LEVEL II SCOUR ANALYSIS FOR BRIDGE 16 (TROYTH00290016) on TOWN HIGHWAY 29, crossing BEETLE BROOK, TROY, VERMONT

U.S. Geological Survey
Open-File Report 97-413

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

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By MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1997

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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 16 (TROYTH00290016) ON TOWN HIGHWAY 29, CROSSING BEETLE BROOK, TROY, VERMONT

By **Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure TROYTH00290016 on Town Highway 29 crossing Beetle Brook, Troy, 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 8.70-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, Beetle Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 42 ft and an average bank height of 3 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 61.9 mm (0.203 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 8, 1995, indicated that the reach was stable.

The Town Highway 29 crossing of Beetle Brook is a 26-ft-long, one-lane bridge consisting of one 23-foot log-beam span (Vermont Agency of Transportation, written communication, March 7, 1995). The opening length of the structure parallel to the bridge face is 20.0 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 5 degrees to the opening while the measured opening-skew-to-roadway is 10 degrees.

A scour hole 1.2 ft deeper than the mean thalweg depth was observed along the failed downstream right wingwall during the Level I assessment. The scour counter-measures at the site included type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream right wingwall and at the downstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). 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 1.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 9.2 to 13.4 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

North Troy, VT. Quadrangle, 1:24,000, 1986

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 TROYTH00290016 ***Stream*** Beetle Brook

County Orleans ***Road*** TH 29 ***District*** 9

Description of Bridge

Bridge length 26 ***ft*** ***Bridge width*** 14.4 ***ft*** ***Max span length*** 23 ***ft***

Alignment of bridge to road (on curve or straight) Straight, right; curve, left

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

Stone fill on abutment? No ***Date of inspection*** 6/8/95

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

Abutments and wingwalls are concrete. There is a one foot deep scour hole in front of the failed downstream right wingwall.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 5

There is a mild channel bend in the upstream reach.

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*
	6/8/95	0	0
Level I	6/8/95	0	0
Level II			

High. There are some felled trees across the channel upstream.

None 6/8/95.

Potential for debris

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

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with steep valley walls on both sides.

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

Date of inspection 6/8/95

DS left: Steep channel bank to terrace.

DS right: Moderately sloped overbank.

US left: Moderately sloped overbank.

US right: Steep valley wall.

Description of the Channel

Average top width 42 ***ft*** ***Average depth*** 3 ***ft***

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

Sinuous but stable with non-alluvial channel boundaries and no flood plain.

Vegetative co 6/8/95

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

date of observation.

The assessment of 6/8/95 noted flow conditions up to bank-full level are influenced by trees across the channel 140 ft upstream of the bridge.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 8.70 ***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 No

Calculated Discharges

Q100 1,700 ***ft³/s*** ***Q500*** 2,550 ***ft³/s***

Flood frequencies were computed using methods described in "Peak rates of runoff in the New England Hill and Lowland area" (Potter, 1957 b) and graphically extrapolated to the 100-year and 500-year discharge. These results were chosen due to their central tendency among other empirical techniques (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Talbot, 1887). For example, the Q100 result was the median and within 3 percent of the average.

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 downstream end of the left abutment (elev. 498.03 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 498.86 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	-18	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	37	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 0.048 to 0.065, and overbank "n" values ranged from 0.066 to 0.072.

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 0.013 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1986).

The approach section (APPRO) was surveyed 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 500.1 ***ft***
Average low steel elevation 498.7 ***ft***

100-year discharge 1,700 ***ft³/s***
Water-surface elevation in bridge opening 499.3 ***ft***
Road overtopping? Yes ***Discharge over road*** 600 ***ft³/s***
Area of flow in bridge opening 111 ***ft²***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.3 ***ft/s***

Water-surface elevation at Approach section with bridge 501.9
Water-surface elevation at Approach section without bridge 499.3
Amount of backwater caused by bridge 2.6 ***ft***

500-year discharge 2,550 ***ft³/s***
Water-surface elevation in bridge opening 499.3 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,280 ***ft³/s***
Area of flow in bridge opening 111 ***ft²***
Average velocity in bridge opening 11.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.2 ***ft/s***

Water-surface elevation at Approach section with bridge 502.7
Water-surface elevation at Approach section without bridge 500.4
Amount of backwater caused by bridge 2.3 ***ft***

Incipient overtopping discharge 740 ***ft³/s***
Water-surface elevation in bridge opening 499.1 ***ft***
Area of flow in bridge opening 111 ***ft²***
Average velocity in bridge opening 6.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 7.6 ***ft/s***

Water-surface elevation at Approach section with bridge 499.6
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 2.0 ***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 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, the 100-year and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow. The 500-year discharge resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Additional estimates of contraction scour also were computed by use of Laursen's clear-water scour equation (Richardson and others, 1995, p. 32, equation 20) and the results are presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting alternative estimates for the depth of flow in the bridge at the downstream face in the Chang equation and Laursen's clear-water equation. Contraction scour results with respect to these substitutions also are provided in Appendix F.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.8	1.8	0.0
Depth to armoring	8.1	15.1	10.6
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour	12.1	13.4	9.2
Left abutment	10.1	10.2	9.2
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	2.0	2.3	1.5
Left abutment	2.0	2.3	1.5
Right abutment			
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

