LEVEL II SCOUR ANALYSIS FOR BRIDGE 15 (TROYTH00290015) on TOWN HIGHWAY 29, crossing BEETLE BROOK, TROY, VERMONT

U.S. Geological Survey
Open-File Report 97-408

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

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By MICHAEL A. IVANOFF & LAURA MEDALIE

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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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 15 (TROYTH00290015) ON TOWN HIGHWAY 29, CROSSING BEETLE BROOK, TROY, VERMONT

By **Michael A. Ivanoff and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure TROYTH00290015 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 8.97-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest except for the downstream right bank which is grass.

In the study area, Beetle Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 41 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 118 mm (0.387 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 7, 1995, indicated that the reach was stable.

The Town Highway 29 crossing of Beetle Brook is a 30-ft-long, one-lane bridge consisting of one 25-foot steel-beam span (Vermont Agency of Transportation, written communication, March 7, 1994). The opening length of the structure parallel to the bridge face is 23.4 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

A scour hole 0.5 ft deeper than the mean thalweg depth was observed along the right abutment during the Level I assessment. Scour counter measures at the site include type-3 stone fill (less than 48 inches diameter) at the downstream end of the downstream right wingwall, type-2 stone fill (less than 36 inches diameter) along the downstream left wingwall and the upstream left road embankment, and type-1 stone fill (less than 12 inches diameter) at the upstream right road embankment. 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 0.6 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge. Left abutment scour ranged from 8.0 to 8.9 ft. The worst-case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 15.4 to 16.5 ft. The worst-case right abutment scour occurred at the incipient-overtopping 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 TROYTH00290015 ***Stream*** Beetle Brook

County Orleans ***Road*** TH29 ***District*** 9

Description of Bridge

Bridge length 30 ***ft*** ***Bridge width*** 15.4 ***ft*** ***Max span length*** 25 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 6/7/95

Description of stone fill Type-3, at the downstream end of the downstream right wingwall. Type-2, along the downstream left wingwall and at the upstream left road embankment. Type-1, at the upstream right road embankment.

Abutments and wingwalls are concrete. There is a half-foot deep scour hole in front of the right abutment.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 15

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*
	6/7/95	0	0
Level I	6/7/95	0	0
Level II			

Potential for debris Moderate. There is some debris caught on boulders and trees leaning over the channel upstream.

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

None 6/7/95.

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 6/7/95

DS left: Moderately sloped channel bank to a narrow terrace.

DS right: Moderately sloped channel bank to a narrow terrace.

US left: Steep valley wall

US right: Moderately sloped channel bank to a narrow terrace.

Description of the Channel

Average top width 41 ***ft*** ***Average depth*** 4 ***ft***

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

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

6/7/95

Vegetative co... Trees and brush.

DS left: Trees and brush on bank with grass on the narrow terrace.

DS right: Trees and brush.

US left: Trees and brush.

US right:

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

None noted 6/7/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 8.97 ***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***:

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 1,750 ***ft³/s*** ***Q500*** 2,500 ***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 per cent 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 upstream end of the right abutment (elev. 499.47 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the downstream right wingwall (elev. 499.76 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-26	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	42	2	Modelled Approach section (Templated from APTEM)
APTEM	49	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 0.045 to 0.065, and overbank "n" values ranged from 0.038 to 0.050.

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

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0248 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.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles for the discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.5 ***ft***
Average low steel elevation 499.9 ***ft***

100-year discharge 1,750 ***ft³/s***
Water-surface elevation in bridge opening 500.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 63 ***ft³/s***
Area of flow in bridge opening 198 ***ft²***
Average velocity in bridge opening 8.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.1 ***ft/s***

Water-surface elevation at Approach section with bridge 501.4
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 3.8 ***ft***

500-year discharge 2,500 ***ft³/s***
Water-surface elevation in bridge opening 500.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 514 ***ft³/s***
Area of flow in bridge opening 199 ***ft²***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.0 ***ft/s***

Water-surface elevation at Approach section with bridge 502.4
Water-surface elevation at Approach section without bridge 498.4
Amount of backwater caused by bridge 4.0 ***ft***

Incipient overtopping discharge 1,690 ***ft³/s***
Water-surface elevation in bridge opening 496.8 ***ft***
Area of flow in bridge opening 127 ***ft²***
Average velocity in bridge opening 13.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.8 ***ft/s***

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 497.5
Amount of backwater caused by bridge 2.6 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

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

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

Abutment scour 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	0.0	0.0	0.6
Depth to armoring	14.5	12.9	34.8
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	8.5	8.9	8.0
Right abutment	15.4	15.8	16.5
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.3	2.6	2.3
Right abutment	2.3	2.6	2.3
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

