LEVEL II SCOUR ANALYSIS FOR BRIDGE 24 (CLARTH00160024) on TOWN HIGHWAY 16, crossing the CLARENDON RIVER, CLARENDON, VERMONT

Open-File Report 98-153

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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By MICHAEL A. IVANOFF AND DONALD L. SONG

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Pembroke, New Hampshire

1998

U.S. DEPARTMENT OF THE INTERIOR
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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 24 (CLARTH00160024) ON TOWN HIGHWAY 16, CROSSING THE CLARENDON RIVER, CLARENDON, VERMONT

***By* Michael A. Ivanoff and Donald L. Song**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CLARTH00160024 on Town Highway 16 crossing the Clarendon River, Clarendon, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Taconic section of the New England physiographic province in central Vermont. The 24.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest on the right bank and wetlands on the left bank upstream of the bridge and pasture on the right bank and shrub and brushland on the left bank downstream of the bridge.

In the study area, the Clarendon River has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 47 ft and an average bank height of 1 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 37.3 mm (0.122 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 13, 1995, indicated that the reach was stable.

The Town Highway 16 crossing of the Clarendon River is a 41-ft-long, one-lane bridge consisting of one 35-foot steel-beam span (Vermont Agency of Transportation, written communication, March 20, 1995). The opening length of the structure parallel to the bridge face is 33.2 ft. The bridge is supported by a vertical, concrete abutment with an upstream wingwall on the right and a “laid-up” stone abutment on the left. The channel is skewed approximately 40 degrees to the opening while the opening-skew-to-roadway is zero degrees.

During the Level I assessment a scour hole 2.0 ft deeper than the mean thalweg depth was observed along the upstream channel, under the bridge, and ending in the downstream channel. The only scour protection measure at the site was type-1 stone fill (less than 12 inches diameter) along the upstream and downstream left and right road embankments. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 1.8 to 2.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 13.2 to 25.3 ft. The worst-case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 7.1 to 8.8 ft. The worst-case right abutment scour occurred at the maximum free surface 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.

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.

West Rutland, VT. Quadrangle, 1:24,000, 1964
Photorevised 1972

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 CLARTH00160024 ***Stream*** Clarendon River

County Rutland ***Road*** TH 16 ***District*** 3

Description of Bridge

Bridge length 41 ***ft*** ***Bridge width*** 14.1 ***ft*** ***Max span length*** 35 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 6/13/95

Description of stone fill None.

Brief description of piers/abutments The right abutment and upstream wingwall are concrete. The left abutment is made of "laid-up" stones.

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

Yes

There is a severe channel bend in the upstream reach. A scour hole has developed in the upstream channel and continues through the bridge.

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	6/13/95	0	0
Level II	6/13/95	0	0

Potential for debris Moderate. There are trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 6/13/95.

Description of the Geomorphic Setting

General topography The channel is located within a low relief valley with a flat to slightly irregular and narrow flood plain.

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

Date of inspection 6/13/95

DS left: Steep channel bank to a moderately sloped overbank

DS right: Moderately sloped channel bank to a narrow flood plain

US left: Narrow flood plain

US right: Moderately sloped channel bank to a narrow flood plain

Description of the Channel

Average top width 47 *ft* ***Average depth*** 1 *ft*

Predominant bed material Gravel & Cobbles ***Bank material*** Silt, clay, & Cobbles

Perennial, sinuous but stable, with semi-alluvial channel boundaries, and greater width at the bends.

6/13/95

Vegetative co Trees and brush

DS left: Short grass and brush with a few trees

DS right: Wetland with 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 as of 6/13/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 24.1 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 3,620 ***ft³/s*** ***Q500*** 6,300 ***ft³/s***

The 100- and 500-year discharge were computed using a drainage area relationship [(24.1/24.7)^0.67] with the flood frequency estimates available from the Flood Insurance Study for Clarendon, VT (FEMA, 1980). The Flood Insurance Study was done for the drainage area of the Clarendon River above Ira Brook which is 24.7 square miles. The flood frequency curve was extended graphically to the 500-year discharge.

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. Add 180 ft to the USGS arbitrary survey to obtain the National Geodetic Vertical Datum of 1929.

Description of reference marks used to determine USGS datum. RM1 is a chiseled "X" on top of the upstream end of the upstream right wingwall extension (elev. 495.56 ft, arbitrary survey datum). RM2 is a chiseled "X" on top of the downstream end of the right abutment (elev. 495.76 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT2	-122	1	Exit section at a bedrock control
EXITX	-48	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	50	1	Approach section

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

Normal depth at the exit section (EXIT2) 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 0.0164 ft/ft, which was estimated from the 100-year discharge flood profile in the Flood Insurance Study for Clarendon, VT (FEMA, 1980).

The approach section (APPRO) was surveyed one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 498.4 *ft*
Average low steel elevation 495.0 *ft*

100-year discharge 3,620 *ft³/s*
Water-surface elevation in bridge opening 495.4 *ft*
Road overtopping? Yes *Discharge over road* 1,340 *ft³/s*
Area of flow in bridge opening 254 *ft²*
Average velocity in bridge opening 9.1 *ft/s*
Maximum WSPRO tube velocity at bridge 11.1 *ft/s*

Water-surface elevation at Approach section with bridge 497.2
Water-surface elevation at Approach section without bridge 495.4
Amount of backwater caused by bridge 1.8 *ft*

500-year discharge 6,300 *ft³/s*
Water-surface elevation in bridge opening 495.4 *ft*
Road overtopping? Yes *Discharge over road* 3,750 *ft³/s*
Area of flow in bridge opening 254 *ft²*
Average velocity in bridge opening 9.7 *ft/s*
Maximum WSPRO tube velocity at bridge 11.8 */s*

Water-surface elevation at Approach section with bridge 498.9
Water-surface elevation at Approach section without bridge 497.3
Amount of backwater caused by bridge 1.6 *ft*

Maximum free surface discharge 1,870 *ft³/s*
Water-surface elevation in bridge opening 491.8 *ft*
Road overtopping? Yes *Discharge over road* 89 *ft³/s*
Area of flow in bridge opening 153 *ft²*
Average velocity in bridge opening 11.6 *ft/s*
Maximum WSPRO tube velocity at bridge 14.3 *ft/s*

Water-surface elevation at Approach section with bridge 495.2
Water-surface elevation at Approach section without bridge 493.5
Amount of backwater caused by bridge 1.7

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the maximum free surface discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100-year discharge resulted in unsubmerged orifice flow and the 500-year discharge resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). These results are presented in appendix F. Furthermore, for the 100-year discharge which resulted in unsubmerged orifice flow, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution are provided in appendix F.

Abutment scour was computed by use of the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE 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-year discharge	500-year discharge	Maximum free surface discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.8	2.1	1.8
Depth to armoring	4.8	4.9	27.1
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	18.4	25.3	13.2
Right abutment	7.1	8.1	8.8
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge (D_{50} in feet)	Maximum free surface discharge
Abutments:			
Left abutment	1.7	1.8	2.0
Right abutment	1.7	1.8	2.0
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

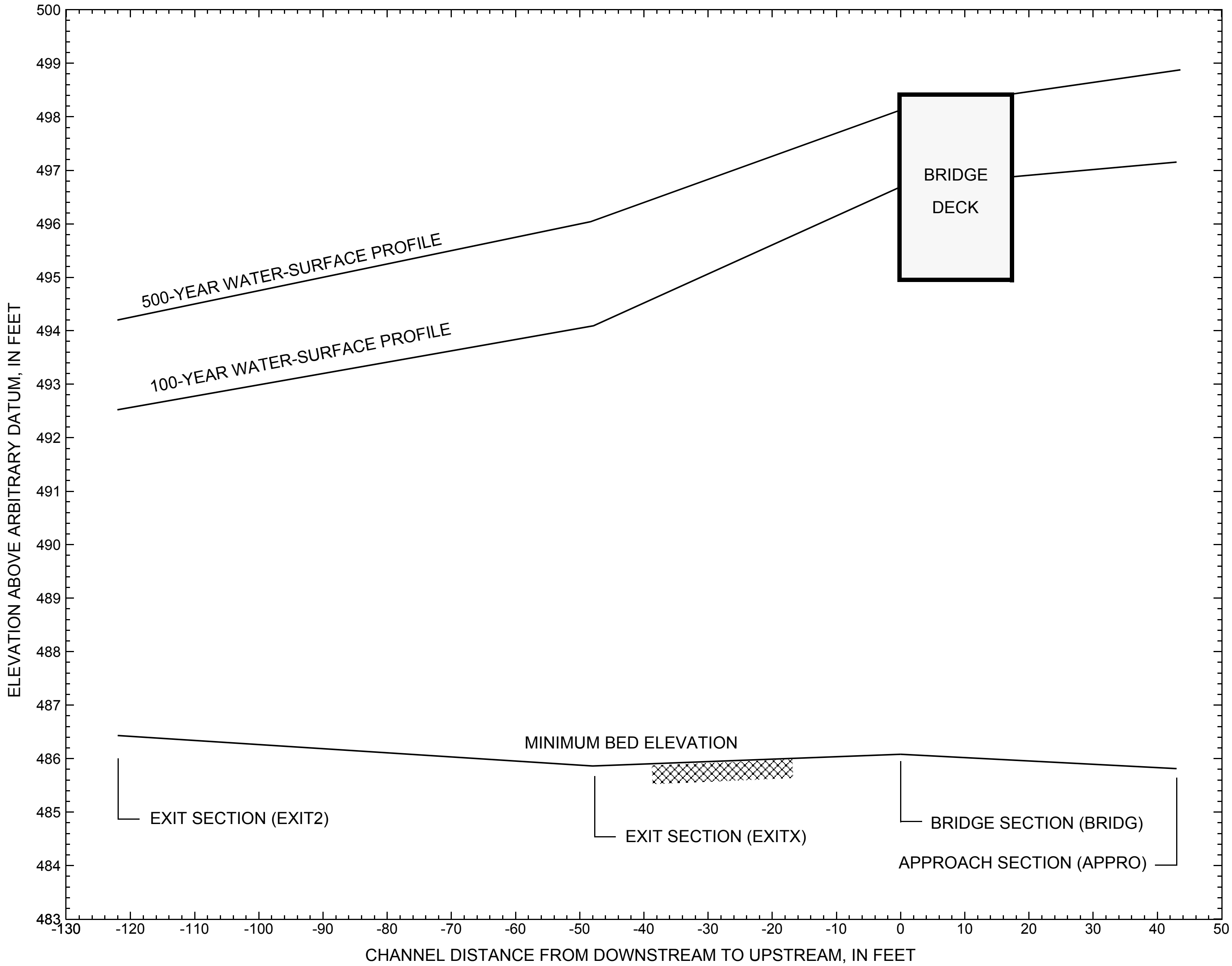

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure CLARTH00160024 on Town Highway 16, crossing the Clarendon River, Clarendon, Vermont.

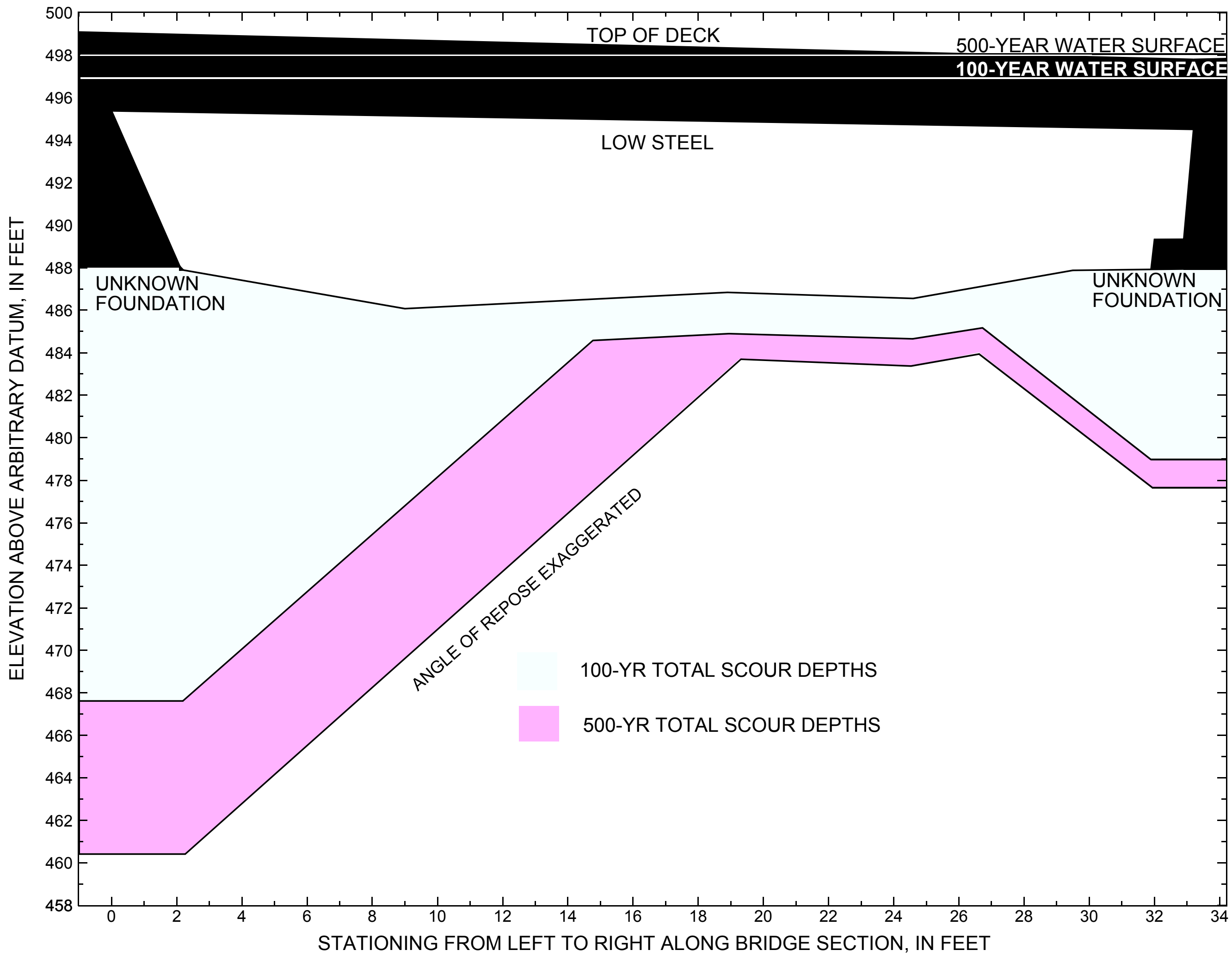

Figure 8. Scour elevations for the 100- and 500-year discharges at structure CLARTH00160024 on Town Highway 16, crossing the Clarendon River, Clarendon, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CLARTH00160024 on Town Highway 16, crossing the Clarendon River, Clarendon, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 3,620 cubic-feet per second											
Left abutment	0.0	--	495.4	--	487.9	1.8	18.4	--	20.2	467.7	--
Right abutment	33.2	--	494.5	--	487.9	1.8	7.1	--	8.9	479.0	--

