LEVEL II SCOUR ANALYSIS FOR BRIDGE 34 (ROCHTH00210034) on TOWN HIGHWAY 21, crossing the WHITE RIVER, ROCHESTER, VERMONT

Open-File Report 97-670

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 EMILY C. WILD and JAMES DEGNAN

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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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 34 (ROCHTH00210034) ON TOWN HIGHWAY 21, CROSSING THE WHITE RIVER, ROCHESTER, VERMONT

By **Emily C. Wild and James Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ROCHTH00210034 on Town Highway 21 crossing the White River, Rochester, 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, obtained from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in central Vermont. The 74.8-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is suburban on the upstream and downstream left overbanks, though brush prevails along the immediate banks. On the upstream and downstream right overbanks, the surface cover is pasture with brush and trees along the immediate banks.

In the study area, the White River has an incised, straight channel with a slope of approximately 0.002 ft/ft, an average channel top width of 102 ft and an average bank height of 5 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 74.4 mm (0.244 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 23, 1996, indicated that the reach was stable.

The Town Highway 21 crossing of the White River is a 72-ft-long, two-lane bridge consisting of 70-foot steel stringer span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 67.0 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is zero degrees.

Channel scour, 1.5 ft deeper than the mean thalweg depth was observed along the left abutment and wingwalls during the Level I assessment. Scour countermeasures at the site includes type-1 stone fill (less than 12 inches diameter) along the upstream left bank and the upstream and downstream left road embankments, type-2 (less than 36 inches diameter) along the upstream end of the upstream left wingwall and downstream left bank, and type-3 (less than 48 inches diameter) along the downstream end of the downstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). In addition, the incipient roadway-overtopping discharge is analyzed since it has the potential of being the 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 discharges was zero. Left abutment scour ranged from 6.8 to 21.2 ft. Right abutment scour ranged from 13.9 to 18.4 ft. The worst-case abutment scour occurred at the 500-year discharge at the left and right abutments. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number ROCHTH00210034 ***Stream*** White River

County Windsor ***Road*** TH21 ***District*** 4

Description of Bridge

Bridge length 72 ***ft*** ***Bridge width*** 16 ***ft*** ***Max span length*** 70 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 7/23/96

Description of stone fill Type-2, around the upstream end of the upstream left wingwall which is slumped. Type-3, around the downstream end of the downstream left wingwall.

Abutments and wingwalls are concrete. Footings are exposed on the downstream end of the upstream left wingwall, left abutment, and upstream end of the downstream left wingwall.

Y 15

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

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	7/23/96	0	0
Level II	7/23/96	0	0

Potential for debris Low. There is some debris caught on the vegetation along upstream left and right banks.

Describe any features near or at the bridge that may affect flow (include observation date) None. 7/23/96

Description of the Geomorphic Setting

General topography The channel is located within a narrow, flat to slightly irregular flood plain with moderately sloped valley walls.

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

Date of inspection 7/23/96

DS left: Steep channel bank to a narrow flood plain.

DS right: Shallow sloped narrow flood plain.

US left: Narrow flood plain.

US right: Narrow flood plain with a shallow sloped overbank.

Description of the Channel

Average top width 102 ft ***Average depth*** 5 ft

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

Sinuous but stable with alluvial channel boundaries and a narrow flood plain.

7/23/96

Vegetative co Brush and the Village of Rochester.

DS left: Pasture with brush

DS right: Brush and the Village of Rochester.

US left: Pasture and brush.

US right:

Y

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

None. 7/23/96

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 74.8 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: The drainage is rural, however the bridge itself is located in the Village of Rochester..

Is there a USGS gage on the stream of interest? Yes

USGS gage description White River near Bethel, VT.

USGS gage number 01142000 - discontinued

Gage drainage area 241 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 14,830 ***ft³/s*** ***Q500*** 21,960 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(74.8/65)exp 0.7] with Flood Insurance Study discharge values at the upstream corporate limits of Rochester (Federal Emergency Management Agency, 1991). The drainage area at the upstream corporate limits of Rochester is 65 square miles. The values computed are within a range defined by several empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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. 496.40 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 496.51 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	-70	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APTEM	82	1	Approach section as surveyed (Used as a template)
APPRO	89	2	Modelled Approach section (Templated from APTEM)

[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 0.035 to 0.045, and overbank "n" values ranged from 0.045 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 0.0020 ft/ft which was estimated from the 100-year water-surface slope downstream of the bridge in the Flood Insurance Study for Rochester, VT (Federal Emergency Management Agency, 1991).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0014 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.6 *ft*
Average low steel elevation 496.7 *ft*

100-year discharge 14,830 *ft³/s*
Water-surface elevation in bridge opening 496.7 *ft*
Road overtopping? Y *Discharge over road* 9,460 *ft³/s*
Area of flow in bridge opening 722 *ft²*
Average velocity in bridge opening 7.2 *ft/s*
Maximum WSPRO tube velocity at bridge 8.4 *ft/s*

Water-surface elevation at Approach section with bridge 498.8
Water-surface elevation at Approach section without bridge 497.9
Amount of backwater caused by bridge 0.9 *ft*

500-year discharge 21,960 *ft³/s*
Water-surface elevation in bridge opening 496.7 *ft*
Road overtopping? Y *Discharge over road* 17,200 *ft³/s*
Area of flow in bridge opening 722 *ft²*
Average velocity in bridge opening 6.9 *ft/s*
Maximum WSPRO tube velocity at bridge 8.1 *ft/s*

Water-surface elevation at Approach section with bridge 500.2
Water-surface elevation at Approach section without bridge 499.3
Amount of backwater caused by bridge 0.9 *ft*

Incipient overtopping discharge 2,950 *ft³/s*
Water-surface elevation in bridge opening 493.5 *ft*
Area of flow in bridge opening 508 *ft²*
Average velocity in bridge opening 5.8 *ft/s*
Maximum WSPRO tube velocity at bridge 7.0 *ft/s*

Water-surface elevation at Approach section with bridge 493.9
Water-surface elevation at Approach section without bridge 493.9
Amount of backwater caused by bridge 0.0 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100-year and 500-year discharges resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Hence, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146).

For the discharges resulting in orifice flow, estimates of contraction scour were also computed by use of the Laursen clear-water contraction scour equation and are presented in Appendix F. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	0.3 0.2	0.1	--
Left overbank	--	--	--
Right overbank	--	--	20.4

Local scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
Abutment scour	21.2	6.8	13.9
Left abutment	18.4	14.1	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	1.0
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	0.9	0.7	1.0
Left abutment	0.9	0.7	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	
Pier 2			

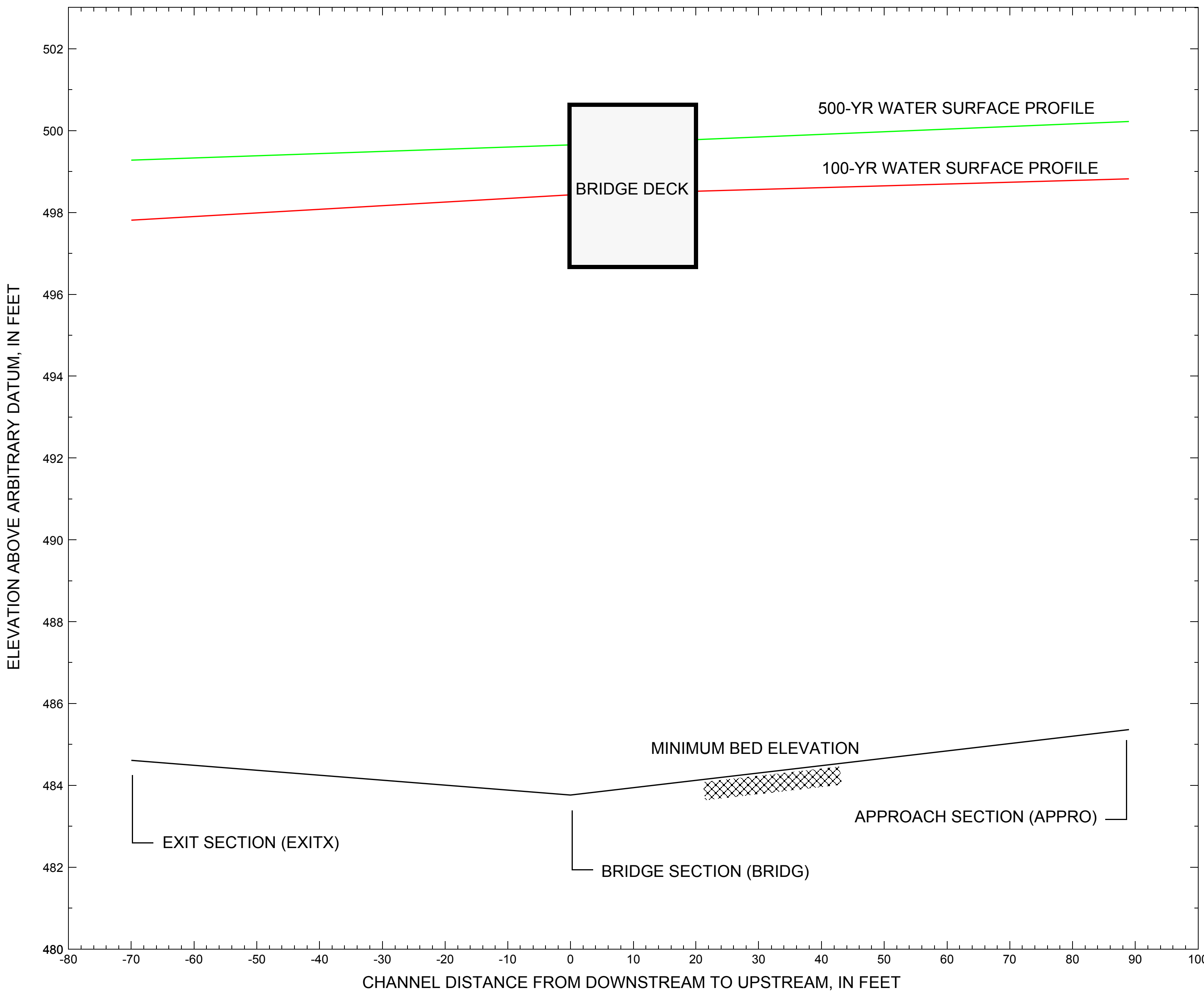

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ROCHTH00210034 on Town Highway 21, crossing the White River, Rochester, Vermont.

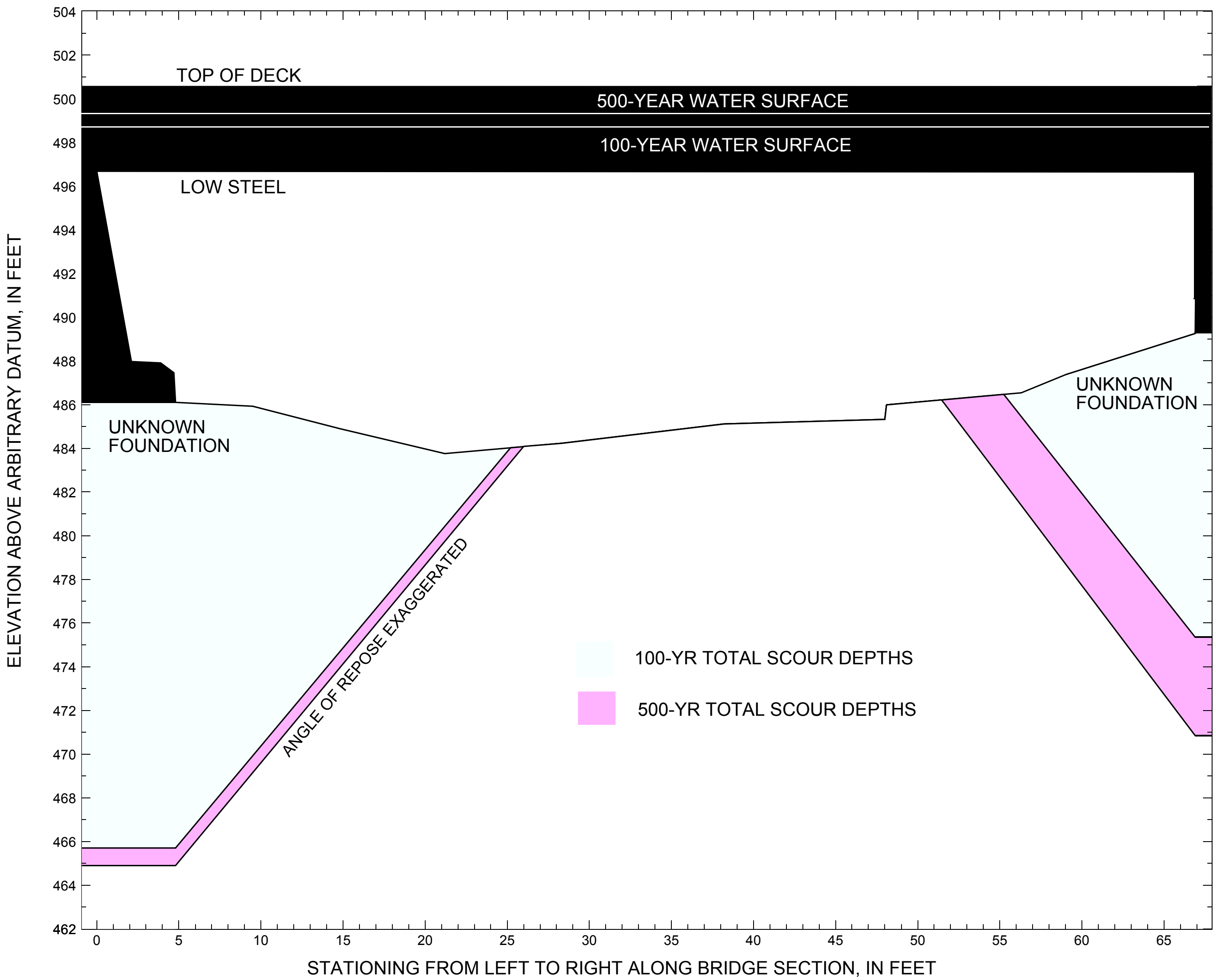

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ROCHTH00210034 on Town Highway 21, crossing the White River, Rochester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ROCHTH00210034 on Town Highway 21, crossing the White River, Rochester, 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 14,830 cubic-feet per second											
Left abutment	0.0	--	496.7	--	486.1	0.0	20.4	--	20.4	465.7	--
Right abutment	67.0	--	496.7	--	489.3	0.0	13.9	--	13.9	475.4	--

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 ROCHTH00210034 on Town Highway 21, crossing the White River, Rochester, 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 21,960 cubic-feet per second											
Left abutment	0.0	--	496.7	--	486.1	0.0	21.2	--	21.2	464.9	--
Right abutment	67.0	--	496.7	--	489.3	0.0	18.4	--	18.4	470.9	--

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, 1970, Rochester, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File roch034.wsp
T2        Hydraulic analysis for structure ROCHTH00210034   Date: 8-May-97
T3        Town Highway 21, WHITE RIVER, ROCHESTER, VERMONT     ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          14830.0  21960.0  2950.0
SK          0.0020   0.0020  0.0020
WS          497      497     493.47
*
XS   EXITX    -70
GR         -232.6, 517.42   -210.7, 502.41   -178.9, 502.71   -163.7, 500.38
GR         -100.0, 499.47    -60.0, 498.89    -11.1, 498.96      0.0, 490.97
GR            8.5, 487.35     23.4, 485.35     30.0, 484.61     40.2, 484.84
GR           54.0, 485.75     67.6, 486.23     71.7, 487.40     82.0, 491.42
GR           94.1, 492.60    155.1, 494.09    188.3, 493.74    618.5, 494.11
GR          665.6, 499.92    691.4, 516.07
*
N           0.055        0.045        0.045
SA                   0.0         94.1
*
*
XS   FULLV      0  * * *   0.0017
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    496.67       0.0
GR            0.0, 496.68      2.1, 487.97      3.9, 487.91
GR            4.7, 487.46      4.8, 486.10      9.5, 485.92     14.8, 484.90
GR           21.2, 483.76     28.3, 484.23     38.2, 485.11     48.0, 485.32
GR           48.1, 485.98     56.3, 486.54     59.0, 487.37     66.9, 489.25
GR           67.0, 496.65      0.0, 496.68
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      22.3      3.5    500.6     26.1
N           0.035
*
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     11      16.0     1
GR         -270.1, 518.12   -251.5, 505.37   -243.7, 506.21   -218.3, 504.93
GR         -169.8, 500.32    -94.7, 498.69    -64.9, 499.05      0.0, 500.56
GR           66.8, 500.55     93.8, 499.34    161.7, 494.48    188.3, 493.74
GR          534.3, 497.67    661.5, 499.92    688.6, 516.07
*
*
XT   APTEM     82
GR         -255.5, 509.29   -167.1, 500.47    -92.2, 497.92    -61.3, 493.28
GR            0.0, 492.01     11.2, 487.53     15.8, 486.45     37.4, 485.35
GR           50.1, 486.04     60.2, 486.75     76.8, 486.83     86.8, 487.54
GR           98.3, 491.98    109.4, 493.53    161.2, 494.48    425.7, 497.77
GR          530.7, 497.40    691.9, 499.92    717.7, 516.07
*
AS   APPRO   89  * * * 0.0014
GT
N           0.055        0.045        0.045
SA                   0.0        109.4
*
*
HP 1 BRIDG 496.68 1 496.68
HP 2 BRIDG 496.68 * * 5211
HP 2 RDWAY 498.43 * * 9455
HP 1 APPRO 498.82 1 498.82
HP 2 APPRO 498.82 * * 14830
*
HP 1 BRIDG 496.68 1 496.68
HP 2 BRIDG 496.68 * * 4988
HP 2 RDWAY 499.65 * * 17226
HP 1 APPRO 500.22 1 500.22
HP 2 APPRO 500.22 * * 21960
*
HP 1 BRIDG 493.46 1 493.46
HP 2 BRIDG 493.46 * * 2950
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File roch034.wsp
        Hydraulic analysis for structure ROCHTH00210034   Date: 8-May-97
        Town Highway 21, WHITE RIVER, ROCHESTER, VERMONT     ECW
           *** RUN DATE & TIME: 05-21-97  15:00
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      722     87258      0    151                            0
   496.68           722     87258      0    151  1.00      0     67        0


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.68     0.0    67.0   721.6   87258.    5211.   7.22

X STA.         0.0        6.9       10.6       13.8       16.6       19.3
  A(I)            55.8       39.6       35.3       34.1       32.7
  V(I)            4.67       6.58       7.38       7.64       7.96

X STA.        19.3       21.8       24.2       26.7       29.2       31.7
  A(I)            31.7       30.9       31.3       31.6       31.1
  V(I)            8.23       8.44       8.33       8.24       8.39

X STA.        31.7       34.4       37.2       40.0       42.9       45.8
  A(I)            32.1       32.4       32.8       33.0       33.2
  V(I)            8.12       8.04       7.93       7.90       7.85

X STA.        45.8       49.0       52.4       56.0       60.2       67.0
  A(I)            36.1       35.6       37.0       40.5       54.9
  V(I)            7.21       7.32       7.05       6.44       4.75

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.43   106.5   577.3  1183.1   72391.    9455.   7.99

X STA.       106.5      153.4      167.1      178.3      188.2      197.8
  A(I)            78.6       52.2       47.5       45.3       44.4
  V(I)            6.01       9.05       9.96      10.44      10.65

X STA.       197.8      207.6      217.6      228.1      239.2      251.1
  A(I)            44.3       44.3       45.0       46.5       48.0
  V(I)           10.68      10.68      10.52      10.16       9.85

X STA.       251.1      264.0      277.7      292.6      308.9      327.4
  A(I)            50.3       51.5       53.6       55.5       59.4
  V(I)            9.40       9.18       8.82       8.52       7.96

X STA.       327.4      348.7      373.6      404.8      449.9      577.3
  A(I)            63.8       67.8       75.2       88.9      121.0
  V(I)            7.41       6.97       6.29       5.32       3.91

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      489     34012    118    119                         5636
             2     1214    197428    109    111                        22934
             3     1151     65478    512    512                         9803
   498.82          2854    296918    739    742  1.74   -117    621    24100


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.82  -118.3   620.9  2853.7  296918.   14830.   5.20

X STA.      -118.3      -35.5       -7.1        9.3       17.0       23.8
  A(I)           260.3      180.8      128.0       90.6       85.1
  V(I)            2.85       4.10       5.79       8.18       8.72

X STA.        23.8       30.2       36.3       42.5       48.8       55.5
  A(I)            83.2       81.0       81.7       81.9       84.6
  V(I)            8.91       9.16       9.07       9.05       8.76

X STA.        55.5       62.6       69.7       77.1       85.0       95.9
  A(I)            86.6       85.6       89.4       91.6      107.0
  V(I)            8.57       8.66       8.30       8.10       6.93

X STA.        95.9      124.4      165.8      223.6      311.7      620.9
  A(I)           162.2      191.5      226.2      264.8      391.7
  V(I)            4.57       3.87       3.28       2.80       1.89
```

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     U.S. Geological Survey WSPRO Input File roch034.wsp
     Hydraulic analysis for structure ROCHTH00210034   Date: 8-May-97
     Town Highway 21, WHITE RIVER, ROCHESTER, VERMONT     ECW
        *** RUN DATE & TIME: 05-21-97  15:00

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

  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1      722     87258     0    151                              0
496.68           722     87258     0    151  1.00      0     67        0


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

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.68     0.0    67.0   721.6   87258.    4988.   6.91

X STA.         0.0        6.9       10.6       13.8       16.6       19.3
  A(I)            55.8       39.6       35.3       34.1       32.7
  V(I)            4.47       6.30       7.06       7.32       7.62

X STA.        19.3       21.8       24.2       26.7       29.2       31.7
  A(I)            31.7       30.9       31.3       31.6       31.1
  V(I)            7.87       8.08       7.97       7.89       8.03

X STA.        31.7       34.4       37.2       40.0       42.9       45.8
  A(I)            32.1       32.4       32.8       33.0       33.2
  V(I)            7.78       7.69       7.59       7.56       7.51

X STA.        45.8       49.0       52.4       56.0       60.2       67.0
  A(I)            36.1       35.6       37.0       40.5       54.9
  V(I)            6.90       7.00       6.74       6.16       4.55


 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

      WSEL     LEW     REW    AREA        K        Q    VEL
    499.65  -138.9   646.2  1862.5  133037.   17226.   9.25

X STA.      -138.9      144.3      162.4      176.1      188.4      200.3
  A(I)           160.1       82.6       74.1       70.6       69.1
  V(I)            5.38      10.42      11.62      12.19      12.46

X STA.       200.3      212.1      224.8      237.7      251.5      266.1
  A(I)            67.5       70.5       70.1       72.6       74.9
  V(I)           12.76      12.22      12.29      11.87      11.50

X STA.       266.1      281.9      298.6      316.9      336.7      359.3
  A(I)            77.8       79.7       83.1       86.2       92.5
  V(I)           11.07      10.81      10.37      10.00       9.32

X STA.       359.3      384.2      414.4      451.2      500.7      646.2
  A(I)            95.3      105.8      115.5      130.8      183.7
  V(I)            9.03       8.14       7.45       6.59       4.69

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1      683     48745   159    160                           8025
          2     1367    240681   109    111                          27411
          3     1928    141633   583    583                          19889
500.22          3977    431059   852    854  1.67   -158    692    37691

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

      WSEL     LEW     REW    AREA        K        Q    VEL
    500.22  -159.5   692.4  3977.5  431059.   21960.   5.52

X STA.      -159.5      -39.2       -7.6       10.4       19.3       27.3
  A(I)           378.0      243.2      169.4      118.5      113.4
  V(I)            2.90       4.52       6.48       9.27       9.69

X STA.        27.3       35.1       42.4       50.1       58.4       67.0
  A(I)           112.8      108.6      110.5      115.5      115.6
  V(I)            9.73      10.11       9.94       9.51       9.50

X STA.        67.0       75.8       85.0       98.5      128.1      164.7
  A(I)           118.5      119.6      145.1      202.7      219.9
  V(I)            9.27       9.18       7.57       5.42       4.99

X STA.       164.7      209.1      264.7      339.1      462.7      692.4
  A(I)           240.2      266.2      296.1      350.9      432.8
  V(I)            4.57       4.12       3.71       3.13       2.54
```

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        U.S. Geological Survey WSPRO Input File roch034.wsp
        Hydraulic analysis for structure ROCHTH00210034   Date: 8-May-97
        Town Highway 21, WHITE RIVER, ROCHESTER, VERMONT     ECW
           *** RUN DATE & TIME: 05-21-97  15:00

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      508     75967     66     77                          7991
   493.46           508     75967     66     77  1.00      1     67     7991


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.46     0.8    67.0   508.2   75967.    2950.   5.81

X STA.         0.8        7.9       11.5       14.6       17.3       19.7
  A(I)            41.8       27.7       25.2       23.8       22.4
  V(I)            3.53       5.32       5.85       6.19       6.57

X STA.        19.7       22.0       24.2       26.5       28.7       31.2
  A(I)            21.4       21.3       21.5       21.0       21.9
  V(I)            6.89       6.93       6.86       7.03       6.74

X STA.        31.2       33.6       36.2       38.8       41.6       44.4
  A(I)            21.6       22.4       22.1       23.0       23.5
  V(I)            6.84       6.59       6.66       6.42       6.27

X STA.        44.4       47.3       50.9       54.5       58.8       67.0
  A(I)            23.8       26.7       26.2       29.1       41.8
  V(I)            6.20       5.52       5.64       5.08       3.53

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       80      2481     66     66                           503
             2      680     75128    109    111                          9613
             3        4        49     22     22                            11
   493.94           764     77659    197    199  1.15    -65    131     7976


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.94   -65.6   131.2   764.2   77659.    2950.   3.86

X STA.       -65.6        6.5       13.4       18.0       22.1       26.0
  A(I)           101.1       40.1       34.3       31.2       31.0
  V(I)            1.46       3.68       4.30       4.73       4.75

X STA.        26.0       29.8       33.4       36.8       40.3       43.9
  A(I)            30.6       29.8       29.3       29.7       30.0
  V(I)            4.81       4.95       5.03       4.96       4.92

X STA.        43.9       47.7       51.6       55.7       60.2       64.9
  A(I)            30.1       31.2       31.7       32.6       34.1
  V(I)            4.90       4.72       4.65       4.53       4.32

X STA.        64.9       69.8       74.7       80.1       86.4      131.2
  A(I)            34.6       35.1       37.7       41.9       68.0
  V(I)            4.26       4.20       3.91       3.52       2.17
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File roch034.wsp
       Hydraulic analysis for structure ROCHTH00210034   Date: 8-May-97
       Town Highway 21, WHITE RIVER, ROCHESTER, VERMONT     ECW
          *** RUN DATE & TIME: 05-21-97  15:00

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

EXITX:XS   ******     -8     3156  0.47 *****  498.28  496.13   14830  497.81
       -69 ******    648   331313  1.38 ***** *******    0.44    4.70

FULLV:FV       70     -9     3184  0.46  0.14  498.43 *******   14830  497.97
         0     70    649   335531  1.38  0.00    0.01    0.44    4.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.85     497.86     496.51

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   497.47     516.08    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   497.47     516.08     496.51

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.68

APPRO:AS       89    -91     2183  1.22  0.26  499.07  496.51   14830  497.85
        89     89    559   227245  1.69  0.38    0.01    0.85    6.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   497.97     496.67

            <<<<<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       70      0      722  0.81 *****  497.49  491.54    5211  496.68
         0 ******     67    87258  1.00 ***** *******    0.39    7.22

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   6.  0.800  0.000  496.67 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG      11.    73.  0.18  0.73  499.37   -0.01   9455.  498.43

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    76.  -126.   -51.   0.7   0.4   5.6  15.0   1.5   3.0
   RT:   9455.   471.   107.   577.   4.7   2.5   8.7   8.0   3.5   3.1

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

APPRO:AS       67   -117     2851  0.73  0.32  499.55  496.51   14830  498.82
        89     80    621   296598  1.74  0.00   -0.01    0.62    5.20

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

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

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -70.    -9.   648.  14830.  331313.    3156.    4.70  497.81
   FULLV:FV      0.    -10.   649.  14830.  335531.    3184.    4.66  497.97
   BRIDG:BR      0.      0.    67.   5211.   87258.     722.    7.22  496.68
   RDWAY:RG     11.*******     0.   9455.       0.*********    1.00  498.43
   APPRO:AS     89.  -118.   621.  14830.  296598.    2851.    5.20  498.82

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

   SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    496.13    0.44  484.61  517.42************  0.47  498.28  497.81
   FULLV:FV  ********    0.44  484.73  517.54  0.14  0.00  0.46  498.43  497.97
   BRIDG:BR    491.54    0.39  483.76  496.68************  0.81  497.49  496.68
   RDWAY:RG  ****************  493.74  518.12  0.18******  0.73  499.37  498.43
   APPRO:AS    496.51    0.62  485.36  516.08  0.32  0.00  0.73  499.55  498.82
```

WSPRO OUTPUT FILE (continued)

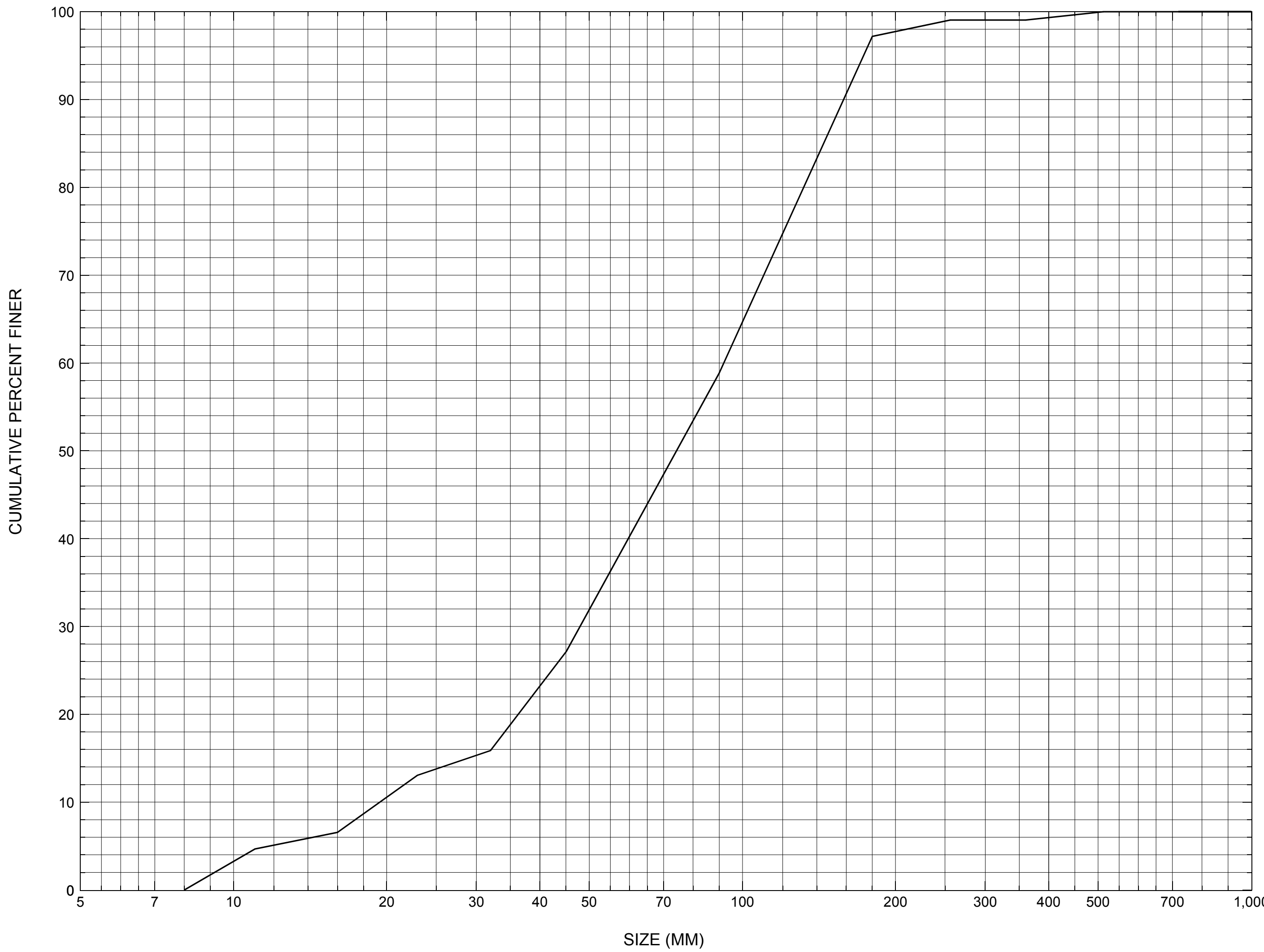
```
        U.S. Geological Survey WSPRO Input File roch034.wsp
        Hydraulic analysis for structure ROCHTH00210034   Date: 8-May-97
        Town Highway 21, WHITE RIVER, ROCHESTER, VERMONT      ECW
           *** RUN DATE & TIME: 05-21-97  15:00

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

EXITX:XS   ******    -86     4159  0.55 *****  499.83  496.98   21960  499.28
       -69 ******    660   490721  1.27 ***** *******    0.44    5.28

FULLV:FV       70    -89     4193  0.54  0.14  499.99 *******   21960  499.44
         0     70    661   496138  1.27  0.00    0.02    0.44    5.24
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.69

APPRO:AS       89   -132     3245  1.24  0.25  500.57 *******   21960  499.33
        89     89    654   340842  1.74  0.35   -0.02    0.77    6.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =    499.44     496.67

            <<<<<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       70      0      722  0.74 *****  497.42  491.37    4988  496.68
         0 ******     67    87258  1.00 ***** *******    0.37    6.91

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   6.  0.800  0.000  496.67 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    73.  0.19  0.79  500.83    0.01  17226.  499.65

               Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    674.    99.  -139.   -39.   1.0   0.5   6.0  13.0   1.7   3.1
   RT:  16552.   559.    87.   646.   5.9   3.2  10.1   9.2   4.4   3.2

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

APPRO:AS       67   -159     3981  0.79  0.41  501.02  498.48   21960  500.22
        89     87    692   431513  1.67  0.00    0.01    0.58    5.52

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW        Q        K      AREA     VEL    WSEL
   EXITX:XS     -70.   -87.   660.  21960.  490721.    4159.    5.28  499.28
   FULLV:FV       0.   -90.   661.  21960.  496138.    4193.    5.24  499.44
   BRIDG:BR       0.     0.    67.   4988.   87258.     722.    6.91  496.68
   RDWAY:RG      11.*******   674.  17226.*****************    1.00  499.65
   APPRO:AS      89.  -160.   692.  21960.  431513.    3981.    5.52  500.22

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    496.98    0.44  484.61  517.42************  0.55  499.83  499.28
   FULLV:FV  ********    0.44  484.73  517.54  0.14  0.00  0.54  499.99  499.44
   BRIDG:BR    491.37    0.37  483.76  496.68************  0.74  497.42  496.68
   RDWAY:RG  ***************  493.74  518.12  0.19******  0.79  500.83  499.65
   APPRO:AS    498.48    0.58  485.36  516.08  0.41  0.00  0.79  501.02  500.22
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File roch034.wsp
        Hydraulic analysis for structure ROCHTH00210034   Date: 8-May-97
        Town Highway 21, WHITE RIVER, ROCHESTER, VERMONT     ECW
           *** RUN DATE & TIME: 11-07-97  09:03

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

 EXITX:XS   ******     -2      610  0.38 *****  493.86  489.76    2950  493.48
       -69 ******    130    65902  1.05 ***** *******    0.41    4.84

 FULLV:FV       70     -3      614  0.38  0.14  494.01 *******    2950  493.63
         0      70    131    66548  1.05  0.00    0.01    0.41    4.80
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS       89    -64      753  0.27  0.15  494.15 *******    2950  493.88
        89      89    128    76289  1.14  0.00    0.00    0.37    3.92
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   493.94       0.00     493.46     493.74

  ===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       70      1      508  0.55  0.14  494.02  489.69    2950  493.46
         0      70     67    76037  1.06  0.02   -0.02    0.38    5.80

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        4. ****   4.  0.972 ******  496.67 ****** ****** ******

     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       67    -65      764  0.27  0.12  494.20  489.97    2950  493.94
        89      71    131    77618  1.15  0.07    0.01    0.37    3.86

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.657  0.154   65523.    14.    80. ********

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -70.    -3.   130.   2950.   65902.     610.    4.84  493.48
    FULLV:FV       0.    -4.   131.   2950.   66548.     614.    4.80  493.63
    BRIDG:BR       0.     1.    67.   2950.   76037.     508.    5.80  493.46
    RDWAY:RG      11.**************      0.       0.       0.    1.00********
    APPRO:AS      89.   -66.   131.   2950.   77618.     764.    3.86  493.94

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS      14.    80.   65523.

  SECOND USER DEFINED TABLE.

     XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    489.76    0.41  484.61  517.42************  0.38  493.86  493.48
    FULLV:FV  ********    0.41  484.73  517.54  0.14  0.00  0.38  494.01  493.63
    BRIDG:BR    489.69    0.38  483.76  496.68  0.14  0.02  0.55  494.02  493.46
    RDWAY:RG  ****************  493.74  518.12  0.11******  0.27  494.10********
    APPRO:AS    489.97    0.37  485.36  516.08  0.12  0.07  0.27  494.20  493.94
   ER

NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ROCHTH00210034, in Rochester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ROCHTH00210034

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)* 60100

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

Waterway *(I - 6)* WHITE RIVER

Road Name *(I - 7)*: -

Route Number TH021

Vicinity *(I - 9)* AT JCT TH 52 + TH 21

Topographic Map Hancock

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43527

Longitude *(i - 17; nnnnn.n)* 72484

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10141500341415

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

Maximum span length *(I - 48; nnnn)* 0070

Year built *(I - 27; YYYY)* 1927

Structure length *(I - 49; nnnnnn)* 000072

Average daily traffic, ADT *(I - 29; nnnnnn)* 000060

Deck Width *(I - 52; nn.n)* 160

Year of ADT *(I - 30; YY)* 91

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

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

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

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

Comments:

The structural inspection report of 7/2/93 indicates the structure is a single span steel stringer type bridge with a concrete deck. The abutments are concrete with minor cracks and spalls noted. The footing of the right abutment is not exposed, but the left one is exposed and has some minor spalling near the centerline of the roadway and at the upstream end of the footing. The adjacent streambed is up to 2 feet below the top of the left abutment footing but there is no apparent undermining reported. The streambed consists of mainly stone and gravel. There is a shallow gravel point bar present along the right abutment. Channel scour is noted as minor, if any. The report indicates there is no bank erosion or debris **(Cont., page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

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:
accumulation evident and little or no riprap protection.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **74.75** mi^2 Lake/pond/swamp area **0.04** mi^2
Watershed storage *(ST)* **0.1** %
Bridge site elevation **820** ft Headwater elevation **3780** ft
Main channel length **13.24** mi
10% channel length elevation **835** ft 85% channel length elevation **1720** ft
Main channel slope *(S)* **89.12** 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: - (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness - Footing bottom elevation: 4

If 2: Pile Type: ____ (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: ____

If 3: Footing bottom elevation: N

Is boring information available? - *If no, type ctrl-n bi* Number of borings taken: -

Foundation Material Type: 3 (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
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: 9/27/96
Computerized by: EW Date: 9/27/96
Reviewd by: EW Date: 6/4/97

Structure Number ROCHTH00210034

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 07 / 23 / 1996
2. Highway District Number 04 Mile marker 000000
County 027 Town ROCHESTER 60100
Waterway *(I - 6)* WHITE RIVER Road Name -
Route Number TH 021 Hydrologic Unit Code: 01080105
3. Descriptive comments:
Single span, steel stringer bridge with a concrete deck and asphalt overlay. Bridge is located at junction with TH52 and TH51.

B. Bridge Deck Observations

4. Surface cover... LBUS 2 RBUS 4 LBDS 2 RBDS 4 Overall 4
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 2 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 72 *(feet)* Span length 70 *(feet)* Bridge width 16 *(feet)*

Road approach to bridge:

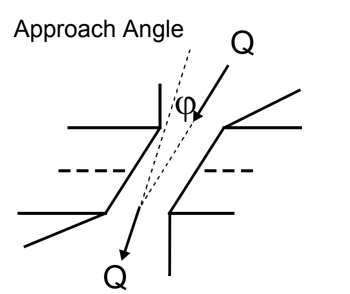
8. LB 1 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 1.3:1 US right 1.5:1

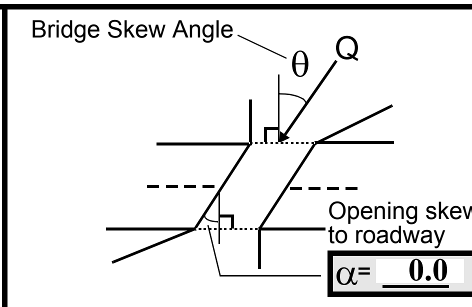
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	3	1	2
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	1	2	0	-

*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: 10 16. Bridge skew: 15





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 30 feet US *(US, UB, DS)* to 0 feet DS
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: **4**

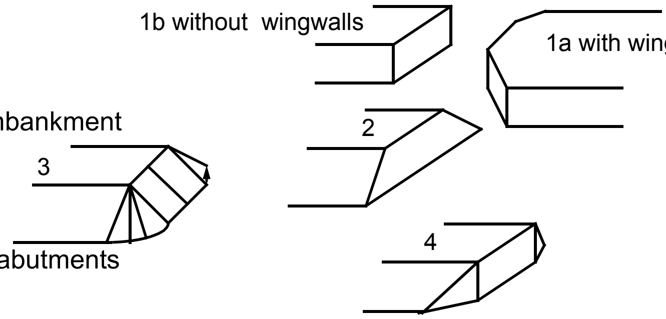
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#4: A horse farm exists on the upstream and downstream right overbanks beyond bank trees and paved road, as indicated in plan view sketch. A Department of Public Works facility exists on the downstream left overbank. The upstream left overbank is lawn with an old industrial building.

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
66.0	**4.5**			**6.0**	**2**	**4**	**432**	**234**	**2**	**1**

23. Bank width **20.0** 24. Channel width **15.0** 25. Thalweg depth **109.5** 29. Bed Material **432**

30 .Bank protection type: LB **1** RB **0** 31. Bank protection condition: LB **3** RB **-**

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

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

#29: The bed material is larger along the left bank and in the scour hole from the cross-section to under the bridge

#30: Left bank protection extends from 28 feet upstream to the end of the wingwall at 8 feet upstream. The protection is stone fill.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 40 35. Mid-bar width: 25

36. Point bar extent: 112 feet US (US, UB) to 25 feet US (US, UB, DS) positioned 65 %LB to 100 %RB

37. Material: 32

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

There is an additional point bar from 250 feet upstream to 195 feet upstream. It is composed of cobble and gravel with some grass. The mid-bank is 215 feet upstream where it is 25 feet wide. The point bar is positioned 0% LB to 20% RB.

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

41. Mid-bank distance: 130 42. Cut bank extent: 158 feet US (US, UB) to 112 feet US (US, UB, DS)

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

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

The cut-bank is protected by eroded type 2 protection, dumped concrete pieces.

There is an additional cut-bank extending from 360 feet upstream to 265 feet upstream. It is presently eroding via eddying; at bank full, the bank will be directly impacted.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 130

47. Scour dimensions: Length 90 Width 20 Depth : 2 Position 0 %LB to 25 %RB

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

Scour depth is based on thalweg of 2.0 feet.
A second scour hole, 1.5 feet, extends from 30 feet upstream to 35 feet downstream. Mid-scour is at the downstream bridge face. There is third scour hole with a mid-scour distance located 200 feet upstream. It is 60 feet long, 30 feet wide and 2 feet deep based on a thalweg of 2 feet.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
76.5		2.0		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.):

432

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

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

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

70. Debris and Ice Comments:

1

There is debris caught in the vegetation along both banks.

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		15	82	2	2	0	2	90.0
RABUT	1	-	90			2	0	67.0

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

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

-

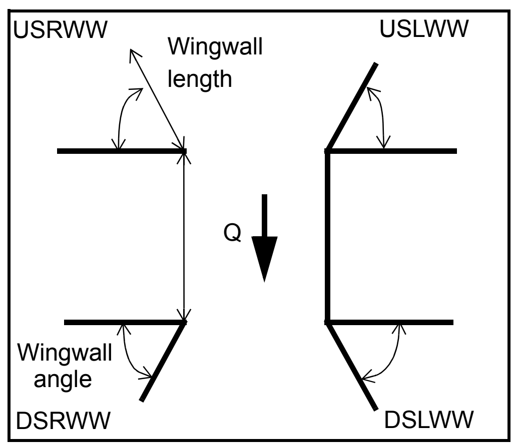
-

1

#76: Exposure depth measured from top of footing to channel bed.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						67.0	
USRWW:	Y		1		2	3.5	
DSLWW:	0		2		Y	24.0	
DSRWW:	1		0		-	20.5	