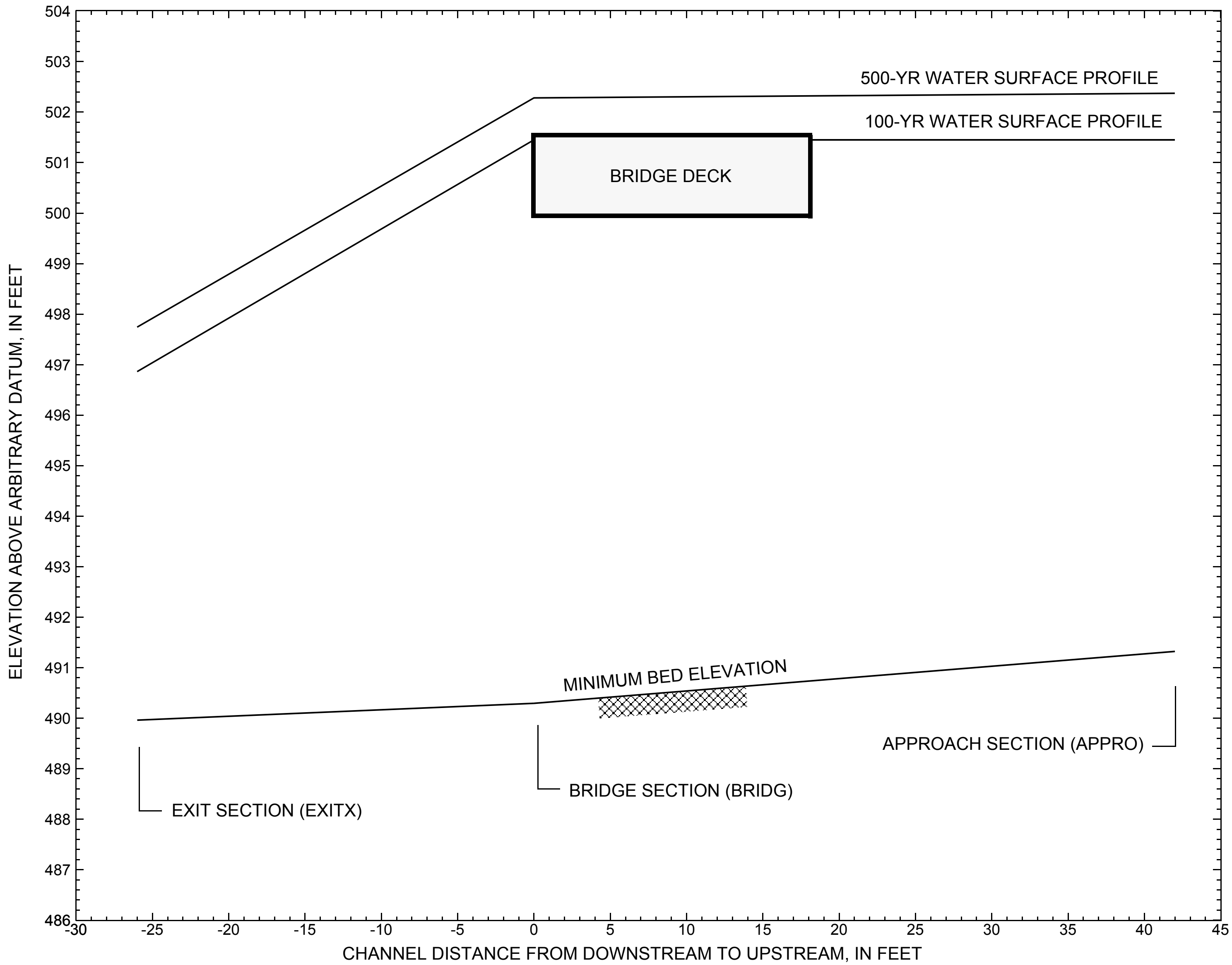

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure TROYTH00290015 on Town Highway 29, crossing Beetle Brook, Troy, Vermont.

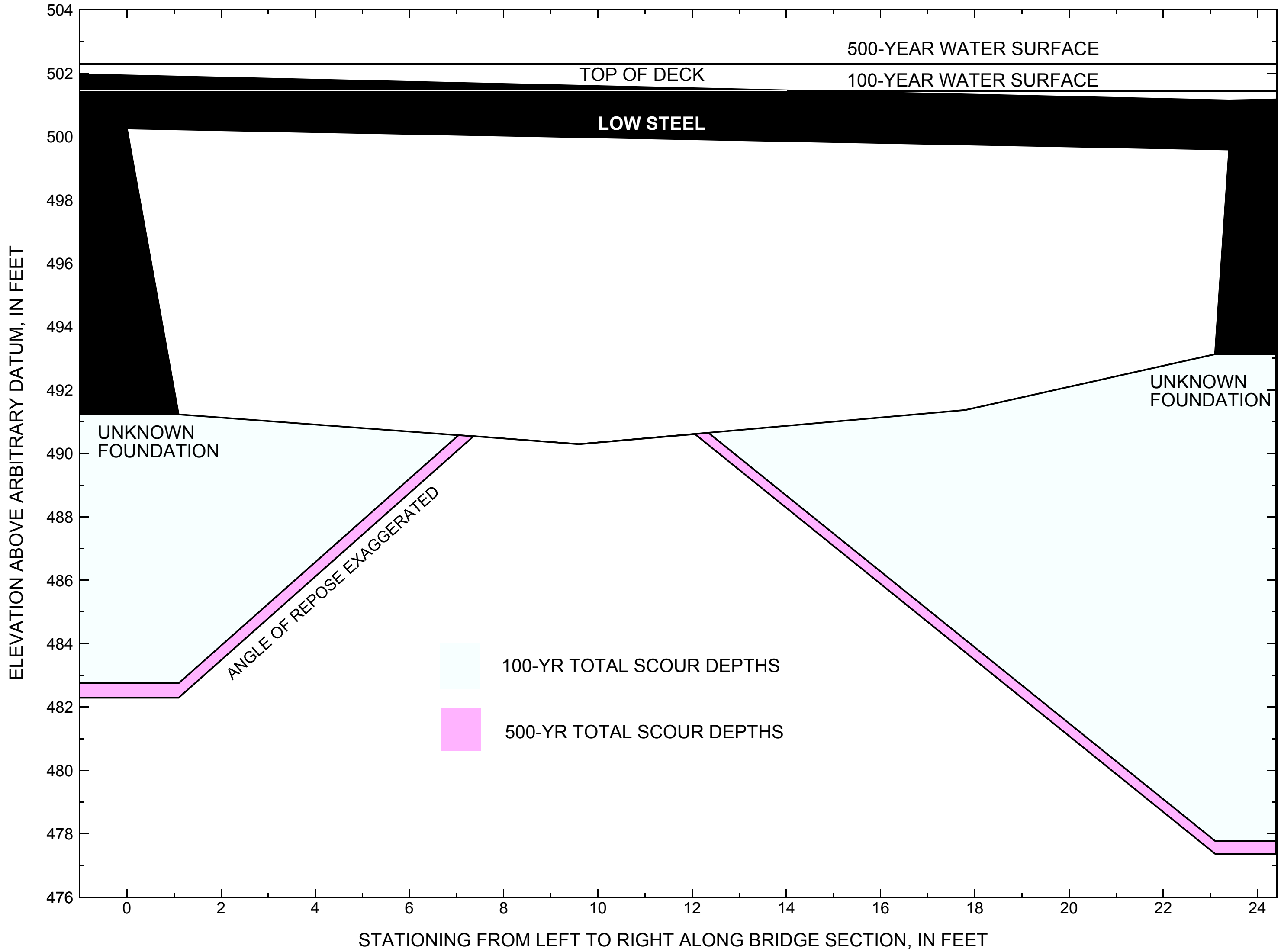

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure TROYTH00290015 on Town Highway 29, crossing Beetle Brook, Troy, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure TROYTH00290015 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 1,750 cubic-feet per second											
Left abutment	0.0	--	500.2	--	491.2	0.0	8.5	--	8.5	482.7	--
Right abutment	23.4	--	499.6	--	493.1	0.0	15.4	--	15.4	477.7	--

