LEVEL II SCOUR ANALYSIS FOR BRIDGE 21 (MORETH00010021) on TOWN HIGHWAY 1, crossing COX BROOK, MORETOWN, VERMONT

Open-File Report 97-662

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 21 (MORETH00010021) on TOWN HIGHWAY 1, crossing COX BROOK, MORETOWN, 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

U.S. GEOLOGICAL SURVEY
Mark Schaefer, Acting Director

For additional information
write to:

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

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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	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 21 (MORETH00010021) ON TOWN HIGHWAY 1, CROSSING COX BROOK, MORETOWN, 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 MORETH00010021 on Town Highway 1 crossing Cox Brook, Moretown, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in north-central Vermont. The 2.85-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly forested.

In the study area, Cox Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 23 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to cobble with a median grain size (D_{50}) of 47.5 mm (0.156 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 18, 1996, indicated that the reach was stable.

The Town Highway 1 crossing of Cox Brook is a 29-ft-long, two-lane bridge consisting of one 27-foot steel-beam span (Vermont Agency of Transportation, written communication, October 13, 1995). The opening length of the structure parallel to the bridge face is 24.8 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 60 degrees to the opening while the measured opening-skew-to-roadway is 40 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the left abutment downstream during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the left bank upstream. 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-year and 500-year discharges. In addition, the incipient roadway-overtopping discharge is 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 0.2 to 0.5 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 2.8 to 4.0 ft. The worst-case abutment scour occurred at the left abutment at the 100-year discharge and at the right abutment 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.

Northfield, VT. Quadrangle, 1:24,000, 1980

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 MORETH00010021 ***Stream*** Cox Brook

County Washington ***Road*** TH 1 ***District*** 6

Description of Bridge

Bridge length 29 ***ft*** ***Bridge width*** 21.4 ***ft*** ***Max span length*** 27 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 07/18/96

Description of stone fill -

Brief description of piers/abutments Abutments and wingwalls are concrete. There are random cracks with displacement at the wingwalls. The abutment concrete has cracks and spalls. The left abutment footing is exposed.

Is bridge located on a bend in channel? Y ***If so, describe (mild, moderate, severe)*** There is a mild channel bend in the upstream reach.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 40

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	07/18/96	0	0
Level II	07/18/96	0	0

Potential for debris Moderate. The low vertical clearance contributes to the capture efficiency of the bridge.

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 moderately sloping overbanks.

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

Date of inspection 07/18/96

DS left: Steep channel bank to moderately sloping overbank

DS right: Steep channel bank to valley wall

US left: Steep channel bank to moderately sloping overbank

US right: Steep channel bank to moderately sloping overbank

Description of the Channel

Average top width 23 ***ft*** ***Average depth*** 4 ***ft***

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

Sinuous but stable with semi-alluvial channel boundaries.

07/18/96

Vegetative co

DS left: Trees and brush

DS right: Trees and brush

US left: Brush and tall grasses

US right: Brush and tall grasses

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

None, 07/18/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 2.85 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: 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 [illegible] No

Calculated Discharges

Q100 660 ***ft³/s*** ***Q500*** 900 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(2.85/1.10)exp 0.7] with bridge number 33 in Moretown. Bridge number 33 crosses Cox Brook upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 33 is 1.1 square miles. The drainage area adjusted discharge values are within a range defined by several empirical flood frequency curves. (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887)

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

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

Datum tie between USGS survey and VTAOT plans None.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream left wingwall (elev. 499.04 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream right curbing (elev. 500.71ft, arbitrary survey datum). RM3 is a nail in the telephone pole on the right bank, pole #103 (elev. 504.78 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-21	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	48	2	Modelled Approach section (Templated from APTEM)
APTEM	59	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.055 and overbank "n" values ranged from 0.043 to 0.070.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0182 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1980).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0053 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.2 ***ft***
Average low steel elevation 497.4 ***ft***

100-year discharge 660 ***ft³/s***
Water-surface elevation in bridge opening 497.8 ***ft***
Road overtopping? Yes ***Discharge over road*** 150 ***ft³/s***
Area of flow in bridge opening 70 ***ft²***
Average velocity in bridge opening 7.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.6 ***ft/s***

Water-surface elevation at Approach section with bridge 499.6
Water-surface elevation at Approach section without bridge 498.9
Amount of backwater caused by bridge 0.7 ***ft***

500-year discharge 900 ***ft³/s***
Water-surface elevation in bridge opening 497.8 ***ft***
Road overtopping? Yes ***Discharge over road*** 390 ***ft³/s***
Area of flow in bridge opening 70 ***ft²***
Average velocity in bridge opening 7.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.5 ***ft/s***

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 499.4
Amount of backwater caused by bridge 0.7 ***ft***

Incipient overtopping discharge 560 ***ft³/s***
Water-surface elevation in bridge opening 497.7 ***ft***
Area of flow in bridge opening 70 ***ft²***
Average velocity in bridge opening 8.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.3 ***ft/s***

Water-surface elevation at Approach section with bridge 499.1
Water-surface elevation at Approach section without bridge 498.4
Amount of backwater caused by bridge 0.7 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

At this site, all modelled discharges 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). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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.

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

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.2	0.2	0.5
Depth to armoring	1.6 1.4	3.0	--
Left overbank	--	--	--
Right overbank	--	--	2.8 3.4

Local scour:			
Abutment scour			
Left abutment	3.0	4.0	3.9
Right abutment	3.5–	---	---
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	1.3	1.3

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:	1.5	1.3	1.3
Left abutment	1.5	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--		
Pier 2			