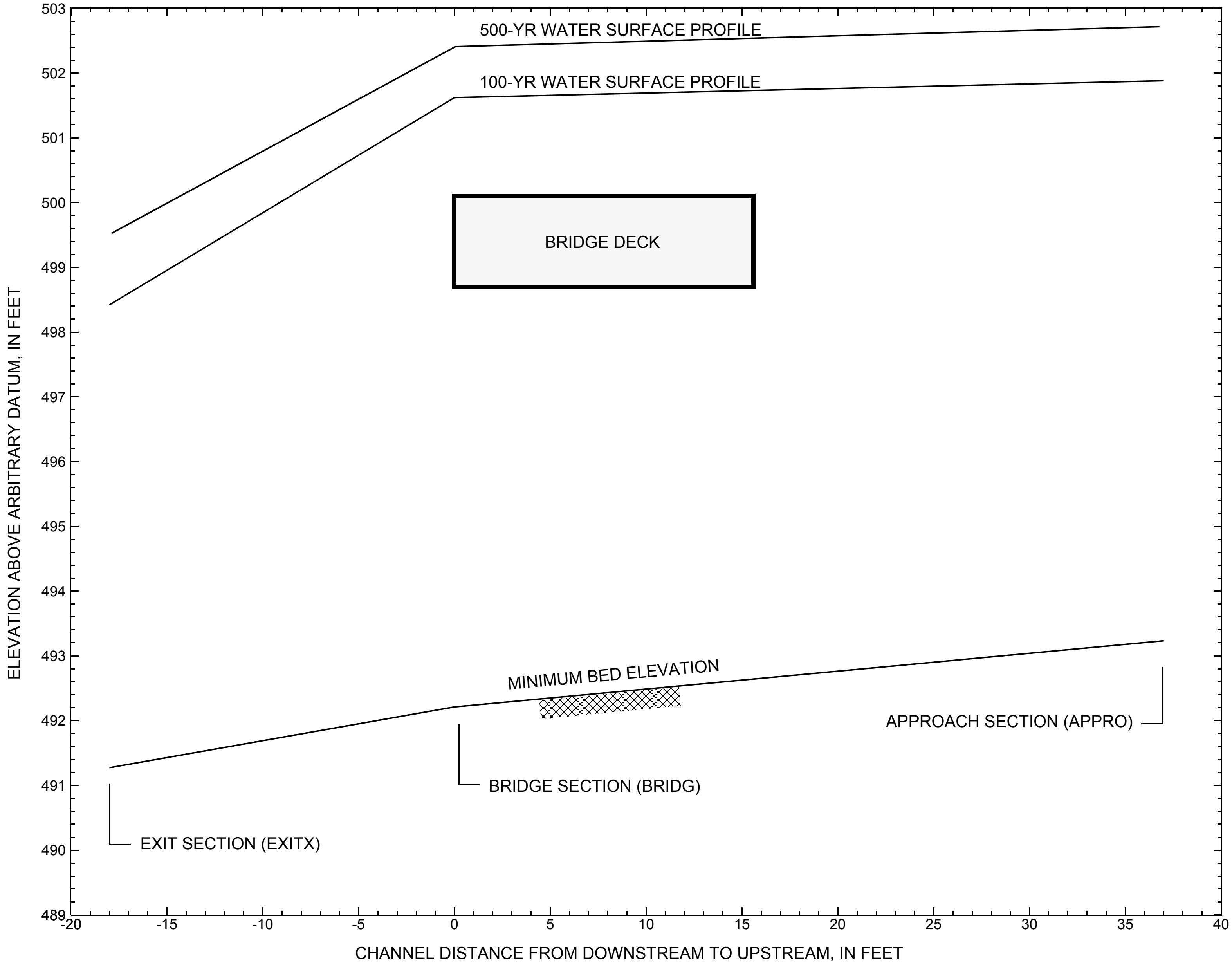

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure TROYTH00290016 on Town Highway 29, crossing Beetle Brook, Troy, Vermont.

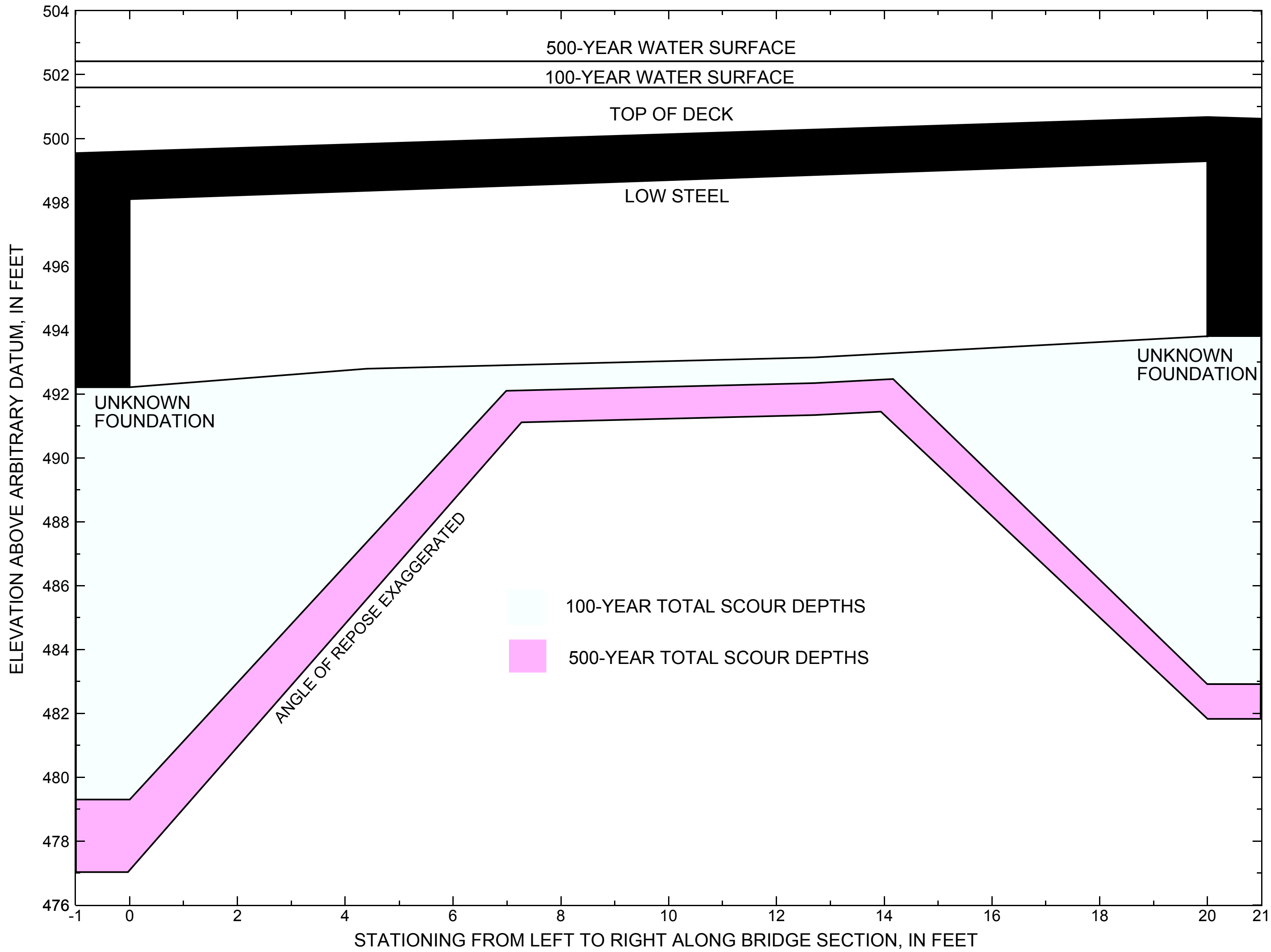

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure TROYTH00290016 on Town Highway 29, crossing Beetle Brook, Troy, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure TROYTH00290016 on Town Highway 29, crossing Beetle Brook, Troy, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,700 cubic-feet per second											
Left abutment	0.0	--	498.1	--	492.2	0.8	12.1	--	12.9	479.3	--
Right abutment	20.0	--	499.3	--	493.8	0.8	10.1	--	10.9	482.9	--

