
Area of full opening, ft2	198.2	198.2	198.2
Hb, depth of full opening, ft	5.68	5.68	5.68
Fr, Froude number, bridge MC	0.56	0.69	0.59
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	137	156	140
**Hb, depth at downstream face, ft	3.93	4.47	4.01
**Fr, Froude number at DS face	0.97	0.98	1.00
**Cf, for downstream face (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	497.34	497.34	497.34
Elevation of Bed, ft	491.66	491.66	491.66
Elevation of Approach, ft	498.9	500.14	499.15
Friction loss, approach, ft	0.29	0.31	0.3
Elevation of WS immediately US, ft	498.61	499.83	498.85
ya, depth immediately US, ft	6.95	8.17	7.19
Mean elevation of deck, ft	499.9	499.9	499.9
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.91	0.94
**Cc, for downstream face (<=1.0)	0.812124	0.799396	ERR
Ys, scour w/Chang equation, ft	**-0.25**	**1.06**	**0.08**
Ys, scour w/Umbrell equation, ft	-0.86	-0.17	-0.74

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

**Ys, scour w/Chang equation, ft	2.42	3.17	ERR

**Ys, scour w/Umbrell equation, ft	0.89	1.04	0.93

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	4.76	5.66	5.00
WSEL at downstream face, ft	495.57	496.14	495.66
Depth at downstream face, ft	3.93	4.47	4.01
Ys, depth of scour (Laursen), ft	0.83	1.19	0.99

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	1500	2100	1590	1500	2100	1590
a', abut.length blocking flow, ft	121.5	175.5	134.4	7.6	9.3	7.9
Ae, area of blocked flow ft2	139.65	279.3	171.72	28.02	39.5	30.32
Qe, discharge blocked abut.,cfs	272.73	--	337.88	59.38	--	63.44
(If using Qtotal_overbank to obtain Ve, leave Qe blank and e						
Ve, (Qe/Ae), ft/s	1.95	2.15	1.97	2.12	2.03	2.09
ya, depth of f/p flow, ft	1.15	1.59	1.28	3.69	4.25	3.84

--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)

K1	1	1	1	1	1	1

--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	0.321	0.277	0.307	0.194	0.170	0.188
ys, scour depth, ft	10.83	14.07	11.72	**7.89**	**8.83**	**8.13**

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)	121.5	175.5	134.4	7.6	9.3	7.9

y1 (depth f/p flow, ft)	1.15	1.59	1.28	3.69	4.25	3.84
a'/y1	105.71	110.28	105.19	2.06	2.19	2.06
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.32	0.28	0.31	0.19	0.17	0.19
Ys w/ corr. factor K1/0.55:						
vertical	**5.75**	**7.58**	**6.29**	ERR	ERR	ERR
vertical w/ ww's	4.71	6.21	5.16	ERR	ERR	ERR
spill-through	3.16	4.17	3.46	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.97	0.98	1	0.97	0.98	1
y, depth of flow in bridge, ft	3.93	4.47	4.01	3.93	4.47	4.01
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	**1.63**	**1.86**	**1.68**	**1.63**	**1.86**	**1.68**