LEVEL II SCOUR ANALYSIS FOR BRIDGE 19 (CHARTH00390019) on TOWN HIGHWAY 39, crossing MAD BROOK, CHARLESTON, VERMONT

U.S. Geological Survey
Open-File Report 97-212

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

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By Erick M. Boehmler and Robert E. Hammond

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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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Box 25286
Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Slope		
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
Area		
square mile (mi^2)	2.590	square kilometer (km^2)
Volume		
cubic foot (ft^3)	0.02832	cubic meter (m^3)
Velocity and Flow		
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	MC	main channel
D_{50}	median diameter of bed material	RAB	right abutment
DS	downstream	RABUT	face of right abutment
elev.	elevation	RB	right bank
f/p	flood plain	ROB	right overbank
ft^2	square feet	RWW	right wingwall
ft/ft	feet per foot	TH	town highway
JCT	junction	UB	under bridge
LAB	left abutment	US	upstream
LABUT	face of left abutment	USGS	United States Geological Survey
LB	left bank	VTAOT	Vermont Agency of Transportation
LOB	left overbank	WSPRO	water-surface profile model

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 19 (CHARTH00390019) ON TOWN HIGHWAY 39, CROSSING MAD BROOK, CHARLESTON, VERMONT

By **Erick M. Boehmler and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHARTH00390019 on Town Highway 39 crossing Mad Brook, Charleston, 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 investigation also are included in this report in Appendix E. A Level I study provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the White Mountain section of the New England physiographic province in northeastern Vermont in the town of Charleston. The 6.54-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 upstream left side which is covered primarily with shrubs and brush. The immediate banks have dense woody vegetation.

In the study area, Mad Brook has an incised, sinuous channel with a slope of approximately 0.023 ft/ft, an average channel top width of 40 ft and an average channel depth of 4 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 135.0 mm (0.443 ft). The geomorphic assessment on October 26, 1994 indicated that the reach was laterally unstable due to long-term lateral migration of the channel. Data collection for the level II analysis was accomplished on October 26, 1994 and July 24, 1995.

The Town Highway 39 crossing of Mad Brook is a 34-ft-long, two-lane bridge consisting of one 31-foot steel-beam span (Vermont Agency of Transportation, written communication, August 4, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening while the opening-skew-to-roadway is 45 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the right abutment during the Level I assessment. The scour protection measures evident at the site were type-2 stone fill (less than 36 inches diameter) on the upstream left wingwall and upstream end of the left abutment wall. Type-3 stone fill (less than 48 inches diameter) was noted on the upstream right wingwall and the upstream side of the left road approach embankment. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and 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 was 0.0 ft. Abutment scour ranged from 9.5 to 16.7 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.

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

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 CHARTH00390019 ***Stream*** Mad Brook

County Orleans ***Road*** TH 39 ***District*** 09

Description of Bridge

Bridge length 34 ***ft*** ***Bridge width*** 24.4 ***ft*** ***Max span length*** 31 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 10/26/94

Description of stone fill Type-2 on the US end of the left abutment, and the US left wingwall. Type-3 on the US right wingwall and the upstream left road approach embankment. The right abutment is not protected.

Abutments and wingwalls are concrete. There is a 1.5 ft deep scour hole in front of the right abutment.

Y 40

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

There is a mild channel bend in the upstream reach. The scour hole has developed in the location where the bend impacts the right abutment.

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	10/26/94	0	0
Level II	7/24/95	0	0

Potential for debris Moderate. Trees, shrubs and brush cover the banks of this sinuous, laterally unstable reach.

Describe any features near or at the bridge that may affect flow (include observation date) The left abutment has a two-tiered subfooting and the right abutment has a three-tiered subfooting noted on 10/26/94. Combined, the subfootings constrict the lower 1/4 of the bridge opening up to 8 feet. 11/08/94.

Description of the Geomorphic Setting

General topography The channel is located within a narrow, moderate relief valley setting with little to no flood plains and steep valley walls on both sides.

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

Date of inspection 10/26/94

DS left: Steep channel bank to a narrow overbank area.

DS right: Steep channel bank to a narrow overbank area.

US left: Steep channel bank to TH 39 roadway embankment and surface.

US right: Steep channel bank to a narrow overbank area.

Description of the Channel

Average top width 40 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material Cobbles ***Bank material*** Cobbles/Boulders

Steep and sinuous with semi-alluvial to non-alluvial channel boundaries and little to no flood plain.

10/26/94

Vegetative co

DS left: Trees

DS right: Trees

US left: Shrubs and brush with a few trees.

US right: Tress.

Do banks appear stable? N On 10/26/94 there were cut-banks noted on the right bank upstream and the left bank downstream with heavy tree root exposure and slumping bank material, which indicate long-term channel migration.

date of observation.

Describe any obstructions in channel and date of observation. Noted on 10/26/94, the left abutment wall and footings were formed around a 2 by 1 by 1 meter size boulder, which projects into the channel. The footings and subfootings also block and constrict flow through the lower 1/4 of the bridge opening.

Hydrology

Drainage area 6.54 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None.

Is there a USGS gage on the stream of interest? No

USGS gage description -

USGS gage number -

Gage drainage area - ***mi²***

Is there a lake/ No

-

Calculated Discharges

Q100 1,300 ***ft³/s*** ***Q500*** 1,780 ***ft³/s***

The 100- and 500-year discharges were based on a range determined from several empirical relationships (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Johnson and Laraway, unpublished draft, 1971; Potter, 1957; and Talbot, 1887). The values from the FHWA method were selected for this site due to the central tendency of the relationship with the others.

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 the center point of a chiseled “X” on top of the DS end of the DS left wingwall (elev. 497.43 ft, arbitrary survey datum). RM2 is the center point of a chiseled “X” on top of the US end of the US left wingwall (elev. 496.38 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-40	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
APPRO	60	2	Modelled Approach section (Templated from APTEM)
APTEM	69	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 step-backwater computer program, WSPRO (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 0.050 to 0.060, and overbank "n" values ranged from 0.030 to 0.095.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.023 ft/ft which was estimated from surveyed thalweg points in the channel reach downstream of the site.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0361 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.

The 100- and 500-year discharge models indicate orifice flow conditions existed at the bridge. The Bridge Waterways Analysis Model Research Report (Shearman, et al., 1986) indicates that orifice flow (type 2) occurs when the water surface is in contact with the low steel at the upstream bridge face only. A composite model was developed for the 100- and 500-year discharges. From this model it was determined that even though the water surface may be in contact with the low steel at the upstream face of the bridge, the water surface profile does pass through critical depth within the bridge opening. Therefore, the assumptions of critical depth are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.4 *ft*
Average low steel elevation 497.0 *ft*

100-year discharge 1,300 *ft^3/s*
Water-surface elevation in bridge opening 497.0 *ft*
Road overtopping? No *Discharge over road* 0 *ft^3/s*
Area of flow in bridge opening 180 *ft^2*
Average velocity in bridge opening 7.2 *ft/s*
Maximum WSPRO tube velocity at bridge 9.1 *ft/s*

Water-surface elevation at Approach section with bridge 498.1
Water-surface elevation at Approach section without bridge 494.2
Amount of backwater caused by bridge 3.9 *ft*

500-year discharge 1,780 *ft^3/s*
Water-surface elevation in bridge opening 497.0 *ft*
Road overtopping? No *Discharge over road* 0 *ft^3/s*
Area of flow in bridge opening 180 *ft^2*
Average velocity in bridge opening 9.9 *ft/s*
Maximum WSPRO tube velocity at bridge 12.5 *ft/s*

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 495.2
Amount of backwater caused by bridge 4.9

Incipient overtopping discharge -- *ft^3/s*
Water-surface elevation in bridge opening -- *ft*
Area of flow in bridge opening -- *ft^2*
Average velocity in bridge opening -- *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge --
Water-surface elevation at Approach section without bridge --
Amount of backwater caused by bridge -- *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 was computed by use of Chang's pressure-flow scour equation for the 100- and 500-year discharges. The Chang equation is recommended at bridges with orifice flow (oral communication, J. Sterling Jones, October 4, 1996 and Richardson and others, 1995, p. 145-146). Although an unusual low steel configuration exists at this site, the 100- and 500-year discharges are assumed to result in unsubmerged orifice flow. 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.

Contraction scour for each discharge modeled also was 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, contraction scour was computed substituting the critical depth in the bridge and the average main channel depth at the full valley section individually for the average depth in the contracted section. Contration scour results with respect to these substitutions also are provided in Appendix F.

Abutment scour at all modelled discharges 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	--
Depth to armoring	0.6	4.6	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	9.5	9.6	--
Right abutment	13.6	16.7	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.1	2.6	--
Right abutment	2.1	2.6	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

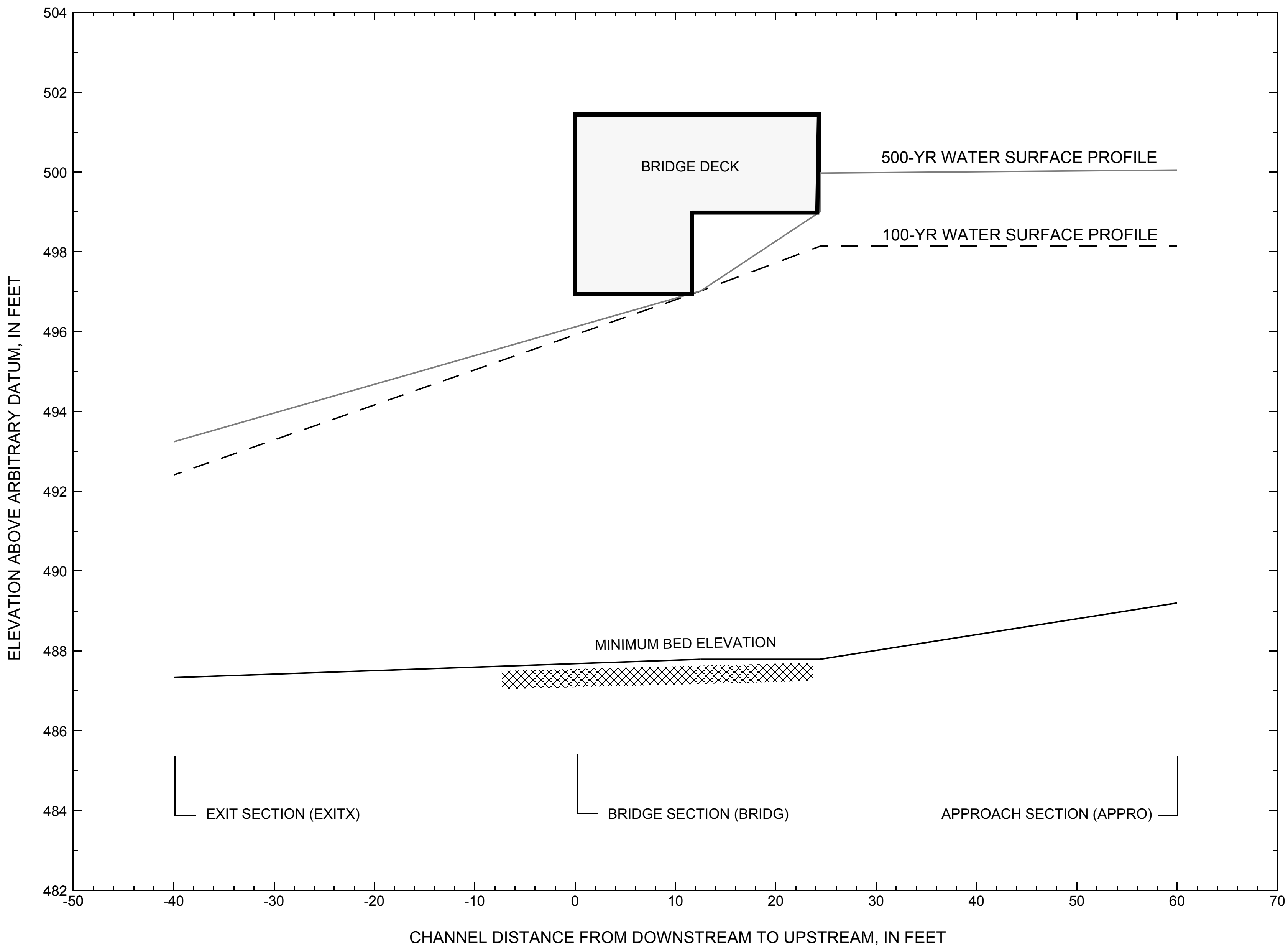

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHARTH00390019 on town highway 39, crossing Mad Brook, Charleston, Vermont.

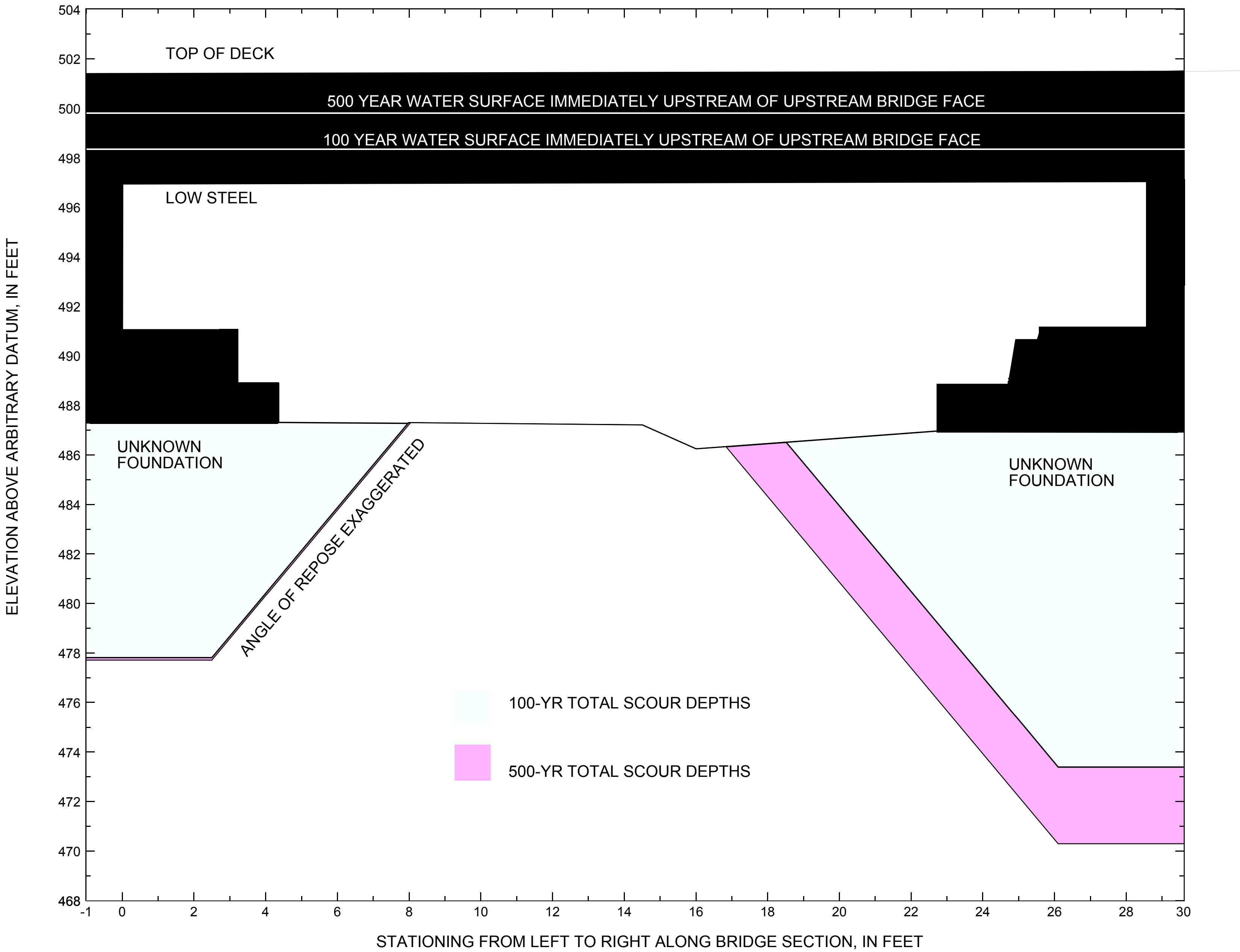

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CHARTH00390019 on town highway 39, crossing Mad Brook, Charleston, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHARTH00390019 on Town Highway 39, crossing Mad Brook, Charleston, 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 1,300 cubic-feet per second											
Left abutment	0.0	--	497.0	--	487.3	0.0	9.5	--	9.5	477.8	--
Right abutment	28.6	--	497.0	--	487.0	0.0	13.6	--	13.6	473.4	--

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 CHARTH00390019 on Town Highway 39, crossing Mad Brook, Charleston, 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 1,780 cubic-feet per second											
Left abutment	0.0	--	497.0	--	487.3	0.0	9.6	--	9.6	477.7	--
Right abutment	28.6	--	497.0	--	487.0	0.0	16.7	--	16.7	470.3	--

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, 1988, Island Pond, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Aerial Photography, 1983; Contour interval, 20 feet; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File char019.wsp
T2        Hydraulic analysis for structure CHARTH00390019   Date: 08-MAY-96
T3        Town Highway 39 Bridge Crossing of Mad Brook, Charleston, VT       EMB
Q           1300.0   1780.0
SK          0.0230   0.0230
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -40
GR          -70.6, 494.45    -52.8, 494.15    -32.1, 493.13    -13.5, 492.26
GR           -2.7, 492.39      0.0, 488.39      3.5, 487.95      6.1, 487.88
GR           11.8, 487.33     21.5, 487.50     21.9, 488.38     32.9, 488.70
GR           37.4, 491.73     45.1, 494.85     70.9, 498.40    114.6, 499.54
GR          151.8, 501.39    245.1, 504.43
N           0.095        0.060        0.095        0.045
SA                  -2.7         21.9         70.9
*
XS   FULLV      0
*
BR   BRIDG     0 497.0 45
GR            0.0, 497.02      0.2, 491.05      2.8, 490.83      3.1, 488.79
GR            4.0, 488.80      4.0, 487.31     10.1, 487.29     14.5, 487.21
GR           16.0, 486.24     23.0, 486.99     23.1, 488.70     24.8, 488.74
GR           25.0, 490.56     25.5, 490.55     25.6, 491.02     28.6, 491.01
GR           28.6, 496.98      0.0, 497.02
N           0.050
CD          1 46.4 * * 59 5.3
*
XR   RDWAY     20 24.4 2
GR         -148.4, 506.65   -117.1, 502.99    -80.4, 501.98    -39.9, 501.04
GR            0.0, 501.34     27.6, 501.56     67.3, 500.68     90.9, 500.50
GR          124.4, 500.97    178.6, 503.03    201.3, 507.11
*
XT   APTEM     69
GR         -126.4, 505.45    -93.1, 503.92    -32.2, 500.63    -19.1, 500.26
GR          -11.0, 498.25     -7.0, 495.92     -2.2, 491.52      0.0, 490.62
GR            3.5, 490.93      8.8, 490.57     10.8, 490.07     15.3, 489.52
GR           18.2, 489.74     21.2, 490.60     26.0, 491.16     29.7, 491.35
GR           33.1, 494.25     64.7, 494.61     83.6, 493.89     94.3, 493.77
GR          109.5, 503.13
*
AS   APPRO     60 * * * 0.0361
GT
N           0.030        0.060        0.080
SA                 -19.1        33.1
*
HP 1 BRIDG  493.15 1 493.15
HP 2 BRIDG  493.15 * * 1300
HP 1 BRIDG  497.02 1 497.02
HP 2 BRIDG  497.02 * * 1300
HP 1 APPRO  498.14 1 498.14
HP 2 APPRO  498.14 * * 1300
*
HP 1 BRIDG  494.29 1 494.29
HP 2 BRIDG  494.29 * * 1780
HP 1 BRIDG  497.02 1 497.02
HP 2 BRIDG  497.02 * * 1780
HP 1 APPRO  500.05 1 500.05
HP 2 APPRO  500.05 * * 1780
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File char019.wsp
        Hydraulic analysis for structure CHARTH00390019   Date: 08-MAY-96
        Town Highway 39 Bridge Crossing of Mad Brook, Charleston, VT       EMB
           *** RUN DATE & TIME: 08-01-96  15:17
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     102.    6624.    20.    32.                       1306.
   493.15          102.    6624.    20.    32.  1.00     0.    29.   1306.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.15     0.1    28.6   102.2    6624.    1300.  12.73

X STA.         0.1         4.7         6.2         7.4         8.5         9.5
  A(I)            10.6         5.9         5.0         4.5         4.4
  V(I)            6.12       11.05       12.96       14.45       14.88

X STA.         9.5        10.5        11.5        12.5        13.4        14.3
  A(I)             4.2         4.1         3.9         3.9         3.9
  V(I)           15.44       15.97       16.47       16.61       16.56

X STA.        14.3        15.3        16.2        17.0        17.8        18.7
  A(I)             4.2         4.1         3.9         3.9         4.1
  V(I)           15.32       15.88       16.67       16.81       15.66

X STA.        18.7        19.6        20.6        21.7        23.6        28.6
  A(I)             4.3         4.7         5.1         7.5         9.9
  V(I)           15.14       13.78       12.81        8.72        6.55

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     180.   11171.     0.    60.                    9909081.
   497.02          180.   11171.     0.    60.  1.00     0.    29.9909081.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.02     0.0    28.6   179.8   11171.    1300.   7.23

X STA.         0.0         3.7         5.4         6.7         7.9         9.0
  A(I)            16.6        11.4         8.9         8.2         7.8
  V(I)            3.92        5.72        7.34        7.93        8.35

X STA.         9.0        10.1        11.2        12.2        13.3        14.3
  A(I)             7.7         7.2         7.3         7.2         7.2
  V(I)            8.44        9.02        8.93        9.02        9.00

X STA.        14.3        15.4        16.3        17.3        18.3        19.3
  A(I)             7.5         7.2         7.1         7.4         7.4
  V(I)            8.72        9.04        9.10        8.83        8.75

X STA.        19.3        20.3        21.5        22.8        24.7        28.6
  A(I)             7.7         8.3         9.2        11.7        17.0
  V(I)            8.43        7.86        7.09        5.54        3.82

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      60.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     301.   25064.    45.    49.                       4411.
             3     275.   12705.    69.    70.                       3113.
   498.14          575.   37769.   114.   119.  1.24   -12.   102.   6599.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      60.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.14   -11.9   101.9   575.3   37769.    1300.   2.26

X STA.       -11.9        -0.7         2.6         5.6         8.3        10.9
  A(I)            39.6        24.9        22.8        21.3        21.3
  V(I)            1.64        2.61        2.85        3.05        3.06

X STA.        10.9        13.3        15.4        17.6        19.8        22.3
  A(I)            19.7        19.0        19.1        19.0        20.0
  V(I)            3.29        3.41        3.41        3.41        3.25

X STA.        22.3        25.0        27.8        31.3        40.0        49.6
  A(I)            20.3        20.8        23.5        37.8        39.1
  V(I)            3.20        3.12        2.77        1.72        1.66

X STA.        49.6        59.8        70.3        79.5        87.9       101.9
  A(I)            40.7        41.2        38.8        38.5        47.6
  V(I)            1.60        1.58        1.67        1.69        1.37
```

```
        U.S. Geological Survey WSPRO Input File char019.wsp
        Hydraulic analysis for structure CHARTH00390019   Date: 08-MAY-96
        Town Highway 39 Bridge Crossing of Mad Brook, Charleston, VT       EMB
           *** RUN DATE & TIME: 08-01-96  15:17
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     125.    8869.    20.    34.                       1769.
   494.29          125.    8869.    20.    34.  1.00     0.    29.   1769.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.29     0.1    28.6   125.1    8869.    1780.  14.23

X STA.         0.1        4.5        5.9        7.2        8.4        9.4
  A(I)            13.1        7.2        6.3        5.6        5.3
  V(I)            6.79      12.34      14.11      15.83      16.79

X STA.         9.4       10.5       11.4       12.4       13.4       14.3
  A(I)             5.1        4.9        4.8        4.8        4.8
  V(I)           17.43      18.31      18.50      18.67      18.62

X STA.        14.3       15.3       16.2       17.0       17.9       18.8
  A(I)             5.0        4.9        4.8        4.8        5.0
  V(I)           17.69      18.00      18.60      18.39      17.69

X STA.        18.8       19.8       20.8       22.0       24.0       28.6
  A(I)             5.2        5.7        6.2        9.0       12.4
  V(I)           17.07      15.51      14.38       9.85       7.16

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     180.   11171.     0.    60.                    9909081.
   497.02          180.   11171.     0.    60.  1.00     0.    29.9909081.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.02     0.0    28.6   179.8   11171.    1780.   9.90

X STA.         0.0        3.7        5.4        6.7        7.9        9.0
  A(I)            16.6       11.4        8.9        8.2        7.8
  V(I)            5.37       7.83      10.04      10.86      11.44

X STA.         9.0       10.1       11.2       12.2       13.3       14.3
  A(I)             7.7        7.2        7.3        7.2        7.2
  V(I)           11.56      12.35      12.23      12.35      12.33

X STA.        14.3       15.4       16.3       17.3       18.3       19.3
  A(I)             7.5        7.2        7.1        7.4        7.4
  V(I)           11.94      12.38      12.46      12.10      11.99

X STA.        19.3       20.3       21.5       22.8       24.7       28.6
  A(I)             7.7        8.3        9.2       11.7       17.0
  V(I)           11.54      10.76       9.71       7.59       5.23

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      60.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       0.       2.     4.     4.                          0.
             2     394.   35763.    52.    56.                       6138.
             3     409.   23860.    72.    74.                       5536.
   500.05          803.   59625.   128.   134.  1.14   -23.   105.  10663.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      60.
         WSEL     LEW     REW    AREA        K        Q    VEL
       500.05   -23.2   105.0   803.1   59625.    1780.   2.22

X STA.       -23.2       -1.5        2.6        6.0        9.2       12.1
  A(I)            61.1       38.4       32.5       31.3       29.5
  V(I)            1.46       2.32       2.74       2.84       3.02

X STA.        12.1       14.7       17.2       19.8       22.6       25.6
  A(I)            28.0       27.0       26.8       28.2       27.9
  V(I)            3.17       3.29       3.32       3.16       3.19

X STA.        25.6       28.7       33.1       41.1       49.3       57.5
  A(I)            28.5       34.8       48.7       48.7       48.5
  V(I)            3.12       2.55       1.83       1.83       1.84

X STA.        57.5       66.0       74.4       82.2       89.7      105.0
  A(I)            49.5       50.2       48.6       48.9       65.9
  V(I)            1.80       1.77       1.83       1.82       1.35
```

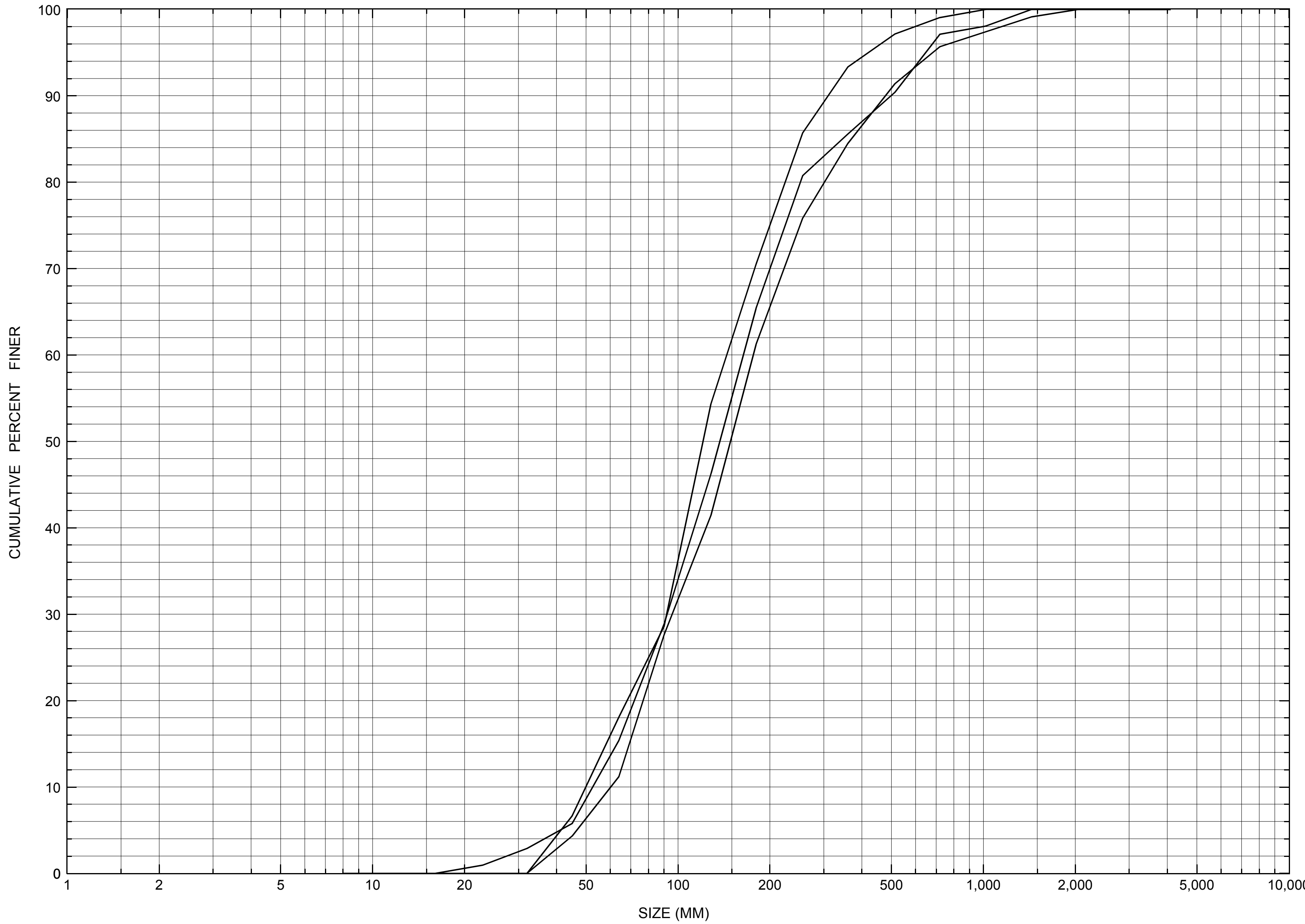
```
        U.S. Geological Survey WSPRO Input File char019.wsp
        Hydraulic analysis for structure CHARTH00390019   Date: 08-MAY-96
        Town Highway 39 Bridge Crossing of Mad Brook, Charleston, VT       EMB
           *** RUN DATE & TIME: 08-01-96  15:17

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

 EXITX:XS   ******   -17.     164.  1.20 *****  493.61  491.74   1300.  492.41
       -40. ******    39.    8567.  1.23 ***** *******    0.90    7.94

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                               "FULLV"     KRATIO =  1.53

 FULLV:FV      40.   -40.     242.  0.66  0.60  494.20 *******   1300.  493.54
         0.    40.    42.   13085.  1.48  0.00   -0.01    0.67    5.38
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.24     494.21     494.07

  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.04     505.13    0.50

  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.04     505.13     494.07

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                               "APPRO"     KRATIO =  0.60

 APPRO:AS      60.    -5.     156.  1.29  0.99  495.51  494.07   1300.  494.21
        60.    60.    96.    7856.  1.19  0.32    0.00    1.24    8.35
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.15     497.32     497.45     497.00

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

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

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

 BRIDG:BR      40.     0.     180.  0.81 *****  497.83  493.15   1300.  497.02
         0. ******    29.   11171.  1.00 ***** *******    0.51    7.23

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   2.  0.434  0.000  497.00 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      20.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPRO:AS      14.   -12.     576.  0.10  0.06  498.24  494.07   1300.  498.14
        60.    16.   102.   37794.  1.24  1.79    0.00    0.20    2.26

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      ****** ****** ******** ****** ******   498.10

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL   WSEL
    EXITX:XS     -40.   -17.    39.   1300.    8567.     164.    7.94  492.41
    FULLV:FV       0.   -40.    42.   1300.   13085.     242.    5.38  493.54
    BRIDG:BR       0.     0.    29.   1300.   11171.     180.    7.23  497.02
    RDWAY:RG      20.**************      0.       0.*********    2.00********
    APPRO:AS      60.   -12.   102.   1300.   37794.     576.    2.26  498.14

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

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    EXITX:XS    491.74    0.90  487.33  504.43************  1.20  493.61  492.41
    FULLV:FV  ********    0.67  487.33  504.43  0.60  0.00  0.66  494.20  493.54
    BRIDG:BR    493.15    0.51  486.24  497.02************  0.81  497.83  497.02
    RDWAY:RG  ****************  500.50  507.11************  0.03  501.09********
    APPRO:AS    494.07    0.20  489.20  505.13  0.06  1.79  0.10  498.24  498.14
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File char019.wsp
       Hydraulic analysis for structure CHARTH00390019   Date: 08-MAY-96
       Town Highway 39 Bridge Crossing of Mad Brook, Charleston, VT       EMB
          *** RUN DATE & TIME: 08-01-96  15:17

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

EXITX:XS   ******   -34.     218.  1.46 *****  494.70  492.72   1780.  493.24
      -40. ******    41.   11730.  1.41 ***** *******    1.00    8.16

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

 ===140 AT SECID "FULLV":  END OF CROSS SECTION EXTENDED VERTICALLY.
                          WSEL,YLT,YRT =   494.54     494.45     504.43

FULLV:FV      40.   -71.     338.  0.75  0.59  495.28 *******   1780.  494.54
        0.    40.    44.   18331.  1.73  0.00    0.00    0.71    5.27
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.93     495.18     495.04

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   494.04     505.13    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   494.04     505.13     495.04

APPRO:AS      60.    -7.     254.  1.07  0.80  496.25  495.04   1780.  495.17
       60.    60.    97.   12883.  1.40  0.16    0.00    0.94    7.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.32     499.17     499.29     497.00

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

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

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

BRIDG:BR      40.     0.     180.  1.51 *****  498.53  494.29   1772.  497.02
        0. ******    29.   11171.  1.00 ***** *******    0.69    9.85

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.494  0.000  497.00 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      14.   -23.     803.  0.09  0.08  500.13  495.04   1780.  500.05
       60.    17.   105.   59580.  1.14  1.85    0.00    0.17    2.22

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   500.02

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -40.   -34.    41.   1780.   11730.     218.    8.16  493.24
   FULLV:FV       0.   -71.    44.   1780.   18331.     338.    5.27  494.54
   BRIDG:BR       0.     0.    29.   1772.   11171.     180.    9.85  497.02
   RDWAY:RG      20.**************      0.       0.*********    2.00********
   APPRO:AS      60.   -23.   105.   1780.   59580.     803.    2.22  500.05

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    492.72    1.00  487.33  504.43************  1.46  494.70  493.24
   FULLV:FV  ********    0.71  487.33  504.43  0.59  0.00  0.75  495.28  494.54
   BRIDG:BR    494.29    0.69  486.24  497.02************  1.51  498.53  497.02
   RDWAY:RG  ****************  500.50  507.11************  0.06  501.11********
   APPRO:AS    495.04    0.17  489.20  505.13  0.08  1.85  0.09  500.13  500.05
  ER
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure CHARTH00390019, in Charleston, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHARTH00390019

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. WEBER

Date *(MM/DD/YY)* 08 / 04 / 94

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

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

Town *(FIPS place code; I - 4; nnnnn)* 13150

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

Waterway *(I - 6)* Mad Brook

Road Name *(I - 7):* -

Route Number TH039

Vicinity *(I - 9)* 0.3 MI TO JCT W CL2 TH1

Topographic Map Island.Pond

Hydrologic Unit Code: 01110000

Latitude *(I - 16; nnnn.n)* 44488

Longitude *(i - 17; nnnnn.n)* 71584

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10100400191004

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

Maximum span length *(I - 48; nnnn)* 0031

Year built *(I - 27; YYYY)* 1940

Structure length *(I - 49; nnnnnn)* 000034

Average daily traffic, ADT *(I - 29; nnnnnn)* 000250

Deck Width *(I - 52; nn.n)* 244

Year of ADT *(I - 30; YY)* 90

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

Opening skew to Roadway *(I - 34; nn)* 45

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

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

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

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 1969

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 010.5

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

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

Comments:

Structural inspection of 6/17/94 indicates a concrete slab type bridge. Numerous subfootings were constructed due to ongoing channel scour. The abutments and wingwalls are stable with no apparent settlement. Heavy embankment erosion is noted downstream. Stone fill is noted as needed along the right abutment. There is a slight channel turn into the bridge with a somewhat constrictive opening. A boulder bar is reported on the upstream left bank.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: Boulders and gravel

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)* : Light Debris *(Heavy, Moderate, Light)*: Light

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Existing surface velocity at the time of the inspection was 2 feet/second.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **6.54** mi^2 Lake and pond area **0** mi^2

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

Bridge site elevation **1280** ft Headwater elevation **3300** ft

Main channel length **4.06** mi

10% channel length elevation **1340** ft 85% channel length elevation **7340** ft

Main channel slope *(S)* **328.32** 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:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS.

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: **2/12/96**

Computerized by: **MAI** Date: **3/22/95**

Reviewd by: **EMB** Date: **7/17/96**

Structure Number **CHARTH00390019**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. HAMMOND** Date *(MM/DD/YY)* **10** / **26** / 19**94**

2. Highway District Number **09** Mile marker **0**

County **ORLEANS (019)** Town **CHARLESTON (13150)**

Waterway *(I - 6)* **MAD BROOK** Road Name **-**

Route Number **TH039** Hydrologic Unit Code: **01110000**

3. Descriptive comments:

Located about 0.3 miles from the junction of TH 39 with TH 1.

B. Bridge Deck Observations

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

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

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

7. Bridge length **34** *(feet)* Span length **31** *(feet)* Bridge width **24.4** *(feet)*

Road approach to bridge:

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

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

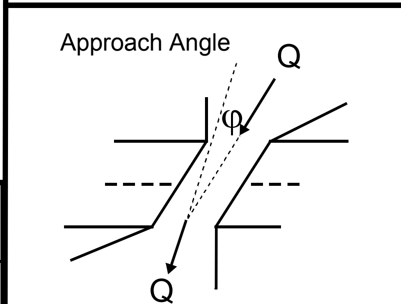
10. Embankment slope (*run / rise in feet / foot*):
US left **0.0:1** US right **0.0:1**

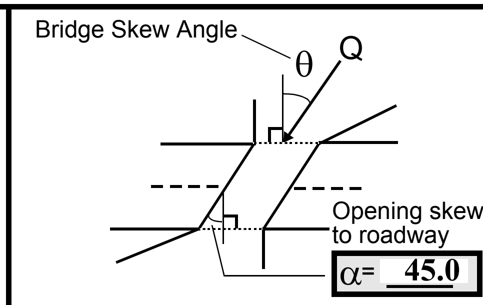
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	3	1	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

*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: **40**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **165** feet **US** *(US, UB, DS)* to **60** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **160** feet **DS** *(US, UB, DS)* to **200** feet **DS**

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

18. Bridge Type: **1a**

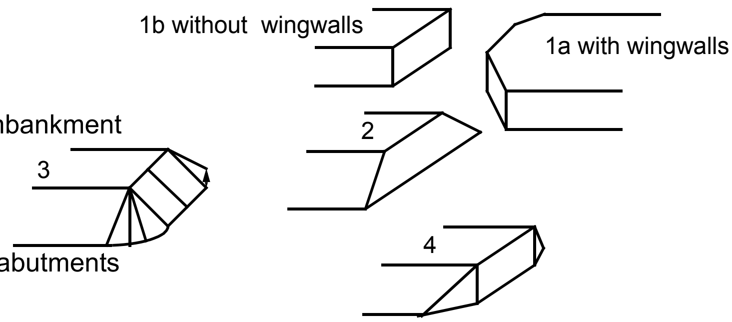
1a- Vertical abutments with wingwalls

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.)

4. LBUS: road is within the forested area.
7. Measured bridge length: 31, span: 30, and width: 24 feet.
8. LB: is even with the bridge elevation for 30 ft. then rises.
18. The bridge is type 4 above end of wingwall elevation.
Although the computed opening skew to the roadway was 40 degrees, the abutment lengths were different. Therefore, the skew angle is closer to 45 degrees than the angle computed.

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
35.5	**4.5**			**3.0**	**3**	**4**	**45**	**45**	**2**	**0**

23. Bank width **35.0** 24. Channel width **40.0** 25. Thalweg depth **40.0** 29. Bed Material **45**

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.):

30. Both the left and right bank have natural protection consisting of cobble and boulder; left bank is exposed and the right bank is covered by some soil.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **138** 35. Mid-bar width: **23**

36. Point bar extent: **172** feet **US** (US, UB) to **0** feet **US** (US, UB, DS) positioned **30** %LB to **100** %RB

37. Material: **4**

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

Flow comes around the bend upstream of 200 ft. towards the left bank causing erosion, and depositing the point bar on the right bank.

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

41. Mid-bank distance: **110** 42. Cut bank extent: **165** feet **US** (US, UB) to **60** 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.):

Slight cut bank on the right bank about 60 to 5 ft. upstream. Possibly due to constriction of the channel by road protection along the left bank just upstream of the bridge.

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
Some local scour DS of boulders.

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) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
32.0		1.0		2	7	7	0

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **90.0** 63. Bed Material **0**

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.):

54

There is a 3-step subfooting on the right abutment and a 2-step one on the left abutment. Both abutment walls are a combination of an old abutment extended upstream by newer abutments on both sides. The older wooden deck was left in place and new deck extends over the upstream side of the older deck. The new deck is curved while the old deck is straight.

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

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

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

70. Debris and Ice Comments:

1

67. While there was no debris accumulation near the bridge, the upstream reach is laterally stable with a few cut banks, and may contribute debris.

68. Although the channel gradient is steep, the narrow bridge opening and the point bar upstream may result in debris capture near this site.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		-	90	2	2	0	3.5	90.0
RABUT	1	5	90			2	3	21.0

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

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

1.5
3.5
1

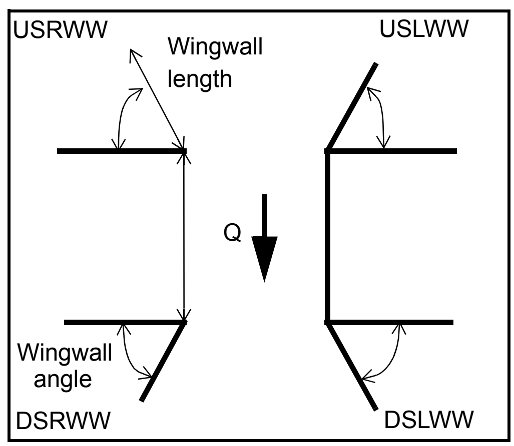
75. The streambed along the right abutment is 0.5 feet below the bottom of the 3-step subfooting and the hole penetrates up to 2 feet under the subfooting.

76. The left abutment is a two step footing and was formed over a large boulder midway under the bridge. The right abutment is a three step footing.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						21.0	
USRWW:	Y		1		2	2.0	
DSLWW:	-		2.5		Y	43.5	
DSRWW:	1		2		-	35.0	

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	3	2	Y	-	1	1	1	-
Condition	Y	-	1	3	1	1	2	-
Extent	1	3	2	2	3	2	0	-

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

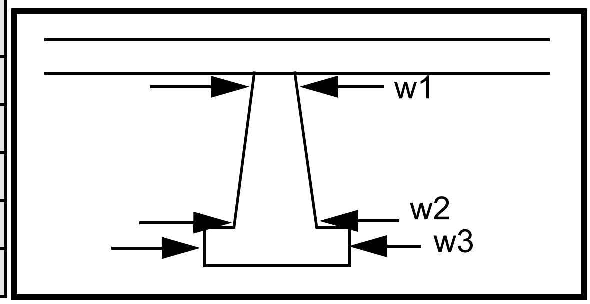
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
2
3
1
0
-
-

Piers:

84. Are there piers? **82.** *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**35.0**	**12.0**	**80.0**
Pier 2	**7.5**	**6.0**		**70.0**	**30.0**	**10.0**
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**s on**	**wing**	**the**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**3-**	**the**	**wall.**	**wing**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**step**	**upst**	**Larg**	**wall.**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**right**	**ream**	**e**	**The**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**abut**	**right**	**boul-**	**abut**	*Y- yes; N- no*
91. Attack ∠ (BF)	**ment**	**wing**	**ders**	**ment**	
92. Pushed	**foot-**	**wall**	**are**	**foot-**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**ing**	**to**	**in**	**ing**	
95. Cross-members	**expo**	**the**	**place**	**expo**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**sure**	**end**	**to**	**sure**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**con-**	**of**	**pro-**	**also**	
98. Exposure depth	**tinue**	**the**	**tect**	**con-**	

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

tinues on the downstream left and right wingwalls.

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 (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? N (Y or if N type ctrl-n cb) Where? O (LB or RB) Mid-bank distance: PIE

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

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

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

Is channel scour present? _____ (Y or if N type ctrl-n cs) Mid-scour distance: 4

Scour dimensions: Length 4 Width 54 Depth: 45 Positioned 2 %LB to 0 %RB

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

54
0
0
-

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

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

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

Confluence comments (eg. confluence name):

native material. The left bank erosion has exposed mostly boulders except at mid-cut bank where sand is evident. (170 to 200 ft. downstream)

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N

109. G. Plan View Sketch

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:	CHARTH00390019	Town:	Charleston
Road Number:	TH 39	County:	Orleans
Stream:	Mad Brook		

Initials EMB   Date: 7/17/96 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	1300	1780	0
Main Channel Area, ft2	301	394	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	275	409	0
Top width main channel, ft	45	52	0
Top width L overbank, ft	0	4.1	0
Top width R overbank, ft	68.8	71.9	0
D50 of channel, ft	0.443	0.443	0
D50 left overbank, ft	--	--	0
D50 right overbank, ft	--	--	0
y1, average depth, MC, ft	6.7	7.6	ERR
y1, average depth, LOB, ft	ERR	0.0	ERR
y1, average depth, ROB, ft	4.0	5.7	ERR
Total conveyance, approach	37769	59625	0
Conveyance, main channel	25064	35763	0
Conveyance, LOB	0	2	0
Conveyance, ROB	12705	23860	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	862.7	1067.6	ERR
Ql, discharge, LOB, cfs	0.0	0.1	ERR
Qr, discharge, ROB, cfs	437.3	712.3	ERR
Vm, mean velocity MC, ft/s	2.9	2.7	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	1.6	1.7	ERR
Vc-m, crit. velocity, MC, ft/s	11.7	12.0	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	N/A
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	N/A

Results

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

ARMORING			
D90	1.3797	1.3797	
D95	1.9797	1.9797	
Critical grain size,Dc, ft	0.2757	0.5170	ERR
Decimal-percent coarser than Dc	0.5667	0.2527	
Depth to armoring,ft	0.63	4.59	ERR

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)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	301	394	0
Main channel width, ft	45	52	0
y1, main channel depth, ft	6.69	7.58	ERR

Bridge Section			
(Q) total discharge, cfs	1300	1780	0
(Q) discharge thru bridge, cfs	1300	1780	
Main channel conveyance	11171	11171	
Total conveyance	11171	11171	
Q2, bridge MC discharge,cfs	1300	1780	ERR
Main channel area, ft2	180	180	0
Main channel width (skewed), ft	20.2	20.2	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.2	20.2	0
y_bridge (avg. depth at br.), ft	8.91	8.91	ERR
Dm, median (1.25*D50), ft	0.55375	0.55375	0
y2, depth in contraction,ft	5.20	6.81	ERR
ys, scour depth (y2-ybridge), ft	-3.71	-2.10	N/A
Critical WSEL in bridge, ft	493.15	494.29	0
Critical depth (approx), ft	5.060891	6.200891	N/A
ys, depth of scour (critical), ft	0.139109	0.609109	N/A
Full valley WSEL, ft	493.54	494.54	0
Full valley depth (approx), ft	5.450891	6.450891	N/A
ys, depth of scour (FULLV), ft	-0.25089	0.359109	N/A

Pressure Flow Scour (contraction scour for orifice flow condtions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10*(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richardson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	1300	1780	0
Vc, critical velocity, ft/s	11.7	12	0
Vc, critical velocity, m/s	3.565986	3.657422	0
Main channel width (skewed), ft	20.2	20.2	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	20.2	20.2	0
qbr, unit discharge, ft^2/s	64.35644	88.11881	ERR
qbr, unit discharge, m^2/s	5.978325	8.185707	N/A
Area of full opening, ft^2	180	180	0
Hb, depth of full opening, ft	8.910891	8.910891	ERR
Hb, depth of full opening, m	2.715907	2.715907	N/A
Fr, Froude number MC	0.51	0.69	1
Cf, Fr correction factor (<=1.0)	1	1	1.5
Elevation of Low Steel, ft	497	497	0
Elevation of Bed, ft	488.0891	488.0891	N/A
Elevation of approach WS, ft	498.14	500.05	0
HF, bridge to approach, ft	0.06	0.08	0
Elevation of WS immediately US, ft	498.08	499.97	0
ya, depth immediately US, ft	9.990891	11.88089	N/A
ya, depth immediately US, m	3.10469	3.692011	N/A
Mean elev. of deck, ft	501.45	501.45	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	0.972182	0.927847	ERR
Ys, depth of scour (chang), ft	-3.25295	-0.99662	N/A

Abutment Scour

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

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1300	1780	0	1300	1780	0
a', abut.length blocking flow, ft	16.2	27.5	0	77.4	80.5	0
Ae, area of blocked flow ft2	77.4	115.8	0	331.8	482.5	0
Qe, discharge blocked abut.,cfs	166.8	222.5	0	597	922.6	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.16	1.92	ERR	1.80	1.91	ERR
ya, depth of f/p flow, ft	4.78	4.21	ERR	4.29	5.99	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	45	45	0	135	135	0
K2	0.91	0.91	0.00	1.05	1.05	0.00
Fr, froude number f/p flow	0.174	0.165	ERR	0.153	0.138	ERR
ys, scour depth, ft	9.50	9.56	N/A	13.58	16.71	N/A

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)	16.2	27.5	0	77.4	80.5	0
y1 (depth f/p flow, ft)	4.78	4.21	ERR	4.29	5.99	ERR
a'/y1	3.39	6.53	ERR	18.06	13.43	ERR
Skew correction (p. 49, fig. 16)	0.80	0.80	0.00	1.10	1.10	0.00
Froude no. f/p flow	0.17	0.17	N/A	0.15	0.14	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	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)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	1		1	1	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.05	6.22		5.05	6.22	
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0
Fr>0.8 (vertical abut.)	2.11	2.60	ERR	2.11	2.60	ERR