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 CLARTH00160024 on Town Highway 16, crossing the Clarendon River, Clarendon, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 6,300 cubic-feet per second											
Left abutment	0.0	--	495.4	--	487.9	2.1	25.3	--	27.4	460.5	--
Right abutment	33.2	--	494.5	--	487.9	2.1	8.1	--	10.2	477.7	--

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

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U.S. Geological Survey, 1964, West Rutland, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1972, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File clar024.wsp
T2        Hydraulic analysis for structure CLARTH00160024   Date: 03-FEB-98
T3        Bridge 24 on Town Highway 16 over the Clarendon River Clarendon, VT MI
*                * * This file was generated by AWISPP v2.5 * *
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3620.0   6300.0   1870.0
SK          0.0164   0.0164   0.0164
*
XS   EXIT2    -122
GR          -22.0, 500.00    -20.3, 495.40    -17.6, 493.87
GR            0.0, 489.20      6.9, 488.65     11.4, 486.67     42.5, 486.86
GR           53.0, 486.51     62.0, 486.43     64.7, 486.54     69.1, 488.63
GR           77.8, 491.99    131.4, 494.04    169.1, 495.80    170.0, 500.00
N           0.060        0.040
SA                  77.8
*
XS   EXITX    -48
GR          -22.0, 500.00    -20.3, 495.40    -17.6, 493.87      0.0, 491.52
GR            6.1, 489.27     21.0, 485.86     28.6, 486.04     37.2, 486.39
GR           44.6, 486.39     47.9, 487.08     49.2, 489.15     74.4, 490.65
GR          119.9, 492.50    199.3, 496.23    200.0, 500.00
N           0.060
*
XS   FULLV      0  * * *   0.0173
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    494.95       0.0
GR            0.0, 495.38      2.1, 488.05      2.2, 487.89      9.0, 486.08
GR           18.9, 486.84     24.6, 486.55     29.5, 487.88     32.0, 487.94
GR           32.0, 489.33     32.9, 489.34     33.2, 494.51      0.0, 495.38
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      17.5      2.5    498.4     45.0
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      9      14.1     2
GR         -233.2, 506.62   -123.8, 502.49    -37.6, 499.07    -15.2, 499.63
GR            0.0, 499.05     32.9, 497.80     36.0, 497.53     51.2, 496.20
GR           78.7, 494.49    100.6, 494.21    100.7, 494.19    154.0, 495.48
GR          205.5, 496.15    238.0, 500.00    240.0, 505.00
*
AS   APPRO     50
GR         -212.0, 499.00   -200.0, 496.50   -120.4, 493.35
GR          -98.6, 491.61    -54.1, 490.46    -15.1, 489.58      0.0, 489.54
GR            9.7, 487.81     14.6, 485.81     23.7, 486.81     32.2, 487.11
GR           35.0, 488.03     48.2, 488.38     69.6, 489.98    100.6, 494.21
GR          100.7, 494.19    154.0, 495.48    205.5, 496.15    238.0, 500.00
GR          240.0, 505.00
* GR           92.2, 493.19     99.8, 494.49    111.0, 500.00
N            0.055        0.065        0.065
SA                  0.0         35.0
*
HP 1 BRIDG   495.38 1 495.38
HP 2 BRIDG   495.38 * * 2320
HP 1 BRIDG   494.63 1 494.63
HP 2 RDWAY   496.69 * * 1348
HP 1 APPRO   497.15 1 497.15
HP 2 APPRO   497.15 * * 3620
*
HP 1 BRIDG   495.38 1 495.38
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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     U.S. Geological Survey WSPRO Input File clar024.wsp
     Hydraulic analysis for structure CLARTH00160024   Date: 03-FEB-98
     Bridge 24 on Town Highway 16 over the Clarendon River Clarendon, VT MI
        *** RUN DATE & TIME: 03-19-98  11:34
 CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     254.   16530.     0.    79.                           0.
495.38          254.   16530.     0.    79.  1.00     0.    33.      0.

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

      WSEL     LEW     REW    AREA        K        Q    VEL
    495.38     0.0    33.2   254.1   16530.    2320.   9.13

X STA.        0.0        4.7        6.0        7.3        8.5        9.7
  A(I)            28.0       10.8       10.9       10.7       10.7
  V(I)            4.14      10.76      10.68      10.86      10.83

X STA.        9.7       10.9       12.1       13.4       14.6       16.0
  A(I)            10.4       10.8       10.9       10.8       11.0
  V(I)           11.13      10.75      10.63      10.71      10.54

X STA.       16.0       17.3       18.6       20.0       21.4       22.7
  A(I)            11.1       10.9       11.3       11.0       11.0
  V(I)           10.49      10.67      10.29      10.57      10.58

X STA.       22.7       24.1       25.5       26.9       28.6       33.2
  A(I)            11.2       11.1       11.2       11.8       28.6
  V(I)           10.40      10.41      10.32       9.85       4.05

 CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     243.   21092.    29.    49.                        4009.
494.62          243.   21092.    29.    49.  1.00     0.    33.   4009.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       9.

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.69    45.6   210.1   235.0    7401.    1348.   5.74

X STA.       45.6       69.7       75.4       79.8       84.0       88.1
  A(I)            21.0       10.4        9.5        9.3        9.3
  V(I)            3.21       6.50       7.09       7.22       7.21

X STA.       88.1       92.1       96.0       99.8      103.6      107.2
  A(I)             9.4        9.3        9.4        9.3        8.5
  V(I)            7.13       7.24       7.17       7.22       7.95

X STA.      107.2      110.5      114.6      118.9      123.6      128.9
  A(I)             7.8        9.0        9.1        9.4        9.9
  V(I)            8.69       7.49       7.40       7.18       6.82

X STA.      128.9      134.7      141.7      150.5      163.4      210.1
  A(I)            10.1       11.2       12.3       15.3       35.5
  V(I)            6.65       6.04       5.47       4.42       1.90

 CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     945.   71260.   203.   203.                       11561.
          2     345.   35838.    35.    36.                        6145.
          3     642.   34434.   179.   179.                        6900.
497.15         1932.  141532.   417.   418.  1.17  -203.   214.  21780.

 VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      50.
      WSEL     LEW     REW    AREA        K        Q    VEL
    497.15  -203.1   213.9  1931.7  141532.    3620.   1.87

X STA.     -203.1      -98.4      -83.9      -70.9      -58.8      -47.9
  A(I)           281.3       83.1       79.1       77.3       73.0
  V(I)            0.64       2.18       2.29       2.34       2.48

X STA.      -47.9      -37.6      -27.8      -18.5       -9.6       -0.7
  A(I)            71.7       70.3       68.8       67.2       67.5
  V(I)            2.52       2.58       2.63       2.69       2.68

X STA.       -0.7        8.5       15.2       20.9       27.2       34.0
  A(I)            76.2       68.4       62.9       65.6       67.9
  V(I)            2.38       2.65       2.88       2.76       2.66

X STA.       34.0       41.8       49.9       59.3       69.7      213.9
  A(I)            70.7       71.5       77.7       78.9      352.4
  V(I)            2.56       2.53       2.33       2.29       0.51
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        U.S. Geological Survey WSPRO Input File clar024.wsp
        Hydraulic analysis for structure CLARTH00160024   Date: 03-FEB-98
        Bridge 24 on Town Highway 16 over the Clarendon River Clarendon, VT MI
           *** RUN DATE & TIME: 03-19-98  11:34
    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     254.  16530.     0.    79.                           0.
   495.38          254.  16530.     0.    79.  1.00     0.    33.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.38     0.0    33.2   254.1   16530.    2458.   9.68

X STA.         0.0        4.7        6.0        7.3        8.5        9.7
  A(I)            28.0       10.8       10.9       10.7       10.7
  V(I)            4.39      11.41      11.32      11.50      11.48

X STA.         9.7       10.9       12.1       13.4       14.6       16.0
  A(I)            10.4       10.8       10.9       10.8       11.0
  V(I)           11.79      11.39      11.26      11.34      11.17

X STA.        16.0       17.3       18.6       20.0       21.4       22.7
  A(I)            11.1       10.9       11.3       11.0       11.0
  V(I)           11.12      11.31      10.90      11.20      11.21

X STA.        22.7       24.1       25.5       26.9       28.6       33.2
  A(I)            11.2       11.1       11.2       11.8       28.6
  V(I)           11.02      11.03      10.94      10.44       4.29


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.14    24.0   222.3   495.2   22614.    3746.   7.56

X STA.        24.0       66.4       73.4       79.2       84.6       89.9
  A(I)            59.1       21.7       20.4       19.7       19.9
  V(I)            3.17       8.64       9.16       9.53       9.41

X STA.        89.9       95.0      100.1      105.1      110.5      116.1
  A(I)            19.6       19.9       19.5       20.4       20.4
  V(I)            9.56       9.42       9.61       9.16       9.20

X STA.       116.1      121.9      128.1      134.6      141.8      149.7
  A(I)            20.4       20.8       20.9       22.0       22.5
  V(I)            9.19       9.01       8.98       8.51       8.32

X STA.       149.7      158.7      168.3      179.1      190.8      222.3
  A(I)            24.0       24.3       26.0       26.3       47.4
  V(I)            7.81       7.71       7.20       7.11       3.95

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1299. 117950.   211.   212.                       18277.
             2     405.  46789.    35.    36.                        7812.
             3     960.  63959.   193.   194.                       12144.
   498.86         2664. 228698.   440.   441.  1.12  -211.   228.  35222.


    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.86  -211.3   228.4  2664.2  228698.    6300.   2.36

X STA.      -211.3     -122.0     -100.7      -85.5      -71.4      -58.6
  A(I)           317.9      132.9      112.3      109.6      103.5
  V(I)            0.99       2.37       2.81       2.87       3.04

X STA.       -58.6      -46.3      -34.9      -23.8      -13.5       -3.4
  A(I)           103.7       99.3       99.3       95.5       93.6
  V(I)            3.04       3.17       3.17       3.30       3.37

X STA.        -3.4        7.4       15.9       23.3       31.4       40.7
  A(I)           105.9      100.0       92.4       97.2      102.3
  V(I)            2.98       3.15       3.41       3.24       3.08

X STA.        40.7       50.4       61.5       74.6       98.0      228.4
  A(I)           101.8      110.5      117.1      154.2      415.3
  V(I)            3.09       2.85       2.69       2.04       0.76
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        U.S. Geological Survey WSPRO Input File clar024.wsp
        Hydraulic analysis for structure CLARTH00160024   Date: 03-FEB-98
        Bridge 24 on Town Highway 16 over the Clarendon River Clarendon, VT MI
           *** RUN DATE & TIME: 03-19-98  11:34
    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW     REW     QCR
             1     153.   11303.    32.    39.                         1897.
   491.84          153.   11303.    32.    39.  1.00     1.    33.   1897.


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       491.84     1.0    33.0   153.0   11303.    1778.  11.62

X STA.        1.0        5.4        6.8        8.0        9.1       10.2
  A(I)            16.6        6.9        6.4        6.2        6.2
  V(I)            5.35      12.94      13.90      14.23      14.26

X STA.       10.2       11.3       12.5       13.7       14.9       16.1
  A(I)             6.3        6.4        6.3        6.6        6.5
  V(I)           14.00      13.90      14.10      13.51      13.76

X STA.       16.1       17.4       18.7       20.0       21.2       22.5
  A(I)             6.5        6.6        6.5        6.5        6.4
  V(I)           13.68      13.52      13.69      13.62      13.86

X STA.       22.5       23.7       24.9       26.3       27.8       33.0
  A(I)             6.5        6.4        6.6        7.0       19.6
  V(I)           13.62      13.99      13.54      12.77       4.54


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.01    70.3   134.6    30.6     463.      92.   3.01

X STA.       70.3       79.9       82.4       84.7       86.8       88.9
  A(I)             2.8        1.4        1.3        1.3        1.3
  V(I)            1.65       3.32       3.47       3.51       3.52

X STA.       88.9       90.8       92.7       94.4       96.2       97.8
  A(I)             1.3        1.3        1.3        1.2        1.2
  V(I)            3.57       3.63       3.61       3.68       3.81

X STA.       97.8       99.2      100.7      102.1      103.6      105.2
  A(I)             1.1        1.2        1.1        1.2        1.2
  V(I)            4.09       3.99       4.03       3.98       3.86

X STA.      105.2      107.0      109.0      111.2      113.9      134.6
  A(I)             1.2        1.3        1.3        1.4        5.2
  V(I)            3.78       3.63       3.52       3.18       0.89

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW     REW     QCR
             1     567.   34810.   166.   166.                         5944.
             2     275.   24557.    35.    36.                         4373.
             3     333.   16424.   105.   106.                         3363.
   495.15         1175.   75790.   306.   307.  1.16  -166.   140.  12104.


    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.15  -165.9   140.4  1175.0   75790.    1870.   1.59

X STA.     -165.9      -78.9      -65.9      -54.5      -44.0      -34.5
  A(I)           173.8       55.0       51.4       50.5       47.8
  V(I)            0.54       1.70       1.82       1.85       1.96

X STA.      -34.5      -25.8      -17.4       -9.3       -1.5        6.7
  A(I)            45.4       45.4       45.1       44.1       49.6
  V(I)            2.06       2.06       2.07       2.12       1.88

X STA.        6.7       12.5       16.9       21.4       26.2       31.2
  A(I)            43.7       39.9       39.7       40.3       40.6
  V(I)            2.14       2.34       2.36       2.32       2.30

X STA.       31.2       37.1       43.6       50.5       58.1      140.4
  A(I)            44.5       45.3       46.4       48.2      178.1
  V(I)            2.10       2.06       2.01       1.94       0.52
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File clar024.wsp
        Hydraulic analysis for structure CLARTH00160024   Date: 03-FEB-98
        Bridge 24 on Town Highway 16 over the Clarendon River Clarendon, VT MI
           *** RUN DATE & TIME: 03-19-98  11:34

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

EXIT2:XS   ******   -12.     419.  1.17 *****  493.65  491.46   3620.  492.48
     -122. ******    91.   28260.  1.01 ***** *******    0.76    8.64

EXITX:XS      74.   -18.     610.  0.55  0.98  494.64 *******   3620.  494.09
      -48.    74.   154.   34912.  1.00  0.00    0.00    0.56    5.94

FULLV:FV      48.   -17.     559.  0.65  0.58  495.27 *******   3620.  494.62
        0.    48.   147.   31111.  1.00  0.05    0.00    0.62    6.48
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  2.61

APPRO:AS      50.  -172.    1245.  0.15  0.26  495.53 *******   3620.  495.37
       50.    50.   150.   81138.  1.17  0.00    0.00    0.28    2.91
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.82       0.00     494.45     494.19

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.48     496.83     496.96     494.95

 ===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      48.     0.     254.  1.30 *****  496.68  492.54   2320.  495.38
        0. ******    33.   16530.  1.00 ***** *******    0.58    9.13

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.467  0.000  494.95 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    36.  0.02  0.06  497.19    0.01   1348.  496.69

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    15.     1.    16.   0.6   0.3   4.8  14.1   1.3   2.9
   RT:   1348.   164.    46.   210.   2.5   1.4   6.4   5.7   1.9   3.1

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

APPRO:AS      33.  -203.    1931.  0.06  0.15  497.21  492.09   3620.  497.15
       50.    41.   214.  141463.  1.17  0.27    0.01    0.17    1.87

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT2:XS    -122.   -12.    91.   3620.   28260.     419.    8.64  492.48
   EXITX:XS     -48.   -18.   154.   3620.   34912.     610.    5.94  494.09
   FULLV:FV       0.   -17.   147.   3620.   31111.     559.    6.48  494.62
   BRIDG:BR       0.     0.    33.   2320.   16530.     254.    9.13  495.38
   RDWAY:RG       9.*******     0.   1348.       0.*********    2.00  496.69
   APPRO:AS      50.  -203.   214.   3620.  141463.    1931.    1.87  497.15

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT2:XS    491.46    0.76  486.43  500.00************  1.17  493.65  492.48
   EXITX:XS  ********    0.56  485.86  500.00  0.98  0.00  0.55  494.64  494.09
   FULLV:FV  ********    0.62  486.69  500.83  0.58  0.05  0.65  495.27  494.62
   BRIDG:BR    492.54    0.58  486.08  495.38************  1.30  496.68  495.38
   RDWAY:RG  ****************  494.19  506.62  0.02******  0.06  497.19  496.69
   APPRO:AS    492.09    0.17  485.81  505.00  0.15  0.27  0.06  497.21  497.15
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        U.S. Geological Survey WSPRO Input File clar024.wsp
        Hydraulic analysis for structure CLARTH00160024   Date: 03-FEB-98
        Bridge 24 on Town Highway 16 over the Clarendon River Clarendon, VT MI
           *** RUN DATE & TIME: 03-19-98  11:34

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

EXIT2:XS   ******   -18.     640.  1.60 *****  495.80  493.57   6300.  494.20
     -122. ******   135.   49146.  1.06 ***** *******    0.88    9.84

EXITX:XS      74.   -21.     991.  0.63  0.89  496.68 *******   6300.  496.05
      -48.    74.   196.   67290.  1.00  0.00   -0.01    0.52    6.36

FULLV:FV      48.   -20.     902.  0.76  0.48  497.22 *******   6300.  496.46
        0.    48.   187.   59255.  1.00  0.06    0.00    0.59    6.98
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  2.48

APPRO:AS      50.  -204.    1979.  0.18  0.23  497.45 *******   6300.  497.26
       50.    50.   215.  146755.  1.17  0.00    0.00    0.28    3.18
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                     WS3N,LSEL =   496.46     494.95

            <<<<<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      48.     0.     254.  1.46 *****  496.84  492.75   2458.  495.38
        0. ******    33.   16530.  1.00 ***** *******    0.62    9.67

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   6.  0.800  0.000  494.95 ****** ****** ******

   XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
  RDWAY:RG        9.    36.  0.03  0.10  498.93   -0.02   3746.  498.14

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
  LT:      0.     9.     7.    16.   0.4   0.2   4.5  18.5   1.1   2.8
  RT:   3746.   198.    24.   222.   4.0   2.5   8.6   7.6   3.3   3.2

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

APPRO:AS      33.  -211.    2666.  0.10  0.23  498.96  493.15   6300.  498.86
       50.    44.   228.  228969.  1.12  0.27   -0.02    0.18    2.36

  FIRST USER DEFINED TABLE.

   XSID:CODE     SRD    LEW    REW       Q         K     AREA     VEL    WSEL
  EXIT2:XS     -122.   -18.   135.   6300.   49146.     640.    9.84  494.20
  EXITX:XS      -48.   -21.   196.   6300.   67290.     991.    6.36  496.05
  FULLV:FV        0.   -20.   187.   6300.   59255.     902.    6.98  496.46
  BRIDG:BR        0.     0.    33.   2458.   16530.     254.    9.67  495.38
  RDWAY:RG        9.*******     0.   3746.       0.*********    2.00  498.14
  APPRO:AS       50.  -211.   228.   6300.  228969.    2666.    2.36  498.86

 SECOND USER DEFINED TABLE.

   XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
  EXIT2:XS     493.57    0.88  486.43  500.00************  1.60  495.80  494.20
  EXITX:XS   ********    0.52  485.86  500.00  0.89  0.00  0.63  496.68  496.05
  FULLV:FV   ********    0.59  486.69  500.83  0.48  0.06  0.76  497.22  496.46
  BRIDG:BR     492.75    0.62  486.08  495.38************  1.46  496.84  495.38
  RDWAY:RG   ****************  494.19  506.62  0.03******  0.10  498.93  498.14
  APPRO:AS     493.15    0.18  485.81  505.00  0.23  0.27  0.10  498.96  498.86
```

```
        U.S. Geological Survey WSPRO Input File clar024.wsp
        Hydraulic analysis for structure CLARTH00160024   Date: 03-FEB-98
        Bridge 24 on Town Highway 16 over the Clarendon River Clarendon, VT MI
           *** RUN DATE & TIME: 03-19-98  11:34

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

EXIT2:XS   ******    -6.     267.  0.76 *****  491.51  489.90   1870.  490.75
     -122. ******    75.   14596.  1.00 ***** *******    0.68    7.00

EXITX:XS      74.    -4.     324.  0.52  1.11  492.63 *******   1870.  492.11
      -48.    74.   110.   15909.  1.00  0.00    0.01    0.60    5.76

FULLV:FV      48.    -3.     309.  0.57  0.70  493.37 *******   1870.  492.80
        0.    48.   107.   15028.  1.00  0.03    0.02    0.64    6.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  2.98

APPRO:AS      50.  -125.     759.  0.11  0.26  493.63 *******   1870.  493.53
       50.    50.    96.   44815.  1.11  0.00    0.00    0.25    2.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   495.53       0.00     491.79     494.19
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   491.84     495.00     495.15     494.95
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                        YU/Z,WSIU,WS = 1.10     495.71     495.77
 ===270 REJECTED 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      48.     1.     153.  2.58  0.89  494.41  491.65   1778.  491.84
        0.    48.    33.   11290.  1.22  0.89    0.00    1.04   11.63

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   4.  0.904 ******  494.95 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    36.  0.02  0.05  495.17    0.00     92.  495.01

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    15.     1.    16.   0.6   0.3   4.8  13.9   1.3   2.9
   RT:     92.    64.    70.   135.   0.8   0.5   3.3   3.0   0.6   2.8

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

APPRO:AS      33.  -166.    1176.  0.05  0.15  495.20  491.02   1870.  495.15
       50.    39.   140.   75848.  1.16  0.64    0.00    0.15    1.59

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.853  0.705   22351.    -1.    31. ********

  FIRST USER DEFINED TABLE.

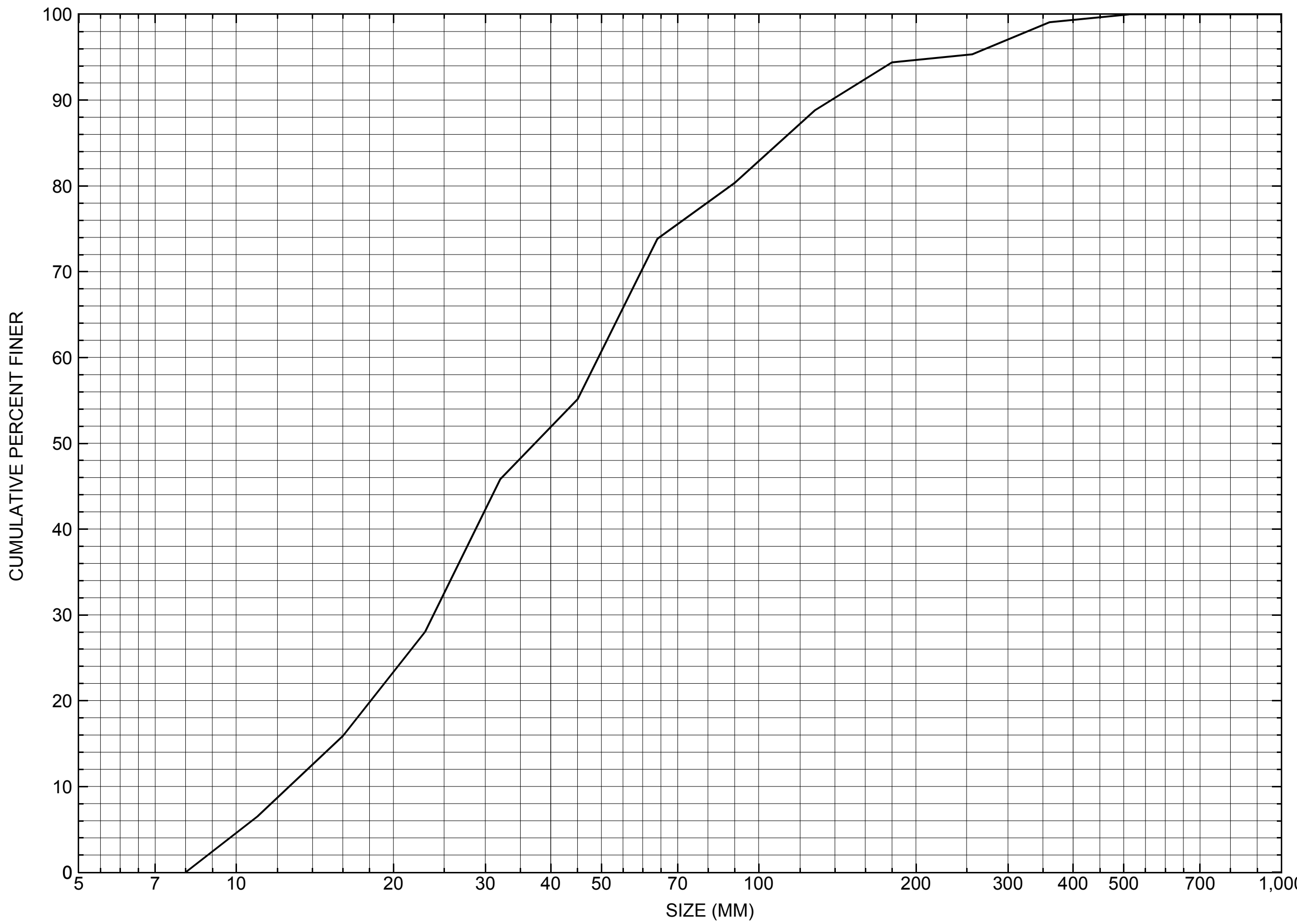
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT2:XS    -122.    -6.    75.   1870.   14596.     267.    7.00  490.75
   EXITX:XS     -48.    -4.   110.   1870.   15909.     324.    5.76  492.11
   FULLV:FV       0.    -3.   107.   1870.   15028.     309.    6.06  492.80
   BRIDG:BR       0.     1.    33.   1778.   11290.     153.   11.63  491.84
   RDWAY:RG       9.*******     0.     92.       0.*********    2.00  495.01
   APPRO:AS      50.  -166.   140.   1870.   75848.    1176.    1.59  495.15

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    31.   22351.
 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT2:XS     489.90    0.68  486.43  500.00************  0.76  491.51  490.75
   EXITX:XS   ********    0.60  485.86  500.00  1.11  0.00  0.52  492.63  492.11
   FULLV:FV   ********    0.64  486.69  500.83  0.70  0.03  0.57  493.37  492.80
   BRIDG:BR     491.65    1.04  486.08  495.38  0.89  0.89  2.58  494.41  491.84
   RDWAY:RG   ***************  494.19  506.62  0.02******  0.05  495.17  495.01
   APPRO:AS     491.02    0.15  485.81  505.00  0.15  0.64  0.05  495.20  495.15
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CLARTH00160024, in Clarendon, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CLARTH00160024

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 20 / 95

Highway District Number *(I - 2; nn)* 03

County *(FIPS county code; I - 3; nnn)* 021

Town *(FIPS place code; I - 4; nnnnn)* 14500

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

Waterway *(I - 6)* Clarendon River

Road Name *(I - 7):* -

Route Number TH016

Vicinity *(I - 9)* 0.2 MI TO JCT W CL2 TH3

Topographic Map West Rutland

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 43328

Longitude *(i - 17; nnnnn.n)* 73012

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10110500241105

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

Maximum span length *(I - 48; nnnn)* 0035

Year built *(I - 27; YYYY)* 1949

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

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

Deck Width *(I - 52; nn.n)* 141

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

Channel & Protection *(I - 61; n)* 6

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

Waterway adequacy *(I - 71; n)* 7

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

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

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 008.4

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

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

Comments:

The structural inspection report of 6/3/94 indicates the structure is a single span steel beam type bridge with a timber deck. The right abutment and its wingwall are concrete while the left abutment is "laid-up" stone. There are some fine cracks reported in the right abutment concrete and some spalling on the upstream right wingwall. On the left abutment there is a large area noted where there has been stone displacement of up to one foot. There is general scour reported under the bridge near the centerline of the channel. The streambed is mostly gravel. There is a small stone dam downstream of the bridge. There is also some log debris noted in the channel at the upstream face of the bridge. The channel makes a sharp bend into the structure.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -
Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **24.13** mi^2 Lake/pond/swamp area **1.26** mi^2

Watershed storage *(ST)* **5.2** %

Bridge site elevation **670** ft Headwater elevation **1607** ft

Main channel length **15.3** mi

10% channel length elevation **790** ft 85% channel length elevation **1130** ft

Main channel slope *(S)* **29.63** 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:

NO BENCHMARK INFORMATION

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? - *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:

-

Cross-sectional Data

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

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

Comments: **This survey is from the bridge section for this site in the Flood Insurance Study for Clarendon, VT.**

Station	375	375.01	382	390	400	408	408.01	-	-	-	-
Feature	LB						RB	-	-	-	-
Low chord elevation	668.1	675.3	675.0	674.7	674.4	674.2	665.7	-	-	-	-
Bed elevation	668.1	668.1	665.5	664.7	664.3	665.7	665.6	-	-	-	-
Low chord to bed	0	7.2	9.5	10.0	10.1	8.5	0	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **JD** Date: **4/30/96**
Computerized by: **JD** Date: **4/30/96**
Reviewd by: **MAI** Date: **02/17/98**

Structure Number **CLARTH00160024**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **D**. **Song** Date *(MM/DD/YY)* **6** / **13** / 19**95**

2. Highway District Number **3** Mile marker **0**

County **Rutland (021)** Town **Clarendon (145000)**

Waterway *(I - 6)* **Clarendon River** Road Name **-**

Route Number **TH016** Hydrologic Unit Code: **02010002**

3. Descriptive comments:
This site is located 0.2 mile from the junction with Town Highway 3.

B. Bridge Deck Observations

4. Surface cover... LBUS **7** RBUS **6** LBDS **5** 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 **1** UB **1** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **41.0** *(feet)* Span length **35.0** *(feet)* Bridge width **14.1** *(feet)*

Road approach to bridge:

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

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

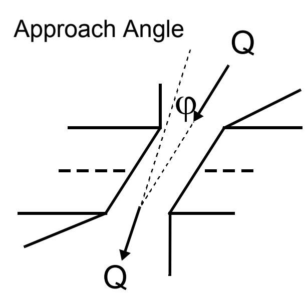
10. Embankment slope (*run / rise in feet / foot*):
US left **3.0:1** US right **2.0:1**

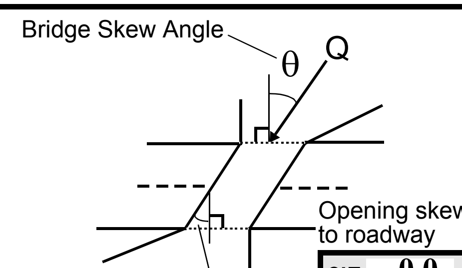
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	1	0	0
RBUS	1	1	3	1
RBDS	1	1	0	0
LBDS	1	1	0	0

*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: **50** 16. Bridge skew: **40**





α= **0.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **30** feet **US** *(US, UB, DS)* to **10** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **5** feet **US** *(US, UB, DS)* to **10** feet **DS**

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

18. Bridge Type: **4**

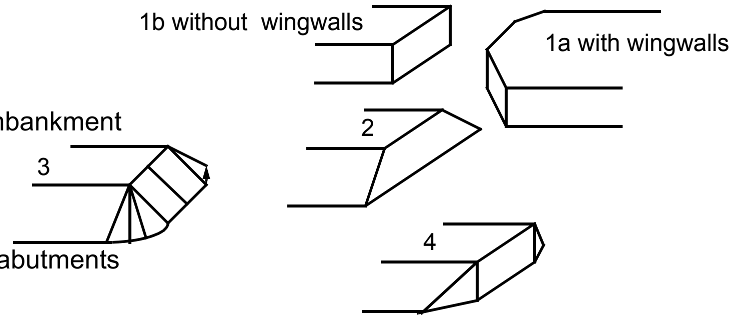
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. The measured structure length was 42 ft. The span length was 36 ft, with a 14 ft width. The road over flow width is 13 ft.

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
78.0	**1.5**			**0.5**	**4**	**4**	**415**	**415**	**1**	**1**

23. Bank width **10.0** 24. Channel width **0.0** 25. Thalweg depth **50.0** 29. Bed Material **345**

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

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

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

27. The banks have a layer of silt between 1 and 2 ft thick, overlying boulders and cobbles.
29. The channel is a scoured out pool with patches of silt and areas of boulders and cobbles.

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

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

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

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

NO CUT BANKS
Mild signs of cutting and exposed roots are seen at bends in the channel.

45. Is channel scour present? Y *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: 10

47. Scour dimensions: Length 60 Width 25 Depth : 2 Position 20 %LB to 80 %RB

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

This deep pooling US and under the bridge ends at a stone dam DS of the bridge.

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
26.5		2.0		2	7	7	-

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

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

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

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

425
There is a layer of silt 0.5 ft thick covering boulders and cobbles in the pool under the bridge.

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

Debris is discussed in the historical form as being at the US face but is no longer there. There are trees leaning over the upstream channel.

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		**40**	**90**	**2**	**0**	**0**	**0**	**90.0**
RABUT	**2**	**-**	**90**			**2**	**2**	**33.0**

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.):

0

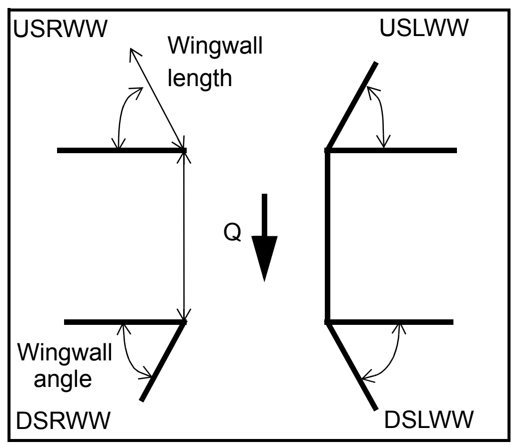
1.5

1

76. The left abutment does not have an exposed footing, but the bed level is the same as the right abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**33.0**	
USRWW:	**N**		**-**		**-**	**1.0**	
DSLWW:	**-**		**-**		**Y**	**18.0**	
DSRWW:	**1**		**2**		**0**	**17.0**	



*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	**1**	**-**	**N**	**-**	**-**	**-**	**-**	**-**
Condition	**N**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Extent	**-**	**-**	**-**	**0**	**0**	**0**	**0**	**0**

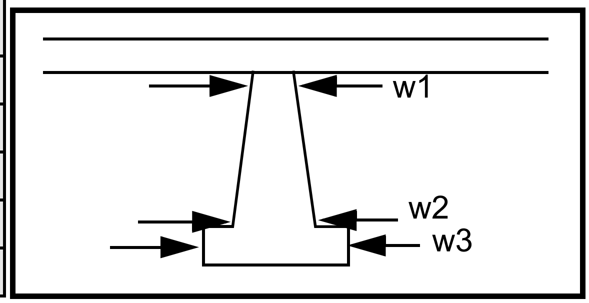
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? __-__ *(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	-			-	45.0	18.5
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

-
-
-
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	NO	PIE	RS		

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

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

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

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

3
2
415
415
0
1
34
0
0
-
-

The DS observations were taken DS of the stone dam. The right bank erosion is impacted from the flow coming around the stone dam. The channel bed is bedrock approximately 90 ft DS of the bridge.

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 **N** feet **-** *(US, UB, DS)* positioned **NO** %LB to **DR** %RB

Material: **OP**

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

STRUCTURE

The stone pile at 30 ft DS acts as a drop structure. The bed drops 1.5 ft past the dam.

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

Cut bank extent: **-** 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? **NO** *(Y or if N type ctrl-n cs)* Mid-scour distance: **POIN**

Scour dimensions: Length **T** Width **BAR** Depth: **S** Positioned ____ %LB to ____ %RB

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

Y
RB
20

Are there major confluences? **0** *(Y or if N type ctrl-n mc)* How many? **DS**

Confluence 1: Distance **35** Enters on **DS** *(LB or RB)* Type **1** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

k is impacted by flow that is diverted by the stone dam.

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 CHANNEL SCOUR

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:	CLARTH00160024	Town:	Clarendon
Road Number:	TH 16	County:	Rutland
Stream:	Clarendon River		

Initials MAI   Date: 02/05/98 Checked: RLB

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 Davis, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3620	6300	1870
Main Channel Area, ft2	345	405	275
Left overbank area, ft2	945	1299	567
Right overbank area, ft2	642	960	333
Top width main channel, ft	35	35	35
Top width L overbank, ft	203	211	166
Top width R overbank, ft	179	193	105
D50 of channel, ft	0.1224	0.1224	0.1224
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.9	11.6	7.9
y1, average depth, LOB, ft	3.4	6.2	3.4
y1, average depth, ROB, ft	3.2	5.0	3.2
Total conveyance, approach	141532	228698	75790
Conveyance, main channel	35838	46789	24557
Conveyance, LOB	71260	117950	34810
Conveyance, ROB	34434	63959	16424
Percent discrepancy, conveyance	-0.0013	0.0000	-0.0013
Qm, discharge, MC, cfs	1172.9	1288.9	605.9
Ql, discharge, LOB, cfs	1662.6	3249.2	858.9
Qr, discharge, ROB, cfs	784.5	1761.9	405.2
Vm, mean velocity MC, ft/s	4.3	3.2	2.2
Vl, mean velocity, LOB, ft/s	2.9	2.5	1.5
Vr, mean velocity, ROB, ft/s	2.4	1.8	1.2
Vc-m, crit. velocity, MC, ft/s	7.8	8.4	7.8
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 Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	3620	6300	1870
(Q) discharge thru bridge, cfs	2320	2458	1778
Main channel conveyance	16530	16530	11303
Total conveyance	16530	16530	11303
Q2, bridge MC discharge,cfs	2320	2458	1778
Main channel area, ft2	254	254	153
Main channel width (normal), ft	33.2	33.2	32.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.2	33.2	32
y_bridge (avg. depth at br.), ft	7.65	7.65	4.78
Dm, median (1.25*D50), ft	0.153	0.153	0.153
y2, depth in contraction,ft	8.06	8.47	6.62
ys, scour depth (y2-ybridge), ft	0.41	0.82	**1.84**

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 Davis, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	3620	6300	1870
Q, thru bridge MC, cfs	2320	2458	1778
Vc, critical velocity, ft/s	7.85	8.37	7.85
Va, velocity MC approach, ft/s	4.27	3.18	2.20
Main channel width (normal), ft	33.2	33.2	32.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.2	33.2	32.0
qbr, unit discharge, ft2/s	69.9	74.0	55.6
Area of full opening, ft2	254.1	254.1	153.0
Hb, depth of full opening, ft	7.65	7.65	4.78
Fr, Froude number, bridge MC	0.58	0.62	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	243	N/A	N/A
**Hb, depth at downstream face, ft	7.32	N/A	N/A
**Fr, Froude number at DS face	0.62	ERR	ERR
**Cf, for downstream face (<=1.0)	1.00	N/A	N/A

Elevation of Low Steel, ft	494.95	494.95	0
Elevation of Bed, ft	487.30	487.30	-4.78
Elevation of Approach, ft	497.15	498.86	0
Friction loss, approach, ft	0.15	0.23	0
Elevation of WS immediately US, ft	497.00	498.63	0.00
ya, depth immediately US, ft	9.70	11.33	4.78
Mean elevation of deck, ft	498.42	498.42	0
w, depth of overflow, ft (>=0)	0.00	0.21	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.90	1.00
**Cc, for downstream face (<=1.0)	0.929386	ERR	ERR
Ys, scour w/Chang equation, ft	**1.81**	**2.14**	N/A
Ys, scour w/Umbrell equation, ft	-0.25	-0.76	N/A

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

**Ys, scour w/Chang equation, ft	2.26	N/A	N/A
**Ys, scour w/Umbrell equation, ft	0.08	N/A	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	8.06	8.47	6.62
WSEL at downstream face, ft	494.62	--	--
Depth at downstream face, ft	7.32	N/A	N/A
Ys, depth of scour (Laursen), ft	0.74	N/A	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	2320	2458	1778
Main channel area (DS), ft2	243	254.1	153
Main channel width (normal), ft	33.2	33.2	32.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	33.2	33.2	32.0
D90, ft	0.4521	0.4521	0.4521
D95, ft	0.7425	0.7425	0.7425
Dc, critical grain size, ft	0.3290	0.3321	0.5765
Pc, Decimal percent coarser than Dc	0.170	0.168	0.060
Depth to armoring, ft	**4.82**	**4.93**	**27.10**

Abutment Scour

Froehlich's Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1

(Richardson and Davis, 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	3620	6300	1870	3620	6300	1870
a', abut.length blocking flow, ft	203.1	211.3	166.9	180.7	195.2	107.4
Ae, area of blocked flow ft2	945.1	1300.94	573.62	424.19	499.02	318.32
Qe, discharge blocked abut.,cfs	1823.77	3249.17	870.01	--	--	--
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.93	2.50	1.52	1.41	1.86	1.26

ya, depth of f/p flow, ft	4.65	6.16	3.44	2.35	2.56	2.96

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

K1	1	1	1	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	0.158	0.177	0.144	0.130	0.146	0.123
ys, scour depth, ft	22.01	28.42	16.15	10.50	12.05	10.16

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	203.1	211.3	166.9	180.7	195.2	107.4
y1 (depth f/p flow, ft)	4.65	6.16	3.44	2.35	2.56	2.96
a'/y1	43.65	34.32	48.56	76.98	76.36	36.24
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.16	0.18	0.14	0.13	0.15	0.12
Ys w/ corr. factor K1/0.55:						
vertical	**18.39**	**25.30**	**13.19**	8.71	9.85	10.80
vertical w/ ww's	15.08	20.75	10.82	**7.14**	**8.08**	**8.85**
spill-through	10.12	13.92	7.26	4.79	5.42	5.94

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.62	0.62	1	0.62	0.62	1
y, depth of flow in bridge, ft	7.32	7.65	4.78	7.32	7.65	4.78
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.74**	**1.82**	ERR	**1.74**	**1.82**	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	**2.00**	ERR	ERR	**2.00**