LEVEL II SCOUR ANALYSIS FOR BRIDGE 24 (HARDTH00490024) on TOWN HIGHWAY 49, crossing NICHOLS BROOK at MACKVILLE POND OUTLET, HARDWICK, VERMONT

U.S. Geological Survey
Open-File Report 96-637

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

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By SCOTT A. OLSON

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Pembroke, New Hampshire

1996

U.S. DEPARTMENT OF THE INTERIOR
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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 24 (HARDTH00490024) ON TOWN HIGHWAY 49, CROSSING NICHOLS BROOK AT MACKVILLE POND OUTLET, HARDWICK, VERMONT

By **Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure HARDTH00490024 on Town Highway 49 crossing Nichols Brook at Mackville Pond Outlet, Hardwick, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in north-central Vermont. The 10.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is best described as suburban with residences, lawns, trees and roadways.

There is a dam 54 feet downstream of the bridge which controls Mackville Pond upstream of the bridge. The vertical drop over the dam is 15 feet. Immediately upstream of the bridge the width of the waterway is 146 feet. The predominant channel bed material is sand with a median grain size (D_{50}) of 0.576 mm (0.00189 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 25, 1995, indicated that the reach was stable.

The Town Highway 49 crossing of Nichols Brook at Mackville Pond Outlet is a 42-ft-long, two-lane bridge consisting of one 38-foot steel-beam span (Vermont Agency of Transportation, written communication, April 3, 1995). The bridge is supported by vertical, concrete abutments with wingwalls on the downstream end of the left abutment and upstream and downstream ends of the right abutment. The channel is not skewed to the opening, but the opening-skew-to-roadway is 5 degrees.

Scour protection measures at the site include type-3 stone fill (less than 48 inches diameter) on the upstream side of the left roadway embankment and at the upstream end of the left abutment. Type-2 stone fill (less than 36 inches diameter) was on the upstream right roadway 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 ranged from 4.7 to 21.0 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour at the left abutment ranged from 13.3 to 15.8 ft. with the worst-case occurring at the 500-year discharge. Abutment scour at the right abutment ranged from 8.1 to 9.8 ft. with the worst-case occurring at the incipient roadway-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Cabot, VT. Quadrangle, 1:24,000, 1986

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number HARDTH00490024 ***Stream*** Nichols Brook

County Caledonia ***Road*** TH49 ***District*** 7

Description of Bridge

Bridge length 42 ***ft*** ***Bridge width*** 20.2 ***ft*** ***Max span length*** 38 ***ft***

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

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

Stone fill on abutment? On left ***Date of inspection*** 7/25/95

Description of stone fill Type-3 on upstream left road embankment and left abutment. Type-2 on upstream right road embankment.

Abutments and wingwalls are concrete.

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

N --

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	7/25/95	0	0
Level II	7/25/95	0	0

Potential for debris Low.

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

Upstream of the bridge is Mackville Pond which is controlled by a dam 54 feet downstream of the bridge.

Description of the Geomorphic Setting

General topography The waterway is in a narrow valley with moderate relief.

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

Date of inspection 7/25/95

DS left: Mildly sloping overbank.

DS right: Mildly sloping overbank.

US left: Mildly sloping overbank.

US right: Mildly sloping overbank.

Description of the Channel

Average top width 146 ***ft*** ***Average depth*** - ***ft***

Predominant bed material Sand and Gravel ***Bank material*** Gravel/Boulders

The stream is ponded both upstream and downstream of the bridge.

Vegetative co

7/25/95

Trees, brush, and grass.

DS left: Trees, brush, and grass.

DS right: Lawns with brush on the immediate bank.

US left: Lawns with a road parallel to bank.

US right:

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

There is a dam 54 feet downstream of the bridge controlling Mackville Pond which is upstream of the bridge.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 10.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: -

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p Yes

Mackville Pond Dam is 54 feet downstream of the bridge. The storage in Mackville Pond is assumed to not be large enough to attenuate peak flows. However, the dam ponds water through the bridge which impacts hydraulics.

Calculated Discharges

Q100 1,400 ***ft³/s*** ***Q500*** 2,010 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(10.7/11.0)exp 0.7] with flood frequency estimates at the mouth of Nichols Brook in the Flood Insurance Study for the Town of Hardwick (Federal Emergency Management Agency, 1987).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the granite block on the streamward end of the downstream left wingwall (elev. 899.48 ft, arbitrary survey datum). RM2 is a chiseled X on top of the concrete cap of the right abutment of the dam 54 feet downstream of the dam (elev. 894.98 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	-52	1	Exit section (across dam).
FULLV	0	2	Downstream Full-valley section (Templated from APPRO)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APPRO	55	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 0.026 to 0.035, and overbank "n" values ranged from 0.045 to 0.055.

Since the exit section traversed the dam, critical depth at the exit section (EXITX) was assumed as the starting water surface. Furthermore, all the water in each modelled event was assumed to be going over the dam, although water may bypass the dam if the roadway is overtopped. Thus, the incipient roadway-overtopping discharge may be the most valid model for this site.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 898.4 *ft*
Average low steel elevation 896.5 *ft*

100-year discharge 1,400 *ft³/s*
Water-surface elevation in bridge opening 896.1 *ft*
Road overtopping? Y *Discharge over road* 7 *ft³/s*
Area of flow in bridge opening 393 *ft²*
Average velocity in bridge opening 3.5 *ft/s*
Maximum WSPRO tube velocity at bridge 4.7 *ft/s*

Water-surface elevation at Approach section with bridge 896.4
Water-surface elevation at Approach section without bridge 896.1
Amount of backwater caused by bridge 0.3 *ft*

500-year discharge 2,010 *ft³/s*
Water-surface elevation in bridge opening 896.9 *ft*
Road overtopping? Y *Discharge over road* 316 *ft³/s*
Area of flow in bridge opening 404 *ft²*
Average velocity in bridge opening 4.1 *ft/s*
Maximum WSPRO tube velocity at bridge 5.0 *ft/s*

Water-surface elevation at Approach section with bridge 897.3
Water-surface elevation at Approach section without bridge 896.9
Amount of backwater caused by bridge 0.4 *ft*

Incipient overtopping discharge 1,330 *ft³/s*
Water-surface elevation in bridge opening 896.0 *ft*
Area of flow in bridge opening 389 *ft²*
Average velocity in bridge opening 3.4 *ft/s*
Maximum WSPRO tube velocity at bridge 4.5 *ft/s*

Water-surface elevation at Approach section with bridge 896.3
Water-surface elevation at Approach section without bridge 896.0
Amount of backwater caused by bridge 0.3 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year and incipient roadway-overtopping discharges was computed by use of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). Contraction scour for the 500-year event was computed by use of the Chang pressure-flow scour equation (Richardson and others, 1995, p. 145-146). The 500-year discharge resulted in orifice flow at the bridge. 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). The results of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) for the 500-year discharge was also computed and can be found in appendix F.