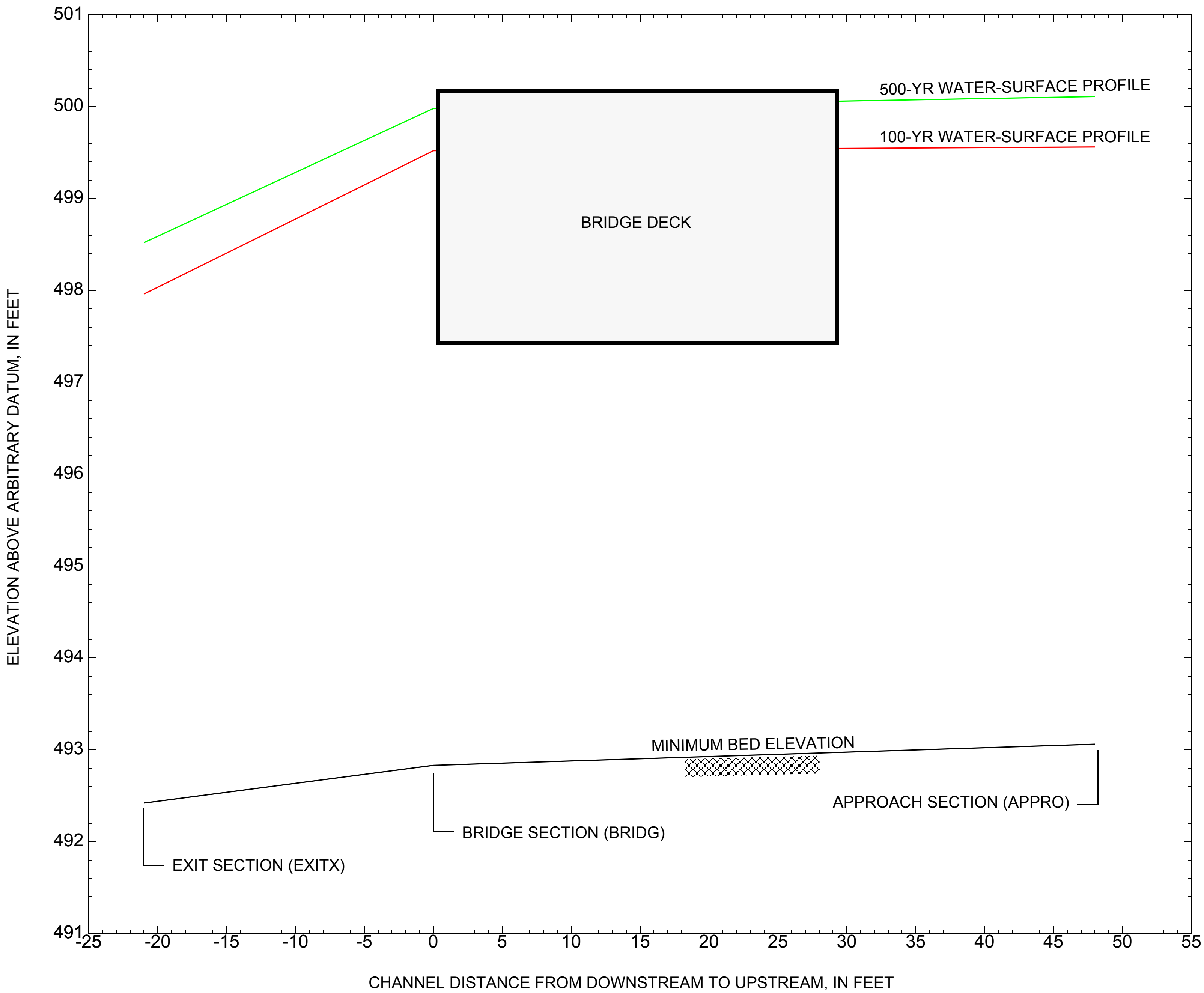

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure MORETH00010021 on Town Highway 1, crossing Cox Brook, Moretown, Vermont.

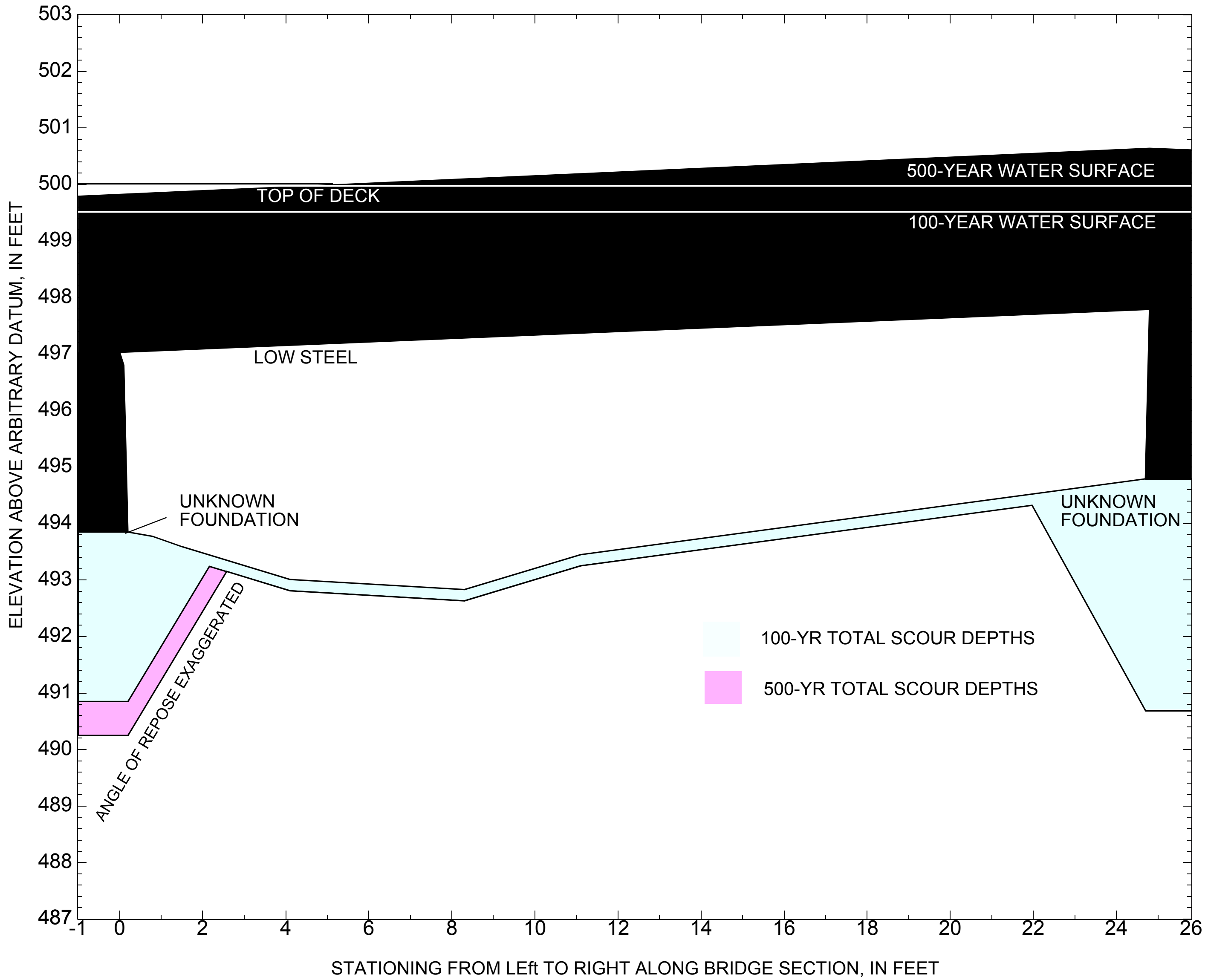

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure MORETH00010021 on Town Highway 1, crossing Cox Brook, Moretown, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MORETH00010021 on Town Highway 1, crossing Cox Brook, Moretown, 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 660 cubic-feet per second											
Left abutment	0.0	--	497.0	--	493.8	0.2	2.8	--	3.0	490.8	--
Right abutment	24.8	--	497.8	--	494.8	0.2	4.0	--	4.2	490.6	--