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

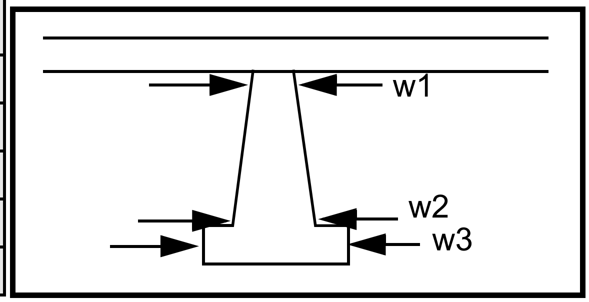
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
3
3
3
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**35.0**	**10.5**	**20.0**
Pier 2			**9.5**	**31.0**	**50.0**	**55.0**
Pier 3	**9.5**	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width (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.):

2
4
342
234
1
1
432
2
0
2
-
The left bank protection extends from the downstream end of the downstream left wingwall (10 feet downstream) to 25 feet downstream. There is also type 1 protection from 160 feet downstream to 550 feet down-

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

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

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

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

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

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **-** feet **-** *(US, UB, DS)* to **-** feet **-** *(US, UB, DS)*

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

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

-
-
-
-

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

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

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

Y
LB
120

Are there major confluences? **95** *(Y or if N type ctrl-n mc)* How many? **DS**

Confluence 1: Distance **130** Enters on **DS** *(LB or RB)* Type **1** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

Y

F. Geomorphic Channel Assessment

107. Stage of reach evolution **0**

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)*:

DS
77
15
1.5
20
45
This scour hole was also mentioned in the upstream channel assessment.

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: ROCHTH00210034 Town: ROCHESTER
Road Number: TH 21 County: WINDSOR
Stream: WHITE RIVER

Initials ECW Date: 5/2/97 Checked: SAO

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	14830	21960	2950
Main Channel Area, ft2	1214	1367	680
Left overbank area, ft2	489	683	80
Right overbank area, ft2	1151	1928	4
Top width main channel, ft	109	109	109
Top width L overbank, ft	118	159	66
Top width R overbank, ft	512	583	22
D50 of channel, ft	0.244	0.244	0.244
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	11.1	12.5	6.2
y1, average depth, LOB, ft	4.1	4.3	1.2
y1, average depth, ROB, ft	2.2	3.3	0.2
Total conveyance, approach	296918	431059	77659
Conveyance, main channel	197428	240681	75128
Conveyance, LOB	34012	48745	2481
Conveyance, ROB	65478	141633	49
Percent discrepancy, conveyance	0.0000	0.0000	0.0013
Qm, discharge, MC, cfs	9860.8	12261.3	2853.9
Ql, discharge, LOB, cfs	1698.8	2483.3	94.2
Qr, discharge, ROB, cfs	3270.4	7215.4	1.9
Vm, mean velocity MC, ft/s	8.1	9.0	4.2
Vl, mean velocity, LOB, ft/s	3.5	3.6	1.2
Vr, mean velocity, ROB, ft/s	2.8	3.7	0.5
Vc-m, crit. velocity, MC, ft/s	10.5	10.7	9.5
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	14830	21960	2950
(Q) discharge thru bridge, cfs	5211	4988	2950
Main channel conveyance	87258	87258	75967
Total conveyance	87258	87258	75967
Q2, bridge MC discharge,cfs	5211	4988	2950
Main channel area, ft2	722	722	508
Main channel width (normal), ft	67.0	67.0	66.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	67	67	66.2
y_bridge (avg. depth at br.), ft	10.78	10.78	7.67
Dm, median (1.25*D50), ft	0.305	0.305	0.305
y2, depth in contraction,ft	7.26	6.99	4.50
ys, scour depth (y2-ybridge), ft	-3.52	-3.79	-3.17

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	5211	4988	2950
Main channel area (DS), ft2	722	722	508
Main channel width (normal), ft	67.0	67	66.2
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	67.0	67.0	66.2
D90, ft	0.5179	0.5179	0.5179
D95, ft	0.5674	0.5674	0.5674
Dc, critical grain size, ft	0.1714	0.1570	0.1259
Pc, Decimal percent coarser than Dc	0.662	0.702	0.781
Depth to armoring, ft	0.26	0.20	0.11

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	14830	21960	2950
Q, thru bridge MC, cfs	5211	4988	2950
Vc, critical velocity, ft/s	10.47	10.68	9.50
Va, velocity MC approach, ft/s	8.12	8.97	4.20
Main channel width (normal), ft	67.0	67.0	66.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	67.0	67.0	66.2
qbr, unit discharge, ft2/s	77.8	74.4	44.6
Area of full opening, ft2	722.0	722.0	508.0
Hb, depth of full opening, ft	10.78	10.78	7.67
Fr, Froude number, bridge MC	0.39	0.37	N/A
Cf, Fr correction factor (<=1.0)	1.00	0.98	ERR
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	496.67	496.67	496.67
Elevation of Bed, ft	485.89	485.89	489.00
Elevation of Approach, ft	498.82	500.22	N/A
Friction loss, approach, ft	0.32	0.41	N/A
Elevation of WS immediately US, ft	498.50	499.81	ERR
ya, depth immediately US, ft	12.61	13.92	N/A
Mean elevation of deck, ft	500.56	500.56	500.56
w, depth of overflow, ft (>=0)	0.00	0.00	N/A
Cc, vert contrac correction (<=1.0)	0.96	0.94	ERR
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	-3.05	-3.16	ERR
Ys, scour w/Umbrell equation, ft	1.15	3.03	ERR

Abutment Scour

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

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	14830	21960	2950	14830	21960	2950
a', abut.length blocking flow, ft	118.3	159.5	66.4	553.9	625.4	64.2
Ae, area of blocked flow ft2	496.5	591	93.1	373.9	632	202.5
Qe, discharge blocked abut.,cfs	1804	--	135.84	--	--	674.3
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.63	3.84	1.46	3.99	4.59	3.33
ya, depth of f/p flow, ft	4.20	3.71	1.40	0.68	1.01	3.15
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.313	0.325	0.217	0.420	0.414	0.330
ys, scour depth, ft	20.35	21.22	6.80	13.93	18.43	14.07

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)	118.3	159.5	66.4	553.9	625.4	64.2
y1 (depth f/p flow, ft)	4.20	3.71	1.40	0.68	1.01	3.15
a'/y1	28.19	43.05	47.36	820.55	618.87	20.35
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.31	0.33	0.22	0.42	0.41	0.33
Ys w/ corr. factor K1/0.55:						
vertical	20.79	18.60	6.16	3.69	5.49	ERR
vertical w/ ww's	17.05	15.25	5.05	3.02	4.50	ERR
spill-through	11.44	10.23	3.39	2.03	3.02	ERR

Abutment riprap Sizing

Isbash Relationship

D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)

(Richardson and others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.39	0.37	0.38	0.39	0.37	0.38
y, depth of flow in bridge, ft	10.78	10.78	7.67	10.78	10.78	7.67
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.01	0.91	0.68	1.01	0.91	0.68
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR