LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (READTH00540028) on TOWN HIGHWAY 54, crossing the NORTH BRANCH BLACK RIVER, READING, VERMONT

Open-File Report 98-292

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

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By MICHAEL A. IVANOFF AND MATTHEW A. WEBER

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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	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 28 (READTH00540028) ON TOWN HIGHWAY 54, CROSSING THE NORTH BRANCH BLACK RIVER, READING, VERMONT

By Michael A. Ivanoff and Matthew A. Weber

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure READTH00540028 on Town Highway 54 crossing the North Branch Black River, Reading, 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 New England Upland section of the New England physiographic province in central Vermont. The 8.16-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is shrub and brush along the left bank and forest along the right bank.

In the study area, the North Branch Black River has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 64 ft and an average bank height of 7 ft. The channel bed material ranges from gravel to cobbles with a median grain size (D_{50}) of 66.1 mm (0.217 ft). The geomorphic assessment at the time of the Level I site visit on March 29, 1995 and the Level II site visit on June 3, 1996, indicated that the reach was stable.

The Town Highway 54 crossing of the North Branch Black River is a 31-ft-long, one-lane bridge consisting of one 30-foot steel-beam span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 27.4 ft. The bridge is supported by a vertical, concrete right abutment with wingwalls and a “laid-up” stone left abutment and upstream left wingwall. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

A scour hole 1 ft deeper than the mean thalweg depth was observed along the downstream end of the right abutment during the Level I assessment. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the upstream left and right banks and type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream right wingwall and the downstream end of the left abutment. 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 incipient roadway-overtopping 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 0.0 to 1.9 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge. Left abutment scour ranged from 8.5 to 11.5 ft. The worst-case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 13.0 to 13.9 ft. The worst-case right abutment scour occurred at the 100-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). 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.

Cavendish, VT. Quadrangle, 1:24,000, 1972
Photoinspected 1983

NORTH

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

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

LEVEL II SUMMARY

Structure Number READTH00540028 ***Stream*** North Branch Black River

County Windsor ***Road*** TH 54 ***District*** 4

Description of Bridge

Bridge length 31 ***ft*** ***Bridge width*** 15.7 ***ft*** ***Max span length*** 30 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 3/29/95

Description of stone fill Type-1, along the upstream left and right banks. Type-2, along the upstream end of the upstream right wingwall and the downstream end of the left abutment.

The right abutment and wingwalls are concrete. The left abutment and wingwalls consist of "laid-up" stone with a concrete cap. There is a one foot deep scour hole in front of the right abutment at the downstream end.

Yes

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

3/29/95

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	0	0	6/3/96
Level II	0	0	Moder

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

None observed on 3/29/95 or 6/3/96.

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

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley with little to no flood plain.

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

Date of inspection 3/29/95

DS left: Steep channel bank to a narrow, irregular overbank

DS right: Steep channel bank to a narrow, flat overbank

US left: Steep channel bank to a narrow, irregular overbank

US right: Steep bank and valley wall

Description of the Channel

Average top width 64 ft ***Average depth*** 7 ft

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

Perennial but flashy, and sinuous with semi-alluvial channel boundaries and narrow point bars.

3/29/95

Vegetative co Trees and brush along the bank with pasture on the overbank.

DS left: Trees and brush

DS right: Trees and brush along the bank with pasture on the overbank.

US left: Trees and brush

US right: Yes

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

None observed on 3/29/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 8.16 ***mi***^{2}

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***: None

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 2,100 ***ft***^{3}***/s*** ***Q500*** 3,100 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database (written communication, May 1995) for this site. These database values were within a range defined by flood frequency curves derived from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 499.80 ft, arbitrary survey datum). RM2 is the head of a nail in a maple tree 4 ft up from the base located on the downstream left bank 30 ft from the bridge (elev. 501.56 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	-38	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	42	2	Modelled Approach section (Templated from APTEM)
APTEM	54	1	Approach section as surveyed (Used as a template)

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.065, and overbank "n" values ranged from 0.040 to 0.055.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0252 ft/ft, which was estimated from thalweg points surveyed downstream.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.064 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 499.4 *ft*
Average low steel elevation 497.5 *ft*

100-year discharge 2,100 *ft³/s*
Water-surface elevation in bridge opening 497.6 *ft*
Road overtopping? Yes *Discharge over road* 24 *ft³/s*
Area of flow in bridge opening 229 *ft²*
Average velocity in bridge opening 9.0 *ft/s*
Maximum WSPRO tube velocity at bridge 13.5 *ft/s*

Water-surface elevation at Approach section with bridge 499.4
Water-surface elevation at Approach section without bridge 495.1
Amount of backwater caused by bridge 4.3 *ft*

500-year discharge 3,100 *ft³/s*
Water-surface elevation in bridge opening 497.8 *ft*
Road overtopping? Yes *Discharge over road* 720 *ft³/s*
Area of flow in bridge opening 230 *ft²*
Average velocity in bridge opening 10.4 *ft/s*
Maximum WSPRO tube velocity at bridge 13.6 */s*

Water-surface elevation at Approach section with bridge 500.5
Water-surface elevation at Approach section without bridge 496.3
Amount of backwater caused by bridge 4.2 *ft*

Incipient overtopping discharge 2,060 *ft³/s*
Water-surface elevation in bridge opening 494.4 *ft*
Area of flow in bridge opening 150 *ft²*
Average velocity in bridge opening 13.7 *ft/s*
Maximum WSPRO tube velocity at bridge 18.9 *ft/s*

Water-surface elevation at Approach section with bridge 497.7
Water-surface elevation at Approach section without bridge 495.0
Amount of backwater caused by bridge 2.7 *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 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 incipient roadway-overtopping discharge also 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- and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and 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 100- and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results from these computations are presented in appendix F. Furthermore, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in appendix F.

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

Scour Results

Contraction scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.8	1.9
Depth to armoring	34.3	19.1	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
Abutment scour			
Left abutment	10.1	11.5	8.5
Right abutment	13.9	13.0	13.6
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.4	2.8	2.4
Right abutment	2.4	2.8	2.4
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

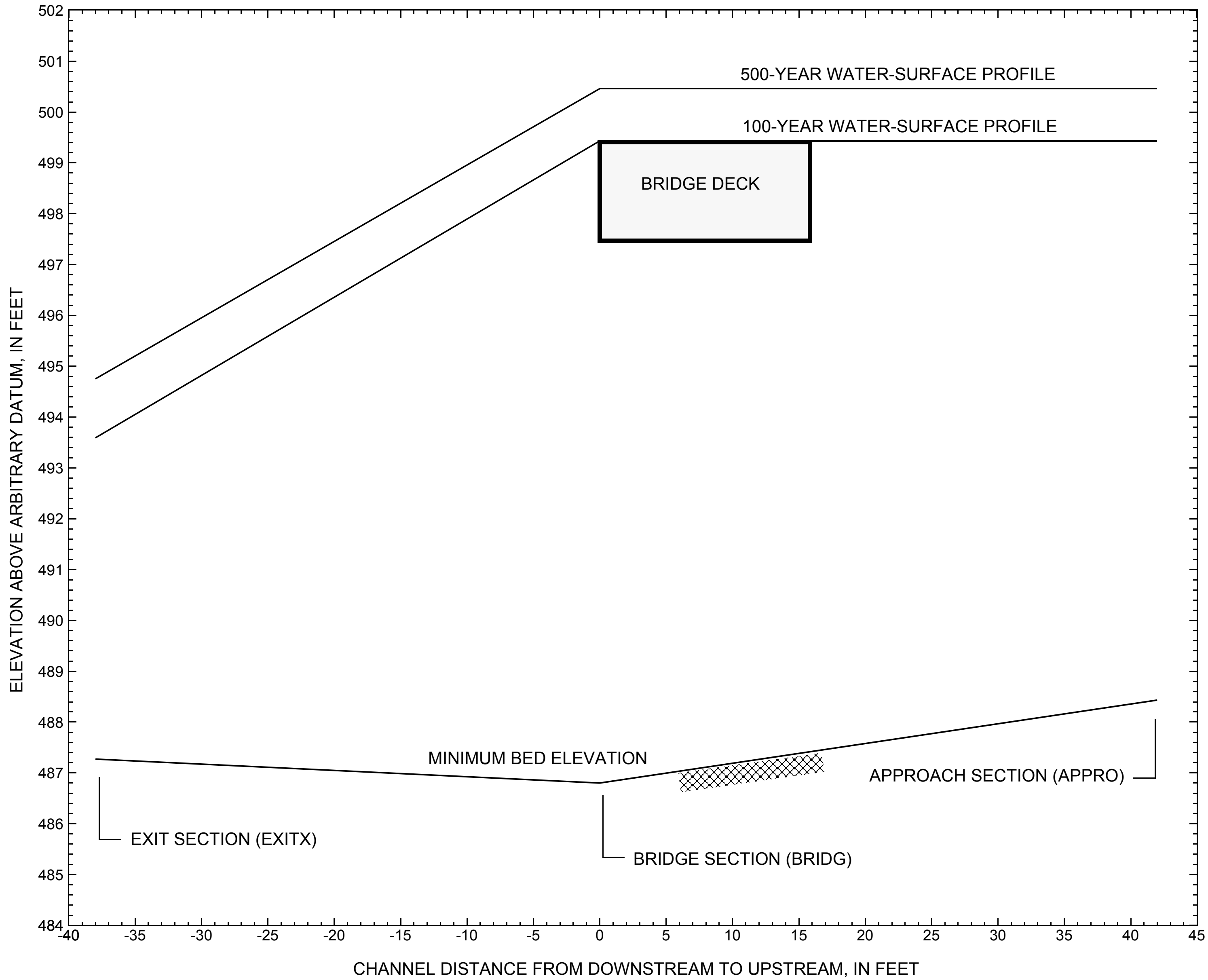

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure READTH00540028 on Town Highway 54, crossing the North Branch Black River, Reading, Vermont.

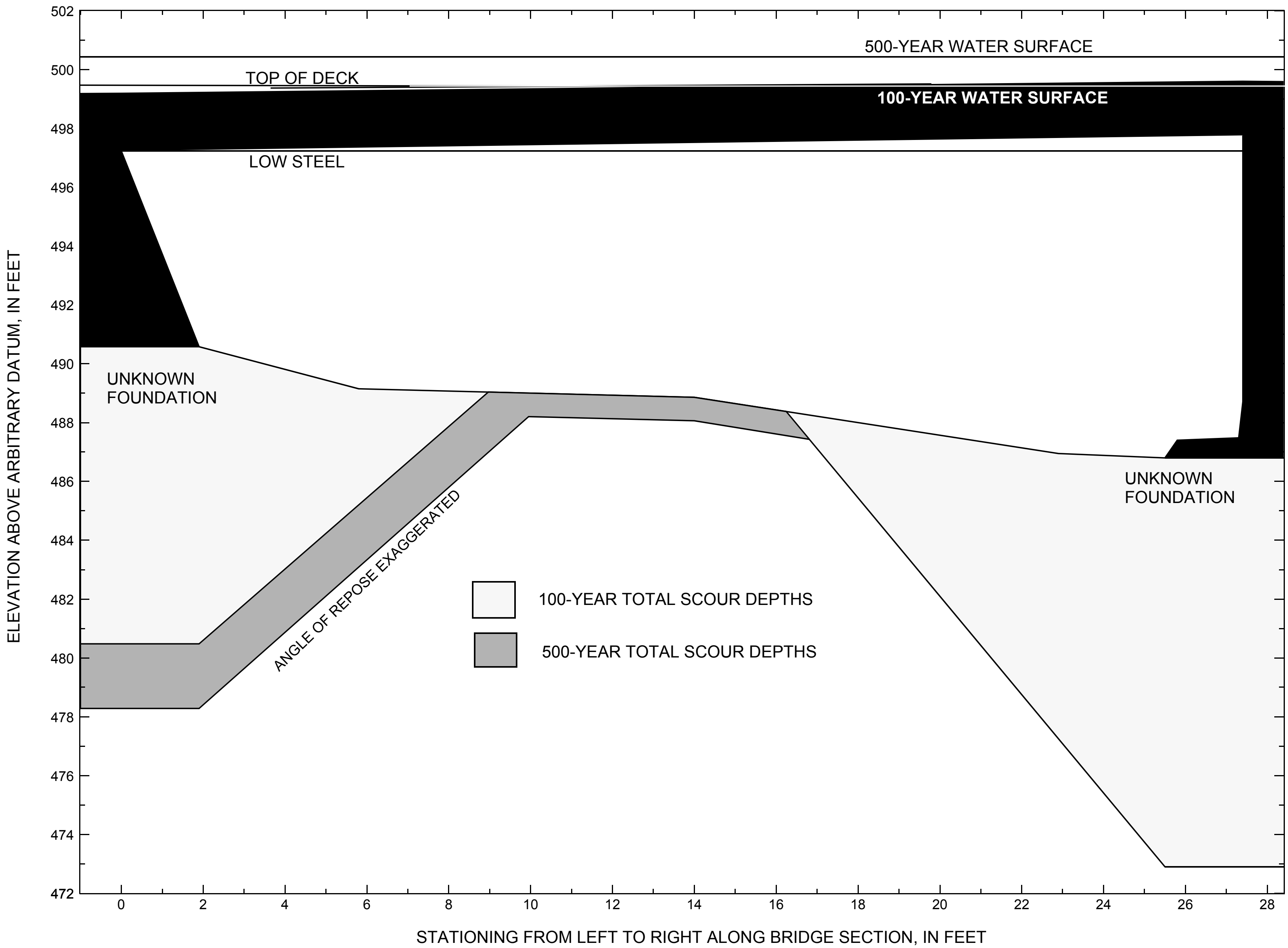

Figure 8. Scour elevations for the 100- and 500-year discharges at structure READTH00540028 on Town Highway 54, crossing the North Branch Black River, Reading, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure READTH00540028 on Town Highway 54, crossing the North Branch Black River, Reading, 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 2,100 cubic-feet per second											
Left abutment	0.0	--	497.2	--	490.6	0.0	10.1	--	10.1	480.5	--
Right abutment	27.4	--	497.8	--	486.8	0.0	13.9	--	13.9	472.9	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure READTH00540028 on Town Highway 54, crossing the North Branch Black River, Reading, 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 3,100 cubic-feet per second											
Left abutment	0.0	--	497.2	--	490.6	0.8	11.5	--	12.3	478.3	--
Right abutment	27.4	--	497.8	--	486.8	0.8	13.0	--	13.8	473.0	--

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, 1972, Cavendish, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File read028.wsp
T2        Hydraulic analysis for structure READTH00540028   Date: 05-NOV-97
T3        Bridge 28 on Town Highway 54 over N. Branch Black R. Reading, VT  MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2100.0   3100.0  2060.0
SK          0.0252   0.0252  0.0252
*
XS   EXITX    -38
GR          -71.8, 509.85    -61.6, 496.29    -11.3, 497.79     -8.1, 496.54
GR            0.0, 489.14      5.3, 488.73     10.2, 487.98     14.1, 487.27
GR           20.2, 487.70     30.4, 488.75     35.8, 489.67     40.9, 490.78
GR           61.4, 494.20     69.0, 496.29     85.2, 496.80    152.0, 499.01
GR          163.3, 506.76
N           0.040        0.065        0.050
SA                 -11.3         69.0
*
XS   FULLV      0  * * *  0.000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.49      15.0
GR            0.0, 497.23      1.9, 490.58      5.8, 489.15     14.0, 488.86
GR           22.9, 486.95     25.5, 486.80     25.8, 487.40     27.3, 487.48
GR           27.4, 488.71     27.4, 497.76      0.0, 497.23
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      15.8      1.7    499.4     62.6
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      15.7     2
GR         -247.1, 514.79   -146.6, 503.82    -69.9, 499.85      0.0, 499.21
GR           28.1, 499.62     53.6, 499.24    124.0, 499.82    163.3, 506.76
*
XT   APTEM     54
GR         -247.1, 514.79   -146.6, 503.82
GR          -72.2, 499.86    -17.6, 497.49    -10.5, 497.07
GR            0.0, 490.48      3.2, 490.09     10.7, 489.41     19.4, 489.55
GR           26.6, 489.20     31.3, 490.14     37.7, 494.99     52.9, 496.11
GR           67.1, 500.23     81.5, 501.18     91.3, 505.43    100.0, 510.14
*    -22.6, 500.34
AS   APPRO     42 * * * 0.064
GT
N           0.040        0.065        0.055
SA                 -10.5         37.7
*
HP 1 BRIDG 497.59 1 497.59
HP 2 BRIDG 497.59 * * 2065
HP 1 BRIDG 494.73 1 494.73
HP 1 APPRO 499.43 1 499.43
HP 2 APPRO 499.43 * * 2100
*
HP 1 BRIDG 497.76 1 497.76
HP 2 BRIDG 497.76 * * 2384
HP 1 BRIDG 495.99 1 495.99
HP 2 RDWAY 500.43 * * 720
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File read028.wsp
       Hydraulic analysis for structure READTH00540028   Date: 05-NOV-97
       Bridge 28 on Town Highway 54 over N. Branch Black R. Reading, VT  MAI
          *** RUN DATE & TIME: 03-31-98  09:09
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     229.   18501.     8.    60.                        6769.
  497.59          229.   18501.     8.    60.  1.00     0.    27.   6769.


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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.59     0.0    27.4   229.5   18501.    2065.   9.00

X STA.         0.0         5.7         7.1         8.4         9.8        11.1
  A(I)            33.1        11.3        10.6        10.9        10.7
  V(I)            3.12        9.13        9.73        9.45        9.66

X STA.        11.1        12.4        13.7        14.9        16.1        17.1
  A(I)            10.8        10.6        10.5        10.2         8.7
  V(I)            9.59        9.74        9.83       10.11       11.87

X STA.        17.1        18.0        19.0        19.9        20.8        21.6
  A(I)             8.9         9.4         8.6         8.2         8.1
  V(I)           11.59       10.97       12.00       12.56       12.77

X STA.        21.6        22.4        23.1        23.9        24.6        27.4
  A(I)             8.0         7.8         7.7         7.7        27.7
  V(I)           12.94       13.25       13.39       13.48        3.73

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

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     158.   13762.    26.    37.                        2217.
  494.73          158.   13762.    26.    37.  1.00     1.    27.   2217.

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

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     105.    5215.    68.    68.                         740.
            2     447.   43067.    48.    52.                        7725.
            3      99.    6002.    29.    30.                        1040.
  499.43          651.   54283.   146.   150.  1.15   -79.    67.   7284.


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

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.43   -78.6    67.0   651.4   54283.    2100.   3.22

X STA.       -78.6       -22.4        -6.2        -1.0         1.9         4.4
  A(I)            71.7        52.5        38.9        27.7        25.7
  V(I)            1.46        2.00        2.70        3.80        4.09

X STA.         4.4         6.8         9.2        11.5        13.8        16.0
  A(I)            24.8        25.0        24.6        24.4        24.3
  V(I)            4.23        4.20        4.26        4.30        4.32

X STA.        16.0        18.4        20.7        23.0        25.3        27.5
  A(I)            25.1        25.1        24.7        24.3        24.5
  V(I)            4.18        4.18        4.24        4.31        4.28

X STA.        27.5        29.9        32.8        39.2        46.3        67.0
  A(I)            25.2        28.3        42.6        34.3        57.5
  V(I)            4.16        3.71        2.46        3.06        1.83
```

```
        U.S. Geological Survey WSPRO Input File read028.wsp
        Hydraulic analysis for structure READTH00540028   Date: 05-NOV-97
        Bridge 28 on Town Highway 54 over N. Branch Black R. Reading, VT  MAI
           *** RUN DATE & TIME: 03-31-98  09:09
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     230.   17008.     0.    69.                    ********
   497.76          230.   17008.     0.    69.  1.00     0.    27.********

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.76     0.0    27.4   230.2   17008.    2384.  10.36

X STA.         0.0        4.9        6.3        7.5        8.8       10.0
  A(I)            27.5       10.4        9.9       10.0       10.0
  V(I)            4.33      11.48      12.02      11.89      11.96

X STA.        10.0       11.2       12.4       13.6       14.8       15.9
  A(I)             9.8       10.0       10.0        9.8        9.8
  V(I)           12.12      11.89      11.93      12.14      12.17

X STA.        15.9       17.0       18.1       19.1       20.1       21.0
  A(I)             9.7        9.7        9.5        9.3        9.1
  V(I)           12.27      12.32      12.54      12.82      13.07

X STA.        21.0       21.9       22.8       23.6       24.5       27.4
  A(I)             9.4        8.8        9.1        8.7       29.6
  V(I)           12.69      13.60      13.12      13.65       4.03

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     191.   18008.    26.    40.                       2920.
   495.99          191.   18008.    26.    40.  1.00     0.    27.   2920.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.43   -81.1   127.5   184.6    4860.     720.   3.90

X STA.       -81.1      -54.6      -44.0      -35.4      -28.0      -21.5
  A(I)            13.2        8.2        7.4        6.9        6.5
  V(I)            2.74       4.40       4.89       5.25       5.56

X STA.       -21.5      -15.5       -9.1       -0.9        7.2       17.1
  A(I)             6.3        7.0        9.6        9.6       10.3
  V(I)            5.68       5.11       3.75       3.76       3.51

X STA.        17.1       30.6       42.5       51.7       59.8       69.0
  A(I)            11.9       11.1       10.0        9.6       10.0
  V(I)            3.03       3.23       3.59       3.77       3.58

X STA.        69.0       76.6       85.5       95.2      107.6      127.5
  A(I)             7.9        8.5        8.7        9.9       12.2
  V(I)            4.54       4.24       4.15       3.65       2.96
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     185.   11352.    87.    88.                       1527.
             2     497.   51330.    48.    52.                       9047.
             3     137.    7870.    44.    45.                       1377.
   500.46          819.   70553.   180.   184.  1.18   -98.    82.   9145.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.46   -97.9    81.6   818.9   70553.    3100.   3.79

X STA.       -97.9      -36.6      -23.1      -12.6       -2.5        1.0
  A(I)            93.9       43.3       39.3       61.7       36.1
  V(I)            1.65       3.58       3.94       2.51       4.30

X STA.         1.0        3.8        6.6        9.2       11.7       14.2
  A(I)            30.8       31.4       29.8       30.0       30.0
  V(I)            5.03       4.94       5.21       5.17       5.17

X STA.        14.2       16.8       19.4       22.0       24.6       27.1
  A(I)            30.3       30.2       30.7       30.1       30.0
  V(I)            5.12       5.14       5.06       5.15       5.17

X STA.        27.1       29.7       32.8       39.2       45.8       81.6
  A(I)            31.0       34.0       48.3       39.2       89.0
  V(I)            5.00       4.56       3.21       3.95       1.74
```

WSPRO OUTPUT FILE (continued)

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       U.S. Geological Survey WSPRO Input File read028.wsp
       Hydraulic analysis for structure READTH00540028   Date: 05-NOV-97
       Bridge 28 on Town Highway 54 over N. Branch Black R. Reading, VT  MAI
          *** RUN DATE & TIME: 03-31-98  09:09
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     150.   12800.    26.    36.                       2060.
  494.43          150.   12800.    26.    36.  1.00     1.    27.   2060.



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

        WSEL     LEW     REW    AREA        K        Q    VEL
      494.43     0.8    27.4   150.1   12800.    2060.  13.72

 X STA.        0.8        5.5        6.8        8.1        9.3       10.5
   A(I)            17.9        6.4        6.5        6.4        6.3
   V(I)            5.77      15.97      15.80      16.17      16.27

 X STA.       10.5       11.7       12.9       14.0       15.2       16.3
   A(I)             6.2        6.4        6.3        6.4        6.3
   V(I)           16.50      16.19      16.23      16.04      16.38

 X STA.       16.3       17.4       18.3       19.3       20.2       21.0
   A(I)             6.2        6.1        5.9        5.9        5.7
   V(I)           16.52      16.99      17.54      17.39      18.11

 X STA.       21.0       21.8       22.6       23.4       24.1       27.4
   A(I)             5.7        5.6        5.6        5.4       22.9
   V(I)           18.20      18.47      18.44      18.92       4.49

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

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      20.     581.    30.    30.                         95.
            2     365.   30731.    48.    52.                       5702.
            3      55.    2575.    23.    24.                        473.
  497.73          440.   33887.   102.   106.  1.11   -41.    61.   4915.



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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.73   -40.8    61.1   440.1   33887.    2060.   4.68

 X STA.      -40.8       -1.2        1.3        3.5        5.6        7.6
   A(I)            61.1       19.2       18.6       17.8       17.4
   V(I)            1.69       5.36       5.54       5.79       5.93

 X STA.        7.6        9.5       11.5       13.3       15.3       17.2
   A(I)            17.4       17.3       17.1       17.4       17.4
   V(I)            5.94       5.95       6.04       5.92       5.94

 X STA.       17.2       19.1       21.1       23.0       24.9       26.8
   A(I)            17.3       17.9       17.4       17.1       17.3
   V(I)            5.94       5.75       5.92       6.01       5.94

 X STA.       26.8       28.7       30.8       33.6       41.9       61.1
   A(I)            17.5       17.9       21.6       34.8       40.5
   V(I)            5.87       5.74       4.77       2.96       2.54
```

```
        U.S. Geological Survey WSPRO Input File read028.wsp
        Hydraulic analysis for structure READTH00540028   Date: 05-NOV-97
        Bridge 28 on Town Highway 54 over N. Branch Black R. Reading, VT  MAI
           *** RUN DATE & TIME: 03-31-98  09:09

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

EXITX:XS   ******    -5.     241.  1.18 *****  494.77  492.91   2100.  493.59
      -38. ******    58.   13220.  1.00 ***** *******    0.78    8.72

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.47

FULLV:FV      38.    -6.     317.  0.68  0.65  495.41 *******   2100.  494.73
        0.    38.    63.   19403.  1.00  0.00   -0.01    0.55    6.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      42.    -9.     244.  1.19  0.61  496.27 *******   2100.  495.09
       42.    42.    49.   15688.  1.03  0.25    0.00    0.75    8.61
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.51     497.57     497.83     497.49

 ===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      38.     0.     229.  1.26 *****  498.83  494.45   2065.  497.57
        0. ******    27.   18696.  1.00 ***** *******    0.55    9.01

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.451  0.000  497.49 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG       8.    26.  0.04  0.19  499.57   -0.01     24.  499.43

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     13.    39.   -24.    15.   0.2   0.1   2.0   3.1   0.3   2.6
   RT:     11.    35.    41.    76.   0.2   0.1   1.9   3.3   0.2   2.6

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

APPRO:AS      26.   -79.     651.  0.19  0.12  499.61  493.83   2100.  499.43
       42.    27.    67.   54243.  1.15  0.48   -0.01    0.29    3.23

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -38.    -5.    58.   2100.   13220.     241.     8.72  493.59
   FULLV:FV       0.    -6.    63.   2100.   19403.     317.     6.63  494.73
   BRIDG:BR       0.     0.    27.   2065.   18696.     229.     9.01  497.57
   RDWAY:RG       8.*******    13.     24.*********       0.     2.00  499.43
   APPRO:AS      42.   -79.    67.   2100.   54243.     651.     3.23  499.43

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    492.91    0.78  487.27  509.85************  1.18  494.77  493.59
   FULLV:FV  ********    0.55  487.27  509.85  0.65  0.00  0.68  495.41  494.73
   BRIDG:BR    494.45    0.55  486.80  497.76************  1.26  498.83  497.57
   RDWAY:RG ****************  499.21  514.79  0.04******  0.19  499.57  499.43
   APPRO:AS    493.83    0.29  488.43  514.02  0.12  0.48  0.19  499.61  499.43
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File read028.wsp
        Hydraulic analysis for structure READTH00540028   Date: 05-NOV-97
        Bridge 28 on Town Highway 54 over N. Branch Black R. Reading, VT  MAI
           *** RUN DATE & TIME: 03-31-98  09:09

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

EXITX:XS   ******    -6.     318.  1.48 *****  496.23  494.05   3100.  494.75
      -38. ******    63.   19520.  1.00 ***** *******    0.80    9.75

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.43

FULLV:FV      38.    -7.     408.  0.90  0.67  496.89 *******   3100.  495.99
        0.    38.    68.   27915.  1.00  0.00   -0.01    0.58    7.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      42.   -11.     321.  1.54  0.64  497.84 *******   3100.  496.30
       42.    42.    56.   22506.  1.06  0.32   -0.01    0.80    9.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   500.78       0.00     496.30     499.21

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.83     499.64     499.87     497.49

 ===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      38.     0.     230.  1.67 *****  499.43  495.05   2388.  497.76
        0. ******    27.   17008.  1.00 ***** *******    0.63   10.37

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.480  0.000  497.49 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    26.  0.05  0.26  500.67    0.00    720.  500.43

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    326.    97.   -81.    16.   1.2   0.9   4.6   3.9   1.1   2.9
   RT:    394.   112.    16.   127.   1.2   0.9   4.6   3.9   1.1   2.9

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

APPRO:AS      26.   -98.     819.  0.26  0.17  500.72  495.37   3100.  500.46
       42.    27.    82.   70564.  1.18  0.41    0.00    0.34    3.78

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW     REW       Q         K      AREA     VEL    WSEL
   EXITX:XS     -38.     -6.     63.   3100.   19520.     318.    9.75  494.75
   FULLV:FV       0.     -7.     68.   3100.   27915.     408.    7.60  495.99
   BRIDG:BR       0.      0.     27.   2388.   17008.     230.   10.37  497.76
   RDWAY:RG       8.*******    326.    720.******************    2.00  500.43
   APPRO:AS      42.    -98.     82.   3100.   70564.     819.    3.78  500.46

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    494.05    0.80  487.27  509.85************  1.48  496.23  494.75
   FULLV:FV  ********    0.58  487.27  509.85  0.67  0.00  0.90  496.89  495.99
   BRIDG:BR    495.05    0.63  486.80  497.76************  1.67  499.43  497.76
   RDWAY:RG  ****************  499.21  514.79  0.05******  0.26  500.67  500.43
   APPRO:AS    495.37    0.34  488.43  514.02  0.17  0.41  0.26  500.72  500.46
```

```
        U.S. Geological Survey WSPRO Input File read028.wsp
        Hydraulic analysis for structure READTH00540028   Date: 05-NOV-97
        Bridge 28 on Town Highway 54 over N. Branch Black R. Reading, VT  MAI
           *** RUN DATE & TIME: 03-31-98  09:09

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

EXITX:XS   ******    -5.     237.  1.17 *****  494.71  492.84   2060.  493.54
      -38. ******    57.   12969.  1.00 ***** *******    0.78    8.68

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "FULLV"     KRATIO =  1.47

FULLV:FV      38.    -6.     312.  0.68  0.65  495.35 *******   2060.  494.67
        0.    38.    63.   19048.  1.00  0.00   -0.01    0.55    6.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      42.    -8.     241.  1.17  0.61  496.20 *******   2060.  495.03
       42.    42.    49.   15419.  1.02  0.25    0.00    0.74    8.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    2060.      494.43

            <<<<<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      38.     1.     150.  2.93 *****  497.36  494.43   2060.  494.43
        0.    38.    27.   12791.  1.00 ***** *******    1.00   13.73

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  497.49 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG       8.       <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      26.   -41.     440.  0.38  0.27  498.11  493.76   2060.  497.73
       42.    27.    61.   33842.  1.11  0.48    0.01    0.42    4.69

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.533  0.311   23281.     1.    28.   497.63

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -38.    -5.    57.   2060.   12969.     237.    8.68  493.54
   FULLV:FV       0.    -6.    63.   2060.   19048.     312.    6.59  494.67
   BRIDG:BR       0.     1.    27.   2060.   12791.     150.   13.73  494.43
   RDWAY:RG       8.**************       0.*****************    2.00********
   APPRO:AS      42.   -41.    61.   2060.   33842.     440.    4.69  497.73

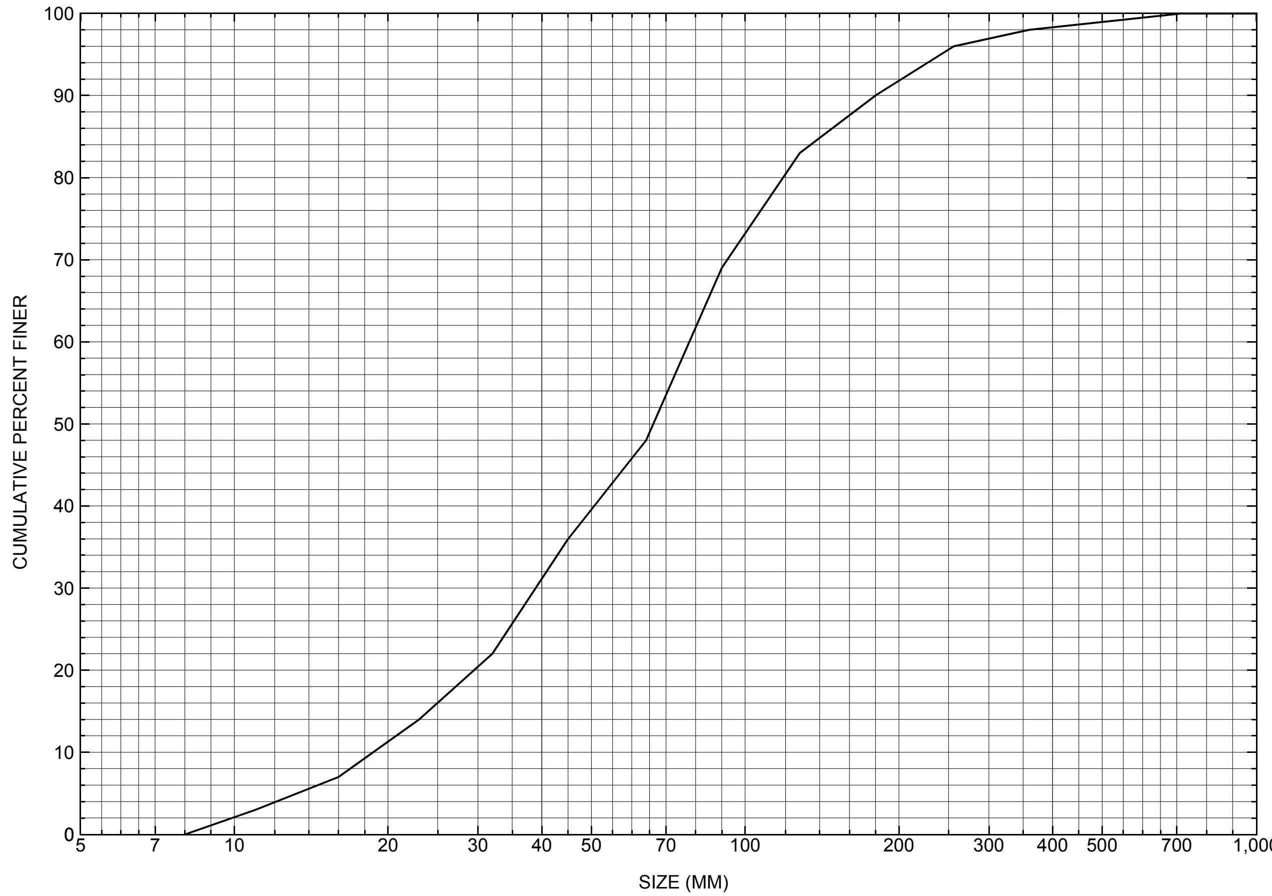
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    28.   23281.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    492.84    0.78  487.27  509.85************  1.17  494.71  493.54
   FULLV:FV  ********    0.55  487.27  509.85  0.65  0.00  0.68  495.35  494.67
   BRIDG:BR    494.43    1.00  486.80  497.76************  2.93  497.36  494.43
   RDWAY:RG  ****************  499.21  514.79**********************************
   APPRO:AS    493.76    0.42  488.43  514.02  0.27  0.48  0.38  498.11  497.73
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure READTH00540028, in Reading, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number READTH00540028

General Location Descriptive

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

Date (MM/DD/YY) 03 / 22 / 95

Highway District Number (I - 2; nn) 04

County (FIPS county code; I - 3; nnn) 027

Town (FIPS place code; I - 4; nnnnn) 58375

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

Waterway (I - 6) N. BRANCH BLACK RIVER

Road Name (I - 7): -

Route Number TH054

Vicinity (I - 9) 0.05 MI TO JCT W CL2 TH1

Topographic Map Cavendish

Hydrologic Unit Code: 01080106

Latitude (I - 16; nnnn.n) 43283

Longitude (i - 17; nnnnn.n) 72352

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10141400281414

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0030

Year built (I - 27; YYYY) 1974

Structure length (I - 49; nnnnnn) 000031

Average daily traffic, ADT (I - 29; nnnnnn) 000050

Deck Width (I - 52; nn.n) 157

Year of ADT (I - 30; YY) 91

Channel & Protection (I - 61; n) 7

Opening skew to Roadway (I - 34; nn) 15

Waterway adequacy (I - 71; n) 6

Operational status (I - 41; X) P

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) 026.1

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 009.0

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

Waterway of full opening (nnn.n ft^2) 235.0

Comments:

The structural inspection report of 9/10/93 indicates the structure is a single span, steel stringer type bridge with a timber deck. The right abutment is constructed of concrete, and the left abutment is "laid-up" stone with a concrete cap. There is no cracking reported but the footing is exposed for the entire length of the right abutment. Except at the upstream end, the adjacent streambed level is flush with the top of the footing. The footing at the upstream end is about 0.5 ft above the streambed level. There are no signs of undermining. The report indicates no cracks or breaks in the concrete cap or the stone wall of the left abutment. The waterway is noted as making a slight bend into the crossing. The streambed is reported to consist of mainly stone and gravel with a few small boulders. **(Continued, page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

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} (*ft³/ sec*): -

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

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

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

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

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

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

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

Comments:

The report notes that bank erosion and debris are not evident. A sand and gravel point bar that has developed along the left abutment.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **8.16** mi^2 Lake/pond/swamp area **0.09** mi^2

Watershed storage *(ST)* **1.1** %

Bridge site elevation **1220** ft Headwater elevation **2478** ft

Main channel length **3.31** mi

10% channel length elevation **1260** ft 85% channel length elevation **1820** ft

Main channel slope *(S)* **225.44** 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? **Yes** *If no, type ctrl-n xs*

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

Comments: **The station and low chord to bed differences are from a sketch dated 9/10/93 that is attached to a bridge inspection report. The low chord elevations are taken from the 6/3/96 survey done for this report.**

Station	0	16.00	25.00	25.01	27.00	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	497.23	497.54	497.72	497.72	497.76	-	-	-	-	-	-
Bed elevation	491.23	488.24	487.15	487.49	487.53	-	-	-	-	-	-
Low chord to bed	6.00	9.30	10.57	10.23	10.23	-	-	-	-	-	-

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: MS Date: 07/01/97
Computerized by: MS Date: 07/01/97
Reviewd by: MAI Date: 04/07/98

Structure Number READTH00540028

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. WEBER Date *(MM/DD/YY)* 03 / 29 / 1995

2. Highway District Number 04 Mile marker 000000
   County WINDSOR (027) Town READING (58375)
   Waterway *(I - 6)* North Branch Black River Road Name Town Farm Road
   Route Number TH 54 Hydrologic Unit Code: 01080106

3. Descriptive comments:
This structure consists of a timber deck, and is located 0.05 miles from the junction with Town Highway 1.

B. Bridge Deck Observations

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

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

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

7. Bridge length 31 *(feet)* Span length 30 *(feet)* Bridge width 15.7 *(feet)*

Road approach to bridge:

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

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

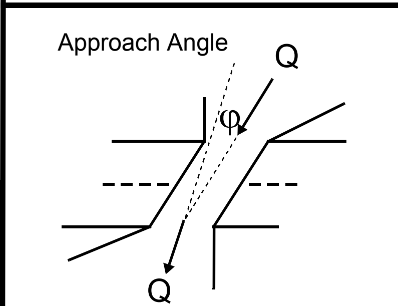
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right 1.7:1

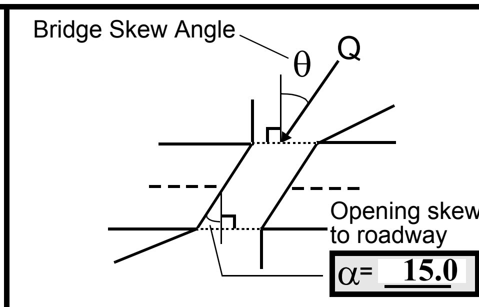
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	2	1	0	0
RBDS	1	1	0	0
LBDS	1	1	2	2

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

Channel approach to bridge (BF):

15. Angle of approach: 5 16. Bridge skew: 15





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 0 feet US *(US, UB, DS)* to 50 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 30 feet DS *(US, UB, DS)* to 80 feet DS

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

18. Bridge Type: **4**

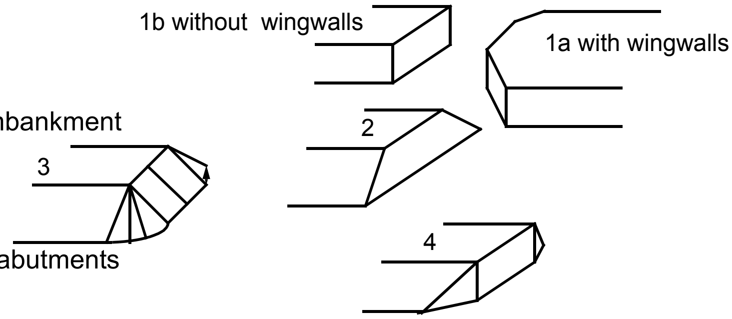
1a- Vertical abutments with wingwalls

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.)

4. The US left bank consists of saplings and brush, while the US right bank has saplings, a dirt road, and larger trees approximately 100 ft away from the bridge. The DS left bank has a few large trees, brush, pasture, and a garden. The DS right bank has young trees and TH 54.

7. The measured values for bridge length, span length, and bridge width are 32.5 ft, 27.5 ft, and 15.5 ft, respectively.

18. There is a constructed gully entering on the left bank, 5 ft DS. Type 2 stone fill lines part of the US side of the gully, while cobbles line part of the DS side of it. There are also stones in the gully channel.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
36.5	6.5			5.0	2	2	4	4	0	0

23. Bank width **30.0** 24. Channel width **35.0** 25. Thalweg depth **48.0** 29. Bed Material **3**

30. Bank protection type: LB **1** RB **1** 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.):

26. The percent vegetation cover increases to greater than 50% on the RB further than 60 ft upstream.

27. Cobbles and boulders line both banks to about 200 ft US. This native fill comprises the bank material for the US reach.

29. The bed material consists of gravel, cobbles and boulders.

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

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

37. Material: -

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

NO POINT BARS

39. Is a cut-bank present? **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.):

There is some cutting on the LB greater than 200 feet US, with trees leaning into the channel.

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) LB	RB	57 Angle (BF) LB	RB	61. Material (BF) LB	RB	62. Erosion (BF) LB	RB
31.5		1.0		2	7	7	0

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

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

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

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

4

The US side of the left abutment (wingwall) is an unmortared stone wall, while under the bridge is mortared rock capped with concrete. The right abutment is concrete.

63. The bed material consists of cobbles and boulders with some gravel and a lot of surficial sand.

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

Cutting has occurred with trees leaning into the channel seen far US. Thus, the site is categorized with a moderate debris potential. The bridge will not constrict much of bank full flow.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		-	90	0	0	0	0	90.0
RABUT	2	5	90			2	2	26.5

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

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

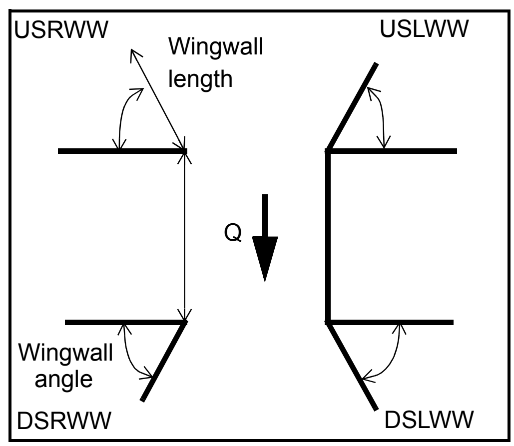
1
1
1

At the DS end of the LABUT, there is a void in the stone wall with free poured concrete supporting the material above the bed. There is no mortar on the abutment below the level of the free poured concrete.
There is a 1 ft deep scour hole along the downstream end of the right abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						26.5	
USRWW:	Y		2		0	2.0	
DSLWW:	-		-		Y	15.0	
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	0	-	Y	1	-	1	1	-
Condition	N	-	1	1	-	2	3	-
Extent	-	-	2	-	2	2	0	-

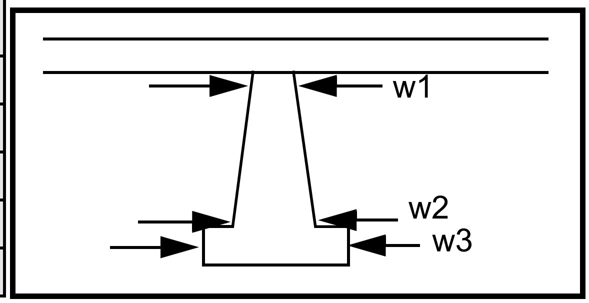
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

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				**65.0**	**16.0**	**60.0**
Pier 2		-		**11.5**	-	**75.0**
Pier 3	**9.0**	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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
-	-			-	-	-	-	-	-	-

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.):
-
-
-
-
-
-
-
NO PIERS

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):
1
3
2
2
1
1

106. Point/Side bar present? **3** (Y or N. if N type ctrl-n pb) Mid-bar distance: **0** Mid-bar width: **0**

Point bar extent: **-** feet **-** (US, UB, DS) to **The** feet **left** (US, UB, DS) positioned **ba** %LB to **nk** %RB

Material: **ma**

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

terial is sand, gravel, and cobbles, with clay just under the surface about 75 ft DS. The right bank material is sand, gravel, and cobbles. The bed material is gravel, cobbles, and sand, with scattered boulders.

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

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

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

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

N

-

Is channel scour present? **NO** (Y or if N type ctrl-n cs) Mid-scour distance: **DRO**

Scour dimensions: Length **P** Width **STR** Depth: **UC** Positioned **TU** %LB to **RE** %RB

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

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

Confluence 1: Distance **5** Enters on **11** (LB or RB) Type **10** (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance **UB** Enters on **25** (LB or RB) Type **DS** (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

0

45

F. Geomorphic Channel Assessment

107. Stage of reach evolution **2**

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)*:

This sand side bar along the downstream end of the left abutment is unvegetated.

N
-
-
-
-
-
-
-
The fluvial erosion on the left bank DS is between light and moderate, but it is not classified as a cut-bank

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:	READTH00540028	Town:	Reading
Road Number:	TH 54	County:	Windsor
Stream:	North Branch Black River		

Initials MAI Date: 03/12/98 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 Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2100	3100	2060
Main Channel Area, ft2	447	497	365
Left overbank area, ft2	105	185	20
Right overbank area, ft2	99	137	55
Top width main channel, ft	48	48	48
Top width L overbank, ft	68	87	30
Top width R overbank, ft	29	44	23
D50 of channel, ft	0.2169	0.2169	0.2169
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.3	10.4	7.6
y1, average depth, LOB, ft	1.5	2.1	0.7
y1, average depth, ROB, ft	3.4	3.1	2.4
Total conveyance, approach	54283	70553	33887
Conveyance, main channel	43067	51330	30731
Conveyance, LOB	5215	11352	581
Conveyance, ROB	6002	7870	2575
Percent discrepancy, conveyance	-0.0018	0.0014	0.0000
Qm, discharge, MC, cfs	1666.1	2255.4	1868.1
Ql, discharge, LOB, cfs	201.7	498.8	35.3
Qr, discharge, ROB, cfs	232.2	345.8	156.5
Vm, mean velocity MC, ft/s	3.7	4.5	5.1
Vl, mean velocity, LOB, ft/s	1.9	2.7	1.8
Vr, mean velocity, ROB, ft/s	2.3	2.5	2.8
Vc-m, crit. velocity, MC, ft/s	9.8	9.9	9.4
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	2100	3100	2060
(Q) discharge thru bridge, cfs	2065	2384	2060
Main channel conveyance	18501	17008	12800
Total conveyance	18501	17008	12800
Q2, bridge MC discharge,cfs	2065	2384	2060
Main channel area, ft2	230	230	150
Main channel width (normal), ft	26.5	26.5	25.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	26.5	26.5	25.7
y_bridge (avg. depth at br.), ft	8.66	8.69	5.84
Dm, median (1.25*D50), ft	0.271125	0.271125	0.271125
y2, depth in contraction,ft	7.52	8.50	7.70
ys, scour depth (y2-ybridge), ft	-1.14	-0.19	**1.86**

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	2100	3100	2060
Q, thru bridge MC, cfs	2065	2384	2060
Vc, critical velocity, ft/s	9.77	9.94	9.44
Va, velocity MC approach, ft/s	3.73	4.54	5.12
Main channel width (normal), ft	26.5	26.5	25.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	26.5	26.5	25.7
qbr, unit discharge, ft2/s	77.9	90.0	80.2
Area of full opening, ft2	229.5	230.2	150.1
Hb, depth of full opening, ft	8.66	8.69	5.84
Fr, Froude number, bridge MC	0.55	0.63	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	158	191	N/A
**Hb, depth at downstream face, ft	5.96	7.21	N/A
**Fr, Froude number at DS face	0.94	0.82	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A

Elevation of Low Steel, ft	497.49	497.49	497.49
Elevation of Bed, ft	488.83	488.80	491.65
Elevation of Approach, ft	499.43	500.46	0
Friction loss, approach, ft	0.12	0.18	0
Elevation of WS immediately US, ft	499.31	500.28	0.00
ya, depth immediately US, ft	10.48	11.48	-491.65
Mean elevation of deck, ft	499.41	499.41	499.41
w, depth of overflow, ft (>=0)	0.00	0.87	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.95	ERR
**Cc, for downstream face (<=1.0)	0.819829	0.899326	ERR
Ys, scour w/Chang equation, ft	**-0.29**	**0.83**	N/A
Ys, scour w/Umbrell equation, ft	-2.20	-1.17	N/A

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

**Ys, scour w/Chang equation, ft	3.77	2.85	N/A
**Ys, scour w/Umbrell equation, ft	0.50	0.31	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	7.52	8.50	7.70
WSEL at downstream face, ft	494.73	495.99	--
Depth at downstream face, ft	5.96	7.21	N/A
Ys, depth of scour (Laursen), ft	1.55	1.29	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	2065	2384	2060
Main channel area (DS), ft2	158	191	150.1
Main channel width (normal), ft	26.5	26.5	25.7
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	26.5	26.5	25.7
D90, ft	0.5906	0.5906	0.5906
D95, ft	0.7920	0.7920	0.7920
Dc, critical grain size, ft	0.7434	0.6276	0.8268
Pc, Decimal percent coarser than Dc	0.061	0.090	0.043
Depth to armoring, ft	**34.27**	**19.13**	**N/A**

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	2100	3100	2060	2100	3100	2060
a', abut.length blocking flow, ft	79.1	98.4	42.1	40	54.6	34.1
Ae, area of blocked flow ft2	174.79	202.97	80.3	190.15	186.5	130.46
Qe, discharge blocked abut.,cfs	--	--	206	--	--	504.16
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.08	2.80	2.57	2.84	3.22	3.86

ya, depth of f/p flow, ft	2.21	2.06	1.91	4.75	3.42	3.83

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

K1	0.82	0.82	0.82	0.82	0.82	0.82

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

theta	75	75	75	105	105	105
K2	0.98	0.98	0.98	1.02	1.02	1.02
Fr, froude number f/p flow	0.245	0.298	0.327	0.227	0.269	0.348
ys, scour depth, ft	**10.14**	**11.50**	**8.54**	**13.88**	**13.00**	**13.60**

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)	79.1	98.4	42.1	40	54.6	34.1
y1 (depth f/p flow, ft)	2.21	2.06	1.91	4.75	3.42	3.83
a'/y1	35.80	47.70	22.07	8.41	15.98	8.91
Skew correction (p. 49, fig. 16)	0.95	0.95	0.95	1.03	1.03	1.03
Froude no. f/p flow	0.25	0.30	0.33	0.23	0.27	0.35
Ys w/ corr. factor K1/0.55:						
vertical	9.60	9.56	ERR	ERR	ERR	ERR
vertical w/ ww's	7.87	7.84	ERR	ERR	ERR	ERR
spill-through	5.28	5.26	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.94	0.82	1	0.94	0.82	1
y, depth of flow in bridge, ft	5.96	7.21	5.84	5.96	7.21	5.84
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	**2.45**	**2.85**	**2.44**	**2.45**	**2.85**	**2.44**