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 MORETH00010021 on Town Highway 1, crossing Cox Brook, Moretown, 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 900 cubic-feet per second											
Left abutment	0.0	--	497.0	--	493.8	0.2	3.4	--	3.6	490.2	--
Right abutment	24.8	--	497.8	--	494.8	0.2	3.9	--	4.1	490.7	--

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

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U.S. Geological Survey, 1980, Northfield, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File more021.wsp
T2        Hydraulic analysis for structure MORETH00010021   Date: 20-JUN-97
T3        TH 1 crossing Cox Brook at junction with TH 47
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q            660.0    900.0   560.0
SK          0.0182   0.0182   0.0182
*
XS   EXITX    -21           0.
GR          -41.9, 498.39    -19.3, 497.89     -3.3, 497.36
GR            0.0, 494.51      2.8, 493.36      3.2, 492.76      7.3, 492.42
GR           12.0, 492.61     15.4, 493.37     19.0, 496.60     25.3, 496.54
GR           29.7, 496.36     77.5, 506.33
*
N           0.070        0.055        0.070
SA                  19.0         -3.3
*
*
XS   FULLV      0  * * *   0.0204
*
*           SRD     LSEL    XSSKEW
BR   BRIDG     0    497.41      40.0
GR            0.0, 497.03      0.1, 496.80      0.2, 493.85      0.8, 493.77
GR            1.0, 493.31      1.5, 493.59      4.1, 493.01      8.3, 492.83
GR           11.1, 493.45     24.7, 494.79     24.8, 497.79
GR            0.0, 497.03
*
*        BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      34.3 * *     67.7      0.0
N           0.040
*
*
*           SRD    EMBWID   IPAVE
XR   RDWAY     15      21.4     2
GR         -119.0, 505.37   -102.3, 499.15   -27.1, 498.84     -1.1, 499.22
GR            0.0, 499.82     25.6, 500.64     28.3, 500.46     28.5, 499.89
GR           64.7, 501.52    110.1, 508.55
*
*
XT   APTEM     59           0.
GR         -121.0, 505.37   -102.3, 499.15    -15.7, 498.06
GR           -8.7, 498.64      0.0, 497.93      5.0, 493.78      8.3, 493.23
GR           11.6, 493.12     14.2, 493.46     16.9, 493.86     23.6, 499.77
GR           37.5, 500.89     49.5, 500.25     61.7, 500.73    111.1, 508.55
*
AS   APPRO     48  * * * 0.0053
GT
N           0.043        0.055        0.070
SA                   0.0         23.6
*
HP 1 BRIDG   497.79 1 497.79
HP 2 BRIDG   497.79 * *  509
HP 2 RDWAY   499.52 * *  147
HP 1 APPRO   499.56 1 499.56
HP 2 APPRO   499.56 * *  660
*
HP 1 BRIDG   497.79 1 497.79
HP 2 BRIDG   497.79 * *  499
HP 2 RDWAY   499.98 * *  392
HP 1 APPRO   500.11 1 500.11
HP 2 APPRO   500.11 * *  900
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File more021.wsp
        Hydraulic analysis for structure MORETH00010021   Date: 20-JUN-97
        TH 1 crossing Cox Brook at junction with TH 47
           *** RUN DATE & TIME: 07-01-97  13:41

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       70      3528      0     45                            0
   497.79            70      3528      0     45  1.00      0     25        0

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      497.79     0.0    24.8    70.1    3528.     509.  7.26

 X STA.        0.0        2.3        3.5        4.6        5.6        6.5
   A(I)             5.6        3.7        3.4        3.2        3.1
   V(I)            4.52       6.95       7.55       7.90       8.32

 X STA.        6.5        7.4        8.3        9.2       10.1       11.1
   A(I)             3.0        2.9        3.0        3.0        3.1
   V(I)            8.46       8.64       8.55       8.36       8.22

 X STA.       11.1       12.2       13.2       14.4       15.5       16.7
   A(I)             3.1        3.2        3.2        3.3        3.3
   V(I)            8.16       8.05       7.96       7.73       7.67

 X STA.       16.7       18.0       19.4       20.9       22.4       24.8
   A(I)             3.5        3.5        3.7        3.9        5.4
   V(I)            7.32       7.18       6.95       6.51       4.70

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      15.
        WSEL     LEW     REW    AREA        K        Q    VEL
      499.52  -103.3    -0.6    52.5     713.     147.  2.80

X STA.     -103.3      -94.1      -87.0      -80.3      -74.5      -68.9
   A(I)             3.3        3.0        3.0        2.8        2.7
   V(I)            2.20       2.47       2.46       2.65       2.68

 X STA.      -68.9      -63.9      -59.0      -54.6      -50.3      -46.2
   A(I)             2.6        2.6        2.5        2.5        2.4
   V(I)            2.80       2.82       2.99       2.94       3.04

 X STA.      -46.2      -42.3      -38.6      -35.0      -31.5      -28.1
   A(I)             2.4        2.3        2.3        2.3        2.3
   V(I)            3.12       3.14       3.20       3.21       3.24

 X STA.      -28.1      -24.7      -20.8      -16.1      -10.2       -0.6
   A(I)             2.3        2.4        2.6        2.8        3.4
   V(I)            3.20       3.08       2.82       2.61       2.16

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      109      3875    104    104                          630
             2      112      7747     23     27                         1382
   499.56           220     11622    127    131  1.31   -103     23     1439

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
        WSEL     LEW     REW    AREA        K        Q    VEL
      499.56  -103.7    23.4   220.1   11622.     660.  3.00

 X STA.     -103.7      -69.1      -51.3      -38.1      -27.2      -17.8
   A(I)            22.8       17.8       15.8       14.7       13.8
   V(I)            1.45       1.85       2.09       2.25       2.40

 X STA.      -17.8       -6.6        2.2        4.4        5.8        7.0
   A(I)            14.4       15.1        9.9        7.8        7.2
   V(I)            2.29       2.18       3.32       4.24       4.58

 X STA.        7.0        8.1        9.1       10.2       11.2       12.3
   A(I)             6.8        6.8        6.8        6.8        7.0
   V(I)            4.83       4.87       4.88       4.88       4.71

 X STA.       12.3       13.4       14.6       16.0       17.6       23.4
   A(I)             7.2        7.4        8.0        9.4       14.8
   V(I)            4.59       4.46       4.12       3.50       2.24
```

```
       U.S. Geological Survey WSPRO Input File more021.wsp
       Hydraulic analysis for structure MORETH00010021   Date: 20-JUN-97
       TH 1 crossing Cox Brook at junction with TH 47
          *** RUN DATE & TIME: 07-01-97  13:41
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       70      3528      0     45                            0
  497.79            70      3528      0     45  1.00      0     25        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.79     0.0    24.8    70.1    3528.     499.   7.12

X STA.         0.0        2.3        3.5        4.6        5.6        6.5
  A(I)            5.6        3.7        3.4        3.2        3.1
  V(I)           4.43       6.82       7.40       7.75       8.15

X STA.         6.5        7.4        8.3        9.2       10.1       11.1
  A(I)            3.0        2.9        3.0        3.0        3.1
  V(I)           8.30       8.47       8.38       8.19       8.05

X STA.        11.1       12.2       13.2       14.4       15.5       16.7
  A(I)            3.1        3.2        3.2        3.3        3.3
  V(I)           8.00       7.90       7.81       7.58       7.52

X STA.        16.7       18.0       19.4       20.9       22.4       24.8
  A(I)            3.5        3.5        3.7        3.9        5.4
  V(I)           7.17       7.04       6.81       6.38       4.61

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      15.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.98  -104.5    30.5   101.8    2026.     392.   3.85

X STA.      -104.5      -96.4      -90.1      -84.4      -78.8      -73.6
  A(I)            5.9        5.4        5.1        5.1        4.9
  V(I)           3.31       3.63       3.85       3.83       3.97

X STA.       -73.6      -68.3      -63.5      -58.7      -54.0      -49.5
  A(I)            5.0        4.7        4.8        4.8        4.6
  V(I)           3.89       4.13       4.09       4.08       4.26

X STA.       -49.5      -45.1      -40.9      -36.6      -32.5      -28.5
  A(I)            4.6        4.6        4.6        4.6        4.5
  V(I)           4.22       4.28       4.24       4.29       4.32

X STA.       -28.5      -24.4      -19.8      -14.7       -8.6       30.5
  A(I)            4.7        4.8        5.2        5.6        8.2
  V(I)           4.21       4.06       3.80       3.53       2.39

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      166      7781    105    106                         1183
            2      125      9253     24     27                         1624
            3        1         7      5      5                            2
  500.11           292     17041    134    138  1.17   -104     29     2257

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.11  -105.4    28.5   291.6   17041.     900.   3.09

X STA.      -105.4      -82.3      -67.5      -55.0      -44.4      -34.8
  A(I)           24.4       20.2       19.3       17.8       17.4
  V(I)           1.84       2.23       2.34       2.53       2.59

X STA.       -34.8      -26.4      -18.3      -10.2       -0.9        3.8
  A(I)           16.2       16.2       15.9       16.8       16.6
  V(I)           2.77       2.77       2.84       2.68       2.71

X STA.         3.8        5.6        7.1        8.5        9.8       11.2
  A(I)           11.1        9.7        9.5        9.3        9.4
  V(I)           4.06       4.66       4.75       4.84       4.76

X STA.        11.2       12.5       14.0       15.6       17.5       28.5
  A(I)            9.5       10.0       10.7       12.1       19.6
  V(I)           4.73       4.48       4.22       3.72       2.29
```

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      U.S. Geological Survey WSPRO Input File more021.wsp
      Hydraulic analysis for structure MORETH00010021   Date: 20-JUN-97
      TH 1 crossing Cox Brook at junction with TH 47
         *** RUN DATE & TIME: 07-01-97  13:41
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1       70      3648      2     42                         2218
 497.70            70      3648      2     42  1.00      0     25     2218

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     497.70     0.0    24.8    70.0    3648.     560.   8.00

X STA.        0.0        2.3        3.6        4.7        5.7        6.7
  A(I)            5.8        3.8        3.5        3.2        3.2
  V(I)           4.81       7.38       8.02       8.64       8.82

X STA.        6.7        7.6        8.5        9.4       10.4       11.5
  A(I)            3.1        3.0        3.1        3.1        3.2
  V(I)           8.97       9.31       9.14       8.95       8.80

X STA.       11.5       12.6       13.7       14.8       16.0       17.3
  A(I)            3.2        3.2        3.3        3.4        3.4
  V(I)           8.63       8.80       8.57       8.32       8.27

X STA.       17.3       18.6       19.9       21.3       22.7       24.8
  A(I)            3.5        3.5        3.6        3.3        4.7
  V(I)           8.10       8.01       7.81       8.46       5.97

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      48.
   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1       58      1397    101    101                          251
           2      100      6600     23     26                         1191
 499.07           158      7997    123    127  1.44   -100     23      847

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      48.

       WSEL     LEW     REW    AREA        K        Q    VEL
     499.07  -100.6    22.9   158.4    7997.     560.   3.54

X STA.     -100.6      -40.6      -23.5       -7.2        2.6        4.4
  A(I)           22.7       14.7       14.2       12.6        7.3
  V(I)           1.24       1.90       1.97       2.23       3.81

X STA.        4.4        5.6        6.5        7.5        8.3        9.1
  A(I)            6.0        5.4        5.2        4.9        5.0
  V(I)           4.66       5.18       5.39       5.70       5.62

X STA.        9.1       10.0       10.8       11.6       12.5       13.3
  A(I)            4.9        4.9        5.0        5.1        5.2
  V(I)           5.77       5.74       5.65       5.50       5.41

X STA.       13.3       14.3       15.3       16.4       17.8       22.9
  A(I)            5.3        5.6        6.2        7.1       11.2
  V(I)           5.32       4.99       4.55       3.92       2.50
```

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        U.S. Geological Survey WSPRO Input File more021.wsp
        Hydraulic analysis for structure MORETH00010021   Date: 20-JUN-97
        TH 1 crossing Cox Brook at junction with TH 47
           *** RUN DATE & TIME: 07-01-97  13:41

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

EXITX:XS   ******    -21      150  0.33 *****  498.29  497.18     660  497.96
       -20 ******     37     4889  1.09 ***** *******    0.51    4.40

FULLV:FV       21    -19      146  0.36  0.39  498.69 *******     660  498.33
         0     21     37     4812  1.11  0.01    0.00    0.53    4.53
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     0.90     498.88     497.48
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =    497.83     508.49    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =    497.83     508.49     497.48
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.45

APPRO:AS       48    -84      136  0.51  0.62  499.39  497.48     660  498.87
        48     48     23     6998  1.39  0.08    0.00    0.90    4.86
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   498.33     497.41

            <<<<<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       21      0       70  0.82 *****  498.61  496.54     509  497.79
         0 ******     25     3528  1.00 ***** *******    0.76    7.26

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.41 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.    27.  0.09  0.18  499.66    0.00    147.  499.52

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    147.   103.  -103.    -1.   0.7   0.5   3.3   2.8   0.7   2.7
   RT:      0.    29.    11.    43.   0.7   0.3   3.2   4.9   0.6   2.7

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

APPRO:AS       14   -103      221  0.18  0.13  499.75  497.48     660  499.56
        48     16     23    11655  1.30  0.00    0.00    0.46    2.99

       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     -21.   -22.    37.    660.    4889.    150.    4.40  497.96
   FULLV:FV       0.   -20.    37.    660.    4812.    146.    4.53  498.33
   BRIDG:BR       0.     0.    25.    509.    3528.     70.    7.26  497.79
   RDWAY:RG      15.*******   147.    147.       0.      0.    2.00  499.52
   APPRO:AS      48.  -104.    23.    660.   11655.    221.    2.99  499.56

  SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#   YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    497.18    0.51  492.42  506.33************  0.33  498.29  497.96
   FULLV:FV   ********   0.53  492.85  506.76  0.39  0.01  0.36  498.69  498.33
   BRIDG:BR    496.54    0.76  492.83  497.79************  0.82  498.61  497.79
   RDWAY:RG   ****************  498.84  508.55  0.09******  0.18  499.66  499.52
   APPRO:AS    497.48    0.46  493.06  508.49  0.13  0.00  0.18  499.75  499.56
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        U.S. Geological Survey WSPRO Input File more021.wsp
        Hydraulic analysis for structure MORETH00010021   Date: 20-JUN-97
        TH 1 crossing Cox Brook at junction with TH 47
           *** RUN DATE & TIME: 07-01-97  13:41

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

EXITX:XS   ******    -41      204  0.31 *****  498.83  497.82     900  498.52
       -20 ******     40     6670  1.01 ***** *******    0.50    4.42

 ===140 AT SECID "FULLV":  END OF CROSS SECTION EXTENDED VERTICALLY.
                           WSEL,YLT,YRT =   498.91     498.82     506.76

FULLV:FV       21    -41      200  0.32  0.39  499.23 *******     900  498.91
         0     21     40     6467  1.01  0.01    0.00    0.51    4.50
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  1.64

APPRO:AS       48   -102      205  0.41  0.57  499.84 *******     900  499.44
        48     48     23    10613  1.35  0.04    0.00    0.71    4.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   498.91     497.41

            <<<<<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       21      0       70  0.79 *****  498.58  496.49     499  497.79
         0 ******     25     3528  1.00 ***** *******    0.75    7.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.41 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.    27.  0.07  0.17  500.21   -0.01    392.  499.98

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    391.   110.  -105.     5.   1.1   0.9   4.7   3.9   1.1   2.9
   RT:      1.     2.    28.    31.   0.1   0.0   2.0   8.2   0.3   2.6

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

APPRO:AS       14   -104      292  0.17  0.14  500.28  499.18     900  500.11
        48     17     29    17039  1.17  0.00   -0.01    0.40    3.09

       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     -21.   -42.    40.    900.    6670.     204.    4.42  498.52
   FULLV:FV       0.   -42.    40.    900.    6467.     200.    4.50  498.91
   BRIDG:BR       0.     0.    25.    499.    3528.      70.    7.11  497.79
   RDWAY:RG      15.*******   391.    392.******************    2.00  499.98
   APPRO:AS      48.  -105.    29.    900.   17039.     292.    3.09  500.11

  SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    497.82    0.50  492.42  506.33************  0.31  498.83  498.52
   FULLV:FV  ********    0.51  492.85  506.76  0.39  0.01  0.32  499.23  498.91
   BRIDG:BR    496.49    0.75  492.83  497.79************  0.79  498.58  497.79
   RDWAY:RG  ****************  498.84  508.55  0.07******  0.17  500.21  499.98
   APPRO:AS    499.18    0.40  493.06  508.49  0.14  0.00  0.17  500.28  500.11
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```
        U.S. Geological Survey WSPRO Input File more021.wsp
        Hydraulic analysis for structure MORETH00010021   Date: 20-JUN-97
        TH 1 crossing Cox Brook at junction with TH 47
           *** RUN DATE & TIME: 07-01-97  13:41

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

EXITX:XS   ******     -2      106  0.56 *****  497.88  496.30     560  497.32
       -20 ******     34     4147  1.28 ***** *******    0.63    5.30

FULLV:FV       21     -2      103  0.59  0.39  498.29 *******     560  497.70
         0     21     34     4020  1.27  0.02    0.00    0.65    5.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.93     498.39     497.09

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   497.20     508.49    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   497.20     508.49     497.09

APPRO:AS       48    -46       94  0.64  0.71  499.03  497.09     560  498.39
        48     48     22     5252  1.14  0.02    0.00    0.93    5.98
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   497.70     497.41

            <<<<<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       21      0       70  0.96 *****  498.66  496.68     549  497.70
         0 ******     25     3645  1.00 ***** *******    0.82    7.84

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   3.  0.800  0.000  497.41 ****** ****** ******

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

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

APPRO:AS       14   -100      159  0.28  0.16  499.35  497.09     560  499.07
        48     15     23     8008  1.44  0.00   -0.02    0.66    3.53

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.94

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

  FIRST USER DEFINED TABLE.

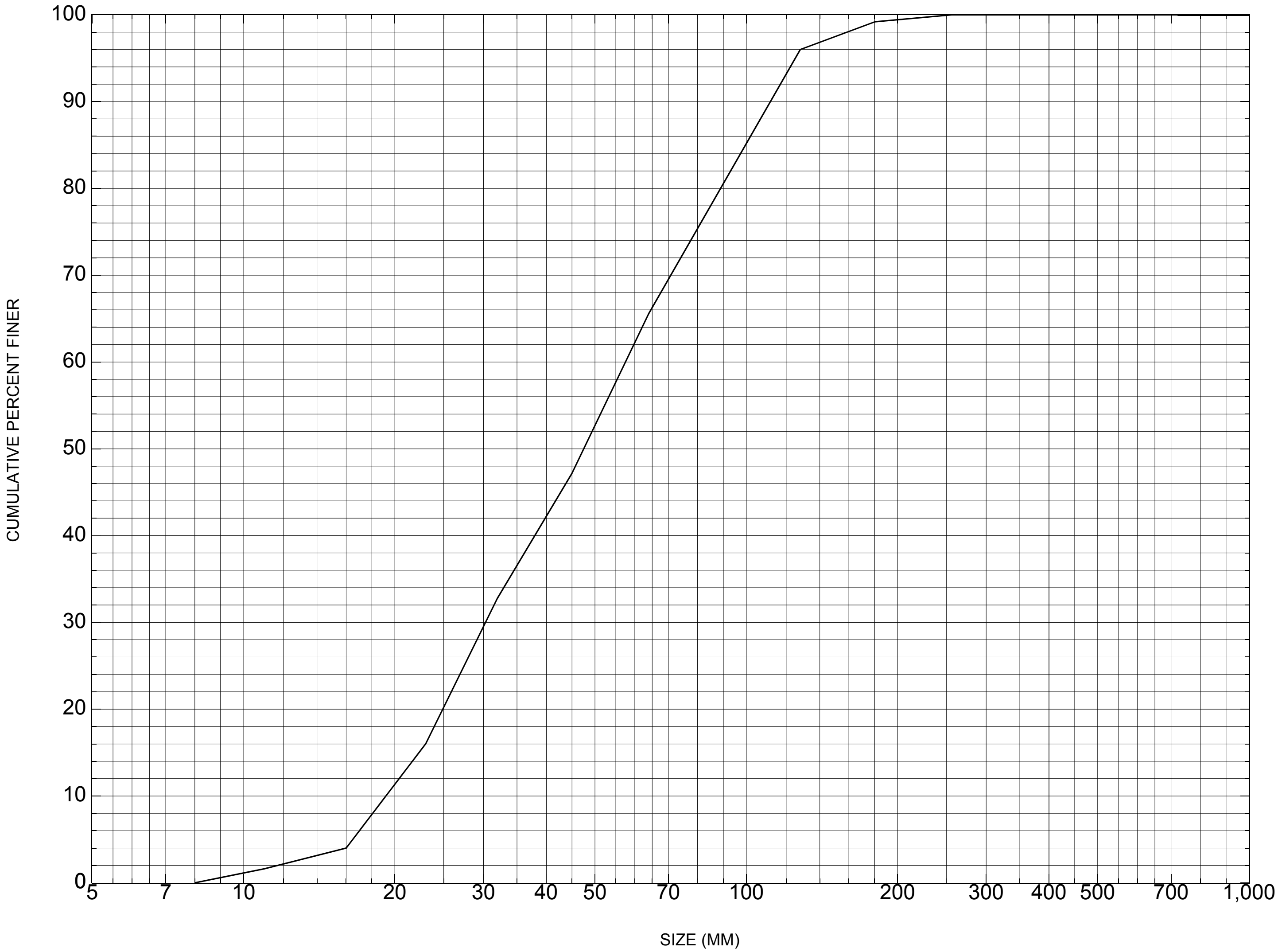
   XSID:CODE    SRD    LEW    REW       Q        K     AREA    VEL   WSEL
   EXITX:XS    -21.    -3.    34.    560.    4147.     106.   5.30  497.32
   FULLV:FV      0.    -3.    34.    560.    4020.     103.   5.46  497.70
   BRIDG:BR      0.     0.    25.    549.    3645.      70.   7.84  497.70
   RDWAY:RG     15.**************      0.       0.       0.   2.00********
   APPRO:AS     48.  -101.    23.    560.    8008.     159.   3.53  499.07

  SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#   YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    496.30    0.63  492.42  506.33************  0.56  497.88  497.32
   FULLV:FV  ********    0.65  492.85  506.76  0.39  0.02  0.59  498.29  497.70
   BRIDG:BR    496.68    0.82  492.83  497.79************  0.96  498.66  497.70
   RDWAY:RG  ****************  498.84  508.55************  0.28  499.22********
   APPRO:AS    497.09    0.66  493.06  508.49  0.16  0.00  0.28  499.35  499.07
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure MORETH00010021, in Moretown, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MORETH00010021

General Location Descriptive

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

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

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

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

Town *(FIPS place code; I - 4; nnnnn)* 46225

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

Waterway *(I - 6)* COX BROOK

Road Name *(I - 7):* -

Route Number C2001

Vicinity *(I - 9)* @ JCT W CL4 TH47

Topographic Map Northfield

Hydrologic Unit Code: 2010003

Latitude *(I - 16; nnnn.n)* 44125

Longitude *(i - 17; nnnnn.n)* 72419

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10121200211212

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

Maximum span length *(I - 48; nnnn)* 0027

Year built *(I - 27; YYYY)* 1954

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

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

Deck Width *(I - 52; nn.n)* 214

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

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

Opening skew to Roadway *(I - 34; nn)* 42

Waterway adequacy *(I - 71; n)* 4

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*) 20.4

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

Vertical clearance from streambed (*nnn.n ft*) 5

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

Waterway of full opening (*nnn.n ft*^{2}) 102

Comments:

According to the structural inspection report dated 7/8/94, deck consists of a gravel wearing surface, with a few small areas of bare concrete showing. There are cracks and spalls at the abutments. The LABUT US footing has separated from the stem. The US stem has moved 1.5" towards the stream. There are random cracks and displacement at the wingwalls. Some undermining is noted at the LABUT. Random spalls are noted mostly at the Labut and the left wingwall. Some settlement is noted at the LABUT US footing. There is heavy spalling and breaks at the LABUT footing. A settlement crack at beam 2 of the LABUT is 0.25" wide at the top and 0.5" at the bottom **(Cont. pg. 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

-

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

Are there other structures nearby? (*Yes, No, Unknown*): N *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:

The LABUT US wingwall stem is displaced towards the stream. There is scour noted along the bottom of the downstream banks. There is a large gravel bar in front of the RABUT that extends 3/4 of the way through the bridge. There are some dead trees and debris blocking the stream 50 ft DS of the bridge. There is some stone fill just US of the LABUT wingwall along the bank. The LABUT is noted as having a poor subfooting. The streambed consists of sand and gravel with a few boulders. The stream takes a sharp turn into the structure.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **2.85** mi^2 Lake/pond/swamp area **0** mi^2

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

Bridge site elevation **960** ft Headwater elevation **1983** ft

Main channel length **2.93** mi

10% channel length elevation **990** ft 85% channel length elevation **1460** ft

Main channel slope *(S)* **213.88** 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)*: - / -

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:

There is no benchmark information available.

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

There is no foundation material information available.

Comments:

There is limited information in plans - no elevation data. The clear span and vertical height were measured from the plans.

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

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

Comments: -

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **10/17/96**
Computerized by: **RB** Date: **10/31/96**
Reviewd by: **LKS** Date: **07/08/97**

Structure Number **MORETH00010021**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. Medalie** Date *(MM/DD/YY)* **07** / **18** / 19**96**

2. Highway District Number **06** Mile marker **0000**

County **Washington (023)** Town **Moretown (46225)**

Waterway *(I - 6)* **Cox Brook** Road Name **Cox Brook Road**

Route Number **TH1** Hydrologic Unit Code: **2010003**

3. Descriptive comments:

The bridge is located at the junction with TH 47.

B. Bridge Deck Observations

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

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

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

7. Bridge length **29** *(feet)* Span length **27** *(feet)* Bridge width **21.4** *(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)*

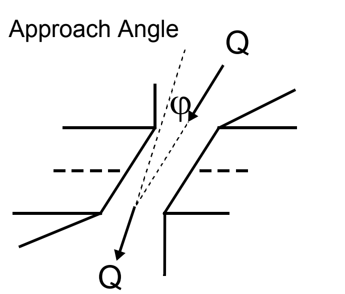
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

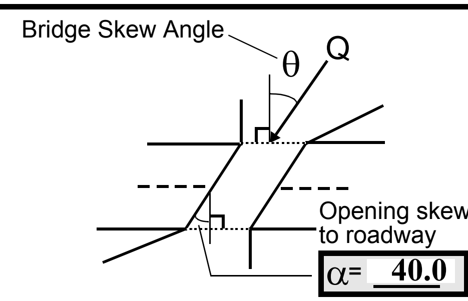
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: **25** 16. Bridge skew: **60**





α= **40.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **12** feet **US** *(US, UB, DS)* to **0** feet **DS**

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: **1a**

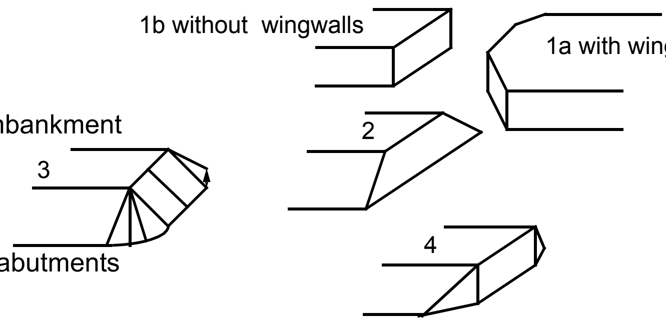
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. Chase Mountain Road runs along the US left bank and Cox Brook Road is on the US right bank.
7. Values are from the VT AOT files. Measured bridge span is 25 ft, bridge length is 29 ft, and the bridge width is 21.4 ft measured perpendicular to the edge of the curb and 23 ft measured at the abutment angle.
11. The US right wingwall acts as road approach protection.
13. The DS left bank road approach is eroded around the end of the DS left wingwall.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
33.5	**4.0**			**6.0**	**3**	**1**	**32**	**23**	**1**	**1**

23. Bank width **40.0**   24. Channel width **40.0**   25. Thalweg depth **23.5**   29. Bed Material **43**

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

30. The left bank protection extends from the end of the wingwall at 5 ft US to 22 ft US.
29. The bed material grades to some sand on the right side.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 51 35. Mid-bar width: 5

36. Point bar extent: 32 feet US (US, UB) to 62 feet US (US, UB, DS) positioned 0 %LB to 35 %RB

37. Material: 3

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

This side bar is vegetated with grass. Another point bar is from 21 ft US to 4 ft DS and positioned from 40% LB to 100% RB. The mid-bar is 10 ft wide and is located at the US face of the bridge. This point bar is gravel and vegetated with grass on the US end.

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.

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 present.

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
12.0		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.):

34

-

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 2____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

3

The pointbar on the right abutment and the low vertical clearance of the bridge contribute to the capture efficiency rating for debris and ice potential. There is also some debris accumulation DS.

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		30	90	0	2	1	1	90.0
RABUT	1	0	90			0	0	19.0

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.):

-

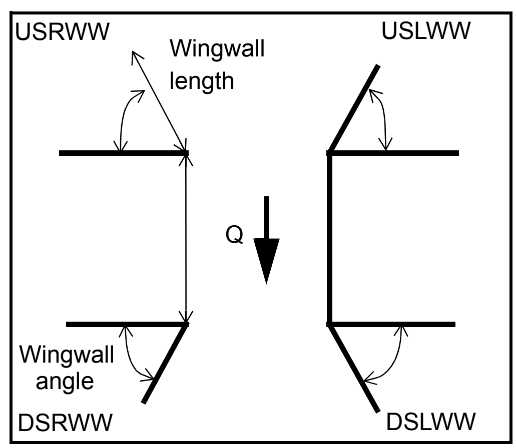
-

1

75. Average thalweg depth is 0.5 ft There is some concrete spalling of the left abutment at the corner between the bottom of the abutment and the top of the footing. In places the streamward edge of the left abutment footing is eroded away 2 in. to 3 in., but it is not undermined.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						19.0	
USRWW:	Y		1		2	0.5	
DSLWW:	1		1		Y	27.5	
DSRWW:	1		0		-	30.5	



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

82. **Bank / Bridge Protection**:

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

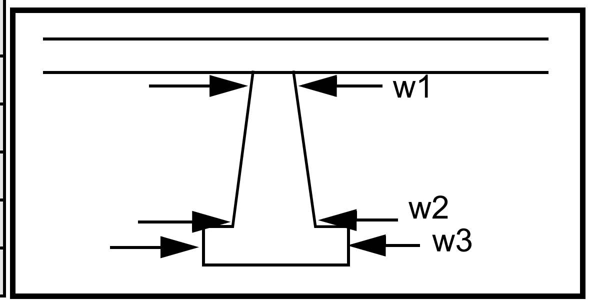
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **80.** *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**14.5**		**135.0**	**0.0**	**10.0**
Pier 2		**7.0**	**7.5**	**55.0**	**130.0**	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width - 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.):
-
-
-
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-

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

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

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

e are no piers.

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

Point bar extent: ______ feet **4** *(US, UB, DS)* to **4** feet **32** *(US, UB, DS)* positioned **32** %LB to **1** %RB

Material: **1**

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

34
0
0
-

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

Cut bank extent: **and** feet **rig** *(US, UB, DS)* to **ht** feet **ba** *(US, UB, DS)*

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

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

vegetation cover is between 0% to 25% from the bridge face to 24 ft DS.

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? **N** *(Y or if N type ctrl-n mc)* How many? **-**

Confluence 1: Distance **Ther** Enters on **e is** *(LB or RB)* Type **no** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

e 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
-
-
-
-
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-

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: WALDTH00180022 Town: MORETOWN
Road Number: TH 18 County: WASHINGTON
Stream: COLES BROOK

Initials LKS Date: 06/27/97 Checked: MAI

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	660	900	560
Main Channel Area, ft2	112	125	100
Left overbank area, ft2	109	166	58
Right overbank area, ft2	0	0	0
Top width main channel, ft	23	24	23
Top width L overbank, ft	104	105	101
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.1558	0.1558	0.1558
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	4.9	5.2	4.3
y1, average depth, LOB, ft	1.0	1.6	0.6
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	11622	17041	7997
Conveyance, main channel	7747	9253	6600
Conveyance, LOB	3875	7781	1397
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0411	0.0000
Qm, discharge, MC, cfs	439.9	488.7	462.2
Ql, discharge, LOB, cfs	220.1	410.9	97.8
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	3.9	3.9	4.6
Vl, mean velocity, LOB, ft/s	2.0	2.5	1.7
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	7.9	7.9	7.7
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	660	900	560
(Q) discharge thru bridge, cfs	509	499	560
Main channel conveyance	3528	3528	3648
Total conveyance	3528	3528	3648
Q2, bridge MC discharge,cfs	509	499	560
Main channel area, ft2	70	70	70
Main channel width (normal), ft	19.0	19.0	19.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19	19	19
y_bridge (avg. depth at br.), ft	3.68	3.68	3.68
Dm, median (1.25*D50), ft	0.19475	0.19475	0.19475
y2, depth in contraction,ft	3.31	3.25	3.59
ys, scour depth (y2-ybridge), ft	-0.38	-0.43	-0.09

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	509	499	560
Main channel area (DS), ft2	70	70	70
Main channel width (normal), ft	19.0	19	19.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	19.0	19.0	19.0
D90, ft	0.3654	0.3654	0.3654
D95, ft	0.4103	0.4103	0.4103
Dc, critical grain size, ft	0.2302	0.2213	0.2787
Pc, Decimal percent coarser than Dc	0.303	0.321	0.218
Depth to armoring, ft	1.59	1.41	3.00

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	660	900	560
Q, thru bridge MC, cfs	509	499	560
Vc, critical velocity, ft/s	7.85	7.94	7.71
Va, velocity MC approach, ft/s	3.93	3.91	4.62
Main channel width (normal), ft	19.0	19.0	19.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.0	19.0	19.0
qbr, unit discharge, ft2/s	26.8	26.3	29.5
Area of full opening, ft2	70.0	70.0	70.0
Hb, depth of full opening, ft	3.68	3.68	3.68
Fr, Froude number, bridge MC	0.76	0.75	0.82
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	497.41	497.41	497.41
Elevation of Bed, ft	493.73	493.73	493.73
Elevation of Approach, ft	499.56	500.11	499.07
Friction loss, approach, ft	0.13	0.14	0.16
Elevation of WS immediately US, ft	499.43	499.97	498.91
ya, depth immediately US, ft	5.70	6.24	5.18
Mean elevation of deck, ft	500.23	500.23	500.23
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.88	0.84	0.91
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	0.18	0.23	0.51
Ys, scour w/Umbrell equation, ft	0.46	0.80	0.51

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	660	900	560	660	900	560
a’, abut.length blocking flow, ft	106.6	108.3	103.5	1.5	6.6	1
Ae, area of blocked flow ft2	65.1	81.71	65.42	3.83	10	2.2
Qe, discharge blocked abut.,cfs	--	--	116.7	8.5	--	5.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.05	2.48	1.78	2.22	2.30	2.50
ya, depth of f/p flow, ft	0.61	0.75	0.63	2.55	1.52	2.20
--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	130	130	130	50	50	50
K2	1.05	1.05	1.05	0.93	0.93	0.93
Fr, froude number f/p flow	0.345	0.342	0.395	0.245	0.303	0.297
ys, scour depth, ft	6.35	7.23	6.91	4.04	3.89	3.49

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)	106.6	108.3	103.5	1.5	6.6	1
y1 (depth f/p flow, ft)	0.61	0.75	0.63	2.55	1.52	2.20
a'/y1	174.56	143.54	163.75	0.59	4.36	0.45
Skew correction (p. 49, fig. 16)	1.09	1.09	1.09	1.00	1.00	1.00
Froude no. f/p flow	0.35	0.34	0.40	0.24	0.30	0.30
Ys w/ corr. factor K1/0.55:						
vertical	3.40	4.19	3.69	ERR	ERR	ERR
vertical w/ ww's	2.79	3.44	3.02	ERR	ERR	ERR
spill-through	1.87	2.31	2.03	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	0.76	0.75	0.82	0.76	0.75	0.82
y, depth of flow in bridge, ft	3.68	3.68	3.68	3.68	3.68	3.68
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.31	1.28	ERR	1.31	1.28	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	1.46	ERR	ERR	1.46
Fr<=0.8 (spillthrough abut.)	1.15	1.12	ERR	1.15	1.12	ERR
Fr>0.8 (spillthrough abut.)	ERR	ERR	1.29	ERR	ERR	1.29