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 TROYTH00290016 on Town Highway 29, crossing Beetle Brook, Troy, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 1,850 cubic-feet per second											
Left abutment	0.0	--	498.1	--	492.2	1.8	13.4	--	15.2	477.0	--
Right abutment	20.0	--	499.3	--	493.8	1.8	10.2	--	12.0	481.8	--

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, 1986, North Troy, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File troy016.wsp
T2        Hydraulic analysis for structure TROYTH00290016   Date: 09-APR-97
T3        Bridge # 16 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1700.0   2550.0   740.0
SK          0.013    0.013    0.013
*
XS   EXITX    -18
GR          -38.0, 504.64    -27.9, 500.11    -17.9, 496.97     -5.5, 496.36
GR            0.0, 496.52      4.1, 494.32      8.8, 493.16     14.0, 491.27
GR           19.2, 492.02     23.8, 492.38     28.3, 493.26     35.7, 495.23
GR           48.0, 496.67     65.4, 498.45     79.7, 499.18
N           0.072        0.065        0.066
SA                   0.0          35.7
*
XS   FULLV      0  * * *   0.0223
*
*             SRD     LSEL    XSSKEW
BR   BRIDG      0    498.70      10.0
GR            0.0, 498.10      0.0, 492.21      4.4, 492.79     12.7, 493.14
GR           20.0, 493.81     20.0, 499.29      0.0, 498.10
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD            1      26.6 * *     54.5      9.3
N           0.048
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      14.4     2
GR         -100.0, 503.29
GR          -45.6, 500.93    -24.3, 500.33      0.0, 499.59     23.4, 500.67
GR           46.1, 501.20     46.1, 508.00
*
AS   APPRO     37
GR         -100.0, 503.29
GR          -45.1, 498.71    -23.7, 498.12    -18.6, 497.07    -12.0, 494.87
GR           -7.6, 494.72      0.0, 493.99     13.2, 493.78     18.9, 493.23
GR           25.8, 493.98     29.9, 499.35     35.1, 502.67     39.0, 504.36
GR           44.0, 508.39
N           0.072        0.065
SA                 -23.7
*
HP 1 BRIDG   499.29 1 499.29
HP 2 BRIDG   499.29 * * 1088
* Downstream bridge face
HP 1 BRIDG   498.61 1 498.61
HP 2 RDWAY   501.62 * * 600
HP 1 APPRO   501.88 1 501.88
HP 2 APPRO   501.88 * * 1700
*
HP 1 BRIDG   499.29 1 499.29
HP 2 BRIDG   499.29 * * 1270
HP 2 RDWAY   502.41 * * 1280
HP 1 APPRO   502.73 1 502.73
HP 2 APPRO   502.73 * * 2550
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File troy016.wsp
        Hydraulic analysis for structure TROYTH00290016   Date: 09-APR-97
        Bridge # 16 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
           *** RUN DATE & TIME: 05-19-97  15:37
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     111.    5814.     0.    51.                           0.
   499.29          111.    5814.     0.    51.  1.00     0.    20.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.29     0.0    20.0   111.2    5814.    1088.   9.78

X STA.         0.0        1.6        2.7        3.7        4.6        5.6
  A(I)             9.4        6.1        5.4        5.3        5.1
  V(I)            5.78       8.95      10.10      10.28      10.76

X STA.         5.6        6.5        7.4        8.3        9.1       10.0
  A(I)             5.1        4.9        4.9        4.8        4.8
  V(I)           10.76      11.03      11.15      11.25      11.22

X STA.        10.0       10.9       11.7       12.6       13.4       14.3
  A(I)             4.8        4.8        4.9        4.9        4.9
  V(I)           11.31      11.28      11.12      11.21      11.05

X STA.        14.3       15.3       16.2       17.2       18.3       20.0
  A(I)             5.1        5.1        5.6        6.0        9.3
  V(I)           10.58      10.72       9.78       9.04       5.83

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     107.    6557.    11.    39.                        1882.
   498.61          107.    6557.    11.    39.  1.00     0.    20.   1882.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.62   -61.5    46.1   117.3    2740.     600.   5.11

X STA.       -61.5      -38.1      -30.4      -24.5      -19.8      -15.8
  A(I)            11.5        7.8        7.0        6.3        6.0
  V(I)            2.61       3.85       4.26       4.74       5.04

X STA.       -15.8      -12.4       -9.2       -6.5       -3.9       -1.5
  A(I)             5.5        5.3        5.0        4.8        4.7
  V(I)            5.41       5.63       6.05       6.29       6.44

X STA.        -1.5        0.6        2.7        5.0        7.5       10.4
  A(I)             4.3        4.0        4.2        4.4        4.7
  V(I)            6.99       7.42       7.10       6.78       6.43

X STA.        10.4       13.7       17.8       23.4       31.6       46.1
  A(I)             4.9        5.3        6.1        7.0        8.6
  V(I)            6.11       5.65       4.92       4.31       3.51

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      37.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     134.    4785.    59.    60.                        1147.
             2     386.   30096.    58.    62.                        5672.
   501.88          520.   34881.   117.   121.  1.21    -83.    34.   5671.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      37.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.88   -83.1    33.9   520.4   34881.    1700.   3.27

X STA.       -83.1      -44.7      -31.7      -21.8      -15.9      -12.2
  A(I)            61.5       43.8       36.7       28.3       23.4
  V(I)            1.38       1.94       2.32       3.00       3.63

X STA.       -12.2       -9.2       -6.2       -3.4       -0.9        1.7
  A(I)            21.4       21.3       20.5       19.9       19.8
  V(I)            3.97       4.00       4.14       4.27       4.29

X STA.         1.7        4.1        6.6        9.0       11.5       13.9
  A(I)            19.7       19.8       19.4       19.8       19.8
  V(I)            4.32       4.30       4.38       4.29       4.29

X STA.        13.9       16.4       18.8       21.4       24.3       33.9
  A(I)            20.6       20.6       21.7       24.0       38.4
  V(I)            4.13       4.12       3.92       3.54       2.22
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        U.S. Geological Survey WSPRO Input File troy016.wsp
        Hydraulic analysis for structure TROYTH00290016   Date: 09-APR-97
        Bridge # 16 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
           *** RUN DATE & TIME: 07-14-97  12:00
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     111.    5814.     0.    51.                          0.
   499.29          111.    5814.     0.    51.  1.00     0.    20.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.29     0.0    20.0   111.2    5814.    1270.  11.42

 X STA.        0.0        1.6        2.7        3.7        4.6        5.6
   A(I)            9.4        6.1        5.4        5.3        5.1
   V(I)           6.75      10.45      11.79      12.00      12.56

 X STA.        5.6        6.5        7.4        8.3        9.1       10.0
   A(I)            5.1        4.9        4.9        4.8        4.8
   V(I)          12.56      12.88      13.01      13.13      13.09

 X STA.       10.0       10.9       11.7       12.6       13.4       14.3
   A(I)            4.8        4.8        4.9        4.9        4.9
   V(I)          13.20      13.17      12.98      13.08      12.90

 X STA.       14.3       15.3       16.2       17.2       18.3       20.0
   A(I)            5.1        5.1        5.6        6.0        9.3
   V(I)          12.35      12.52      11.42      10.55       6.80

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.41   -79.7    46.1   209.5    6429.    1280.   6.11

 X STA.      -79.7      -48.6      -38.8      -31.6      -25.7      -20.4
   A(I)           21.0       14.9       12.9       11.5       11.2
   V(I)           3.04       4.31       4.96       5.58       5.72

 X STA.      -20.4      -15.9      -11.9       -8.2       -4.7       -1.6
   A(I)           10.2        9.7        9.3        9.1        8.6
   V(I)           6.28       6.61       6.86       7.05       7.45

 X STA.       -1.6        1.2        4.0        7.0       10.3       14.0
   A(I)            7.9        7.4        7.7        8.0        8.5
   V(I)           8.13       8.69       8.29       8.05       7.49

 X STA.       14.0       18.2       23.3       29.3       36.4       46.1
   A(I)            8.7        9.4       10.1       10.8       12.8
   V(I)           7.39       6.81       6.35       5.91       5.00

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      37.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     189.    7614.    70.    70.                       1770.
             2     435.   36168.    59.    63.                       6717.
   502.73          625.   43782.   129.   133.  1.22   -93.    35.   7083.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      37.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.73   -93.3    35.2   624.7   43782.    2550.   4.08

 X STA.      -93.3      -51.0      -38.6      -28.3      -20.1      -15.1
   A(I)           74.7       48.9       44.6       38.9       29.9
   V(I)           1.71       2.61       2.86       3.28       4.26

 X STA.      -15.1      -11.6       -8.5       -5.5       -2.6        0.1
   A(I)           26.4       24.6       24.3       23.9       23.2
   V(I)           4.83       5.19       5.24       5.33       5.50

 X STA.        0.1        2.7        5.4        7.9       10.6       13.2
   A(I)           23.1       23.2       22.8       23.2       23.8
   V(I)           5.52       5.50       5.60       5.49       5.36

 X STA.       13.2       15.9       18.4       21.3       24.4       35.2
   A(I)           24.1       24.1       26.4       28.4       46.2
   V(I)           5.30       5.29       4.83       4.49       2.76
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        U.S. Geological Survey WSPRO Input File troy016.wsp
        Hydraulic analysis for structure TROYTH00290016   Date: 09-APR-97
        Bridge # 16 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
           *** RUN DATE & TIME: 05-19-97  15:37

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     111.    6068.     3.    47.                        3641.
   499.09          111.    6068.     3.    47.  1.00     0.    20.   3641.



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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.09     0.0    20.0   110.9    6068.     740.   6.67

X STA.        0.0         1.7         2.8         3.9         4.8         5.8
  A(I)             9.8         6.3         5.8         5.3         5.4
  V(I)            3.78        5.86        6.43        6.94        6.88

X STA.        5.8         6.7         7.7         8.6         9.5        10.4
  A(I)             5.1         5.2         5.1         5.0         5.0
  V(I)            7.20        7.10        7.32        7.38        7.36

X STA.       10.4        11.3        12.2        13.0        13.9        14.8
  A(I)             5.0         5.0         4.9         4.9         5.0
  V(I)            7.43        7.41        7.57        7.48        7.37

X STA.       14.8        15.7        16.6        17.4        18.3        20.0
  A(I)             5.0         5.1         4.4         4.9         8.7
  V(I)            7.45        7.22        8.47        7.62        4.25


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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      75.    4589.    20.    28.                         838.
   496.88           75.    4589.    20.    28.  1.00     0.    20.    838.



    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      37.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      30.     606.    32.    32.                         168.
             2     259.   16266.    54.    57.                        3225.
   499.61          290.   16872.    86.    90.  1.12   -56.    30.   2845.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      37.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.61   -55.9    30.3   289.8   16872.     740.   2.55

X STA.      -55.9       -19.9       -13.8       -10.5        -7.7        -5.0
  A(I)            37.7        19.1        14.9        13.8        13.4
  V(I)            0.98        1.94        2.48        2.69        2.76

X STA.       -5.0        -2.6        -0.3         1.8         4.0         6.0
  A(I)            12.7        12.6        12.0        12.1        11.8
  V(I)            2.92        2.95        3.09        3.06        3.14

X STA.        6.0         8.1        10.1        12.2        14.2        16.1
  A(I)            11.8        11.9        11.7        11.7        11.9
  V(I)            3.13        3.11        3.17        3.16        3.11

X STA.       16.1        18.0        19.9        21.9        24.2        30.3
  A(I)            11.6        12.0        12.2        13.9        21.1
  V(I)            3.19        3.08        3.03        2.66        1.76
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        U.S. Geological Survey WSPRO Input File troy016.wsp
        Hydraulic analysis for structure TROYTH00290016   Date: 09-APR-97
        Bridge # 16 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
           *** RUN DATE & TIME: 05-19-97  15:37

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

EXITX:XS   ******   -23.     268.  0.80 *****  499.21  497.56   1700.  498.42
      -18. ******    65.   14900.  1.27 ***** *******    0.72    6.35

FULLV:FV      18.   -22.     250.  0.91  0.26  499.52 *******   1700.  498.61
        0.    18.    63.   13659.  1.26  0.06   -0.01    0.79    6.81
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      37.   -52.     266.  0.70  0.52  500.03 *******   1700.  499.33
       37.    37.    30.   15167.  1.10  0.00   -0.01    0.66    6.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   504.24       0.00     498.50     499.59

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   498.47     501.43     501.56     498.70

 ===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      18.     0.     111.  1.49 *****  500.78  497.62   1088.  499.29
        0. ******    20.    5814.  1.00 ***** *******    0.73    9.78

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.496  0.000  498.70 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    23.  0.05  0.20  502.03   -0.01    600.  501.62

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    448.    72.   -62.    11.   2.0   1.2   5.8   5.2   1.6   3.1
   RT:    152.    35.    11.    46.   1.5   0.9   5.0   4.9   1.3   2.9

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

APPRO:AS      10.   -83.     520.  0.20  0.12  502.08  497.87   1700.  501.88
       37.    12.    34.   34876.  1.21  0.96   -0.01    0.30    3.27

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -18.   -23.    65.   1700.   14900.     268.    6.35  498.42
   FULLV:FV       0.   -22.    63.   1700.   13659.     250.    6.81  498.61
   BRIDG:BR       0.     0.    20.   1088.    5814.     111.    9.78  499.29
   RDWAY:RG       8.*******   448.    600.******************    2.00  501.62
   APPRO:AS      37.   -83.    34.   1700.   34876.     520.    3.27  501.88

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    497.56    0.72  491.27  504.64************  0.80  499.21  498.42
   FULLV:FV  ********    0.79  491.67  505.04  0.26  0.06  0.91  499.52  498.61
   BRIDG:BR    497.62    0.73  492.21  499.29************  1.49  500.78  499.29
   RDWAY:RG  ****************  499.59  508.00  0.05******  0.20  502.03  501.62
   APPRO:AS    497.87    0.30  493.23  508.39  0.12  0.96  0.20  502.08  501.88
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WSPRO OUTPUT FILE (continued)

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       U.S. Geological Survey WSPRO Input File troy016.wsp
       Hydraulic analysis for structure TROYTH00290016   Date: 09-APR-97
       Bridge # 16 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
          *** RUN DATE & TIME: 07-14-97  11:55

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

EXITX:XS   ******   -26.     372.  0.95 *****  500.44  498.48   2550.  499.48
      -18. ******    80.   22349.  1.31 ***** *******    0.74    6.85

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
           FNTEST,FR#,WSEL,CRWS =  0.80    0.81     499.67     498.88

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   498.98     505.04    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   498.98     505.04     498.88

 ===140 AT SECID "FULLV":  END OF CROSS SECTION EXTENDED VERTICALLY.
                          WSEL,YLT,YRT =   499.66     505.04     499.58

FULLV:FV      18.   -25.     349.  1.09  0.25  500.76  498.88   2550.  499.66
        0.    18.    80.   20541.  1.32  0.07    0.00    0.81    7.30
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      37.   -65.     358.  0.92  0.53  501.28 *******   2550.  500.36
       37.    37.    31.   21956.  1.16  0.00   -0.01    0.70    7.11
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   499.66     498.70

            <<<<<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      18.     0.     111.  2.05 *****  501.34  498.10   1278.  499.29
        0. ******    20.    5814.  1.00 ***** *******    0.86   11.49

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.70 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    23.  0.08  0.32  502.97    0.00   1280.  502.41

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    916.    90.   -80.    10.   2.8   1.7   6.9   6.2   2.2   3.1
   RT:    364.    36.    10.    46.   2.4   1.7   6.7   6.0   2.2   3.0

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

APPRO:AS      10.   -93.     625.  0.32  0.18  503.05  499.09   2550.  502.73
       37.    13.    35.   43795.  1.22  0.96    0.00    0.36    4.08

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -18.   -26.    80.   2550.   22349.     372.    6.85  499.48
   FULLV:FV       0.   -25.    80.   2550.   20541.     349.    7.30  499.66
   BRIDG:BR       0.     0.    20.   1278.    5814.     111.   11.49  499.29
   RDWAY:RG       8.*******   916.   1280.******************    2.00  502.41
   APPRO:AS      37.   -93.    35.   2550.   43795.     625.    4.08  502.73

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    498.48    0.74  491.27  504.64************  0.95  500.44  499.48
   FULLV:FV    498.88    0.81  491.67  505.04  0.25  0.07  1.09  500.76  499.66
   BRIDG:BR    498.10    0.86  492.21  499.29************  2.05  501.34  499.29
   RDWAY:RG  ****************  499.59  508.00  0.08******  0.32  502.97  502.41
   APPRO:AS    499.09    0.36  493.23  508.39  0.18  0.96  0.32  503.05  502.73
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WSPRO OUTPUT FILE (continued)

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       U.S. Geological Survey WSPRO Input File troy016.wsp
       Hydraulic analysis for structure TROYTH00290016   Date: 09-APR-97
       Bridge # 16 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
          *** RUN DATE & TIME: 05-19-97  15:37

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

EXITX:XS   ******   -12.     134.  0.52 *****  497.17  495.53    740.  496.66
      -18. ******    48.    6487.  1.10 ***** *******    0.68    5.50

FULLV:FV      18.    -8.     124.  0.59  0.26  497.47 *******    740.  496.88
        0.    18.    46.    5910.  1.06  0.03    0.00    0.71    5.95
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      37.   -21.     152.  0.37  0.48  497.94 *******    740.  497.58
       37.    37.    29.    7152.  1.00  0.00    0.00    0.49    4.86
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   496.57     499.09     499.20     498.70

 ===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      18.     0.     111.  0.68 *****  499.76  496.55    732.  499.09
        0. ******    20.    6073.  1.00 ***** *******    0.49    6.60

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.426  0.000  498.70 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<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      10.   -56.     290.  0.11  0.06  499.72  496.25    740.  499.61
       37.    12.    30.   16862.  1.12  0.89   -0.01    0.26    2.55



  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -18.   -12.    48.    740.    6487.     134.    5.50  496.66
   FULLV:FV      0.     -8.    46.    740.    5910.     124.    5.95  496.88
   BRIDG:BR      0.      0.    20.    732.    6073.     111.    6.60  499.09
   RDWAY:RG       8.**************      0.       0.       0.    2.00********
   APPRO:AS      37.   -56.    30.    740.   16862.     290.    2.55  499.61


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    495.53    0.68  491.27  504.64************  0.52  497.17  496.66
   FULLV:FV  ********    0.71  491.67  505.04  0.26  0.03  0.59  497.47  496.88
   BRIDG:BR    496.55    0.49  492.21  499.29************  0.68  499.76  499.09
   RDWAY:RG  ****************  499.59  508.00************  0.11  499.68********
   APPRO:AS    496.25    0.26  493.23  508.39  0.06  0.89  0.11  499.72  499.61
```
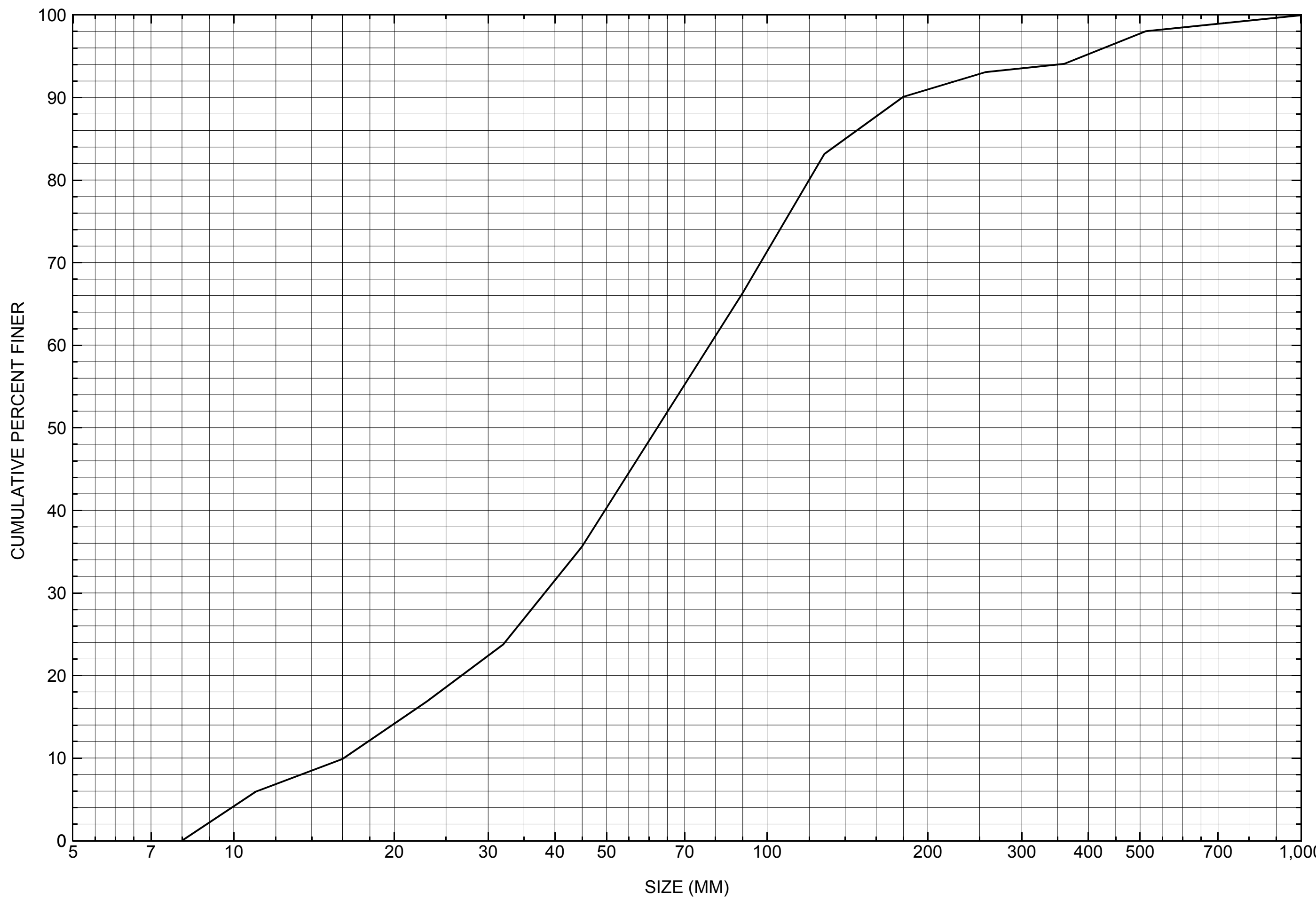

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure TROYTH00290016, in Troy, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number TROYTH00290016

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 07 / 95

Highway District Number *(I - 2; nn)* 09

County *(FIPS county code; I - 3; nnn)* 019

Town *(FIPS place code; I - 4; nnnnn)* 73525

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

Waterway *(I - 6)* BEETLE BROOK

Road Name *(I - 7):* -

Route Number TH029

Vicinity *(I - 9)* 0.3 MI TO JCT W CL3 TH28

Topographic Map North Troy

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44537

Longitude *(i - 17; nnnnn.n)* 72232

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10101700161017

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

Maximum span length *(I - 48; nnnn)* 0023

Year built *(I - 27; YYYY)* 1946

Structure length *(I - 49; nnnnnn)* 000026

Average daily traffic, ADT *(I - 29; nnnnnn)* 000002

Deck Width *(I - 52; nn.n)* 144

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 702

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 22.0

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

Vertical clearance from streambed (*nnn.n ft*) 4.5

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

Waterway of full opening (*nnn.n* ft^2) 99.0

Comments:

The structural inspection report of 6/29/93 indicates the structure is a log stringer type bridge. Both concrete abutments are noted as leaning forward. The forward leaning of the right abutment is about 0.5 feet per 4 feet of wall. The upstream right wingwall leans forward excessively, and has all but fallen over (failed). The downstream right wingwall has failed and is lying in the channel. The upstream left wingwall has rotated backwards, and is lying on the road embankment material. The downstream left wingwall is leaning downstream excessively. The waterway has a skewed alignment to the abutments. The streambed consist of stone and gravel with a few medium to large sized boulders. **(Continued, page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: **Mountain stream**

Streambed material: **Stone and gravel with a few medium to large sized boulders.**

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

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

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

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

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

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

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

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

Comments:

Roughly 200 feet upstream there is a cluster of trees that have fallen across the channel. There is some minor to heavy bank erosion noted upstream from the right abutment. The bridge opening is noted as shallow (constrictive). There is no stone fill protection reported.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **8.70** mi^2 Lake/pond/swamp area **0.03** mi^2

Watershed storage *(ST)* **0.3** %

Bridge site elevation **761** ft Headwater elevation **2146** ft

Main channel length **4.96** mi

10% channel length elevation **846** ft 85% channel length elevation **1240** ft

Main channel slope *(S)* **105.79** 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: 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:

-

Comments:

The footing type may be inferred as a gravity type from the structural inspection. The surrounding streambed material is regolith.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low 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: **NO CROSS SECTION INFORMATION**

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: **4/5/96**
Computerized by: **RB** Date: **4/8/96**
Reviewd by: **MAI** Date: **6/3/97**

Structure Number **TROYTH00290016**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **6** / **8** / 19**95**

2. Highway District Number **09** Mile marker **000**
County **019 ORLEANS** Town **TROY**
Waterway *(I - 6)* **BEETLE BROOK** Road Name **-**
Route Number **TH029** Hydrologic Unit Code: **0201007**

3. Descriptive comments:
The site is located 0.3 miles from the junction with town highway 28.

B. Bridge Deck Observations

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

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

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

7. Bridge length **26** *(feet)* Span length **23** *(feet)* Bridge width **14.4** *(feet)*

Road approach to bridge:

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

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

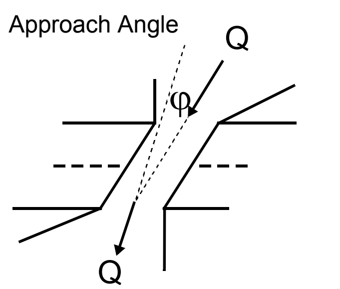
10. Embankment slope (*run / rise in feet / foot*):
US left **--:1** US right **--:1**

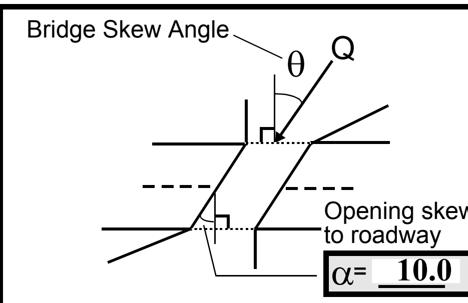
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	3	3
RBUS	0	-	3	2
RBDS	0	-	3	3
LBDS	0	-	2	2

*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: **0** 16. Bridge skew: **5**





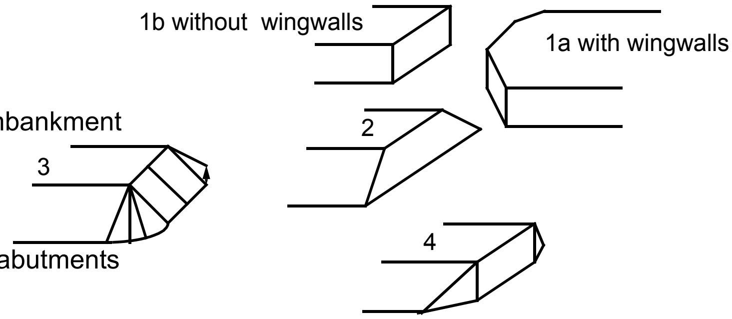
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **35** feet **US** *(US, UB, DS)* to **0** feet **DS**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **0** feet **US** *(US, UB, DS)* to **30** feet **US**

*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 the abutment 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.)

7. The values are from the VT AOT files. The measured span length is 21.5 feet. The abutment lean is as noted on the state inspection of 6/29/93.
13. Road embankment erosion is extensive due to a combination of the wingwalls leaning, the DS right wingwall failure and road wash.
17. Impact zone 1 extends along the right bank to the DS bridge face with an outcrop of material at the US end of the US right wingwall.
18. The tops of the wingwalls are leaning away from the stream and the DS right wingwall is lying horizontal in the channel.

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
22.0	2.0			5.5	4	4	435	345	1	2

23. Bank width **20.0** 24. Channel width **50.0** 25. Thalweg depth **48.5** 29. Bed Material **453**

30 .Bank protection type: LB **0** RB **0** 31. 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*

32. Comments (bank material variation, minor inflows, protection extent, etc.):
27. The left bank material is cobble and gravel with some boulders. The right bank consists of gravel and cobble with some boulders.
28. The right bank erosion has caused a slumping of material with the trees leaning over the channel. There are trees across the channel 140 feet upstream of the bridge.
29. The bed material is cobble and boulders with gravel.

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.):

NO POINT BARS

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

41. Mid-bank distance: **20** 42. Cut bank extent: **10** feet **US** *(US, UB)* to **35** feet **US** *(US, UB, DS)*

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

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

-

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
38.0		**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

The bed is cobble and boulder with gravel.

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

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

The high debris potential is due to the live trees leaning over the channel and the fallen trees in the channel 140 feet US. The capture efficiency is moderate because the span is 50% of the US bank width and the deck is 5 feet from the stream bed.

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		0	90	2	3	0	0.25	90.0
RABUT	1	10	90			2	5	19.5

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

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

0

0.25

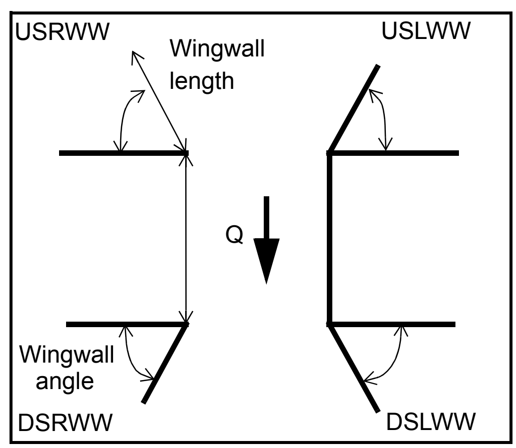
1

The left abutment is undermined about 3 inches with a penetration of 6 inches at the junction with the upstream left wingwall. There is no apparent footing. The right abutment is settled and is leaning into the channel as noted in the state inspection of 6/29/93. This abutment is also undermined at the DS end about 3 inches with 6 inches of penetration. Both abutment walls have boulders protruding from the concrete at the base.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						19.5	
USRWW:	Y		1		6	0.0	
DSLWW:	1		-		Y	15.5	
DSRWW:	1		6		0	15.5	

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	-	6	Y	0	-	2	-	-
Condition	Y	0	1	-	-	2	-	-
Extent	1	-	6	0	2	0	0	-

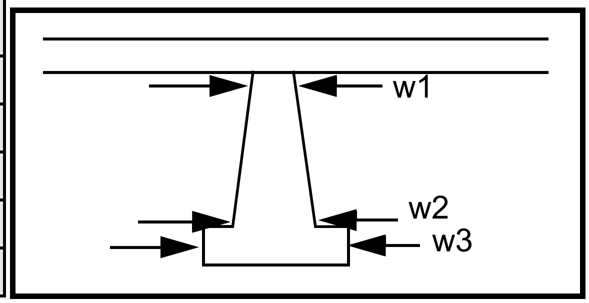
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
2
1
0
-
-

Piers:

84. Are there piers? **All** (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				**35.0**	**19.0**	**70.0**
Pier 2				**11.0**	**30.0**	**14.0**
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**the**	**chan-**	**There**	**ing has**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**wing**	**nel**	**are**	**occu**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**walls**	**with**	**no**	**rred**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**have**	**the**	**foot-**	**on**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**set-**	**DS**	**ings**	**the**	*Y- yes; N- no*
91. Attack ∠ (BF)	**tled**	**right**	**on**	**US**	
92. Pushed	**and**	**wing**	**the**	**left**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**are**	**wall**	**wing**	**wing**	
95. Cross-members	**lean-**	**lying**	**walls**	**wall.**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**ing**	**on**	**and**		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**into**	**its**	**unde**		
98. Exposure depth	**the**	**face.**	**rmin**		

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

N
-
-
-

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -

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

-
NO PIERS

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

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

Bank damage: 4 (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)

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

3
453
453
1

Is channel scour present? 1 (Y or if N type ctrl-n cs) Mid-scour distance: 453

Scour dimensions: Length 0 Width 0 Depth: - Positioned - %LB to The %RB

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

material across the channel is cobble and boulder with gravel. There is some silt and sand on the over banks.

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution N

- ***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)*:

-

NO DROP STRUCTURE

N

-

-

-

-

-

109. G. Plan View Sketch

- -

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: TROYTH00290016 Town: Troy
Road Number: TH 29 County: Orleans
Stream: Beetle Brook

Initials MAI Date: 05/20/97 Checked: LKS

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

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

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1700	2550	740
Main Channel Area, ft2	386	435	259
Left overbank area, ft2	134	189	30
Right overbank area, ft2	0	0	0
Top width main channel, ft	58	59	54
Top width L overbank, ft	59	70	32
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.2032	0.2032	0.2032
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.7	7.4	4.8
y1, average depth, LOB, ft	2.3	2.7	0.9
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	34881	43782	16872
Conveyance, main channel	30096	36168	16266
Conveyance, LOB	4785	7614	606
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1466.8	2106.5	713.4
Ql, discharge, LOB, cfs	233.2	443.5	26.6
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	3.8	4.8	2.8
Vl, mean velocity, LOB, ft/s	1.7	2.3	0.9
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.0	9.2	8.6
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1700	2550	740
(Q) discharge thru bridge, cfs	1088	1270	740
Main channel conveyance	5814	5814	6068
Total conveyance	5814	5814	6068
Q2, bridge MC discharge,cfs	1088	1270	740
Main channel area, ft2	111	111	111
Main channel width (normal), ft	19.7	19.7	19.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.7	19.7	19.7
y_bridge (avg. depth at br.), ft	5.64	5.64	5.63
Dm, median (1.25*D50), ft	0.254	0.254	0.254
y2, depth in contraction,ft	5.70	6.51	4.10
ys, scour depth (y2-ybridge), ft	0.06	0.86	-1.53

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	1700	2550	740
Q, thru bridge MC, cfs	1088	1270	740
Vc, critical velocity, ft/s	9.04	9.19	8.56
Va, velocity MC approach, ft/s	3.80	4.84	2.75
Main channel width (normal), ft	19.7	19.7	19.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.7	19.7	19.7
qbr, unit discharge, ft2/s	55.2	64.5	37.6
Area of full opening, ft2	111.2	111.2	110.9
Hb, depth of full opening, ft	5.64	5.64	5.63
Fr, Froude number, bridge MC	0.73	0.86	0.49
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	107	N/A	75
**Hb, depth at downstream face, ft	5.43	N/A	3.81
**Fr, Froude number at DS face	0.77	ERR	0.89

**Cf, for downstream face (<=1.0)	1.00	N/A	1.00
Elevation of Low Steel, ft	498.7	498.7	498.7
Elevation of Bed, ft	493.06	493.06	493.07
Elevation of Approach, ft	501.88	502.73	499.61
Friction loss, approach, ft	0.12	0.18	0.06
Elevation of WS immediately US, ft	501.76	502.55	499.55
ya, depth immediately US, ft	8.70	9.49	6.48
Mean elevation of deck, ft	500.13	500.13	500.13
w, depth of overflow, ft (>=0)	1.63	2.42	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.94	0.97
**Cc, for downstream face (<=1.0)	0.93413	ERR	0.842504
Ys, scour w/Chang equation, ft	0.83	1.78	-1.08
Ys, scour w/Umbrell equation, ft	-0.62	0.31	-2.03

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

**Ys, scour w/Chang equation, ft	1.11	N/A	1.40
**Ys, scour w/Umbrell equation, ft	-0.41	N/A	-0.20

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	5.70	6.51	4.10
WSEL at downstream face, ft	498.61	--	496.88
Depth at downstream face, ft	5.43	N/A	3.81
Ys, depth of scour (Laursen), ft	0.27	N/A	0.29

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	1088	1270	740
Main channel area (DS), ft2	107	111.2	75
Main channel width (normal), ft	19.7	19.7	19.7
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	19.7	19.7	19.7
D90, ft	0.5877	0.5877	0.5877
D95, ft	1.2842	1.2842	1.2842
Dc, critical grain size, ft	0.4669	0.5796	0.5139
Pc, Decimal percent coarser than Dc	0.147	0.103	0.127
Depth to armoring, ft	8.14	15.14	10.57

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	1700	2550	740	1700	2550	740
a’, abut.length blocking flow, ft	83.1	93.3	55.9	14.2	15.5	10.6
Ae, area of blocked flow ft2	216.7	235.6	125.9	64.2	63.5	48.5
Qe, discharge blocked abut.,cfs	--	--	264.3	--	--	114.9
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.80	3.54	2.10	2.95	3.65	2.37
ya, depth of f/p flow, ft	2.61	2.53	2.25	4.52	4.10	4.58

--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	80	80	80	100	100	100
K2	0.98	0.98	0.98	1.01	1.01	1.01
Fr, froude number f/p flow	0.267	0.318	0.247	0.223	0.268	0.195
ys, scour depth, ft	12.07	13.39	9.24	10.11	10.23	9.15

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)	83.1	93.3	55.9	14.2	15.5	10.6
y1 (depth f/p flow, ft)	2.61	2.53	2.25	4.52	4.10	4.58
a’/y1	31.87	36.95	24.82	3.14	3.78	2.32
Skew correction (p. 49, fig. 16)	0.97	0.97	0.97	1.02	1.02	1.02
Froude no. f/p flow	0.27	0.32	0.25	0.22	0.27	0.20
Ys w/ corr. factor K1/0.55:						
vertical	11.86	12.17	ERR	ERR	ERR	ERR
vertical w/ ww’s	9.73	9.98	ERR	ERR	ERR	ERR
spill-through	6.52	6.69	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship

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

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.77	0.86	0.89	0.77	0.86	0.89
y, depth of flow in bridge, ft	5.43	5.64	3.81	5.43	5.64	3.81
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.99	ERR	ERR	1.99	ERR	ERR
Fr>0.8 (vertical abut.)	ERR	2.26	1.54	ERR	2.26	1.54