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 TROYTH00290015 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 2,500 cubic-feet per second											
Left abutment	0.0	--	500.2	--	491.2	0.0	8.9	--	8.9	482.3	--
Right abutment	23.4	--	499.6	--	493.1	0.0	15.8	--	15.8	477.3	--

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 troy015.wsp
T2        Hydraulic analysis for structure TROYTH00290015   Date: 09-APR-97
T3        Bridge #15 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           1750.0   2500.0   1690.0
SK          0.011    0.011    0.011
*
XS   EXITX    -26
GR          -30.1, 500.23    -15.7, 498.73      0.0, 493.44      8.2, 490.92
GR           16.1, 489.96     24.3, 491.00     37.6, 493.25     41.3, 494.87
GR           66.6, 495.43     86.3, 499.23
*
N          0.05       0.065      0.038
SA              -15.7        41.3
*
XS   FULLV      0  * * *   0.0132
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    499.92      0.0
GR            0.0, 500.25      1.1, 491.23      9.6, 490.29     17.8, 491.37
GR           23.1, 493.13     23.4, 499.59      0.0, 500.25
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      20.2 * *     12.5     10.8
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      9      15.4     2
GR          -37.4, 503.07      0.0, 501.93     25.1, 501.14    105.9, 501.13
GR          138.4, 502.34
*
XT   APTEM     49
GR          -15.0, 505.00
GR          -11.2, 502.33     -3.8, 494.95      0.0, 494.06      7.1, 492.31
GR           12.4, 491.49     21.7, 492.13     25.5, 493.76     33.3, 493.44
GR           47.4, 494.74     59.8, 497.00     94.9, 500.82    138.4, 502.34
GR          150.0, 505.00
*
AS   APPRO     42 * * * 0.0248
GT
N             0.065     0.04
SA                 25.5
*
HP 1 BRIDG   500.09 1 500.09
HP 2 BRIDG   500.09 * * 1658
*  Downstream bridge face
HP 1 BRIDG   497.15 1 497.15
HP 2 RDWAY   501.45 * * 63
HP 1 APPRO   501.45 1 501.45
HP 2 APPRO   501.45 * * 1750
*
HP 1 BRIDG   500.25 1 500.25
HP 2 BRIDG   500.25 * * 1938
*  Downstream bridge face
HP 1 BRIDG   498.04 1 498.04
HP 2 RDWAY   502.28 * * 514
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File troy015.wsp
        Hydraulic analysis for structure TROYTH00290015   Date: 09-APR-97
        Bridge #15 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
           *** RUN DATE & TIME: 05-20-97  13:42
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     198.  15334.     6.    56.                         6663.
   500.09          198.  15334.     6.    56.  1.00     0.    23.   6663.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.09     0.0    23.4   198.3   15334.    1658.   8.36

X STA.         0.0        2.5        3.5        4.4        5.2        6.1
  A(I)            17.1        9.7        8.2        7.5        7.7
  V(I)            4.85       8.58      10.07      11.10      10.78

X STA.         6.1        7.0        7.9        8.8        9.6       10.5
  A(I)             8.5        8.7        8.4        8.4        8.4
  V(I)            9.75       9.57       9.82       9.86       9.90

X STA.        10.5       11.4       12.4       13.3       14.3       15.4
  A(I)             8.8        8.6        8.9        9.2        9.3
  V(I)            9.45       9.60       9.31       9.01       8.91

X STA.        15.4       16.5       17.7       19.0       20.6       23.4
  A(I)             9.8       10.0       10.6       12.1       18.4
  V(I)            8.46       8.26       7.83       6.87       4.50

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     135.  11521.    23.    32.                         1852.
   497.15          135.  11521.    23.    32.  1.00     0.    23.   1852.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.45    15.3   114.5    28.4     441.      63.   2.22

X STA.        15.3       29.3       36.3       42.4       46.3       50.2
  A(I)             2.8        2.2        1.9        1.2        1.2
  V(I)            1.12       1.43       1.66       2.64       2.57

X STA.        50.2       54.1       58.0       61.9       65.7       69.6
  A(I)             1.2        1.2        1.2        1.2        1.2
  V(I)            2.55       2.60       2.57       2.60       2.60

X STA.        69.6       73.4       77.3       81.1       85.0       88.9
  A(I)             1.2        1.2        1.2        1.2        1.2
  V(I)            2.57       2.57       2.63       2.58       2.53

X STA.        88.9       92.7       96.6      100.6      104.7      114.5
  A(I)             1.2        1.2        1.3        1.3        1.8
  V(I)            2.61       2.53       2.47       2.40       1.78

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     285.  24410.    36.    39.                         4553.
             2     345.  30768.    92.    93.                         3777.
   501.45          630.  55178.   128.   132.  1.00   -10.   118.   7909.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.45   -10.5   117.9   629.7   55178.    1750.   2.78

X STA.       -10.5        0.2        4.6        8.1       11.1       13.9
  A(I)            50.7       36.1       31.5       29.4       28.7
  V(I)            1.73       2.42       2.78       2.97       3.04

X STA.        13.9       16.7       19.5       22.5       25.9       28.5
  A(I)            27.1       27.9       28.0       28.6       20.9
  V(I)            3.23       3.14       3.13       3.06       4.19

X STA.        28.5       31.1       33.8       36.6       39.8       43.2
  A(I)            21.1       21.4       22.8       24.5       25.7
  V(I)            4.14       4.09       3.83       3.57       3.41

X STA.        43.2       47.1       51.8       58.4       68.3      117.9
  A(I)            27.3       30.8       35.8       42.3       69.1
  V(I)            3.21       2.84       2.44       2.07       1.27
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        U.S. Geological Survey WSPRO Input File troy015.wsp
        Hydraulic analysis for structure TROYTH00290015   Date: 09-APR-97
        Bridge #15 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
           *** RUN DATE & TIME: 05-20-97  13:42
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     199.   14401.     0.    61.                          0.
   500.25          199.   14401.     0.    61.  1.00     0.    23.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.25     0.0    23.4   198.7   14401.    1938.   9.75

X STA.         0.0        2.6        3.8        4.9        5.8        6.8
  A(I)             18.2       11.3        9.8        9.1        8.9
  V(I)             5.33       8.56       9.90      10.61      10.84

X STA.         6.8        7.7        8.6        9.4       10.3       11.1
  A(I)              8.4        8.5        8.3        8.1        8.2
  V(I)            11.60      11.38      11.68      11.99      11.78

X STA.        11.1       12.0       12.9       13.8       14.8       15.8
  A(I)              8.4        8.2        8.5        8.6        8.8
  V(I)            11.60      11.78      11.43      11.27      10.97

X STA.        15.8       16.9       18.0       19.2       20.7       23.4
  A(I)              9.1        9.5       10.0       11.4       17.4
  V(I)            10.68      10.20       9.71       8.51       5.56

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     155.   14072.    23.    34.                       2282.
   498.04          155.   14072.    23.    34.  1.00     0.    23.   2282.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.28   -11.5   136.8   131.0    4242.     514.   3.92

X STA.       -11.5       20.0       29.3       37.5       43.6       47.9
  A(I)             15.3       10.2        9.4        6.9        4.9
  V(I)             1.68       2.51       2.74       3.72       5.23

X STA.        47.9       52.3       56.7       61.0       65.4       69.8
  A(I)              5.1        5.0        4.9        5.0        5.0
  V(I)             5.05       5.14       5.22       5.10       5.10

X STA.        69.8       74.3       78.7       83.2       87.7       92.3
  A(I)              5.1        5.1        5.1        5.2        5.2
  V(I)             5.06       5.05       4.99       4.93       4.90

X STA.        92.3       97.0      101.8      106.9      113.8      136.8
  A(I)              5.4        5.6        5.8        6.8        9.9
  V(I)             4.80       4.59       4.42       3.80       2.61

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     319.   28722.    37.    41.                       5305.
             2     441.   40446.   114.   114.                       4931.
   502.37          760.   69168.   151.   155.  1.00   -12.   139.   9679.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.37   -11.5   139.3   759.9   69168.    2500.   3.29

X STA.       -11.5        0.2        4.8        8.4       11.7       14.7
  A(I)             61.3       41.5       37.0       34.5       33.3
  V(I)             2.04       3.01       3.38       3.63       3.75

X STA.        14.7       17.7       20.8       24.3       27.4       30.2
  A(I)             32.6       32.9       34.3       28.0       24.7
  V(I)             3.84       3.80       3.64       4.47       5.06

X STA.        30.2       32.9       35.9       39.1       42.6       46.5
  A(I)             25.0       26.5       27.9       29.3       32.0
  V(I)             5.00       4.72       4.48       4.26       3.91

X STA.        46.5       51.2       57.1       65.5       78.3      139.3
  A(I)             35.3       38.7       45.6       54.0       85.5
  V(I)             3.54       3.23       2.74       2.31       1.46
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        U.S. Geological Survey WSPRO Input File troy015.wsp
        Hydraulic analysis for structure TROYTH00290015   Date: 09-APR-97
        Bridge #15 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
           *** RUN DATE & TIME: 05-20-97  13:42

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     127.   10555.    23.    32.                         1691.
   496.80          127.   10555.    23.    32.  1.00     0.    23.   1691.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.80     0.4    23.3   126.6   10555.    1690.  13.35

X STA.        0.4         2.9         4.2         5.2         6.2         7.1
  A(I)            12.3         7.1         6.4         5.9         5.5
  V(I)            6.87       11.87       13.30       14.30       15.36

X STA.        7.1         7.9         8.8         9.5        10.3        11.1
  A(I)             5.4         5.3         5.0         5.2         5.1
  V(I)           15.70       16.04       16.75       16.35       16.62

X STA.       11.1        12.0        12.8        13.7        14.6        15.5
  A(I)             5.1         5.2         5.2         5.4         5.5
  V(I)           16.55       16.33       16.12       15.63       15.49

X STA.       15.5        16.5        17.6        18.9        20.4        23.3
  A(I)             5.7         6.0         6.5         7.3        11.5
  V(I)           14.75       14.04       12.94       11.56        7.33


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     236.   18477.    35.    38.                         3505.
             2     241.   21628.    64.    65.                         2654.
   500.07          478.   40105.    99.   102.  1.01    -9.    90.   5918.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.07    -9.1    89.6   477.5   40105.    1690.   3.54

X STA.       -9.1         0.8         4.8         8.1        11.0        13.6
  A(I)            40.6        28.0        25.4        23.9        22.4
  V(I)            2.08        3.02        3.33        3.53        3.78

X STA.       13.6        16.2        18.8        21.5        24.7        27.5
  A(I)            22.4        21.9        22.4        23.9        18.4
  V(I)            3.77        3.86        3.78        3.53        4.59

X STA.       27.5        30.0        32.5        35.0        37.8        40.9
  A(I)            16.6        16.9        17.1        18.2        19.0
  V(I)            5.08        5.01        4.93        4.65        4.46

X STA.       40.9        44.3        48.3        53.3        61.2        89.6
  A(I)            20.3        22.3        24.7        29.4        43.9
  V(I)            4.16        3.79        3.43        2.88        1.93
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       U.S. Geological Survey WSPRO Input File troy015.wsp
       Hydraulic analysis for structure TROYTH00290015   Date: 09-APR-97
       Bridge #15 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
          *** RUN DATE & TIME: 05-20-97  13:42

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

EXITX:XS   ******   -10.     280.  0.61 *****  497.47  495.84   1750.  496.86
      -26. ******    74.   16670.  1.01 ***** *******    0.61    6.24

FULLV:FV      26.   -10.     276.  0.63  0.29  497.78 *******   1750.  497.15
        0.    26.    74.   16322.  1.01  0.01    0.01    0.62    6.34
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      42.    -7.     262.  0.70  0.45  498.27 *******   1750.  497.57
       42.    42.    67.   17355.  1.01  0.03    0.00    0.62    6.67
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   496.94     500.09     500.26     499.92

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      26.     0.     198.  1.09 *****  501.18  496.72   1658.  500.09
        0. ******    23.   15345.  1.00 ***** *******    0.51    8.36

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.433  0.000  499.92 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    27.  0.03  0.12  501.55   -0.02     63.  501.45

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.     5.     7.    11.   0.1   0.1   1.7   3.0   0.2   2.6
   RT:     63.    99.    15.   115.   0.3   0.3   2.5   2.2   0.4   2.7

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

APPRO:AS      22.   -10.     630.  0.12  0.09  501.57  496.37   1750.  501.45
       42.    26.   118.   55217.  1.00  0.52   -0.02    0.22    2.78

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL   WSEL
   EXITX:XS     -26.   -10.    74.   1750.   16670.     280.    6.24  496.86
   FULLV:FV       0.   -10.    74.   1750.   16322.     276.    6.34  497.15
   BRIDG:BR       0.     0.    23.   1658.   15345.     198.    8.36  500.09
   RDWAY:RG       9.*******     0.     63.       0.       0.    2.00  501.45
   APPRO:AS      42.   -10.   118.   1750.   55217.     630.    2.78  501.45

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    495.84    0.61  489.96  500.23************  0.61  497.47  496.86
   FULLV:FV  ********    0.62  490.30  500.57  0.29  0.01  0.63  497.78  497.15
   BRIDG:BR    496.72    0.51  490.29  500.25************  1.09  501.18  500.09
   RDWAY:RG  ****************  501.13  503.07  0.03******  0.12  501.55  501.45
   APPRO:AS    496.37    0.22  491.32  504.83  0.09  0.52  0.12  501.57  501.45
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File troy015.wsp
        Hydraulic analysis for structure TROYTH00290015   Date: 09-APR-97
        Bridge #15 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
           *** RUN DATE & TIME: 05-20-97  13:42

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

EXITX:XS   ******   -13.     358.  0.76 *****  498.50  496.59   2500.  497.74
      -26. ******    79.   23813.  1.00 ***** *******    0.62    6.98

FULLV:FV      26.   -13.     354.  0.78  0.29  498.82 *******   2500.  498.04
        0.    26.    78.   23399.  1.00  0.01    0.01    0.63    7.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      42.    -7.     330.  0.90  0.47  499.34 *******   2500.  498.44
       42.    42.    75.   23962.  1.01  0.06    0.00    0.67    7.57
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   502.56       0.00     498.48     501.13

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   498.01     501.68     501.85     499.92

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      26.     0.     199.  1.48 *****  501.73  497.34   1938.  500.25
        0. ******    23.   14401.  1.00 ***** *******    0.59    9.75

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.469  0.000  499.92 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    27.  0.03  0.17  502.51   -0.02    514.  502.28

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    28.    23.   -11.    11.   0.7   0.3   3.2   3.6   0.6   2.8
   RT:   486.   125.    11.   137.   1.1   1.0   4.8   4.0   1.2   2.9

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

APPRO:AS      22.   -12.     760.  0.17  0.13  502.54  497.25   2500.  502.37
       42.    26.   139.   69235.  1.00  0.53   -0.02    0.26    3.29

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -26.   -13.    79.   2500.   23813.     358.    6.98  497.74
   FULLV:FV       0.   -13.    78.   2500.   23399.     354.    7.06  498.04
   BRIDG:BR       0.     0.    23.   1938.   14401.     199.    9.75  500.25
   RDWAY:RG       9.*******    28.    514.       0.*********    2.00  502.28
   APPRO:AS      42.   -12.   139.   2500.   69235.     760.    3.29  502.37

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    496.59    0.62  489.96  500.23************  0.76  498.50  497.74
   FULLV:FV  ********    0.63  490.30  500.57  0.29  0.01  0.78  498.82  498.04
   BRIDG:BR    497.34    0.59  490.29  500.25************  1.48  501.73  500.25
   RDWAY:RG ****************  501.13  503.07  0.03******  0.17  502.51  502.28
   APPRO:AS    497.25    0.26  491.32  504.83  0.13  0.53  0.17  502.54  502.37
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File troy015.wsp
        Hydraulic analysis for structure TROYTH00290015   Date: 09-APR-97
        Bridge #15 on Town Highway 29 over Beetle Brook in Troy, VT by MAI
           *** RUN DATE & TIME: 05-20-97  13:42

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

EXITX:XS   ******   -10.     274.  0.60 *****  497.38  495.76   1690.  496.78
      -26. ******    74.   16111.  1.01 ***** *******    0.61    6.17

FULLV:FV      26.   -10.     270.  0.62  0.29  497.69 *******   1690.  497.07
        0.    26.    73.   15766.  1.02  0.01    0.01    0.62    6.27
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      42.    -7.     257.  0.68  0.45  498.17 *******   1690.  497.49
       42.    42.    66.   16831.  1.01  0.03    0.00    0.62    6.58
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1690.     496.80

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

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

BRIDG:BR      26.     0.     127.  2.77 *****  499.57  496.80   1690.  496.80
        0.    26.    23.   10552.  1.00 ***** *******    1.00   13.35

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  499.92 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG       9.         <<<<<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      22.    -9.     478.  0.20  0.18  500.27  496.28   1690.  500.07
       42.    26.    90.   40104.  1.01  0.52    0.00    0.29    3.54

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.684  0.547   18134.    11.    34.   500.02

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW     REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -26.   -10.     74.   1690.   16111.     274.    6.17  496.78
   FULLV:FV       0.   -10.     73.   1690.   15766.     270.    6.27  497.07
   BRIDG:BR       0.     0.     23.   1690.   10552.     127.   13.35  496.80
   RDWAY:RG       9.**************       0.******************    2.00********
   APPRO:AS      42.    -9.     90.   1690.   40104.     478.    3.54  500.07

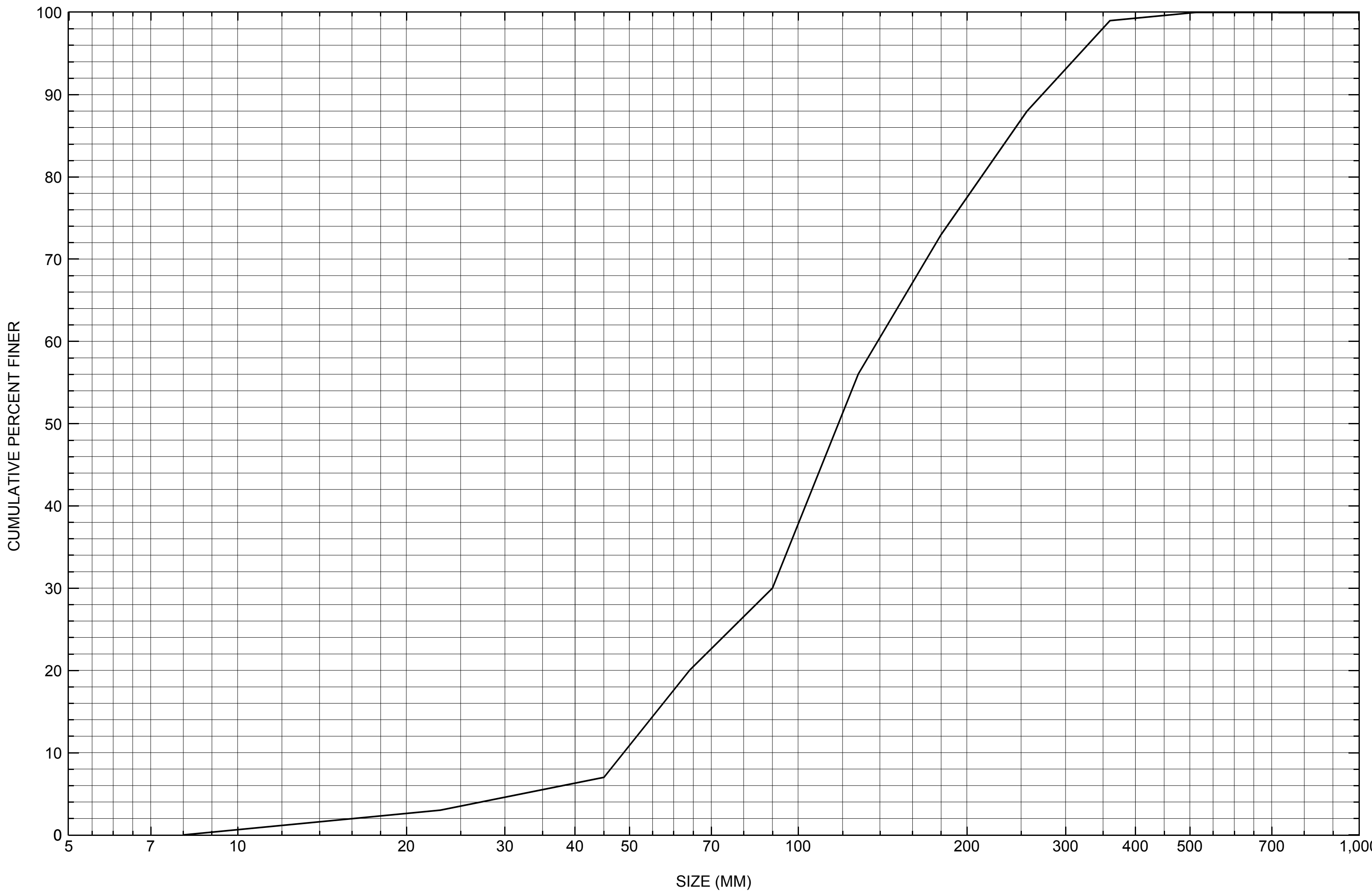
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      11.    34.   18134.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    495.76    0.61  489.96  500.23************  0.60  497.38  496.78
   FULLV:FV  ********    0.62  490.30  500.57  0.29  0.01  0.62  497.69  497.07
   BRIDG:BR    496.80    1.00  490.29  500.25************  2.77  499.57  496.80
   RDWAY:RG  ****************  501.13  503.07**********************************
   APPRO:AS    496.28    0.29  491.32  504.83  0.18  0.52  0.20  500.27  500.07
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure TROYTH00290015, in Troy, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number TROYTH00290015

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)* 0.05 MI TO JCT W C3 TH28

Topographic Map North Troy

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44538

Longitude *(i - 17; nnnnn.n)* 72233

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10101700151017

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

Maximum span length *(I - 48; nnnn)* 0025

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

Structure length *(I - 49; nnnnnn)* 000030

Average daily traffic, ADT *(I - 29; nnnnnn)* 000030

Deck Width *(I - 52; nn.n)* 154

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)* 302

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 25.0

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

Vertical clearance from streambed (*nnn.n ft*) 9.0

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

Waterway of full opening (*nnn.n ft²*) 225.0

Comments:

The structural inspection report of 6/29/93 indicates the structure is a single span steel stringer type bridge with a timber deck. The abutment walls are both concrete. The right abutment has some voids along the bottom upstream half of the wall. The left abutment wall has a vertical crack at the top of the wall, which narrows from the top to the base. There is some free poured concrete resembling a footing along the base of the left abutment, which has some stones cast into it. There are some voids noted below the free-poured concrete. The waterway has a somewhat skewed alignment through the bridge. The streambed is composed of gravel and stone, with numerous medium sized boulders. **(Continued, page 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: **Mountain stream**

Streambed material: **Stone, gravel, and numerous medium 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} (*ft^3/ sec*): -

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

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

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

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

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

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

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

Comments:

The inspection noted some slight degradation of the streambed since the construction of the abutments. Channel general scour is estimated at 1 to 1.5 feet since the abutments were built. Bank erosion is noted as minor. No debris is noted. Stone fill protection is noted as very little along the abutments.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **8.97** mi^2 Lake/pond/swamp area **0.03** mi^2

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

Bridge site elevation **773** ft Headwater elevation **2146** ft

Main channel length **5.27** mi

10% channel length elevation **846** ft 85% channel length elevation **1245** ft

Main channel slope *(S)* **100.88** 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? 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: 3 (*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 foundation type noted was inferred based on the structural inspection. The foundation material is likely just regolith based on notes in the structural inspection. Some settlement is noted as possible consistent with cracking of the left abutment wall.

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: **4/3/96**
Computerized by: **RB** Date: **4/5/96**
Reviewd by: **MAL** Date: **5/28/97**

Structure Number **TROYTH00290015**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. MEDALIE** Date *(MM/DD/YY)* **06** / **07** / 19**95**
2. Highway District Number **09** Mile marker **0000**
County **Orleans (019)** Town **Troy (73525)**
Waterway *(I - 6)* **BETTLE BROOK** Road Name **-**
Route Number **TH029** Hydrologic Unit Code: **02010007**
3. Descriptive comments:
Located 0.05 miles to the junction with C3 TH28.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **4** 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 **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 **30** *(feet)* Span length **25** *(feet)* Bridge width **15.4** *(feet)*

Road approach to bridge:

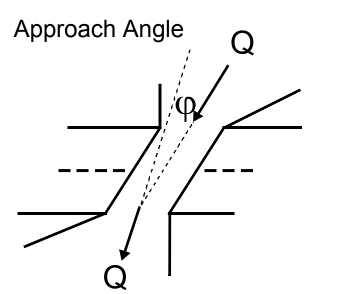
8. LB **0** RB **0** *(**0** even, **1**- lower, **2**- higher)*
9. LB **2** RB **2** *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **--:1** US right **--:1**

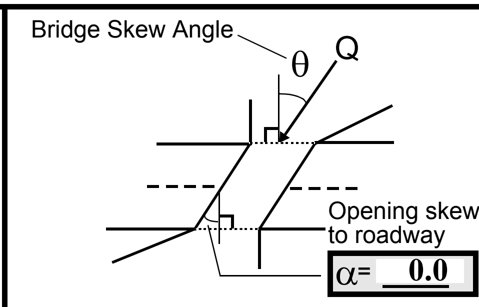
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	-
RBUS	1	1	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **15**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **0** feet **US** *(US, UB, DS)* to **15** feet **US**
Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **0**
Range? **0** feet **UB** *(US, UB, DS)* to **5** feet **US**

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

18. Bridge Type: **1a**

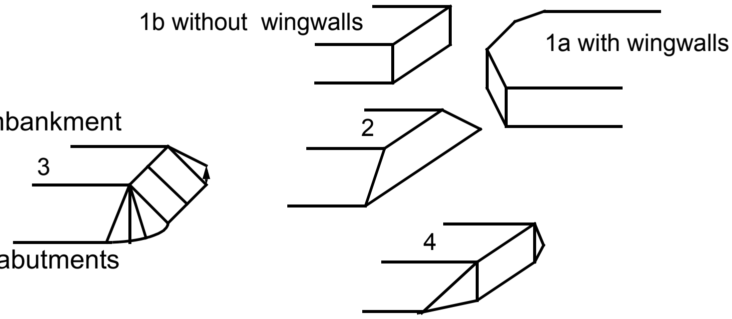
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular 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.)

7. The values are from the VT AOT files. The measured bridge length is 28.7 feet.
11. There is a large 2.5x2.5x10 foot rectangular concrete block on the DS left bank at the base of the embankment. On the right bank US there is a pile of loose dirt around the end of the right wingwall. On the left bank US, a single large boulder on the embankment in front of the wingwall acts as protection. It is covered with loose dirt and there are some long, 6 foot, timbers placed against the wingwall.
17. At impact zone 1 at the US right wingwall there is a large crack in the wall and undermining of the concrete at its base.

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
30.0	**2.0**			**1.5**	**4**	**4**	**54**	**435**	**0**	**1**

23. Bank width **15.0** 24. Channel width **25.0** 25. Thalweg depth **25.5** 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.):
A line of boulders across the stream begins under the bridge at the right abutment and extends to the other side of the channel angled away from the bridge. There is a 6 inch drop over the boulders.

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: 30 42. Cut bank extent: 25 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.):

Minimal erosion. The cut bank is formed behind a large, 2.5 foot, boulder at the right edge of water.

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
14.5		0.5		2	7	7	-

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 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

63. The bed material consists of fines, sand and gravel close to the left abutment with coarser material along the right abutment. Boulders exist throughout.

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? **1**___ (Y or N) Ice Blockage Potential **N**____ (1- Low; 2- Moderate; 3- High)

70. Debris and Ice Comments:

1

The bridge constricts minimally and there is a moderate gradient.

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		**10**	**85**	**2**	**3**	**0**	**2**	**90.0**
RABUT	**1**	**-**	**85**			**2**	**3**	**23.5**

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.):

0.5

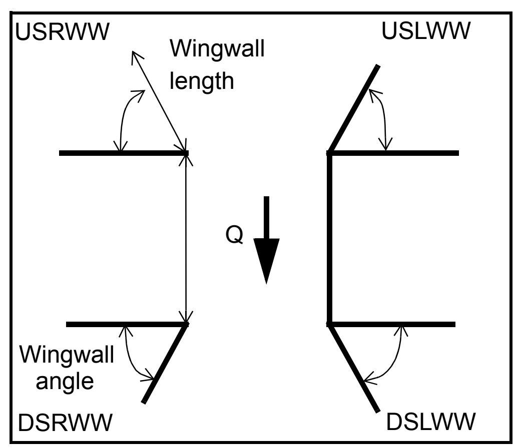
1

1

The right abutment has no footing, but a poured concrete skirt protrudes from the right abutment beginning 3 feet from the US end of the abutment around the corner 5 feet along the upstream right wingwall. The abutment wall is undermined up to 2 feet horizontally in spots beginning in the center of the bridge towards the US side. Scour is most severe behind the concrete skirt at the corner with the wingwall, here undermining is up to 3 feet horizontally. Also, a small scour hole is in front of the corner of the right abutment and US wingwall. On the left abutment the maximum horizontal undermining of the footing is 1.5 feet. About half of the footing is undermined. The footing ends 4 feet from the DS end of the abutment. The footing width starts at

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	**2**		**feet**		**at**	**23.5**	
USRWW:	**the**		**US**		**end**	**1.0**	
DSLWW:	**and**		**decr**		**eases**	**15.0**	
DSRWW:	**grad**		**ually**		**goin**	**21.0**	



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

82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**g**	**footi**	**e of**	**con-**	**over**	**e,**	**and**	**. A**
Condition	**DS.**	**ng is**	**pou**	**cret**	**laid**	**cob-**	**boul**	**ver-**
Extent	**The**	**mad**	**red**	**e**	**ston**	**bles**	**ders**	**tical**

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.):

crack is in the center of the abutment and there is an 8 inch hole in the center at the base of the left abutment.

Y

1

2

0

1

Y

1

3

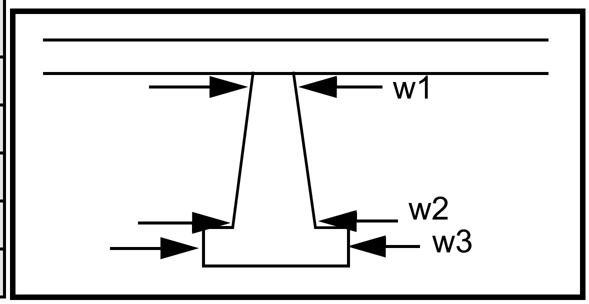
0

1

Piers:

84. Are there piers? **Y** (*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				**15.0**	**10.0**	**10.0**
Pier 2		**5.0**		**12.0**	**6.5**	**35.0**
Pier 3	**9.0**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**1**	**0**	**-**	**wing-**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**3**	**-**	**-**	**wall**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**0**	**-**	**-**	**is**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**0.3**	**0**	**2**	**unde**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**Y**	**-**	**1**	**rmin**	*Y- yes; N- no*
91. Attack ∠ (BF)	**1**	**-**	**1**	**ed**	
92. Pushed	**0**	**0**	**3**	**local**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**-**	**-**	**3**	**ly**	
95. Cross-members	**-**	**-**	**3**	**only**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**0**	**-**	**The**	**at**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**-**	**-**	**US**	**the**	
98. Exposure depth	**-**	**-**	**left**	**cor-**	

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

ner where it joins the abutment. There are long timbers placed along the base of the wingwall. The US right wingwall is protected by concrete poured over cobbles for 5 feet streamward of the wingwall. There is a large vertical crack up to 6 inches wide 1-2 feet from the corner of the right abutment. Also, a large boulder is protruding from the center at the base of the US right wingwall with the concrete around it eroded. At the end of the wingwall is a pile of dirt and tree bark. The DS left wingwall is undermined at 1.5 feet from the corner with the left abutment. The DS right wingwall has a small 4 inch diameter hole on the stream side base where a large boulder protrudes out of the wingwall and the concrete is eroded at the top of the boulder.

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
-	-			-		N	-	-	-	-

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

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

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: -____

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

-
-
-
-

Is a cut-bank present? -____ *(Y or if N type ctrl-n cb)* Where? -____ *(LB or RB)* Mid-bank distance: NO

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

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

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

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

Scour dimensions: Length 3 Width 1 Depth: 54 Positioned 245 %LB to 1 %RB

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

1
435
0
0

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 ____

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

-

NO DROP STRUCTURE

There is a series of boulders that extends across the channel 20 feet DS of the bridge parallel with the bridge face that causes a 4 inch drop in water level.

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: TROYTH00290015   Town: Troy
Road Number: TH 29   County: Orleans
Stream: Beetle Brook

Initials MAI   Date: 05/01/97 Checked: SAO

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	1750	2500	1690
Main Channel Area, ft2	285	319	236
Left overbank area, ft2	0	0	0
Right overbank area, ft2	345	441	241
Top width main channel, ft	36	37	35
Top width L overbank, ft	0	0	0
Top width R overbank, ft	92	114	64
D50 of channel, ft	0.387	0.387	0.387
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.9	8.6	6.7
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	3.8	3.9	3.8
Total conveyance, approach	55178	69168	40105
Conveyance, main channel	24410	28722	18477
Conveyance, LOB	0	0	0
Conveyance, ROB	30768	40446	21628
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	774.2	1038.1	778.6
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	975.8	1461.9	911.4
Vm, mean velocity MC, ft/s	2.7	3.3	3.3
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.8	3.3	3.8
Vc-m, crit. velocity, MC, ft/s	11.5	11.7	11.2
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	1750	2500	1690
(Q) discharge thru bridge, cfs	1658	1938	1690
Main channel conveyance	15334	14401	10555
Total conveyance	15334	14401	10555
Q2, bridge MC discharge,cfs	1658	1938	1690
Main channel area, ft2	198	199	127
Main channel width (normal), ft	23.4	23.4	22.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	23.4	23.4	22.9
y_bridge (avg. depth at br.), ft	8.47	8.49	5.53
Dm, median (1.25*D50), ft	0.48375	0.48375	0.48375
y2, depth in contraction,ft	5.87	6.71	6.08
ys, scour depth (y2-ybridge), ft	-2.60	-1.78	0.55

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	1750	2500	1690
Q, thru bridge MC, cfs	1658	1938	1690
Vc, critical velocity, ft/s	11.53	11.70	11.23
Va, velocity MC approach, ft/s	2.72	3.25	3.30
Main channel width (normal), ft	23.4	23.4	22.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	23.4	23.4	22.9
qbr, unit discharge, ft2/s	70.9	82.8	73.8
Area of full opening, ft2	198.3	198.7	126.6
Hb, depth of full opening, ft	8.47	8.49	5.53
Fr, Froude number, bridge MC	0.51	0.59	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	135	155	N/A
**Hb, depth at downstream face, ft	5.77	6.62	N/A
**Fr, Froude number at DS face	0.90	0.86	ERR

**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	499.92	499.92	0
Elevation of Bed, ft	491.45	491.43	-5.53
Elevation of Approach, ft	501.45	502.37	0
Friction loss, approach, ft	0.09	0.13	0
Elevation of WS immediately US, ft	501.36	502.24	0.00
ya, depth immediately US, ft	9.91	10.81	5.53
Mean elevation of deck, ft	501.54	501.54	0
w, depth of overflow, ft (>=0)	0.00	0.70	0.00
Cc, vert contrac correction (<=1.0)	0.96	0.96	1.00
**Cc, for downstream face (<=1.0)	0.836804	0.887515	ERR
Ys, scour w/Chang equation, ft	-2.09	-1.10	N/A
Ys, scour w/Umbrell equation, ft	-3.91	-3.20	N/A

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

**Ys, scour w/Chang equation, ft	1.57	1.35	N/A
**Ys, scour w/Umbrell equation, ft	-1.20	-1.33	ERR

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

y2, from Laursen's equation, ft	5.87	6.71	6.08
WSEL at downstream face, ft	497.15	498.04	--
Depth at downstream face, ft	5.70	6.61	ERR
Ys, depth of scour (Laursen), ft	0.17	0.10	N/A

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]

Depth to Armoring=3*(1/Pc-1)

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1658	1938	1690
Main channel area (DS), ft2	135	155	126.6
Main channel width (normal), ft	23.4	23.4	22.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	23.4	23.4	22.9
D90, ft	0.8936	0.8936	0.8936
D95, ft	1.0434	1.0434	1.0434
Dc, critical grain size, ft	0.7975	0.7767	0.9608
Pc, Decimal percent coarser than Dc	0.142	0.153	0.077
Depth to armoring, ft	14.46	12.87	34.75

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	1750	2500	1690	1750	2500	1690
a', abut.length blocking flow, ft	10.5	11.5	9.5	94.5	115.9	66.3
Ae, area of blocked flow ft2	49.8	54.7	39	336.2	349.4	257.3
Qe, discharge blocked abut.,cfs	85.9	--	81.1	--	--	966.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.72	2.04	2.08	2.83	3.32	3.76
ya, depth of f/p flow, ft	4.74	4.76	4.11	3.56	3.01	3.88
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.140	0.157	0.181	0.255	0.293	0.336
ys, scour depth, ft	8.48	8.94	7.97	15.35	15.76	16.47

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)	10.5	11.5	9.5	94.5	115.9	66.3
y1 (depth f/p flow, ft)	4.74	4.76	4.11	3.56	3.01	3.88
a'/y1	2.21	2.42	2.31	26.56	38.45	17.08
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.14	0.16	0.18	0.26	0.29	0.34
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	16.48	14.62	ERR
vertical w/ ww's	ERR	ERR	ERR	13.52	11.99	ERR
spill-through	ERR	ERR	ERR	9.07	8.04	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	0.9	0.86	1	0.9	0.86	1
y, depth of flow in bridge, ft	5.77	6.62	5.53	5.77	6.62	5.53
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.34	2.65	2.31	2.34	2.65	2.31