LEVEL II SCOUR ANALYSIS FOR BRIDGE 22 (REDSVT01000022) on STATE ROUTE 100, crossing the WEST BRANCH DEERFIELD RIVER, READSBORO, VERMONT

U.S. Geological Survey
Open-File Report 97-191

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

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Pembroke, New Hampshire

1997

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

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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 22 (REDSVT01000022) ON STATE ROUTE 100, CROSSING THE WEST BRANCH DEERFIELD RIVER, READSBORO, VERMONT

By **Erick M. Boehmler and Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure REDSVT01000022 on State Route 100 crossing the West Branch Deerfield River, Readsboro, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in southern Vermont. The 25.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, the West Branch Deerfield River has an incised, straight channel with a slope of approximately 0.025 ft/ft, an average channel top width of 63 ft and an average channel depth of 10 ft. The predominant channel bed materials are cobbles and boulders with some bedrock exposure noted under the bridge. The bed material has a median grain size (D_{50}) of 141.0 mm (0.463 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 30, 1996, indicated that the reach was stable.

The State Route 100 crossing of the West Branch Deerfield River is a 119-ft-long, two-lane bridge consisting of one 110-foot steel-beam span (Vermont Agency of Transportation, written communication, September 28, 1995). The bridge is supported by vertical, concrete abutments with spill-through embankments. The channel is skewed approximately 50 degrees to the opening while the opening-skew-to-roadway is 50 degrees.

The scour protection measure at the site was type-3 stone fill (less than 48 inches diameter) on the spill-through embankments of each abutment and the banks upstream and downstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

There was no predicted contraction scour for any of the modelled flows. Abutment scour ranged from 4.9 to 11.6 ft. The worst-case abutment scour occurred at the right abutment for the 500-year discharge. However, historical information indicates the right abutment is in contact with bedrock at least in part. 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 REDSVT01000022 ***Stream*** West Branch Deerfield River

County Bennington ***Road*** VT 100 ***District*** 1

Description of Bridge

Bridge length 119 ***ft*** ***Bridge width*** 34.0 ***ft*** ***Max span length*** 110 ***ft***

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

Abutment type Spill-through ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 7/30/96

Description of stone fill Type-3 is present on the spill-through embankments and the banks upstream and downstream of this site.

The abutment walls are concrete with stone fill spill-through embankments in front of each wall.

Yes 50

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

There are sharp bends in the channel immediately upstream and downstream from the bridge.

7/30/96

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

Date of inspection 0 ***Percent of channel blocked horizontally*** 0 ***Percent of channel blocked vertically*** 7/30/

Level I 96 0 0

Level II Moderate due to dense vegetation cover on banks upstream and some localized bank erosion and cut-bank development.

Potential for debris

The right abutment at least partially blocks the usual flow direction and some debris was noted on 7/30/96 as caught on boulders under the bridge.

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 setting with little or no flood plains and steep valley walls on both sides.

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

Date of inspection 7/30/96

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

DS right: Steep channel bank to a narrow overbank (the VT 100 roadway).

US left: Steep channel bank and the VT100 roadway on the overbank.

US right: Steep channel bank and valley wall.

Description of the Channel

Average top width 63 ***ft*** ***Average depth*** 10 ***ft***

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

Straight, incised and stable with non-alluvial channel boundaries.

7/30/96

Vegetative co Trees

DS left: Grass, brush and trees.

DS right: Grass and brush with a few trees.

US left: Trees.

US right:

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

Describe any obstructions in channel and date of observation. The assessment of 7/30/96 noted flow is obstructed by boulders and debris caught on boulders under the bridge. The right abutment also blocks flow.

Hydrology

Drainage area 25.6 ***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***:

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 4,680 ***ft³/s*** ***Q500*** 6,750 ***ft³/s***

The 100- and 500-year discharges are based on discharge frequency curves computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957a&b; Talbot, 1887) and a drainage area relationship applying values provided in the VTAOT database (written communication, VTAOT, May 1995) at bridge 21 in Readsboro over the same river with a drainage area of 23.7 sq. mi. (ie. [(25.6/23.7)exp 0.67]). The values computed with the drainage area relationship were selected for this analysis due to their central tendency to those computed from the empirical methods.

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 Add 1081.6 feet to the USGS survey to obtain VTAOT plans' datum and NGVD.

Description of reference marks used to determine USGS datum. RM1 is an engraved triangle in a brass tablet set in the concrete curb at the downstream right corner of the bridge deck (elev. 498.89 ft, arbitrary survey datum). RM2 is the center point of a chiseled "X" in the concrete curb at the upstream left corner of the bridge deck (elev. 500.36 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	-112	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	24	1	Road Grade section
APPRO	116	2	Modelled Approach section (Templated from APTEM)
APTEM	144	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 0.055 to 0.060, and overbank "n" values were 0.040.

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 0.025 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1987).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.025 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 approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.8 ***ft***
Average low steel elevation 492.6 ***ft***

100-year discharge 4,680 ***ft^3/s***
Water-surface elevation in bridge opening 492.2 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 555 ***ft^2***
Average velocity in bridge opening 8.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.1 ***ft/s***

Water-surface elevation at Approach section with bridge 492.8
Water-surface elevation at Approach section without bridge 492.5
Amount of backwater caused by bridge 0.3 ***t***

500-year discharge 6,750 ***ft^3/s***
Water-surface elevation in bridge opening 493.1 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 581 ***ft^2***
Average velocity in bridge opening 11.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.0 ***/s***

Water-surface elevation at Approach section with bridge 495.1
Water-surface elevation at Approach section without bridge 494.3
Amount of backwater caused by bridge 0.8

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

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

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.

For the 100-year discharge, contraction scour was computed by use of the live-bed and clear-water contraction scour equations (Richardson and others, 1995, p. 30, 32, equations 17, 20) since the average channel velocity and critical velocity are nearly the same. Submerged orifice flow conditions existed at the bridge for the 500-year discharge model. 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). Therefore, contraction scour for the 500-year event was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The results of Laursen's live-bed and clear-water contraction scour for the 500-year event also were computed and provided in appendix F.

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.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the variables for the abutment scour equations applied were computed including the average width of the spill-through embankments. The total scour depths were applied for the entire spill-through embankment below the elevation at the toe of each embankment, as shown in figure 8.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	0.0	0.0	--
Clear-water scour	0.0	0.0	--
Depth to armoring	0.6	3.4	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
Abutment scour			
Left abutment	4.9	7.4	--
Right abutment	9.4	11.6	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.5	4.2	--
Right abutment	2.5	4.2	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

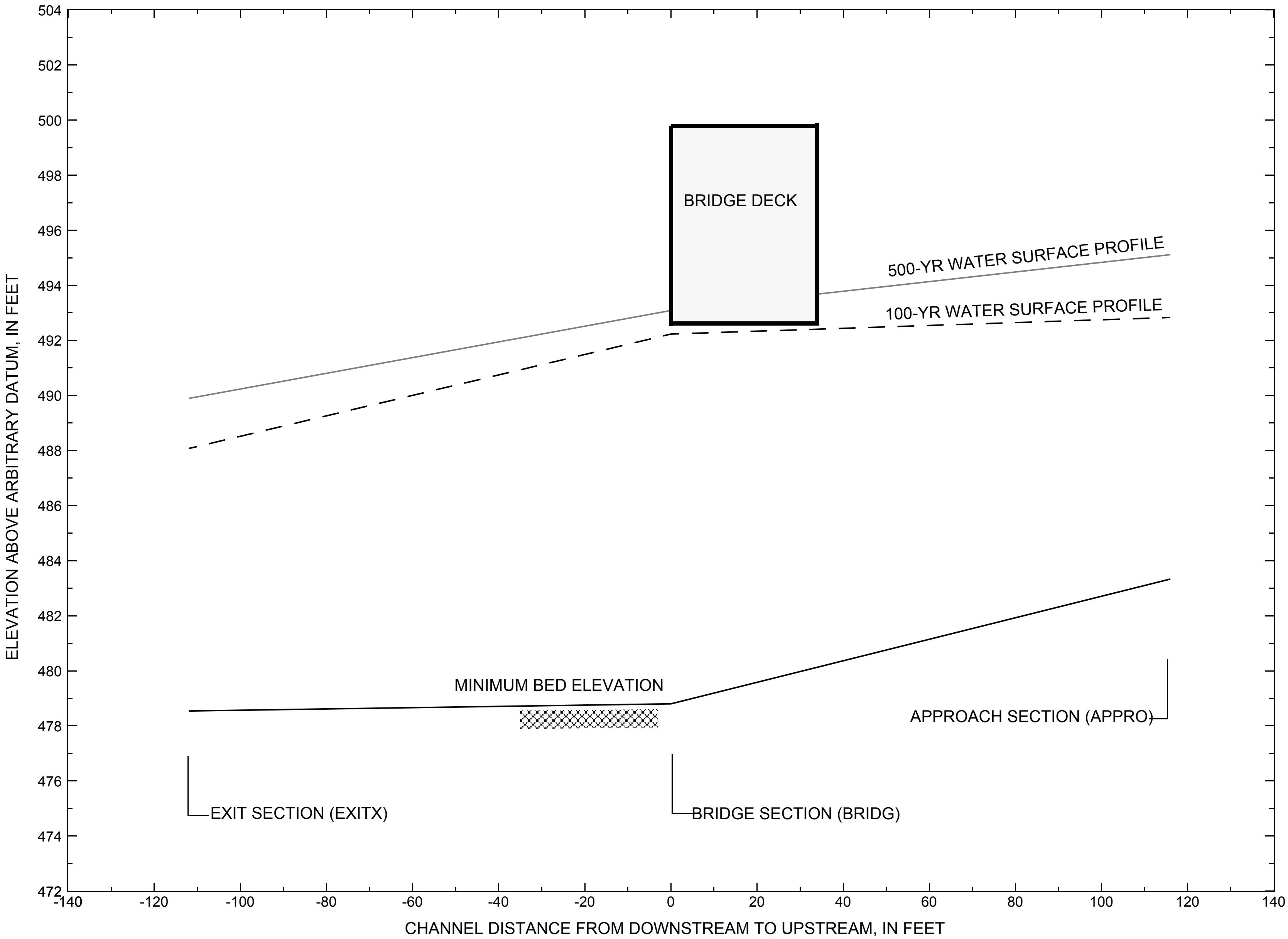

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure REDSVT01000022 on State Route 100, crossing West Branch Deerfield River, Readsboro, Vermont.

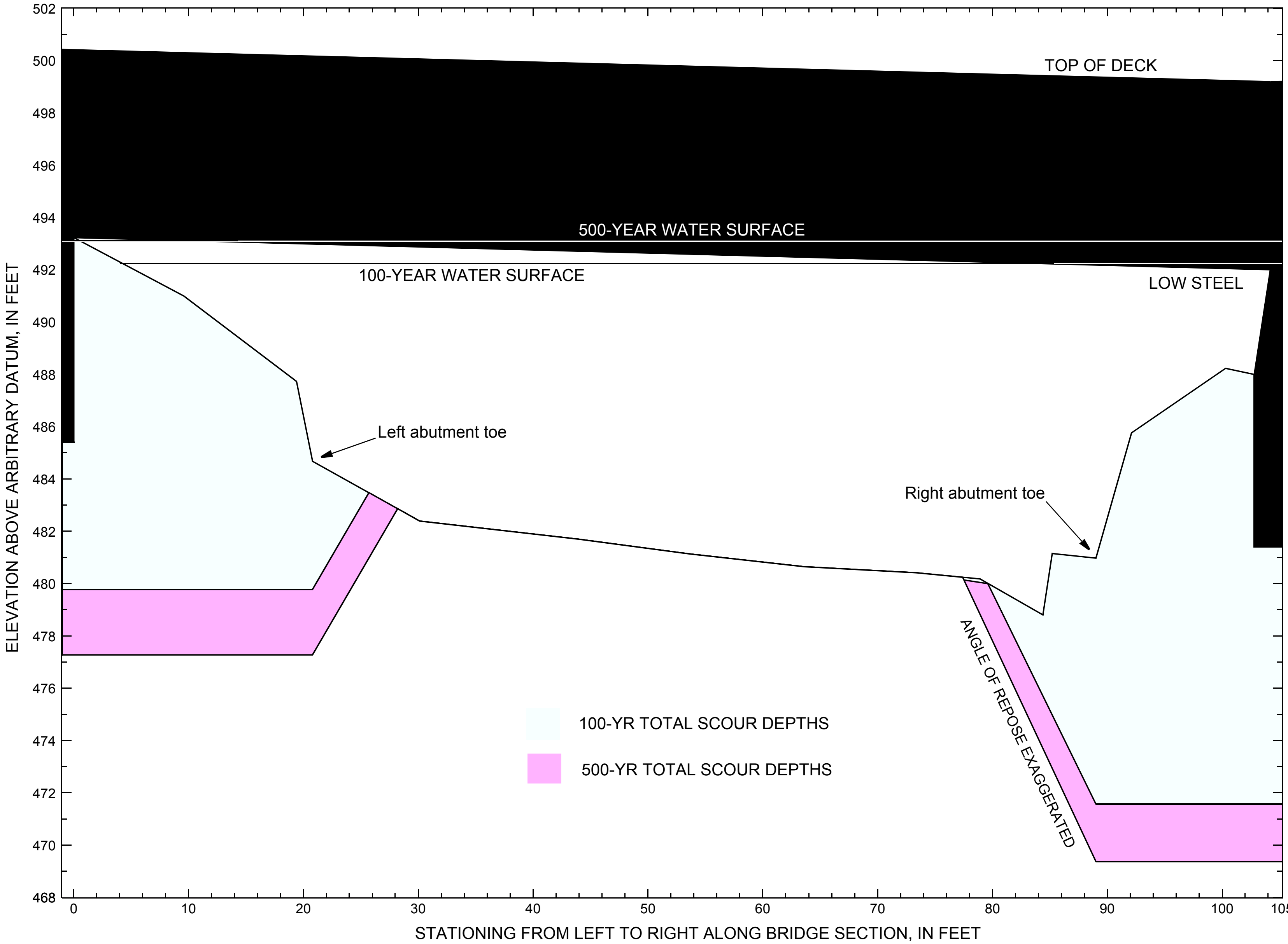

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure REDSVT01000022 on State Route 100, crossing West Branch Deerfield River, Readsboro, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure REDSVT01000022 on State Route 100, crossing West Branch Deerfield River, Readsboro, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT Bridge seat elevation (feet)	Surveyed Bridge seat 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 4,680 cubic-feet per second											
Left abutment	0.0	1574.0	492.4	485.4	492.4	--	--	--	--	--	-5.6
Left abutment toe	20.8	--	--	--	484.7	0.0	4.9	--	4.9	479.8	--
Right abutment toe	89.0	--	--	--	481.0	0.0	9.4	--	9.4	471.6	--
Right abutment	104.2	1572.6	491.1	481.4	488.0	--	--	--	--	--	-9.8

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 REDSVT01000022 on State Route 100, crossing West Branch Deerfield River, Readsboro, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT Bridge seat elevation (feet)	Surveyed Bridge seat 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 6,750 cubic-feet per second											
Left abutment	0.0	1574.0	492.4	485.4	492.4	--	--	--	--	--	-8.1
Left abutment toe	20.8	--	--	--	484.7	0.0	7.4	--	7.4	477.3	--
Right abutment toe	89.0	--	--	--	481.0	0.0	11.6	--	11.6	469.4	--
Right abutment	104.2	1572.6	491.1	481.4	488.0	--	--	--	--	--	-12.0

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, 1987, Readsboro, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photography, 1981, Contour interval, 6 meters; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File reds022.wsp
T2        Hydraulic analysis for structure REDSVT01000022   Date: 03-JAN-97
T3        State Route 100 over the W. Br. Deerfield River, Readsboro, VT     EMB
*
J1         *  *  0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4680.0   6750.0
SK          0.0250   0.0250
*
XS   EXITX   -112
GR          -34.1, 512.46     -2.7, 493.72     28.0, 491.36     43.9, 481.93
GR           51.4, 480.61     55.1, 479.53     58.5, 479.13     64.6, 479.19
GR           70.9, 478.54     78.4, 480.80     93.8, 489.16    114.6, 497.52
GR          145.4, 496.64    153.6, 495.07    156.8, 502.80    165.5, 505.95
*
N           0.040        0.060        0.040
SA                 28.0        114.6
*
XS   FULLV       0  * * *   0.0119
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    492.61      50.0
GR            0.0, 493.23      9.6, 490.99     19.4, 487.73     20.8, 484.67
GR           30.1, 482.39     43.9, 481.70     53.6, 481.13     63.6, 480.64
GR           73.4, 480.41     78.9, 480.18     84.4, 478.80     85.2, 481.15
GR           89.0, 480.97     92.1, 485.76    100.3, 488.23    102.8, 488.00
GR          104.2, 492.00      0.0, 493.23
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD           3      49.0      1.8    499.8
N           0.060
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     24      34.0     1
GR         -266.1, 513.34   -240.0, 503.40   -173.1, 501.96    -23.8, 499.85
GR          -21.7, 500.69      0.0, 500.41    106.4, 499.19    135.5, 498.82
GR          137.6, 497.88    173.4, 497.65    176.4, 496.71    178.0, 505.26
*
XT   APTEM    144
GR          -78.1, 508.45    -51.5, 500.22    -17.8, 500.84     19.5, 500.74
GR           27.5, 497.88     42.8, 487.05     43.4, 484.03     43.9, 485.51
GR           54.4, 484.21     61.9, 484.31     71.1, 485.18     78.5, 485.23
GR           79.2, 485.77     82.6, 486.76     85.3, 497.94     90.5, 500.90
GR          127.0, 501.72    141.7, 510.79
*
*           Notice: the following points were projected to the rest of the
*                   approach section using a difference of -24.4, which is
*                   based on the difference in the easting values of points
*                   164 and 165 in the data file.
*           -97.6, 508.45    -71.0, 500.22    -37.3, 500.84      0.0, 500.74
*
AS   APPRO    116  *  *  *  0.025
GT
N           0.040       0.055        0.040
SA                19.5         90.5
BP          0.0
```

```
*

HP 1 BRIDG 492.23 1 492.23
HP 2 BRIDG 492.23 * * 4680
HP 1 APPRO 492.83 1 492.83
HP 2 APPRO 492.83 * * 4680
*
HP 1 BRIDG 493.08 1 493.08
HP 2 BRIDG 493.08 * * 6755
HP 1 APPRO 495.11 1 495.11
HP 2 APPRO 495.11 * * 6750
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
         U.S. Geological Survey WSPRO Input File reds022.wsp
         Hydraulic analysis for structure REDSVT01000022   Date: 03-JAN-97
         State Route 100 over the W. Br. Deerfield River, Readsboro, VT     EMB
            *** RUN DATE & TIME: 01-03-97  09:10

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      555     46505     52     90                        10328
    492.23           555     46505     52     90  1.00      4    104    10328

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        492.23     4.3   104.2   555.3   46505.    4680.   8.43

 X STA.         4.3        25.3       30.2       34.2       37.9       41.4
   A(I)             49.0        29.5       25.4       24.3       22.7
   V(I)             4.78        7.93       9.22       9.61      10.31

 X STA.        41.4        44.7       47.9       51.0       54.0       57.0
   A(I)             22.6        21.7       21.8       21.2       21.5
   V(I)            10.35       10.79      10.72      11.05      10.89

 X STA.        57.0        59.9       62.9       65.9       68.8       72.0
   A(I)             21.5        21.8       22.3       22.3       24.0
   V(I)            10.87       10.73      10.49      10.51       9.77

 X STA.        72.0        75.3       78.7       82.5       87.8      104.2
   A(I)             25.1        26.1       30.4       41.0       61.3
   V(I)             9.34        8.96       7.71       5.71       3.82

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              2      378     34138     51     62                         5856
    492.83           378     34138     51     62  1.00     34     84     5856

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

          WSEL     LEW     REW    AREA        K        Q    VEL
        492.83    33.6    84.2   377.7   34138.    4680.  12.39

 X STA.        33.6        43.6       46.5       48.9       50.9       52.8
   A(I)             36.5        23.9       19.7       18.0       17.3
   V(I)             6.41        9.77      11.86      12.98      13.49

 X STA.        52.8        54.7       56.3       58.0       59.7       61.4
   A(I)             16.7        15.7       15.8       15.6       15.5
   V(I)            14.03       14.89      14.81      15.02      15.06

 X STA.        61.4        63.1       64.8       66.6       68.4       70.4
   A(I)             15.4        15.6       15.8       15.7       16.7
   V(I)            15.22       15.01      14.82      14.95      14.05

 X STA.        70.4        72.3       74.4       76.6       79.1       84.2
   A(I)             16.4        17.3       18.2       20.5       31.3
   V(I)            14.29       13.51      12.83      11.42       7.48
```

```
        U.S. Geological Survey WSPRO Input File reds022.wsp
        Hydraulic analysis for structure REDSVT01000022   Date: 03-JAN-97
        State Route 100 over the W. Br. Deerfield River, Readsboro, VT     EMB
           *** RUN DATE & TIME: 01-03-97  09:10

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      581     37492      8    138                        28504
   493.08           581     37492      8    138  1.00      1    104    28504

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.08     0.6   104.2   580.6   37492.    6755.  11.63

X STA.         0.6       23.4       28.7       33.1       37.2       41.0
  A(I)            49.8       32.6       29.6       27.7       26.5
  V(I)            6.78      10.35      11.41      12.19      12.75

X STA.        41.0       44.6       48.2       51.7       55.0       58.3
  A(I)            25.8       25.7       25.3       24.4       24.7
  V(I)           13.07      13.16      13.37      13.82      13.66

X STA.        58.3       61.6       64.8       68.0       71.2       74.5
  A(I)            24.4       24.6       24.2       24.6       25.2
  V(I)           13.85      13.72      13.98      13.72      13.41

X STA.        74.5       77.8       81.2       84.7       89.3      104.2
  A(I)            25.9       26.9       29.4       33.1       50.2
  V(I)           13.03      12.57      11.49      10.20       6.73

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      497     50634     54     68                         8536
   495.11           497     50634     54     68  1.00     30     85     8536

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.11    30.4    84.8   497.3   50634.    6750.  13.57

X STA.        30.4       41.6       45.3       47.8       50.0       52.0
  A(I)            44.5       36.3       26.0       24.2       22.5
  V(I)            7.58       9.29      13.00      13.95      14.98

X STA.        52.0       53.9       55.7       57.5       59.2       61.0
  A(I)            21.6       21.1       20.4       20.1       20.1
  V(I)           15.63      15.98      16.55      16.78      16.81

X STA.        61.0       62.7       64.5       66.3       68.2       70.2
  A(I)            20.2       19.9       20.6       20.4       21.3
  V(I)           16.73      16.95      16.42      16.51      15.82

X STA.        70.2       72.2       74.2       76.6       79.1       84.8
  A(I)            21.4       22.0       24.5       26.9       43.2
  V(I)           15.75      15.33      13.76      12.57       7.81
```

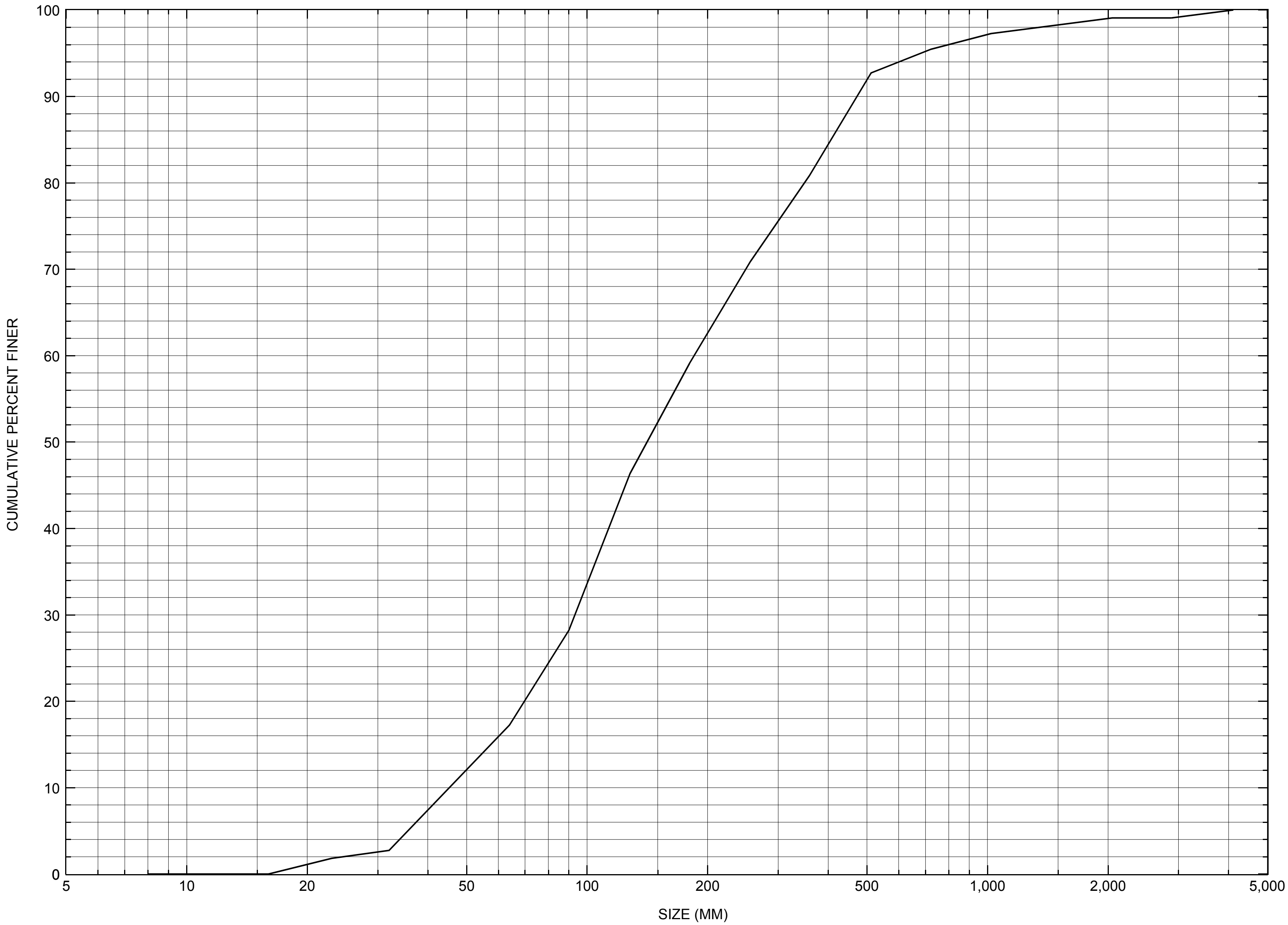
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File reds022.wsp
        Hydraulic analysis for structure REDSVT01000022   Date: 03-JAN-97
        State Route 100 over the W. Br. Deerfield River, Readsboro, VT     EMB
           *** RUN DATE & TIME: 01-03-97  09:10

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

EXITX:XS   ******     34      366  2.54 *****  490.61  487.57    4680  488.07
      -111 ******     92    29573  1.00 ***** *******    0.90   12.78

FULLV:FV      112     31      467  1.56  2.01  492.61 *******    4680  491.05
         0    112     95    41314  1.00  0.00   -0.01    0.66   10.02
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.86     492.45     491.70

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   490.55     510.09    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   490.55     510.09     491.70

APPRO:AS      116     34      358  2.65  1.94  495.10  491.70    4680  492.45
       116    116     84    31656  1.00  0.54    0.00    0.86   13.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR      112      4      555  1.10  2.42  493.33  488.51    4680  492.23
         0    112    104    46504  1.00  0.30   -0.02    0.64    8.43

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  1.000 ******  492.61 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      24.        <<<<<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     34      378  2.39  1.25  495.22  491.70    4680  492.83
       116     67     84    34160  1.00  0.63   -0.01    0.80   12.39

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.000   34232.     6.   106.   491.30

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -112.    34.    92.   4680.   29573.     366.   12.78  488.07
   FULLV:FV       0.    31.    95.   4680.   41314.     467.   10.02  491.05
   BRIDG:BR       0.     4.   104.   4680.   46504.     555.    8.43  492.23
   RDWAY:RG      24.**************      0.*****************     1.00********
   APPRO:AS     116.    34.    84.   4680.   34160.     378.   12.39  492.83

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       6.   106.   34232.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF    HO   VHD      EGL    WSEL
   EXITX:XS    487.57    0.90  478.54  512.46************  2.54  490.61  488.07
   FULLV:FV  ********    0.66  479.87  513.79  2.01  0.00  1.56  492.61  491.05
   BRIDG:BR    488.51    0.64  478.80  493.23  2.42  0.30  1.10  493.33  492.23
   RDWAY:RG  ****************  496.71  513.34*********************************
   APPRO:AS    491.70    0.80  483.33  510.09  1.25  0.63  2.39  495.22  492.83
```

```
        U.S. Geological Survey WSPRO Input File reds022.wsp
        Hydraulic analysis for structure REDSVT01000022   Date: 03-JAN-97
        State Route 100 over the W. Br. Deerfield River, Readsboro, VT     EMB
           *** RUN DATE & TIME: 01-03-97  09:10

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

EXITX:XS   ******     30      478  3.10 *****  492.99  489.41    6750  489.89
      -111 ******     96    42674  1.00 ***** *******    0.92   14.11

FULLV:FV      112     23      607  1.93  2.03  495.01 *******    6750  493.08
         0    112    100    59028  1.00  0.00   -0.01    0.70   11.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.89     494.34     493.64

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.58     510.09    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.58     510.09     493.64

APPRO:AS      116     32      456  3.41  2.00  497.75  493.64    6750  494.34
       116    116     85    44742  1.00  0.74    0.00    0.89   14.80
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   493.08     492.61

            <<<<<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      112      1      581  2.11 *****  495.19  490.29    6755  493.08
         0 ******    104    37487  1.00 ***** *******    0.87   11.63

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   3.  0.800 ******  492.61 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      24.        <<<<<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     30      497  2.87  1.61  497.97  493.64    6750  495.11
       116     67     85    50611  1.00  0.63    0.00    0.79   13.58

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   493.65

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -112.    30.    96.   6750.   42674.     478.   14.11  489.89
   FULLV:FV       0.    23.   100.   6750.   59028.     607.   11.12  493.08
   BRIDG:BR       0.     1.   104.   6755.   37487.     581.   11.63  493.08
   RDWAY:RG      24.**************      0.       0.       0.    1.00********
   APPRO:AS     116.    30.    85.   6750.   50611.     497.   13.58  495.11

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    489.41    0.92  478.54  512.46************  3.10  492.99  489.89
   FULLV:FV  ********    0.70  479.87  513.79  2.03  0.00  1.93  495.01  493.08
   BRIDG:BR    490.29    0.87  478.80  493.23************  2.11  495.19  493.08
   RDWAY:RG  ****************  496.71  513.34************  1.83  498.38********
   APPRO:AS    493.64    0.79  483.33  510.09  1.61  0.63  2.87  497.97  495.11
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure REDSVT01000022, in Readsboro, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number REDSVT01000022

General Location Descriptive

Data collected by *(First Initial, Full last name)* L. Medalie

Date *(MM/DD/YY)* 09 / 28 / 95

Highway District Number *(I - 2; nn)* 01

County *(FIPS county code; I - 3; nnn)* 003

Town *(FIPS place code; I - 4; nnnnn)* 58600

Mile marker *(I - 11; nnn.nnn)* 005020

Waterway *(I - 6)* West Branch Deerfield River

Road Name *(I - 7):* -

Route Number VT100

Vicinity *(I - 9)* 3.3 MI N JCT. VT.8

Topographic Map Readsboro

Hydrologic Unit Code: -

Latitude *(I - 16; nnnn.n)* 42477

Longitude *(i - 17; nnnnn.n)* 72579

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20010200220209

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0110

Year built *(I - 27; YYYY)* 1970

Structure length *(I - 49; nnnnnn)* 000119

Average daily traffic, ADT *(I - 29; nnnnnn)* 000788

Deck Width *(I - 52; nn.n)* 340

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

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

Opening skew to Roadway *(I - 34; nn)* 48

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

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*) 75

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

Vertical clearance from streambed (*nnn.n ft*) 16

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

Waterway of full opening (*nnn.n* ft^2) 1200

Comments:

According to the structural inspection report dated 8/24/93, the structure is a single span plate girder bridge. The right abutment wall has areas of staining and vertical cracking. Both abutments are well protected with heavy stone fill. The footings are not exposed. The channel makes a sharp turn into the structure, and a sharp turn out of it. Some minor stream bank erosion is noted both upstream and downstream. There is vegetation growing along the banks upstream and downstream. Some minor channel scour is noted.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: **26.078**

Terrain character: **mountainous**

Stream character & type: **perennial**

Streambed material: **bedrock, gravel, bounders, sand**

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

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): **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*)	-	-	-	**1571.5**	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): **U** Frequency: **0**

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:

The hydraulic information above was taken from the plans at VTAOT. Additional information on plans included: 1) an "ordinary" high water elevation of 1567 feet; 2) an extreme high water elevation of 1571.5 feet; 3) a low water elevation of 1561 feet; 4) a velocity of the stream at the high water stage of 18.6 fps with and estimated discharge of 8790 cfs; 5) an area below extreme high water of 450 sq ft; 6) a vertical clearance above flood elevation of 2 feet; and 7) a scour potential of moderate.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **25.56** mi^2 Lake and pond area **0.934** mi^2

Watershed storage *(ST)* **3.65** %

Bridge site elevation **1580.4** ft Headwater elevation **3064** ft

Main channel length **8.9** mi

10% channel length elevation **1683** ft 85% channel length elevation **2225** ft

Main channel slope *(S)* **81** 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? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **4** / **1967**

Project Number **S0102(6)** Minimum channel bed elevation: **1564**

Low superstructure elevation: USLAB **1573.61** DSLAB **1574.00** USRAB **1572.21** DSRAB **1572.62**

Benchmark location description:
BM disc on bridge curb at downstream right corner, elev. 1580.47'.

Reference Point (*MSL, Arbitrary, Other*): **MSL** Datum (*NAD27, NAD83, Other*): **NGVD**

Foundation Type: **1** (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness **2** Footing bottom elevation: **1563**

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? **Y** *If no, type ctrl-n bi* Number of borings taken: **7**

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

Briefly describe material at foundation bottom elevation or around piles:
Right abutment footing at least partially is in contact with bedrock. The left abutment footing is set in gravel and boulders at its upstream end and dense sand and gravel with some silt at its downstream end.

Comments:
The footing bottom elevation indicated above is shown for the right abutment. However, the left abutment footing is shown at 1567 feet.
The low superstructure elevations above are the bridge seat elevations from the bridge plans.

Cross-sectional Data

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

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

Comments: **Available bridge cross sections are not replicable due to skew of structure and hence were not retrieved.**

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:

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: **10/28/96**
Computerized by: **EW** Date: **10/28/96**
Reviewd by: **EMB** Date: **1/3/96**

Structure Number **REDSVT01000022**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. BURNS** Date *(MM/DD/YY)* **07** / **30** / 19**96**

2. Highway District Number **01**
Mile marker **005020**
County **BENNINGTON (003)**
Town **READSBORO (58600)**
Waterway *(I - 6)* **West Branch Deerfield River**
Road Name **-**
Route Number **VT 100**
Hydrologic Unit Code: **01080203**

3. Descriptive comments:
Located 3.3 miles north of the VT 8 intersection with VT 100.

B. Bridge Deck Observations

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

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

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

7. Bridge length **119** *(feet)* Span length **110** *(feet)* Bridge width **34** *(feet)*

Road approach to bridge:

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

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

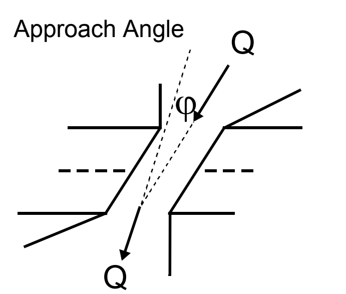
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

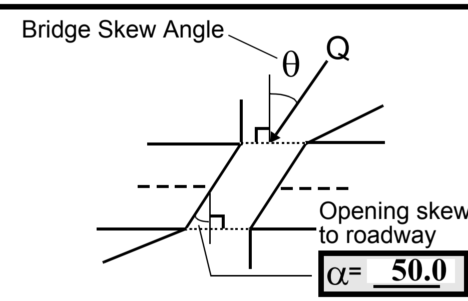
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	3	1	0	-
RBUS	3	1	0	-
RBDS	3	1	1	2
LBDS	3	1	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: **20** 16. Bridge skew: **50**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **20** feet **US** *(US, UB, DS)* to **40** feet **UB**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **15** feet **DS** *(US, UB, DS)* to **40** feet **DS**

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

18. Bridge Type: **1b/ 3**

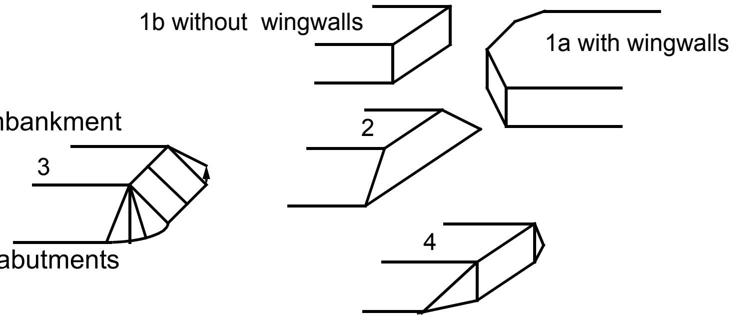
1a- Vertical abutments with wingwalls

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.)

The surface cover consists of forest predominantly. The VT 100 road surface follows along the upstream left bank and the downstream right bank of the river.
The road embankment protection for the left bank upstream and right bank downstream is also bank protection. On the right bank upstream, a large section of the bank protection has slumped leaving a slip-face of soil exposed at the top of the protection.

18: There is extensive protection in front of both abutments. The left side of the bridge opening is type 3 and the right side is both type-3 and type 1b depending on the water surface elevation. There are no wingwalls.

The bridge deck is slightly curved.

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
87.5	12.5			11.0	1	4	543	654	0	1

23. Bank width **35.0** 24. Channel width **75.0** 25. Thalweg depth **59.5** 29. Bed Material **543**

30 .Bank protection type: LB **3** RB **3** 31. Bank protection condition: LB **1** RB **2**

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

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

Bank protection on left bank also is road embankment protection, which extends from 230 feet upstream to the upstream bridge face.

On the right bank there are large stones near the bridge and type 2 protection extending to 30 feet upstream.

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

41. Mid-bank distance: 40 42. Cut bank extent: 55 feet US (US, UB) to 30 feet US (US, UB, DS)

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

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

There is an exposed escarpment of soil and other bank material above the top of the stone fill along the bank in the range indicated above. The stone fill has slipped leaving vegetation roots and finer underlying bank material exposed.

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

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

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

NO CHANNEL SCOUR

Some local scour behind large boulders.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
39.0		1.5		2	7/5	7/5	-

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.):

654

Both abutments are concrete, but are heavily protected by boulders. On the right and left abutment walls the boulder protection extends 8 and 20 feet respectively from each wall toward the channel.

There are some large boulders across the channel under the bridge with some local scour around them.

There is a narrow point bar in front of the protection along the LABUT. It extends from the upstream bridge face to 20 feet downstream. The bar is 8 feet wide and is composed predominantly of cobbles, boulders and

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

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

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

70. Debris and Ice Comments:

2
N
2

67: Debris potential is moderate because of dense vegetation in bank material for which moderate to heavy erosion is evident.

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	**65:**	**Debr**	**is is**	**caug**	**ht on**	**the**	**boul-**	**90.0**
RABUT	**ders**	**alon**	**g the**			**right**	**abut**	**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.):

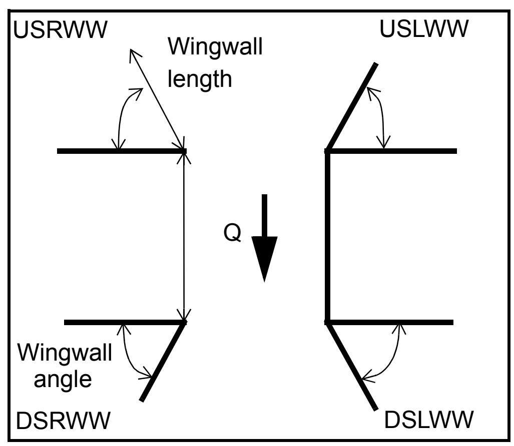
ment.

68/ 69: Moderate ice blockage potential because bridge clearance is low and boulders in channel.

-
30
2
0
-
-
1

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	**10**		**60**		**2**	**35.5**	
USRWW:	**0**		**-**		**-**	**1.5**	
DSLWW:	**1**		**The**		**abut**	**50.5**	
DSRWW:	**ment**		**s are**		**the**	**47.5**	



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	**spill**	**ugh**				**N**	**-**	**-**
Condition	**-**	**type**				**-**	**-**	**-**
Extent	**thro**	**.**				**-**	**N**	**-**

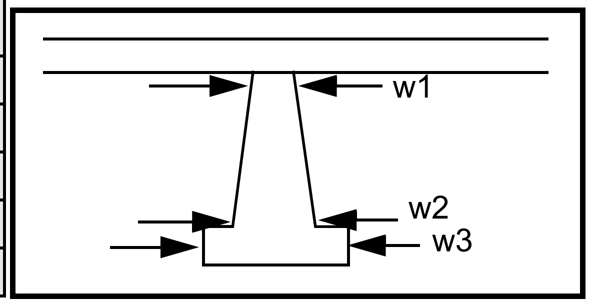
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

N
-

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: _-_

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

-
-
-
NO PIERS

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.):

3
2
543

Is channel scour present? **543** (Y or if N type ctrl-n cs) Mid-scour distance: **1**

Scour dimensions: Length **1** Width **543** Depth: **3** Positioned **3** %LB to **1** %RB

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

2
There is a culvert three feet in diameter entering the top of the downstream left bank immediately downstream. At 272 feet downstream, there are old laid-up stone abutments on the right and left banks. Near the bridge on the left bank are pieces of concrete and re-bar. There are no cut-banks, but there are escarpments

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

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

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

Confluence comments (eg. confluence name):

ream along the top of the bank protection.

F. Geomorphic Channel Assessment

107. Stage of reach evolution **On**

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)*:

the right bank, the protection extends from 0 feet downstream to at least 100 feet downstream and also is road embankment protection for VT 100.

On the left bank, the protection extends from 0 feet downstream to 21 feet downstream.

N

-

NO DROP STRUCTURE

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: REDSVT01000022 Town: Readsboro
Road Number: VT 100 County: Bennington
Stream: West Branch Deerfield River

Initials EMB Date: 1/17/97 Checked: RF

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	4680	6750	0
Main Channel Area, ft2	378	497	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	51	54	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.463	0.463	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.4	9.2	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	34138	50634	0
Conveyance, main channel	34138	50634	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	4680.0	6750.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	12.4	13.6	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	12.1	12.6	N/A
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	1	1	N/A

ARMORING			
D90	1.549	1.549	0
D95	2.232	2.232	0
Critical grain size,Dc, ft	0.3530	0.6656	ERR
Decimal-percent coarser than Dc	0.626	0.369	0
Depth to armoring,ft	0.63	3.41	ERR

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and others, 1995, p. 30, eq. 17 and 18)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	4680	6750	0	4680	6755	0
Total conveyance	34138	50634	0	46505	37492	0
Main channel conveyance	34138	50634	0	46505	37492	0
Main channel discharge	4680	6750	ERR	4680	6755	ERR
Area - main channel, ft2	378	497	0	555.3	580.6	0
(W1) channel width, ft	51	54	0	48.4	49.4	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	51	54	0	48.4	49.4	0
D50, ft	0.463	0.463	0.463			
w, fall velocity, ft/s (p. 32)	5.57	5.57	0			
y, ave. depth flow, ft	7.41	9.20	N/A	11.47	11.75	ERR
S1, slope EGL	0.021	0.024	0			
P, wetted perimeter, MC, ft	62	68	0			
R, hydraulic Radius, ft	6.097	7.309	ERR			
V*, shear velocity, ft/s	2.030	2.377	N/A			
V*/w	0.365	0.427	ERR			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.59	0.59	0			
y2,depth in contraction, ft	7.64	9.71	ERR			
ys, scour depth, ft (y2-y_bridge)	-3.83	-2.05	N/A			

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	378	497	0
Main channel width, ft	51	54	0
y1, main channel depth, ft	7.41	9.20	ERR

Bridge Section

(Q) total discharge, cfs	4680	6750	0
(Q) discharge thru bridge, cfs	4680	6755	0
Main channel conveyance	46505	37492	0
Total conveyance	46505	37492	0
Q2, bridge MC discharge,cfs	4680	6755	ERR
Main channel area, ft2	555	581	0
Main channel width (skewed), ft	48.4	49.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	48.4	49.4	0
y_bridge (avg. depth at br.), ft	11.47	11.75	ERR
Dm, median (1.25*D50), ft	0.57875	0.57875	0
y2, depth in contraction,ft	7.28	9.80	ERR
ys, scour depth (y2-ybridge), ft	-4.19	-1.95	N/A

Comparison of Chang and Laursen results (for unsubmerged orifice flow)

y2, from Laursen's equation, ft	7.65	9.72	0
Full valley WSEL, ft	0	493.08	0
Full valley depth, ft	11.47314	12.22304	N/A
Ys, depth of scour (y2-yfullv), ft	N/A	-2.50304	N/A

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	4680	6750	0
Q, thru bridge, cfs	4680	6755	0
Total Conveyance, bridge	46505	37492	0
Main channel(MC) conveyance, bridge	46505	37492	0
Q, thru bridge MC, cfs	4680	6755	ERR
Vc, critical velocity, ft/s	12.11	12.55	N/A
Vc, critical velocity, m/s	3.69	3.83	N/A
Main channel width (skewed), ft	48.4	49.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	48.4	49.4	0.0
qbr, unit discharge, ft2/s	96.7	136.7	ERR
qbr, unit discharge, m2/s	9.0	12.7	N/A
Area of full opening, ft2	555.3	580.6	0.0
Hb, depth of full opening, ft	11.47	11.75	ERR
Hb, depth of full opening, m	3.50	3.58	N/A
Fr, Froude number, bridge MC	0	0.87	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
Elevation of Low Steel, ft	0	492.61	0
Elevation of Bed, ft	-11.47	480.86	N/A
Elevation of Approach, ft	0	495.11	0
Friction loss, approach, ft	0	1.61	0
Elevation of WS immediately US, ft	0.00	493.50	0.00
ya, depth immediately US, ft	11.47	12.64	N/A
ya, depth immediately US, m	3.50	3.85	N/A
Mean elevation of deck, ft	0	499.8	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.98	ERR
Ys, depth of scour, ft	N/A	-0.66	N/A

Abutment Scour

Froehlich’s Abutment Scour

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

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

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	4680	6750	0	4680	6750	0
a’, abut.length blocking flow, ft	0.5	3.7	0	1.8	2.4	0
Ae, area of blocked flow ft2	1.83	14.7	0	11.1	18.2	0
Qe, discharge blocked abut.,cfs	11.7	111.5	0	82.6	142.1	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	6.39	7.59	ERR	7.44	7.81	ERR
ya, depth of f/p flow, ft	3.66	3.97	ERR	6.17	7.58	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	40	40	40	140	140	140
K2	0.90	0.90	0.90	1.06	1.06	1.06
Fr, froude number f/p flow	0.589	0.671	ERR	0.528	0.500	ERR
ys, scour depth, ft	4.92	7.37	N/A	9.42	11.59	N/A

HIRE equation (a’/ya > 25)

$ys = 4*Fr^{0.33}*y1*K/0.55$

(Richardson and others, 1995, p. 49, eq. 29)

a’(abut length blocked, ft)	0.5	3.7	0	1.8	2.4	0
y1 (depth f/p flow, ft)	3.66	3.97	ERR	6.17	7.58	ERR
a’/y1	0.14	0.93	ERR	0.29	0.32	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.59	0.67	N/A	0.53	0.50	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww’s	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship

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

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.64	0.87	0	0.64	0.87	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	11.50	11.78	0.00	11.50	11.78	0.00

Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (spillthrough abut.)	2.54	ERR	0.00	2.54	ERR	0.00
Fr>0.8 (spillthrough abut.)	ERR	4.19	ERR	ERR	4.19	ERR