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

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	5.3	21.0	4.7
Depth to armoring	--	--	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	13.6	15.8	13.3
Right abutment	9.1	8.1	9.8
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	0.3	0.3	0.3
Right abutment	0.3	0.3	0.3
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

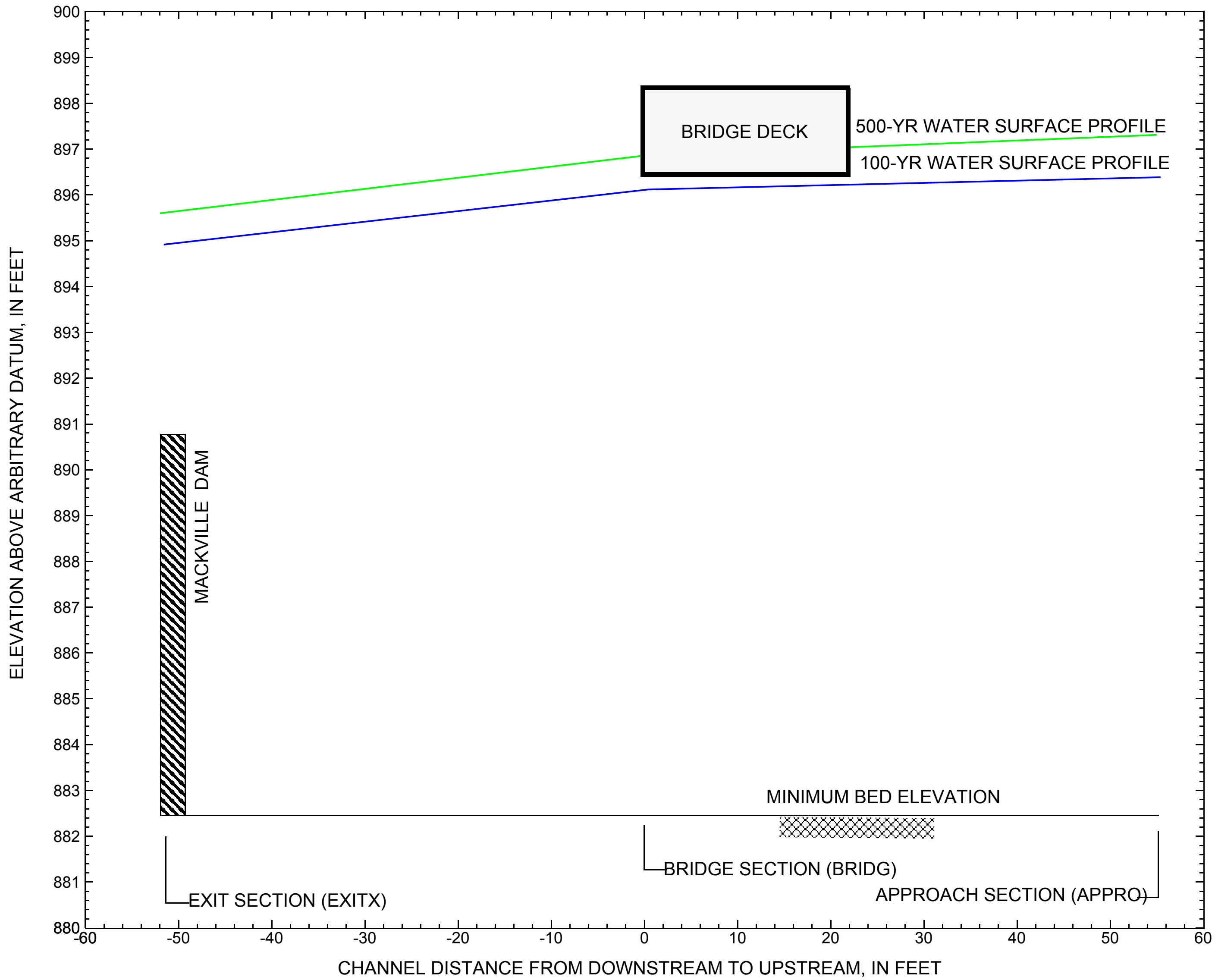

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure HARDTH00490024 on Town Highway 49, crossing Nichols Brook at Mackville Pond Outlet, Hardwick, Vermont.

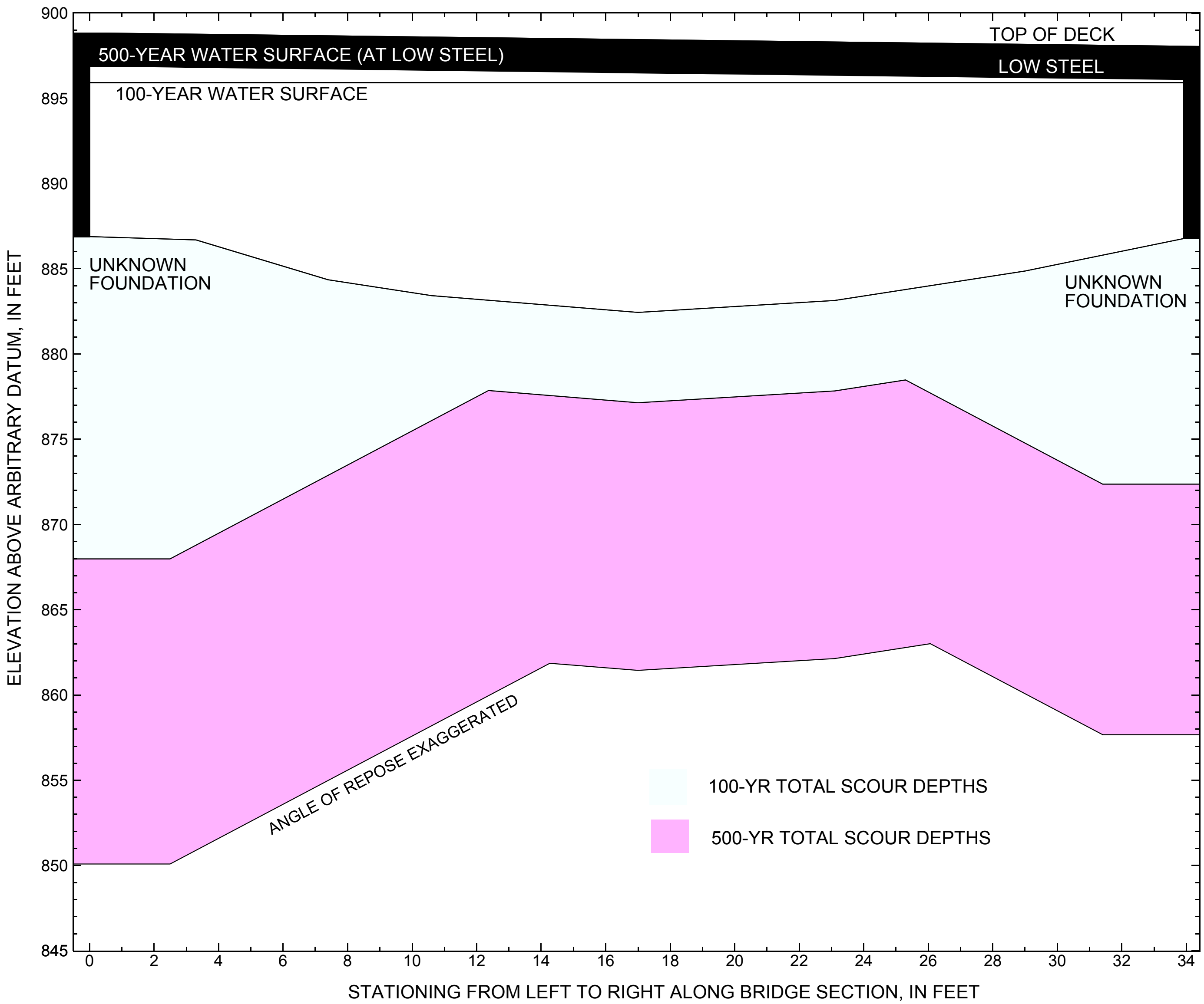

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure HARDTH00490024 on Town Highway 49, crossing Nichols Brook at Mackville Pond Outlet, Hardwick, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure HARDTH00490024 on Town Highway 49, crossing Nichols Brook at Mackville Pond Outlet, Hardwick, 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 1,400 cubic-feet per second											
Left abutment	0.0	--	896.9	--	886.9	5.3	13.6	--	18.9	868.0	--
Right abutment	33.9	--	896.1	--	886.8	5.3	9.1	--	14.4	872.4	--

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 HARDTH00490024 on Town Highway 49, crossing Nichols Brook at Mackville Pond Outlet, Hardwick, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,010 cubic-feet per second											
Left abutment	0.0	--	896.9	--	886.9	21.0	15.8	--	36.8	850.1	--
Right abutment	33.9	--	896.1	--	886.8	21.0	8.1	--	29.1	857.7	--

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard024.wsp
T2        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00490024 USING FILE hard024.dca
T3        HYDRAULIC ANALYSIS OF HARD024   SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          1400 2010 1330
SK         -1 -1 -1
*
XS   EXITX    -52
GR          -94.1, 904.05    -76.3, 900.02    -53.2, 899.28    -39.5, 895.01
GR          -33.3, 894.60    -24.6, 894.19    -19.4, 893.74    -15.8, 893.67
GR          -15.0, 891.41    -12.8, 891.34     -9.8, 891.38     -5.4, 891.66
GR            0.0, 891.56      8.4, 891.77      8.5, 893.70     11.2, 893.92
GR           12.9, 897.15     14.6, 896.96     16.7, 893.57     21.7, 893.60
GR           23.5, 891.23     24.7, 891.02     25.2, 891.38     27.0, 891.41
GR           29.1, 891.48     29.4, 891.24     31.2, 891.05     32.1, 890.79
GR           32.8, 891.33     33.0, 891.56     36.4, 891.65     40.0, 894.09
GR           41.2, 894.98     45.9, 895.03     55.6, 895.67     74.8, 896.74
GR           94.1, 897.41    117.5, 896.45    188.9, 895.98    237.8, 897.68
GR          324.3, 904.71
*
*           The following geometry defines another channel that water will
*           take when the road is overtopped. The water surface elevation in
*           this diverging channel may not be related to the water surface
*           at the dam and water cannot get into this channel without
*           overtopping the roadway. The exit right overbank data is
*           replaced by the right end of the roadway section since it
*           is acting almost as an extension of the dam. Furthermore,
*           additional testing determined that critical depth could
*           be assumed along this overbank section.
*
*           117.5, 896.75    131.1, 895.61    182.8, 892.95
*          198.8, 892.64    242.1, 892.70    263.5, 893.97    302.4, 897.13
N           0.026      0.055
SA                40.0
*
*           Approach geometry is used for the full valley section
XS   FULLV      0
GR         -124.4, 909.22   -102.6, 904.25    -82.8, 902.43    -64.9, 901.98
GR          -54.5, 897.90    -47.5, 893.65    -40.0, 891.34      0.2, 886.89
GR            3.3, 886.7       7.4, 884.36     10.6, 883.43     17.0, 882.44
GR           23.1, 883.14     29.0, 884.87     33.1, 886.77     87.0, 891.33
GR           91.5, 894.57     98.7, 895.92    132.3, 896.14    173.8, 896.53
GR          222.7, 897.98    309.2, 905.01
N            0.033   0.045
SA               98.7
*
BR   BRIDG   0 896.5 5
GR            0.0, 896.86      0.0, 891.40      0.2, 886.89      3.3, 886.70
GR            7.4, 884.36     10.6, 883.43     17.0, 882.44     23.1, 883.14
GR           29.0, 884.87     33.1, 886.77     33.1, 891.32     33.9, 896.07
GR            0.0, 896.86
N            0.035
CD           1 22.7 * * 12.5 6.6
*
XR   RDWAY     11      20.2   2
```

```
GR         -124.3, 909.32   -105.7, 903.67    -92.9, 903.07    -61.1, 902.29
GR           -2.1, 898.62     -2.1, 901.07     36.7, 900.32     43.1, 899.93
GR           43.2, 898.81     46.7, 898.26     67.6, 897.32     89.0, 896.56
GR          106.8, 896.28    120.3, 896.56    143.8, 896.36    188.9, 896.28
GR          237.8, 897.98    324.3, 905.01
*
*           Water overtopping the roadway may not re-enter channel until
*           below the dam. However, all flow is modelled to go over the
*           dam. The most reliable model may be the incipient overtopping
*
AS   APPRO     55
GR         -124.4, 909.22   -102.6, 904.25    -82.8, 902.43    -64.9, 901.98
GR          -54.5, 897.90    -47.5, 893.65    -40.0, 891.34      0.2, 886.89
GR            3.3, 886.7       7.4, 884.36     10.6, 883.43     17.0, 882.44
GR           23.1, 883.14     29.0, 884.87     33.1, 886.77     87.0, 891.33
GR           91.5, 894.57     98.7, 895.92    132.3, 896.14    173.8, 896.53
GR          222.7, 897.98    309.2, 905.01
N             0.033   0.045
SA                98.7
*
HP 1 BRIDG  896.14 1 896.14
HP 2 BRIDG  896.14 * * 1393
HP 2 RDWAY  896.42 * * 7
HP 1 APPRO  896.41 1 896.41
HP 2 APPRO  896.41 * * 1400
*
HP 1 BRIDG  896.86 1 896.86
HP 2 BRIDG  896.86 * * 1661
HP 2 RDWAY  897.17 * * 316
HP 1 APPRO  897.31 1 897.31
HP 2 APPRO  897.31 * * 2010
*
HP 1 BRIDG  896.02 1 896.02
HP 2 BRIDG  896.02 * * 1330
HP 1 APPRO  896.28 1 896.28
HP 2 APPRO  896.28 * * 1330
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard024.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00490024 USING FILE hard024.dca
        HYDRAULIC ANALYSIS OF HARD024   SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     393.   61439.    31.    56.                       7977.
   896.14          393.   61439.    31.    56.  1.00     0.    34.   7977.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       896.14     0.0    33.9   393.3   61439.    1393.   3.54
X STA.        0.0        4.1        6.3        8.0        9.5       10.9
  A(I)            38.0       23.2       19.7       18.1       16.9
  V(I)            1.83       3.00       3.54       3.85       4.13

X STA.       10.9       12.1       13.3       14.5       15.6       16.7
  A(I)            15.7       15.9       15.3       14.8       15.0
  V(I)            4.43       4.39       4.55       4.71       4.65

X STA.       16.7       17.8       18.9       20.0       21.3       22.5
  A(I)            15.0       14.9       15.4       16.1       16.0
  V(I)            4.65       4.68       4.51       4.33       4.35

X STA.       22.5       23.8       25.3       27.0       29.1       33.9
  A(I)            17.3       18.5       20.4       24.6       42.6
  V(I)            4.03       3.76       3.42       2.83       1.64

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1150.  197491.   151.   155.                      18023.
             2      17.     229.    62.    62.                         49.
   896.41         1167.  197719.   213.   217.  1.03   -52.   161.  15295.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.
         WSEL     LEW     REW    AREA        K        Q    VEL
       896.41   -52.0   161.0  1166.6  197719.    1400.   1.20
X STA.      -52.0      -30.2      -20.1      -12.4       -5.6        0.3
  A(I)            90.4       67.8       59.6       57.2       54.3
  V(I)            0.77       1.03       1.17       1.22       1.29

X STA.        0.3        5.5        9.6       13.1       16.3       19.5
  A(I)            52.3       48.5       45.8       44.0       44.7
  V(I)            1.34       1.44       1.53       1.59       1.57

X STA.       19.5       22.8       26.4       30.6       35.8       41.7
  A(I)            44.6       45.2       49.3       51.4       53.9
  V(I)            1.57       1.55       1.42       1.36       1.30

X STA.       41.7       48.2       55.5       64.0       74.8      161.0
  A(I)            56.1       58.8       62.9       70.9      108.9
  V(I)            1.25       1.19       1.11       0.99       0.64
```

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         U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard024.wsp
         CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00490024 USING FILE hard024.dca
         HYDRAULIC ANALYSIS OF HARD024   SAO

     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     404.   47775.     0.    87.                    ********
    896.86          404.   47775.     0.    87.  1.00     0.    34.********

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        896.86     0.0    33.9   404.3   47775.    1661.   4.11
 X STA.         0.0        3.6        5.8        7.6        9.1       10.5
   A(I)            35.6       23.4       21.5       19.0       18.3
   V(I)            2.33       3.55       3.86       4.38       4.54

 X STA.        10.5       11.8       13.1       14.4       15.6       16.8
   A(I)            17.5       17.4       17.1       16.5       16.7
   V(I)            4.74       4.78       4.87       5.04       4.98

 X STA.        16.8       18.0       19.2       20.5       21.7       23.0
   A(I)            16.7       16.5       17.1       17.0       17.4
   V(I)            4.98       5.04       4.87       4.88       4.77

 X STA.        23.0       24.5       26.0       27.7       29.8       33.9
   A(I)            18.6       18.8       20.9       22.9       35.6
   V(I)            4.46       4.42       3.97       3.62       2.33

     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.
          WSEL     LEW     REW    AREA        K        Q    VEL
        897.17    71.8   214.5    95.1    2523.     316.   3.32
 X STA.        71.8       90.3       96.3      101.7      106.7      111.9
   A(I)             6.0        4.1        4.1        4.3        4.3
   V(I)            2.63       3.86       3.83       3.68       3.66

 X STA.       111.9      118.6      126.8      133.8      140.0      145.5
   A(I)             4.8        5.2        4.9        4.6        4.5
   V(I)            3.30       3.03       3.24       3.43       3.54

 X STA.       145.5      150.9      156.2      161.5      166.6      171.7
   A(I)             4.4        4.4        4.4        4.3        4.4
   V(I)            3.61       3.57       3.61       3.67       3.62

 X STA.       171.7      176.8      182.1      187.3      193.5      214.5
   A(I)             4.4        4.6        4.6        5.1        7.7
   V(I)            3.56       3.42       3.43       3.08       2.06

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1    1286.  236280.   152.   157.                      21217.
              2      94.    2944.   101.   101.                        511.
    897.31         1380.  239225.   254.   258.  1.11   -54.   200.  17342.

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.
          WSEL     LEW     REW    AREA        K        Q    VEL
        897.31   -53.5   200.1  1380.0  239225.    2010.   1.46
 X STA.       -53.5      -31.6      -21.5      -13.1       -6.3       -0.1
   A(I)           101.2       75.7       70.6       63.4       62.8
   V(I)            0.99       1.33       1.42       1.59       1.60

 X STA.        -0.1        5.3        9.7       13.4       16.9       20.3
   A(I)            58.4       55.7       52.5       50.4       50.8
   V(I)            1.72       1.80       1.91       1.99       1.98

 X STA.        20.3       23.9       27.8       32.6       38.4       44.7
   A(I)            50.9       52.4       56.9       59.9       61.7
   V(I)            1.97       1.92       1.77       1.68       1.63

 X STA.        44.7       51.5       59.3       68.3       79.3      200.1
   A(I)            63.2       67.1       71.4       78.5      176.6
   V(I)            1.59       1.50       1.41       1.28       0.57
```

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard024.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00490024 USING FILE hard024.dca
        HYDRAULIC ANALYSIS OF HARD024   SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     389.   62807.    34.    53.                       7502.
   896.02          389.   62807.    34.    53.  1.00     0.    34.   7502.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       896.02     0.0    33.9   389.3   62807.    1330.   3.42
X STA.         0.0         4.3         6.5         8.3         9.8        11.1
  A(I)            39.1        23.0        20.6        18.3        17.1
  V(I)            1.70        2.89        3.24        3.63        3.89

X STA.        11.1        12.4        13.7        14.8        16.0        17.1
  A(I)            16.2        16.0        15.4        14.9        15.1
  V(I)            4.10        4.16        4.31        4.46        4.40

X STA.        17.1        18.2        19.3        20.5        21.7        22.9
  A(I)            15.1        14.9        15.5        15.5        15.9
  V(I)            4.41        4.45        4.29        4.29        4.18

X STA.        22.9        24.3        25.7        27.4        29.4        33.9
  A(I)            17.1        17.8        20.0        22.8        38.8
  V(I)            3.89        3.74        3.32        2.91        1.71

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1130.  192127.   151.   155.                      17577.
             2       9.     105.    48.    48.                         24.
   896.28         1140.  192232.   199.   203.  1.02   -52.   147.  15362.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.
         WSEL     LEW     REW    AREA        K        Q    VEL
       896.28   -51.8   147.2  1139.8  192232.    1330.   1.17
X STA.       -51.8       -30.1       -20.1       -12.0        -5.4         0.4
  A(I)            88.2        66.3        60.9        55.7        52.9
  V(I)            0.75        1.00        1.09        1.19        1.26

X STA.         0.4         5.6         9.6        13.0        16.3        19.4
  A(I)            51.0        47.3        44.7        43.6        43.0
  V(I)            1.30        1.40        1.49        1.53        1.55

X STA.        19.4        22.7        26.2        30.3        35.6        41.4
  A(I)            44.0        44.6        47.3        52.1        53.0
  V(I)            1.51        1.49        1.41        1.28        1.26

X STA.        41.4        47.9        55.1        63.6        74.3       147.2
  A(I)            55.0        57.7        61.6        69.5       101.5
  V(I)            1.21        1.15        1.08        0.96        0.66
```

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard024.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00490024 USING FILE hard024.dca
        HYDRAULIC ANALYSIS OF HARD024   SAO

 ===010 WSI BELOW YMIN AT SECID "EXITX":  USED WSI = CRWS.
                        YMIN,WSI,CRWS =     890.8   ********     894.94

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

EXITX:XS   ******   -39.     166.  1.11 *****  896.05  894.94   1400.  894.94
      -52. ******    41.   15232.  1.00 ***** *******    1.00    8.42

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO = 12.03

FULLV:FV      52.   -51.    1099.  0.03  0.04  896.09 *******   1400.  896.06
        0.    52.   120.  183281.  1.00  0.00    0.00    0.09    1.27
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      55.   -51.    1100.  0.03  0.00  896.09 *******   1400.  896.07
       55.    55.   121.  183440.  1.00  0.00    0.00    0.09    1.27
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   896.42       0.00     896.14     896.28

 ===260 ATTEMPTING FLOW CLASS 4 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      52.     0.     393.  0.28  0.11  896.42  888.08   1393.  896.14
        0.    52.    34.   61532.  1.45  0.26    0.00    0.21    3.54

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.830 ******  896.50 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    35.  0.00  0.02  896.45    0.00      7.  896.42

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.     6.    -8.    -2.   0.4   0.2   3.5   9.3   0.7   2.7
   RT:      7.    73.    98.   193.   0.1   0.1   1.3   1.2   0.1   2.6

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

APPRO:AS      32.   -52.    1167.  0.02  0.01  896.44  888.32   1400.  896.41
       55.    37.   161.  197891.  1.03  0.01    0.01    0.09    1.20

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.803  0.522   94564.     2.    36. ********

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -52.   -39.    41.   1400.   15232.     166.    8.42  894.94
   FULLV:FV       0.   -51.   120.   1400.  183281.    1099.    1.27  896.06
   BRIDG:BR       0.     0.    34.   1393.   61532.     393.    3.54  896.14
   RDWAY:RG      11.*******     0.      7.       0.*********    2.00  896.42
   APPRO:AS      55.   -52.   161.   1400.  197891.    1167.    1.20  896.41

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    36.   94564.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    894.94    1.00  890.79  904.71************  1.11  896.05  894.94
   FULLV:FV  ********    0.09  882.44  909.22  0.04  0.00  0.03  896.09  896.06
   BRIDG:BR    888.08    0.21  882.44  896.86  0.11  0.26  0.28  896.42  896.14
   RDWAY:RG  ****************  896.28  909.32  0.00******  0.02  896.45  896.42
   APPRO:AS    888.32    0.09  882.44  909.22  0.01  0.01  0.02  896.44  896.41
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WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard024.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00490024 USING FILE hard024.dca
        HYDRAULIC ANALYSIS OF HARD024   SAO

 ===010 WSI BELOW YMIN AT SECID "EXITX":  USED WSI = CRWS.
                        YMIN,WSI,CRWS =    890.8   ********     895.60

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

EXITX:XS   ******   -41.     223.  1.33 *****  896.93  895.60   2010.  895.60
      -52. ******    55.   22970.  1.05 ***** *******    1.05    9.02

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  9.62

FULLV:FV      52.   -53.    1286.  0.04  0.04  896.97 *******   2010.  896.93
        0.    52.   187.  220935.  1.07  0.00    0.00    0.12    1.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      55.   -53.    1287.  0.04  0.00  896.98 *******   2010.  896.93
       55.    55.   187.  221203.  1.08  0.00    0.00    0.12    1.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   896.93      896.50

            <<<<<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      52.     0.     404.  0.26 *****  897.12  888.56   1661.  896.86
        0. ******    34.   47775.  1.00 ***** *******    0.21    4.11

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800 ******  896.50 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    35.  0.00  0.04  897.35   -0.02    316.  897.17

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.    12.   -15.    -2.   0.8   0.4   4.3   7.4   1.0   2.8
   RT:   316.   143.    72.   214.   0.9   0.7   3.9   3.3   0.8   2.9

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

APPRO:AS      32.   -54.    1381.  0.04  0.01  897.35  889.15   2010.  897.31
       55.    38.   200.  239369.  1.11  0.01   -0.02    0.12    1.46

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

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -52.   -41.    55.   2010.   22970.     223.    9.02  895.60
   FULLV:FV       0.   -53.   187.   2010.  220935.    1286.    1.56  896.93
   BRIDG:BR       0.     0.    34.   1661.   47775.     404.    4.11  896.86
   RDWAY:RG      11.*******     0.    316.        0.*********   2.00  897.17
   APPRO:AS      55.   -54.   200.   2010.  239369.    1381.    1.46  897.31

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    895.60    1.05  890.79  904.71************  1.33  896.93  895.60
   FULLV:FV  ********    0.12  882.44  909.22  0.04  0.00  0.04  896.97  896.93
   BRIDG:BR    888.56    0.21  882.44  896.86************  0.26  897.12  896.86
   RDWAY:RG  ****************  896.28  909.32  0.00******  0.04  897.35  897.17
   APPRO:AS    889.15    0.12  882.44  909.22  0.01  0.01  0.04  897.35  897.31
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         U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard024.wsp
         CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00490024 USING FILE hard024.dca
         HYDRAULIC ANALYSIS OF HARD024   SAO
            *** RUN DATE & TIME: 11-08-96  10:22

 ===010 WSI BELOW YMIN AT SECID "EXITX":  USED WSI = CRWS.
                        YMIN,WSI,CRWS =     890.8   ********     894.85

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

EXITX:XS   ******   -37.     159.  1.09 *****  895.94  894.85   1330.  894.85
      -52. ******    41.   14351.  1.00 ***** *******    1.01    8.36

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "FULLV"     KRATIO = 12.46

FULLV:FV      52.   -51.    1081.  0.02  0.04  895.97 *******   1330.  895.95
        0.    52.   103.  178800.  1.00  0.00    0.00    0.08    1.23
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      55.   -51.    1082.  0.02  0.00  895.98 *******   1330.  895.95
       55.    55.   104.  178949.  1.00  0.00    0.00    0.08    1.23
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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      52.     0.     389.  0.26  0.10  896.28  887.97   1330.  896.02
        0.    52.    34.   62800.  1.45  0.24    0.00    0.21    3.42

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.830 ******  896.50 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<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      32.   -52.    1139.  0.02  0.01  896.30  888.20   1330.  896.28
       55.    37.   147.  192094.  1.01  0.01    0.00    0.09    1.17

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.782  0.517   92829.     2.    36.   896.28

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

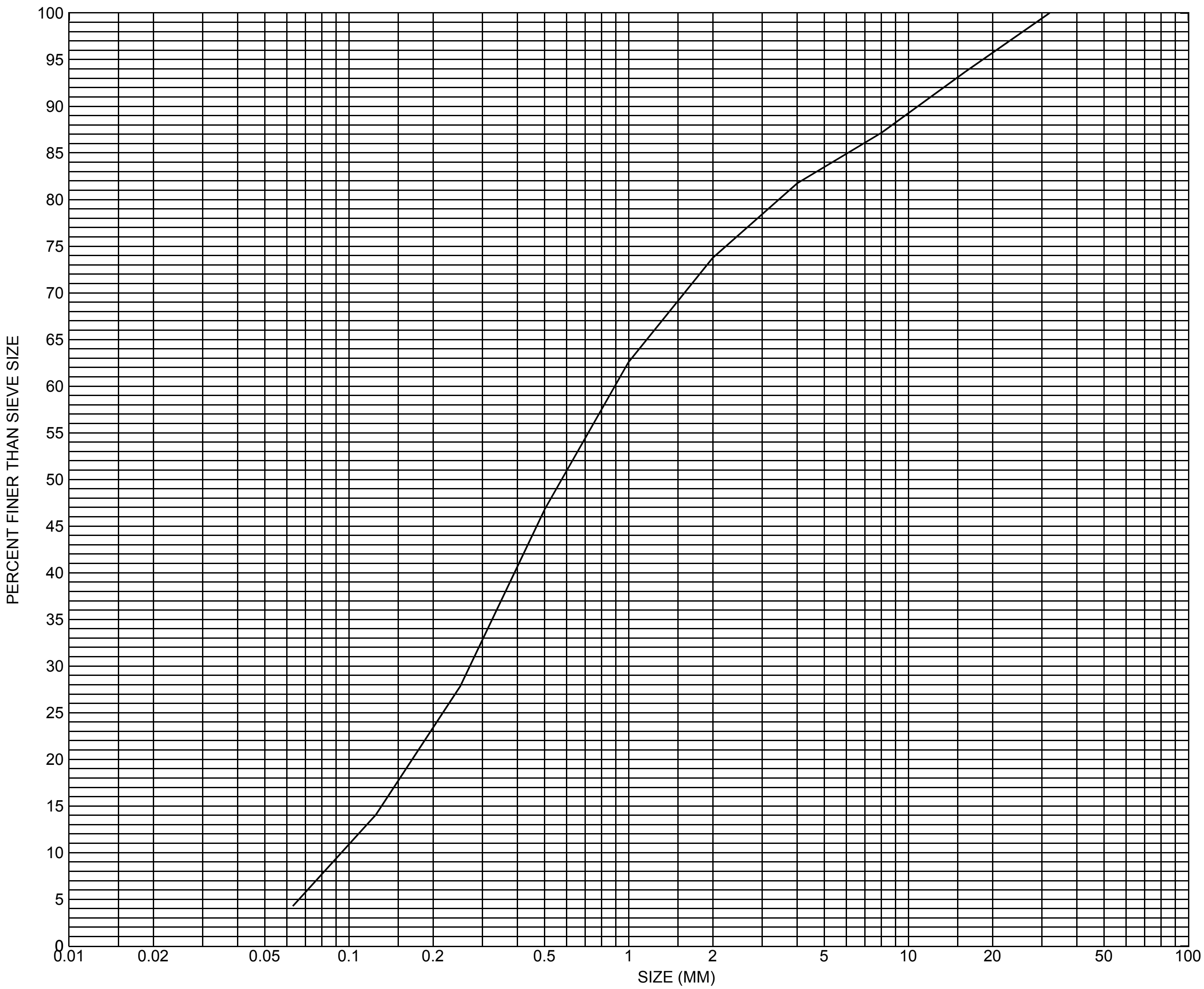
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -52.   -37.    41.   1330.   14351.     159.    8.36  894.85
   FULLV:FV       0.   -51.   103.   1330.  178800.    1081.    1.23  895.95
   BRIDG:BR       0.     0.    34.   1330.   62800.     389.    3.42  896.02
   RDWAY:RG      11.**************      0.*****************     2.00********
   APPRO:AS      55.   -52.   147.   1330.  192094.    1139.    1.17  896.28

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    36.   92829.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    894.85    1.01  890.79  904.71************  1.09  895.94  894.85
   FULLV:FV  ********    0.08  882.44  909.22  0.04  0.00  0.02  895.97  895.95
   BRIDG:BR    887.97    0.21  882.44  896.86  0.10  0.24  0.26  896.28  896.02
   RDWAY:RG ****************  896.28  909.32**********************************
   APPRO:AS    888.20    0.09  882.44  909.22  0.01  0.01  0.02  896.30  896.28
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Particle-size distribution for a sample taken from the streambed at structure HARDTH00490024, in Hardwick, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number HARDTH00490024

General Location Descriptive

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

Date *(MM/DD/YY)* 04 / 03 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 31825

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

Waterway *(I - 6)* MACKVILLE POND

Road Name *(I - 7):* -

Route Number TH049

Vicinity *(I - 9)* AT JCT TH 49 & TH 46

Topographic Map Cabot

Hydrologic Unit Code: 02010005

Latitude *(I - 16; nnnn.n)* 44293

Longitude *(i - 17; nnnnn.n)* 72221

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030500240305

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

Maximum span length *(I - 48; nnnn)* 0038

Year built *(I - 27; YYYY)* 1910

Structure length *(I - 49; nnnnnn)* 000042

Average daily traffic, ADT *(I - 29; nnnnnn)* 000100

Deck Width *(I - 52; nn.n)* 202

Year of ADT *(I - 30; YY)* 93

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)* P

Underwater Inspection Frequency *(I - 92B; XYY)* Y48

Structure type *(I - 43; nnn)* 303

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*) 009.4

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

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

Comments:

The structural inspection report of 06/07/93 indicates the structure is a steel girder and floor beam system type bridge with a concrete deck and a partial asphalt roadway surface. The abutment walls and wing-walls are concrete faced "laid up" stone. The concrete facings are badly spalled on both abutments at the water line. The right abutment has exposure of the laid up stone reported, and there is a crack present under the end of one of the girders. The downstream end of the right abutment reportedly is badly spalled with a section of heavy concrete loss. Most of the concrete facing on the upstream left wingwall is missing, and granite block stone fill has been added. The water under this structure reportedly **(Continued, p. 34)**

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:

is quite deep and appears to be slow moving due to a large concrete dam just downstream. Some settling is noted possible with minor scour. Minor gravel point bars are reported. Backwater from the dam covers banks.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **10.74** mi^2

Lake and pond area **.775** mi^2

Watershed storage *(ST)* **7.22** %

Bridge site elevation **925** ft

Headwater elevation **1929** ft

Main channel length **6.286** mi

10% channel length elevation **942** ft

85% channel length elevation **1447** ft

Main channel slope *(S)* **107.12** 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? 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: EW Date: 04/11/96
Computerized by: EW Date: 04/12/96
Reviewd by: SAO Date: 11/8/96

Structure Number HARDTH00490024

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 07 / 25 / 1995
2. Highway District Number 07 Mile marker 000000
County CALENDONIA 005 Town HARDWICK 31825
Waterway *(I - 6)* NICHOLS BROOK Road Name -
Route Number TH49 Hydrologic Unit Code: 02010005
3. Descriptive comments:
BRIDGE IS OUTLET OF MACKVILLE POND.
NEAR JUNCTION WITH TOWN HIGHWAY 46.

B. Bridge Deck Observations

4. Surface cover... LBUS 2 RBUS 2 LBDS 2 RBDS 2 Overall 2
*(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 1 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 42 *(feet)* Span length 38 *(feet)* Bridge width 20.2 *(feet)*

Road approach to bridge:

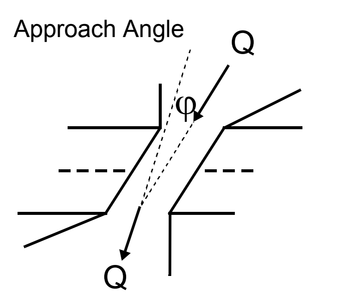
8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

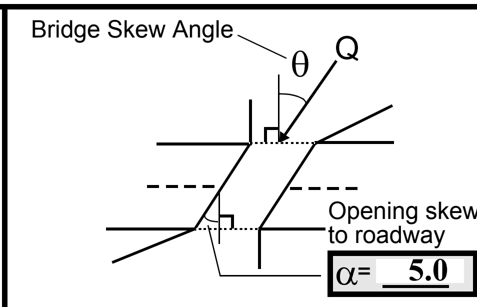
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	3	1	0	-
RBUS	2	1	0	-
RBDS	5	1	0	-
LBDS	5	1	0	-

*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: 0





α= 5.0

17. Channel impact zone 1: Exist? N *(Y or N)*
Where? ____ *(LB, RB)* Severity ____
Range? ____ feet ____ *(US, UB, DS)* to ____ feet ____
Channel impact zone 2: Exist? N *(Y or N)*
Where? ____ *(LB, RB)* Severity ____
Range? ____ feet ____ *(US, UB, DS)* to ____ feet ____
*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: **1a**

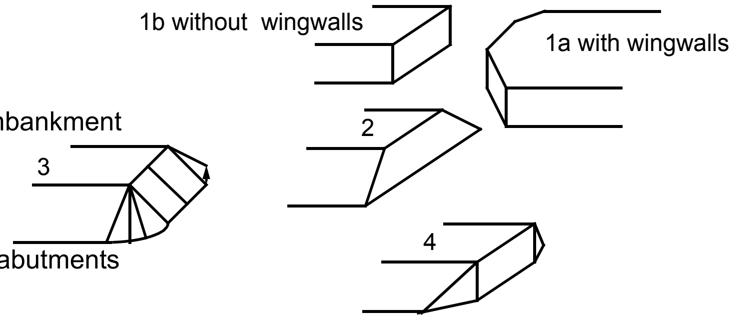
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

Lake formed US and DS of bridge as a result of back water from the dam. Right road approach will form weir flow.

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
0.0	6.5			3.0	1	1	532	532	0	0

23. Bank width **25.0** 24. Channel width **35.0** 25. Thalweg depth **146.0** 29. Bed Material **21**

30 .Bank protection type: LB **2** RB **2** 31. Bank protection condition: LB **1** RB **1**

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.):

Bank protection extends around the pond US of bridge a minimum of 300 feet along the banks protecting the roadways. Protection is heaviest at the upstream end of the road approach.

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

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
127.0		-		2	7	7	-

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

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

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

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

32

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

70. Debris and Ice Comments:

2

Large pond US of bridge face. Ice jamming may be possible under the right conditions.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**2**	**1**	**0**	**0**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**1**	**34.0**

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*

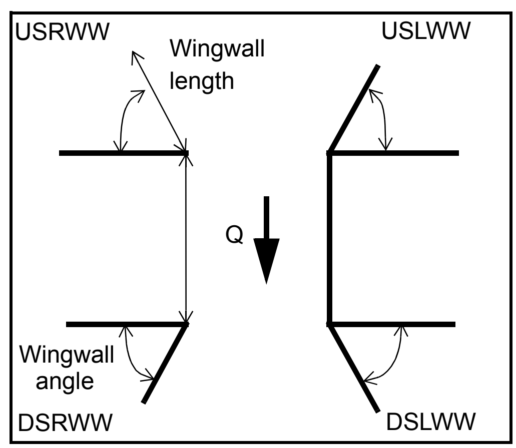
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
0
1

Concrete has spalled along the water line exposing the laid-up stone wall. The most extensive spalling is along the right abutment. Some spalling of the downstream corner of the left abutment is also evident at waterline.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**34.0**	
USRWW:	**N**		**-**		**-**	**9.0**	
DSLWW:	**-**		**-**		**Y**	**21.0**	
DSRWW:	**1**		**0**		**-**	**21.5**	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**0**	**Y**	**-**	**-**	**-**	**1**	**-**
Condition	**Y**	**-**	**1**	**-**	**-**	**-**	**2**	**-**
Extent	**1**	**-**	**0**	**-**	**0**	**3**	**0**	**-**

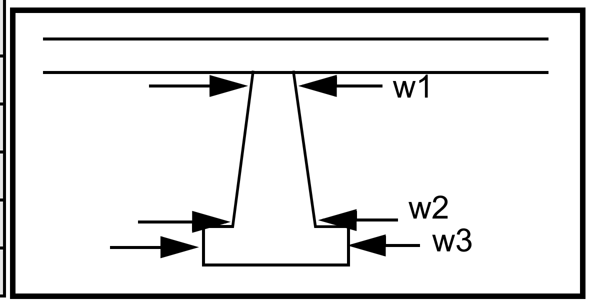
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
5
1
4
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	-			-	25.0	13.5
Pier 2				20.0	41.0	45.0
Pier 3		-	-	10.5	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	:	exte	abov	alon	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	DSL	ndin	e	g	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	WW	g off	wing	wate	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	-	the	wall.	r	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	con-	end	USR	line.	*Y- yes; N- no*
91. Attack ∠ (BF)	crete	of	WW		
92. Pushed	wing	the	-		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	wall	wing	con-		
95. Cross-members	with	wall,	crete		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	stone	as	has		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	maso	well	spall		
98. Exposure depth	nry	as	ed		

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

N
-
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width (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 NO (US, UB, DS) positioned PI %LB to ER %RB

Material: S

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

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

Cut bank extent: _____ feet ____ (US, UB, DS) to 2 feet 4 (US, UB, DS)

Bank damage: 324 (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)

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

732
0
0
2

Is channel scour present? 0 (Y or if N type ctrl-n cs) Mid-scour distance: 5

Scour dimensions: Length - Width 1 Depth: RB Positioned pro %LB to tec- %RB

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

tion - consists of a laid-up stone wall extending beyond the end of the wingwall to the dam and 30 feet DS of the dam.

Bed material is assumed to be primarily sand. Bedrock with some boulders is the primary bed material immediately downstream of the dam. The dam is founded on bedrock.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

Y

4

A concrete capped, laid-up stone dam over bedrock.

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: HARDTH00490024 Town: Hardwick
Road Number: TH49 County: Caledonia
Stream: Nichols Brook/Mackville Pond

Initials SAO Date: 6/12/96 Checked: EMB

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	1400	2010	1330
Main Channel Area, ft2	1150	1286	1130
Left overbank area, ft2	0	0	0
Right overbank area, ft2	17	94	9
Top width main channel, ft	151	152	151
Top width L overbank, ft	0	0	0
Top width R overbank, ft	62	101	48
D50 of channel, ft	0.00189	0.00189	0.00189
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.6	8.5	7.5
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	0.3	0.9	0.2
Total conveyance, approach	197719	239225	192232
Conveyance, main channel	197491	236280	192127
Conveyance, LOB	0	0	0
Conveyance, ROB	229	2944	105
Percent discrepancy, conveyance	-0.0005	0.0004	0.0000
Qm, discharge, MC, cfs	1398.4	1985.3	1329.3
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	1.6	24.7	0.7
Vm, mean velocity MC, ft/s	1.2	1.5	1.2
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	0.1	0.3	0.1
Vc-m, crit. velocity, MC, ft/s	1.94	1.98	1.94
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	1150	1286	1130
Main channel width, ft	151	152	151
y1, main channel depth, ft	7.62	8.46	7.48
Bridge Section			
(Q) total discharge, cfs	1400	2010	1330
(Q) discharge thru bridge, cfs	1393	1661	1330
Main channel conveyance	61439	47775	62807
Total conveyance	61439	47775	62807
Q2, bridge MC discharge,cfs	1393	1661	1330
Main channel area, ft2	393	404	389
Main channel width (skewed), ft	33.8	33.8	33.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.8	33.8	33.8
y_bridge (avg. depth at br.), ft	11.63	11.95	11.52
Dm, median (1.25*D50), ft	0.002363	0.002363	0.002363
y2, depth in contraction,ft	16.88	19.63	16.22
ys, scour depth (y2-ybridge), ft	5.25	7.68	4.71

Pressure Flow Scour (contraction scour for orifice flow conditions)

```
 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	0	1661	0
Vc, critical velocity, ft/s	0	1.98	0
Vc, critical velocity, m/s	0	0.603475	0
Main channel width (skewed), ft	0	33.8	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	0	33.8	0
qbr, unit discharge, ft^2/s	ERR	49.14201	ERR
qbr, unit discharge, m^2/s	N/A	4.564997	N/A
Area of full opening, ft^2	0	404.3	0
Hb, depth of full opening, ft	ERR	11.96154	ERR
Hb, depth of full opening, m	N/A	3.645699	N/A
Fr, Froude number MC	1	0.21	1
Cf, Fr correction factor (<=1.0)	1.5	0.766735	1.5
Elevation of Low Steel, ft	0	896.46	0
Elevation of Bed, ft	N/A	884.4985	N/A

Elevation of approach WS, ft	0	897.31	0
HF, bridge to approach, ft	0	0.01	0
Elevation of WS immediately US, ft	0	897.3	0
ya, depth immediately US, ft	N/A	12.80154	N/A
ya, depth immediately US, m	N/A	3.978104	N/A
Mean elev. of deck, ft	0	900.7	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	ERR	0.98349	ERR
Ys, depth of scour (chang), ft	N/A	20.95183	N/A

ARMORING

D90	0.0355	0.0355	0.0355
D95	0.0605	0.0605	0.0605
Critical grain size,Dc, ft	0.0184	0.0246	0.0172
Decimal-percent coarser than Dc	0.157	0.133	0.162
Depth to armoring,ft	0.30	0.48	0.27

Abutment Scour

Froehlich's Abutment Scour

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

(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1400	2010	1330	1400	2010	1330
a', abut.length blocking flow, ft	52	53.5	51.8	127.2	166.3	113.4
Ae, area of blocked flow ft2	326.5	374.8	320.4	425.2	470.9	416
Qe, discharge blocked abut.,cfs	346.4	504.4	327.9	--	--	421.6
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	1.06	1.35	1.02	1.04	1.21	1.01
ya, depth of f/p flow, ft	6.28	7.01	6.19	3.34	2.83	3.67
--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	95	95	95	85	85	85
K2	1.01	1.01	1.01	0.99	0.99	0.99
Fr, froude number f/p flow	0.075	0.090	0.073	0.099	0.115	0.093
ys, scour depth, ft	13.59	15.82	13.30	10.55	10.89	10.64

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)	52	53.5	51.8	127.2	166.3	113.4
y1 (depth f/p flow, ft)	6.28	7.01	6.19	3.34	2.83	3.67
a'/y1	8.28	7.64	8.37	38.05	58.73	30.91
Skew correction (p. 49, fig. 16)	1.02	1.02	1.02	0.98	0.98	0.98
Froude no. f/p flow	0.07	0.09	0.07	0.10	0.12	0.09
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	11.11	9.89	11.95
vertical w/ ww's	ERR	ERR	ERR	9.11	8.11	9.80
spill-through	ERR	ERR	ERR	6.11	5.44	6.57

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	0.21	0.21	0.21	0.21	0.21	0.21
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	11.63	11.95	11.52	11.63	11.95	11.52
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	0.32	0.33	0.31	0.32	0.33	0.31
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	0.28	0.28	0.27	0.28	0.28	0.27
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR