LEVEL II SCOUR ANALYSIS FOR BRIDGE 35 (RANDTH00650035) on TOWN HIGHWAY 65, crossing the SECOND BRANCH WHITE RIVER, RANDOLPH, VERMONT

U.S. Geological Survey
Open-File Report 96-563

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

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By SCOTT A. OLSON

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Pembroke, New Hampshire

1996

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 35 (RANDTH00650035) ON TOWN HIGHWAY 65, CROSSING THE SECOND BRANCH WHITE RIVER, RANDOLPH, VERMONT

By **Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure RANDTH00650035 on town highway 65 crossing the Second Branch White River, Randolph, 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 of central Vermont. The 47.2-mi^2 drainage area is in a predominantly rural basin. In the vicinity of the study site, the surface cover is pasture except for the downstream left bank which is forested. There is some woody vegetation on the immediate channel banks upstream of the bridge.

In the study area, the Second Branch White River has a sinuous channel with alluvial boundaries and a slope of approximately 0.002 ft/ft, an average channel top width of 52 ft and an average channel depth of 7 ft. The predominant channel bed materials are sand and gravel with a median grain size (D_{50}) of 1.37 mm (0.0045 ft). The geomorphic assessment at the time of the Level I site visits on August 11, 1994 and December 1, 1994, indicated that the reach was laterally unstable.

The town highway 65 crossing of the Second Branch White River is a 33-ft-long, one-lane bridge consisting of one 28-foot steel-beam span (Vermont Agency of Transportation, written communication, July 29, 1994). The bridge is supported by vertical, stone abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway is 15 degrees. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 2.4 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge which was 5,870 cfs less than the 100-year discharge. Abutment scour at the left abutment ranged from 5.7 to 13.9 ft. with the worst-case occurring at the 500-year discharge. Abutment scour at the right abutment ranged from 9.2 to 11.3 ft. with the worst-case occurring at the incipient-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Randolph Center, VT. Quadrangle, 1:24,000, 1981
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 RANDTH00650035 ***Stream*** Second Branch White River

County Orange ***Road*** TH65 ***District*** 4

Description of Bridge

Bridge length 33 ***ft*** ***Bridge width*** 14.3 ***ft*** ***Max span length*** 28 ***ft***

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

Abutment type Vertical, stone ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 11/08/94

Description of stone fill None.

Brief description of piers/abutments Abutments and wingwalls are stone.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 25

There is a moderate channel bend in the upstream reach. The bend causes the left abutment to be impacted by flow.

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	12/1/94	0	0
Level II	8/11/94	0	0

Potential for debris Moderate. Banks are laterally unstable, increasing the potential for debris.

Describe any features near or at the bridge that may affect flow (include observation date) December 1, 1994. A beaver dam exists just downstream of the bridge. The dam was ignored in analysis.

Description of the Geomorphic Setting

General topography The bridge is in an approximately 200-300 ft-wide, flat to irregular valley over a very sinuous stream.

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

Date of inspection 8/11/94 and 12/1/94

DS left: High bank to irregular flood plain.

DS right: Flood plain.

US left: Flood plain.

US right: Irregular flood plain.

Description of the Channel

Average top width 52 ft ***Average depth*** 7 ft

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

Very sinuous with alluvial channel boundaries and flood plains.

8/11/94 and 12/1/94

Vegetative co Forested.

DS left: Pasture

DS right: Pasture with some woody vegetation on immediate channel bank.

US left: Pasture with some woody vegetation on immediate channel bank.

US right: N

Do banks appear stable? ***If not, describe location and type of instability and date of observation.*** August 11, 1994 and December 1, 1994. Cuts into the alluvial channel banks were noted upstream and downstream. A beaver dam noted on December 1, 1994 is also redirecting some of the flow and causing severe bank cutting on the right bank 20 feet downstream of the bridge.

December 1, 1994.

Describe any obstructions in channel and date of observation. There is a beaver dam just downstream of the structure. The beaver dam was ignored in the hydraulic analysis.

Hydrology

Drainage area 47.2 ***mi***^{2}

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***: None.

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

USGS gage description --

USGS gage number --

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

Is there a lake/p No

--

--

--

--

Calculated Discharges

Q100 7,100 ***ft***^{3}***/s*** ***Q500*** 10,000 ***ft***^{3}***/s***

The 100-year discharge was taken from the VTAOT database (VTAOT, written communication, May, 1995). The database had flood frequency estimates for a bridge with a drainage area of 46.0 square miles on the Second Branch White River. The 500-year discharge was graphically extrapolated from the available estimates. The 100- and 500-year discharges are within 2 percent and 12 percent, respectively, of the discharges published in the Flood Insurance Study for the Town of Randolph (Federal Emergency Management Agency, 1991).

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 square on top of the upstream end of the right abutment (elev. 499.17 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	-45	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY		1	Road Grade section
APPRO	40	2	Modelled Approach section (Templated from APTEM)
APTEM	51	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 0.032 to 0.040. Overbank "n" values were 0.040.

Although the Flood Insurance Study profile plot (Federal Emergency Management Agency, 1991) indicated that there was possible backwater from a downstream site, a hydraulic model of the downstream bridge and a step-backwater analysis between the two structures was considered out of the scope of this study. 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 0.0018 ft/ft which was the bed slope measured from the Flood Insurance Study profile plot.

For the 100- and 500-year discharges, a significant portion of the flow was found to be by-passing the bridge and going around an "island" right of the structure. A split flow analysis was necessary to appropriately model this situation. A model for flow through the bridge and a model for flow around the "island", both starting with the water surface found in the normal depth analysis discussed above, were developed. Rating curves at the approach section for each of the two models were then developed and graphically combined to determine the percentage of flow which would by-pass the bridge. Then a final model to be used for the scour analysis was created which included only the channel geometry and discharge "left of the island". Twenty-six percent of the 100-year discharge (1,860 of 7,100 cfs,) and twenty-five percent of the 500-year discharge (2,510 of 10,000 cfs) did *not* by-pass the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.002 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 501.3 *ft*
Average low steel elevation 499.6 *ft*

100-year discharge 7,100 *ft³/s*
Water-surface elevation in bridge opening 500.1 *ft*
Road overtopping? Y *Discharge over road* 5,800 *ft³/s*
Area of flow in bridge opening 260 *ft²*
Average velocity in bridge opening 5.0 *ft/s*
Maximum WSPRO tube velocity at bridge 6.1 *ft/s*

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

500-year discharge 10,000 *ft³/s*
Water-surface elevation in bridge opening 500.1 *ft*
Road overtopping? Y *Discharge over road* 8,800
Area of flow in bridge opening 260 *ft²*
Average velocity in bridge opening 4.6 *ft/s*
Maximum WSPRO tube velocity at bridge 5.6 *ft/s*

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

Incipient overtopping discharge 1,230 *ft³/s*
Water-surface elevation in bridge opening 495.9 *ft*
Area of flow in bridge opening 165 *ft²*
Average velocity in bridge opening 7.5 *ft/s*
Maximum WSPRO tube velocity at bridge 9.3 *ft/s*

Water-surface elevation at Approach section with bridge 496.6
Water-surface elevation at Approach section without bridge 496.4
Amount of backwater caused by bridge 0.2 *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 was computed by use of the live-bed contraction scour equation (Richardson and others, 1995, p. 30, equation 17). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The 100-year and 500-year discharges resulted in submerged orifice orifice flow. The results of Chang's contraction scour (Richardson and others, 1995, p. 145-146) for these events were also computed and can be found in appendix F. Because the Chang equation for pressure-flow scour was derived solely with data for clear-water scour, it is not currently understood how well it would predict in live-bed conditions. Therefore, although pressure-flow conditions exist for some or all of the modelled flows, the reported scour depths were computed using Laursen's live-bed contraction scour equation. In this case, the incipient road-overflow model resulted in the worst case contraction scour with a scour depth of 2.4 ft.

Although the channel bed is primarily sand, a gravel and cobble riffle with a median grain size of 56.1 mm (0.184 ft) existed approximately 50 to 100 ft. downstream. A critical (incipient motion) velocity analysis using this larger material size indicated clear-water scour and a clear-water contraction scour analysis (Richardson and others, 1995, p. 32, equation 20) was made for comparison. The reported armoring (p. 14) potential was analyzed with the grain size distribution of the sample taken at the approach; armoring was also analyzed using the grain-size distribution at the riffle and the results are shown im 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.

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	2.4
Clear-water scour	0.0	0.0	0.0
Depth to armoring	2.7	1.7	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	12.1	13.9	5.7
Right abutment	9.2	10.1	11.3
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	0.5	0.4	1.1
Right abutment	0.5	0.4	1.1
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--
	--	--	--

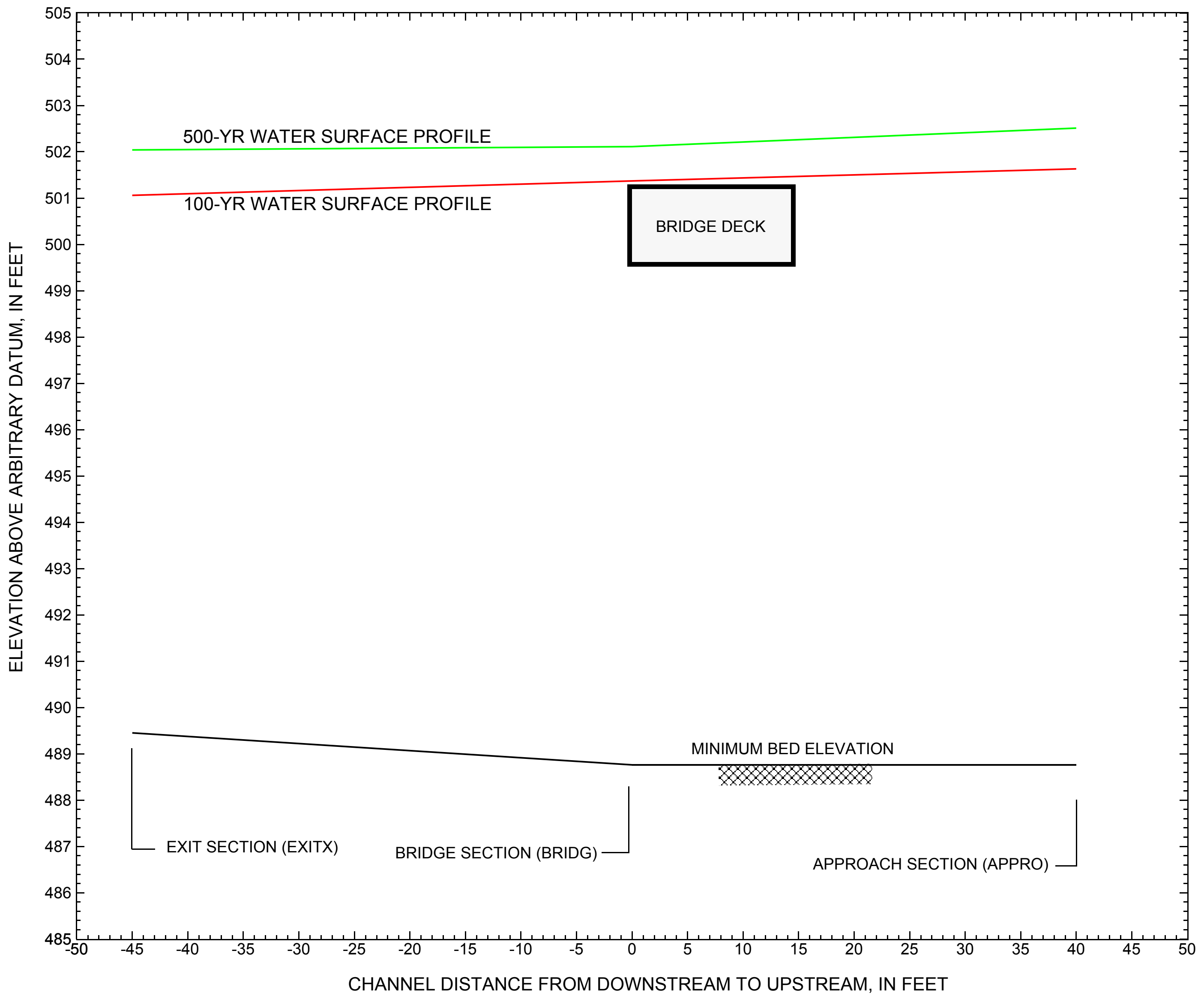

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RANDTH00650035 on town highway 65, crossing the Second Branch White River, Randolph, Vermont.

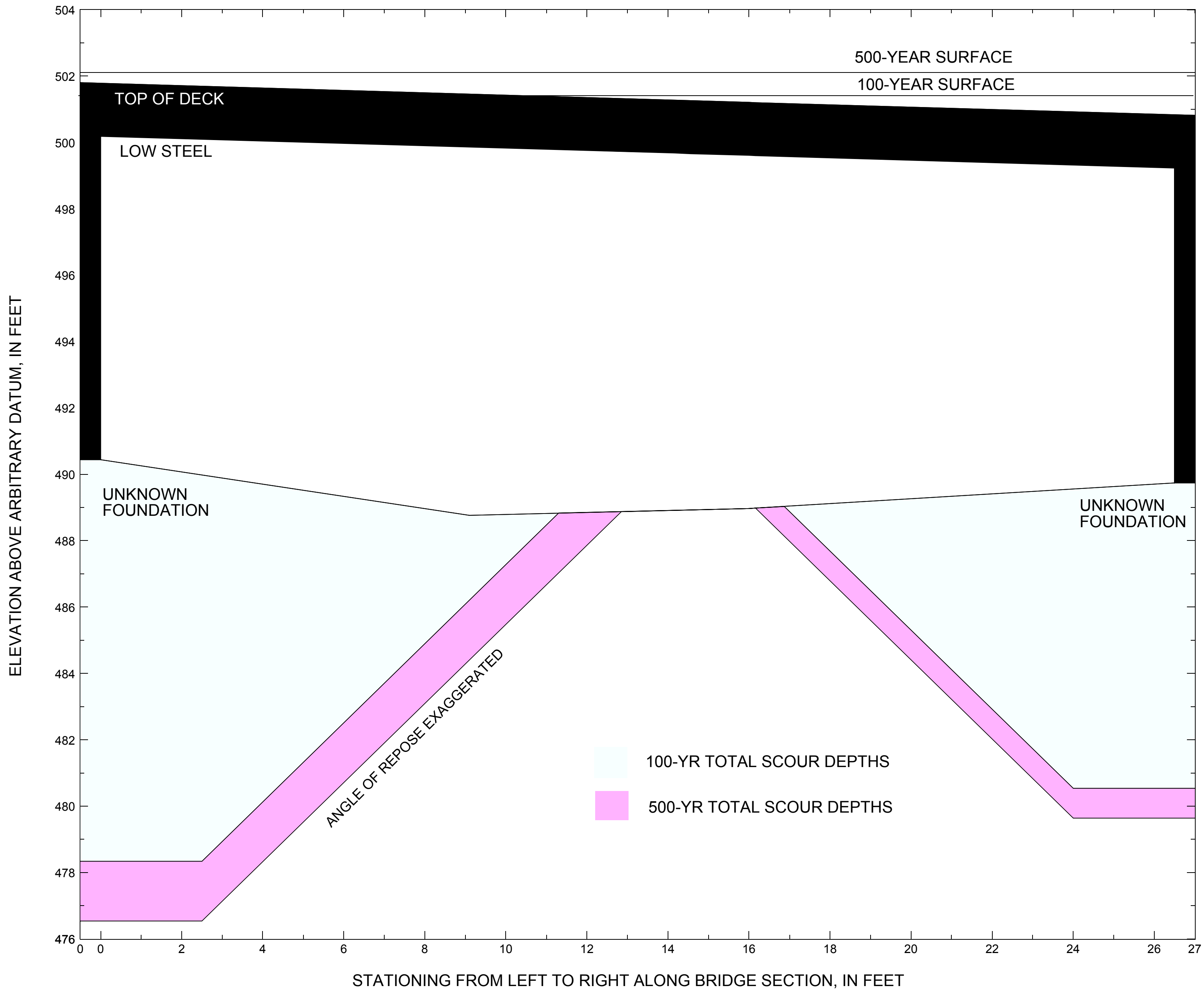

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RANDTH00650035 on town highway 65, crossing the Second Branch White River, Randolph, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RANDTH00650035 on Town Highway 65, crossing the Second Branch White River, Randolph, 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 7,100 cubic-feet per second											
Left abutment	0.0	--	500.1	--	490.4	0.0	12.1	--	12.1	478.3	--
Right abutment	26.5	--	499.1	--	489.7	0.0	9.2	--	9.2	480.5	--

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 RANDTH00650035 on Town Highway 65, crossing the Second Branch White River, Randolph, 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 10,000 cubic-feet per second											
Left abutment	0.0	--	500.1	--	490.4	0.0	13.9	--	13.9	476.5	--
Right abutment	26.5	--	499.1	--	489.7	0.0	10.1	--	10.1	479.6	--

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, 1981, Randolph Center, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File rand035.wsp
T2        Hydraulic analysis for structure RANDTH00650035
T3        This is the final model includes main channel side of island only
*           Note that a ‘split flow analysis was done’ and ratings were created
*           and combined to determine how much of the total flow would be included
*           in this final model. Only this model is shown since it was used
*           to analyze scour potential.
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1860 2510 1230
WS          501.06 502.04 496.18
*
XS   EXITX   -45
GR          -18.1, 506.36     -4.3, 495.01     -3.4, 490.92      0.0, 490.33
GR           18.3, 489.86     34.6, 489.45     35.6, 490.35     41.4, 494.72
GR           42.4, 496.44     45.8, 497.41     77.9, 496.71    109.7, 497.31
GR          130.4, 499.98    159.0, 501.31
N           0.040        0.040
SA                  45.8
*
XS   FULLV     0
*
BR   BRIDG     0    499.62      15.0
GR            0.0, 500.10      0.3, 490.44      9.1, 488.76     16.0, 488.97
GR           26.1, 489.74     26.5, 499.14      0.0, 500.10
N            0.032
CD           1 15 * * 5 11
*
XR   RDWAY    7 14 2
GR          -86.9, 504.61    -70.7, 503.78    -43.9, 502.58      0.0, 501.79
GR           29.5, 500.77     51.1, 500.06     73.8, 499.70    123.9, 500.69
GR          148.6, 501.97    204.2, 505.83
*
XT   APTEM     51
GR        -164.0, 504.23   -133.2, 503.25    -49.3, 497.17    -10.2, 496.49
GR           -2.4, 493.82      0.0, 490.58      1.2, 488.88     20.4, 488.78
GR           30.1, 489.52     33.2, 490.44     38.0, 496.39     42.6, 497.97
GR           53.2, 498.23     70.4, 499.70    120.5, 500.69    145.3, 501.97
GR          201.0, 505.83
*
*           Note incipient overflow at elevation 496.58 (see overbank data)
*
AS   APPRO     40
GT           -0.02
N           0.040        0.040        0.040
SA                 -10.2         42.6
*
HP 1 BRIDG 500.10 1 500.10
HP 2 BRIDG 500.10 * * 1300
HP 2 RDWAY 501.37 * * 568
HP 1 APPRO 501.63 1 501.63
HP 2 APPRO 501.63 * * 1860
*
HP 1 BRIDG 500.10 1 500.10
HP 2 BRIDG 500.10 * * 1202
HP 2 RDWAY 502.11 * * 1309
HP 1 APPRO 502.51 1 502.51
```

APPENDIX B:

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File rand035.wsp
     Hydraulic analysis for structure RANDTH00650035
     This is the final model includes main channel only
        *** RUN DATE & TIME: 07-09-96  10:01
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     260.   29137.     0.    70.                            0.
   500.10          260.   29137.     0.    70.  1.00     0.    27.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      500.10     0.0    26.5   260.3   29137.    1300.   5.00
X STA.         0.0         2.6         4.2         5.4         6.6         7.7
  A(I)             23.5        15.0        12.7        12.2        11.5
  V(I)             2.77        4.34        5.13        5.31        5.66

X STA.         7.7         8.8         9.8        10.9        11.9        12.9
  A(I)             11.3        10.9        11.0        10.8        10.7
  V(I)             5.74        5.94        5.93        6.04        6.07

X STA.        12.9        14.0        15.1        16.1        17.2        18.4
  A(I)             11.0        10.9        11.0        11.2        11.5
  V(I)             5.93        5.96        5.94        5.80        5.66

X STA.        18.4        19.6        20.8        22.2        23.7        26.5
  A(I)             11.8        12.0        13.2        14.7        23.5
  V(I)             5.52        5.43        4.94        4.41        2.76

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       7.
        WSEL     LEW     REW    AREA        K        Q    VEL
      501.37    12.1   137.0   123.0    4700.     568.   4.62
X STA.        12.1        37.5        45.1        49.9        53.9        57.5
  A(I)             11.1         7.5         5.7         5.2         5.1
  V(I)             2.56        3.79        5.00        5.43        5.58

X STA.        57.5        61.0        64.3        67.6        70.6        73.5
  A(I)              5.0         4.9         5.0         4.8         4.8
  V(I)             5.65        5.74        5.71        5.91        5.92

X STA.        73.5        76.5        79.6        83.1        86.8        90.9
  A(I)              4.9         5.0         5.2         5.4         5.6
  V(I)             5.79        5.65        5.41        5.22        5.06

X STA.        90.9        95.6       101.1       107.5       115.9       137.0
  A(I)              6.0         6.5         6.8         7.8        10.5
  V(I)             4.74        4.36        4.17        3.65        2.70

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      40.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     327.   26634.   101.   101.                         3339.
             2     551.   91077.    53.    59.                        10109.
             3     166.    8839.    96.    97.                         1231.
   501.63         1044.  126550.   250.   257.  1.45  -111.   139.  10065.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      40.
        WSEL     LEW     REW    AREA        K        Q    VEL
      501.63  -111.1   139.1  1043.9  126550.    1860.   1.78
X STA.      -111.1       -56.2       -39.1       -25.1       -12.6        -3.5
  A(I)            109.1        75.7        67.0        62.7        54.4
  V(I)             0.85        1.23        1.39        1.48        1.71

X STA.        -3.5         1.7         4.4         7.0         9.6        12.1
  A(I)             51.6        34.5        34.1        32.6        32.6
  V(I)             1.80        2.70        2.72        2.85        2.85

X STA.        12.1        14.7        17.2        19.7        22.3        25.0
  A(I)             32.5        32.5        32.9        32.5        34.3
  V(I)             2.87        2.86        2.83        2.86        2.71

X STA.        25.0        27.8        30.9        35.0        52.8       139.1
  A(I)             35.0        37.5        44.9        78.1       129.4
  V(I)             2.66        2.48        2.07        1.19        0.72
```

```
        U.S. Geological Survey WSPRO Input File rand035.wsp
        Hydraulic analysis for structure RANDTH00650035
        This is the final model includes main channel only
           *** RUN DATE & TIME: 07-09-96  10:01
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     260.   29137.     0.    70.                          0.
   500.10          260.   29137.     0.    70.  1.00     0.    27.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      500.10     0.0    26.5   260.3   29137.    1202.   4.62
X STA.        0.0         2.6         4.2         5.4         6.6         7.7
  A(I)            23.5        15.0        12.7        12.2        11.5
  V(I)            2.56        4.01        4.74        4.91        5.24

X STA.        7.7         8.8         9.8        10.9        11.9        12.9
  A(I)            11.3        10.9        11.0        10.8        10.7
  V(I)            5.31        5.49        5.48        5.58        5.62

X STA.       12.9        14.0        15.1        16.1        17.2        18.4
  A(I)            11.0        10.9        11.0        11.2        11.5
  V(I)            5.48        5.52        5.49        5.36        5.23

X STA.       18.4        19.6        20.8        22.2        23.7        26.5
  A(I)            11.8        12.0        13.2        14.7        23.5
  V(I)            5.10        5.02        4.57        4.08        2.55

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       7.
        WSEL     LEW     REW    AREA        K        Q    VEL
      502.11   -17.8   150.6   229.9   11069.    1309.   5.69
X STA.      -17.8        26.6        37.0        44.5        49.8        54.2
  A(I)            23.6        14.6        12.8        10.1         9.1
  V(I)            2.77        4.47        5.11        6.45        7.17

X STA.       54.2        58.4        62.5        66.4        70.2        73.9
  A(I)             9.0         9.0         8.8         8.8         8.7
  V(I)            7.25        7.24        7.41        7.44        7.48

X STA.       73.9        77.7        81.7        86.0        90.6        95.7
  A(I)             8.9         9.2         9.6         9.7        10.4
  V(I)            7.34        7.12        6.79        6.75        6.32

X STA.       95.7       101.3       107.6       115.0       123.9       150.6
  A(I)            10.7        11.4        12.3        13.6        19.3
  V(I)            6.13        5.74        5.31        4.83        3.38

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      40.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     421.   37644.   113.   113.                       4611.
             2     598.  104227.    53.    59.                      11413.
             3     257.   16794.   111.   111.                       2225.
   502.51         1276.  158665.   277.   283.  1.44  -123.   153.  12944.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      40.
        WSEL     LEW     REW    AREA        K        Q    VEL
      502.51  -123.3   153.4  1276.1  158665.    2510.   1.97
X STA.     -123.3       -63.0       -45.4       -31.5       -18.9        -7.6
  A(I)           131.5        87.6        77.2        72.7        69.2
  V(I)            0.95        1.43        1.63        1.73        1.81

X STA.       -7.6        -0.2         3.3         6.2         9.1        12.0
  A(I)            62.6        46.9        40.0        39.5        39.6
  V(I)            2.00        2.68        3.14        3.17        3.17

X STA.       12.0        14.8        17.6        20.5        23.4        26.4
  A(I)            38.4        38.4        38.9        39.9        40.7
  V(I)            3.27        3.26        3.22        3.14        3.08

X STA.       26.4        29.7        33.4        44.6        71.7       153.4
  A(I)            42.6        47.3        74.9       102.6       145.5
  V(I)            2.94        2.65        1.67        1.22        0.86
```

```
       U.S. Geological Survey WSPRO Input File rand035.wsp
       Hydraulic analysis for structure RANDTH00650035
       This is the final model includes main channel only
          *** RUN DATE & TIME: 07-09-96  10:01
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     165.   20882.    25.    37.                        2384.
   495.87          165.   20882.    25.    37.  1.00     0.    26.   2384.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.87     0.1    26.4   164.8   20882.    1230.   7.47
X STA.         0.1         3.0         4.6         6.0         7.2         8.3
  A(I)            15.3         9.4         8.3         7.8         7.2
  V(I)            4.03        6.52        7.39        7.84        8.53

X STA.         8.3         9.3        10.3        11.3        12.3        13.2
  A(I)             7.0         6.8         6.8         6.7         6.6
  V(I)            8.77        9.10        9.07        9.21        9.25

X STA.        13.2        14.2        15.2        16.3        17.3        18.4
  A(I)             6.7         6.6         6.9         6.9         7.1
  V(I)            9.24        9.28        8.90        8.89        8.68

X STA.        18.4        19.5        20.8        22.1        23.6        26.4
  A(I)             7.3         7.8         8.2         9.5        15.8
  V(I)            8.46        7.85        7.50        6.50        3.88

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      40.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       0.       2.     6.     6.                           0.
             2     287.   32311.    49.    55.                        3957.
   496.58          288.   32313.    55.    61.  1.00   -17.    39.   3726.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      40.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.58   -16.5    38.6   287.7   32313.    1230.   4.27
X STA.       -16.5         1.0         3.3         5.2         6.9         8.6
  A(I)            29.3        17.2        14.7        13.6        13.2
  V(I)            2.10        3.58        4.18        4.51        4.65

X STA.         8.6        10.2        11.8        13.4        14.9        16.4
  A(I)            12.5        12.4        12.0        11.9        11.9
  V(I)            4.91        4.97        5.13        5.19        5.18

X STA.        16.4        17.9        19.5        21.0        22.5        24.1
  A(I)            11.8        11.8        12.0        11.7        12.3
  V(I)            5.21        5.21        5.15        5.25        4.99

X STA.        24.1        25.8        27.6        29.5        31.8        38.6
  A(I)            12.6        13.1        13.6        15.7        24.5
  V(I)            4.88        4.68        4.53        3.91        2.51
```

WSPRO OUTPUT FILE (continued)

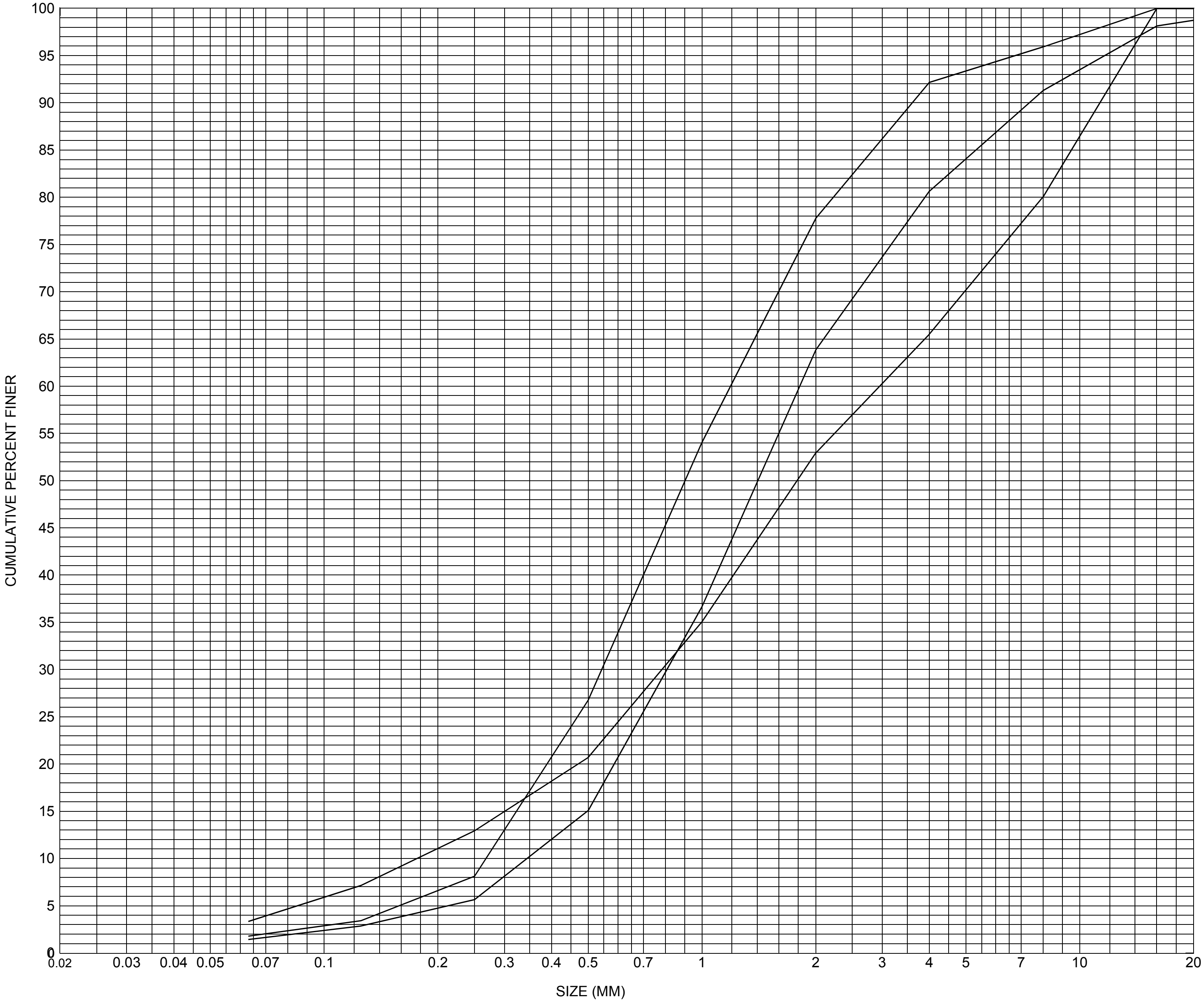
```
        U.S. Geological Survey WSPRO Input File rand035.wsp
        Hydraulic analysis for structure RANDTH00650035
        This is the final model includes main channel only
           *** RUN DATE & TIME: 07-09-96  10:01

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

EXITX:XS   ******   -12.     851.  0.09 *****  501.15  494.03   1860.  501.06
      -45. ******   154.  104223.  1.24 ***** *******    0.19    2.18

FULLV:FV      45.   -12.     854.  0.09  0.01  501.17 *******   1860.  501.08
        0.    45.   154.  104657.  1.24  0.00    0.00    0.19    2.18
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      40.  -104.     914.  0.09  0.01  501.19 *******   1860.  501.09
       40.    40.   129.  109706.  1.43  0.00    0.00    0.22    2.03
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                         WS3N,LSEL =   501.08     499.62

            <<<<<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      45.     0.     260.  0.39 *****  500.49  493.69   1300.  500.10
        0. ******    27.   29137.  1.00 ***** *******    0.28    5.00

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  499.62 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       7.    26.  0.01  0.07  501.70    0.00    568.  501.37

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.     1.    12.    13.   0.0   0.0   2.3  46.5   0.3   2.6
   RT:    568.   124.    13.   137.   1.7   1.0   5.2   4.6   1.3   3.0

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

APPRO:AS      25.  -111.    1045.  0.07  0.02  501.70  493.63   1860.  501.63
       40.    30.   139.  126645.  1.45  0.00    0.00    0.18    1.78

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -45.   -12.   154.   1860.  104223.     851.    2.18  501.06
   FULLV:FV       0.   -12.   154.   1860.  104657.     854.    2.18  501.08
   BRIDG:BR       0.     0.    27.   1300.   29137.     260.    5.00  500.10
   RDWAY:RG       7.*******     0.    568.        0.*********   2.00  501.37
   APPRO:AS      40.  -111.   139.   1860.  126645.    1045.    1.78  501.63

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    494.03    0.19  489.45  506.36************  0.09  501.15  501.06
   FULLV:FV  ********    0.19  489.45  506.36  0.01  0.00  0.09  501.17  501.08
   BRIDG:BR    493.69    0.28  488.76  500.10************  0.39  500.49  500.10
   RDWAY:RG  ****************  499.70  505.83  0.01******  0.07  501.70  501.37
   APPRO:AS    493.63    0.18  488.76  505.81  0.02  0.00  0.07  501.70  501.63
```

```
        U.S. Geological Survey WSPRO Input File rand035.wsp
        Hydraulic analysis for structure RANDTH00650035
        This is the final model includes main channel only
           *** RUN DATE & TIME: 07-09-96  10:01

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

EXITX:XS   ******   -13.    1019.  0.11 *****  502.15  494.90   2510.  502.04
      -45. ******   159.  131714.  1.20 ***** *******    0.20    2.46

 ===140 AT SECID "FULLV":  END OF CROSS SECTION EXTENDED VERTICALLY.
                           WSEL,YLT,YRT =   502.06     506.36     501.31

FULLV:FV      45.   -13.    1022.  0.11  0.02  502.17 *******   2510.  502.06
        0.    45.   159.  132341.  1.19  0.00    0.00    0.19    2.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      40.  -117.    1161.  0.11  0.01  502.19 *******   2510.  502.08
       40.    40.   147.  142338.  1.45  0.00    0.00    0.22    2.16
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   502.06     499.62

            <<<<<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      45.     0.     260.  0.33 *****  500.43  493.47   1202.  500.10
        0. ******    27.   29137.  1.00 ***** *******    0.26    4.62

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  499.62 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       7.    26.  0.01  0.09  502.59    0.00   1309.  502.11

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     63.    31.   -18.    13.   0.8   0.3   3.8   6.4   0.8   2.8
   RT:   1245.   138.    13.   151.   2.4   1.6   6.5   5.7   2.1   3.0

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

APPRO:AS      25.  -123.    1277.  0.09  0.02  502.60  494.67   2510.  502.51
       40.    31.   153.  158840.  1.44  0.00    0.00    0.19    1.96

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -45.   -13.   159.   2510.  131714.    1019.    2.46  502.04
   FULLV:FV       0.   -13.   159.   2510.  132341.    1022.    2.46  502.06
   BRIDG:BR       0.     0.    27.   1202.   29137.     260.    4.62  500.10
   RDWAY:RG       7.*******    63.   1309.******************    2.00  502.11
   APPRO:AS      40.  -123.   153.   2510.  158840.    1277.    1.96  502.51

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    494.90    0.20  489.45  506.36************  0.11  502.15  502.04
   FULLV:FV  ********    0.19  489.45  506.36  0.02  0.00  0.11  502.17  502.06
   BRIDG:BR    493.47    0.26  488.76  500.10************  0.33  500.43  500.10
   RDWAY:RG  ****************  499.70  505.83  0.01******  0.09  502.59  502.11
   APPRO:AS    494.67    0.19  488.76  505.81  0.02  0.00  0.09  502.60  502.51
```

```
        U.S. Geological Survey WSPRO Input File rand035.wsp
        Hydraulic analysis for structure RANDTH00650035
        This is the final model includes main channel only
           *** RUN DATE & TIME: 07-09-96  10:01

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

EXITX:XS   ******    -6.     268.  0.33 *****  496.51  493.06   1230.  496.18
      -45. ******    42.   28974.  1.00 ***** *******    0.34    4.58

FULLV:FV      45.    -6.     273.  0.32  0.08  496.59 *******   1230.  496.28
        0.    45.    42.   29729.  1.00  0.00    0.01    0.33    4.50
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      40.   -10.     277.  0.31  0.07  496.67 *******   1230.  496.36
       40.    40.    38.   30721.  1.00  0.00    0.01    0.33    4.44
         <<<<<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      45.     0.     165.  0.89  0.11  496.76  493.53   1230.  495.87
        0.    45.    26.   20863.  1.03  0.14    0.00    0.52    7.47

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.985 ******  499.62 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       7.        <<<<<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      25.   -17.     288.  0.28  0.06  496.87  492.55   1230.  496.58
       40.    27.    39.   32351.  1.00  0.05    0.01    0.33    4.27

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.451  0.099   29062.     3.    30.   496.55

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -45.    -6.    42.   1230.   28974.     268.    4.58  496.18
   FULLV:FV       0.    -6.    42.   1230.   29729.     273.    4.50  496.28
   BRIDG:BR       0.     0.    26.   1230.   20863.     165.    7.47  495.87
   RDWAY:RG       7.**************      0.******************    2.00********
   APPRO:AS      40.   -17.    39.   1230.   32351.     288.    4.27  496.58

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    30.   29062.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    493.06    0.34  489.45  506.36************  0.33  496.51  496.18
   FULLV:FV  ********    0.33  489.45  506.36  0.08  0.00  0.32  496.59  496.28
   BRIDG:BR    493.53    0.52  488.76  500.10  0.11  0.14  0.89  496.76  495.87
   RDWAY:RG  ****************  499.70  505.83**********************************
   APPRO:AS    492.55    0.33  488.76  505.81  0.06  0.05  0.28  496.87  496.58
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three samples taken at the approach cross-section for structure RANDTH00650035, in Randolph, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number RANDTH00650035

General Location Descriptive

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

Date *(MM/DD/YY)* 07 / 29 / 94

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 58075

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

Waterway *(I - 6)* 2ND. BRANCH WHITE R.

Road Name *(I - 7):* -

Route Number TH065

Vicinity *(I - 9)* 0.1 MI JCT TH 65 + VT 14

Topographic Map Randolph.Center

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43554

Longitude *(i - 17; nnnnn.n)* 72337

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10090900350909

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

Maximum span length *(I - 48; nnnn)* 0028

Year built *(I - 27; YYYY)* 1919

Structure length *(I - 49; nnnnnn)* 000033

Average daily traffic, ADT *(I - 29; nnnnnn)* 000010

Deck Width *(I - 52; nn.n)* 143

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

Channel & Protection *(I - 61; n)* 7

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*) 010.0

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

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

Comments:

Structural report of 7/29/93, there is no mention of channel scour conditions or embankment erosion. A "shallow" sand bar was noted as present along the left abutment. The channel makes a moderate bend toward and through the bridge.

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: Stones and small boulders, sand and mud

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)* : LIGHT Debris *(Heavy, Moderate, Light)*: LIGHT

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 47.18 mi^2 Lake and pond area 0.41 mi^2

Watershed storage *(ST)* 0.9 %

Bridge site elevation 570 ft Headwater elevation 1840 ft

Main channel length 14.85 mi

10% channel length elevation 590 ft 85% channel length elevation 780 ft

Main channel slope *(S)* 17.05 ft / mi

Watershed Precipitation Data

Average site precipitation __________ in Average headwater precipitation __________ in

Maximum 2yr-24hr precipitation event *(I24,2)* ________ in

Average seasonal snowfall *(Sn)* _________ ft

Bridge Plan Data

Are plans available? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: - / -

Project Number --

Minimum channel bed elevation: --

Low superstructure elevation: USLAB -- DSLAB -- USRAB -- DSRAB --

Benchmark location description:

NO BENCHMARK INFORMATION

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness _______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATTION 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: MAW Date: 2/13/95
Computerized by: MAI Date: 3/20/95
Reviewd by: SAO Date: 8/7/96

Structure Number RANDTH00650035

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 12 / 01 / 1994

2. Highway District Number 04 Mile marker 0

County ORANGE (017) Town RANDOLPH (58075)

Waterway *(I - 6)* 2ND BRANCH WHITE RIVER Road Name -

Route Number TH065 Hydrologic Unit Code: 01080105

3. Descriptive comments:

0.1 miles to the junction of TH 65 and VT 14.
Beaver dam 20 ft. downstream, 3.5 ft. high.
Bridge rail 3.3 ft. high (top pipe), 1.5 ft. to center pipe, and curb 0.5 ft. high.
Preliminary Level I data collected on August 11, 1994.

B. Bridge Deck Observations

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

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

7. Bridge length 33 *(feet)* Span length 28 *(feet)* Bridge width 14.3 *(feet)*

Road approach to bridge:

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

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

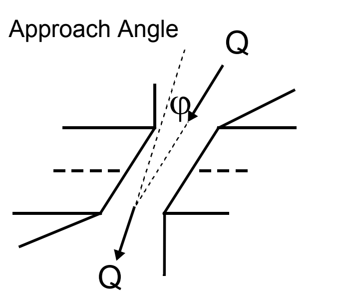
10. Embankment slope (*run / rise in feet / foot*):
US left 0.2:1 US right 0.4:1

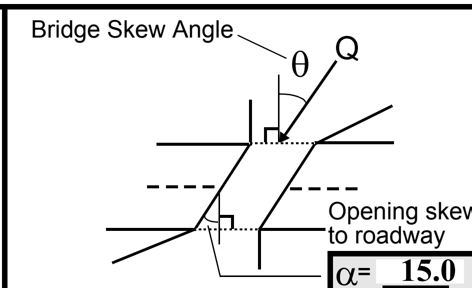
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	0	0
RBDS	0	-	1	2
LBDS	0	-	1	1

*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: 25





α= 15.0

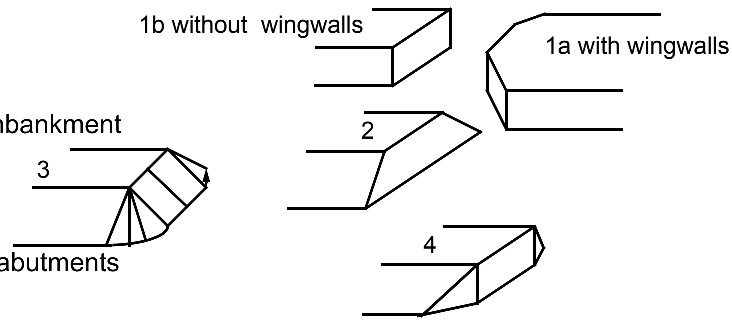
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 30 feet US *(US, UB, DS)* to 0 feet DS

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 3
Range? 10 feet DS *(US, UB, DS)* to 50 feet DS

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

18. Level II Bridge Type: **1a**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

7. Measured bridge length: 32, span: 29,and width: 14.0 feet. Values reported in item #7 are from I-code values.
14. RBDS: Current channel is 10 ft. from the road approach but due to the erosion around the beaver dam there is possible movement of the channel toward the road approach.
19. Right road approach overflow width is 16 feet.

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
39.2	**7.5**			**7.5**	**1**	**2**	**123**	**213**	**1**	**2**

23. Bank width **35.0** 24. Channel width **40.0** 25. Thalweg depth **53.0** 29. Bed Material **243**

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

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

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

27. LB: Silt/ clay and sand with some gravel. RB: Sand and silt/ clay and some gravel.
29. Sand and cobble and some gravel.

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? **LB** (LB or RB)

41. Mid-bank distance: **22** 42. Cut bank extent: **30** feet **US** (US, UB) to **10** 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.):

Bank erosion also exists on the right bank upstream.

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

47. Scour dimensions: Length **47** Width **12** Depth : **1** Position **25** %LB to **75** %RB

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

Scour extends 28 ft. upstream to 5 ft. downstream of the bridge. Water depth under the bridge is now 6 ft. due to the beaver dam.

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
33.5		1.5		2	7	7	0

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

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

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

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

243

63. Sand and cobble and some gravel.

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

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

70. Debris and Ice Comments:

2

67. Some debris accumulation upstream and at the bridge and the channel is laterally unstable and sinuous with some cut banks.

68. Moderate channel gradient and the span length is 54% of the upstream bank width.

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		25	90	2	1	0.5	0	90.0
RABUT	2	0	90			2	1	26.5

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

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

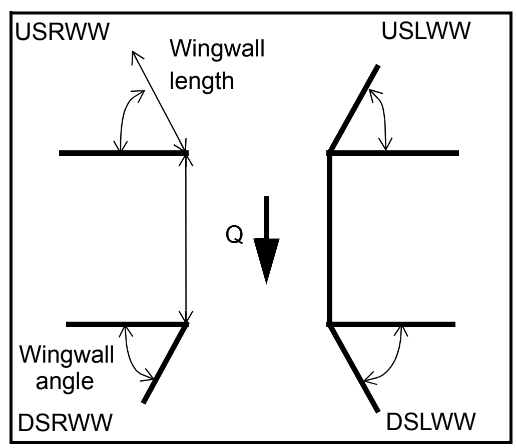
0.5
0
2

75. Scour at the abutments is minor when one considers they have remained stable since 1919 with 0.5 feet of scour depth at the upstream corners of both abutments. Penetration is 0.5 feet under the stones. The scour is the removal of fines below the abutments.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						26.0	
USRWW:	Y		2		0	1.5	
DSLWW:	-		-		Y	14.0	
DSRWW:	2		1		0	14.5	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	0	1	Y	0	-	-	-	-
Condition	Y	1.0	2	0	-	-	-	-
Extent	2	0	1	0	0	0	0	-

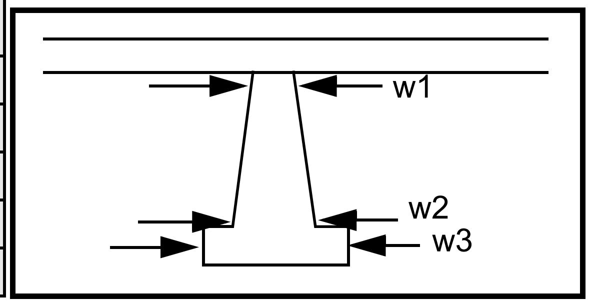
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **80.** *(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	10	0	20	9	13	21.5
Pier 2	20	-	-	13.5	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	Min	sion	pro-		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	or	of	tru-		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	scou	fines	sion		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	r at	and	of		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	the	con-	the		*Y- yes; N- no*
91. Attack ∠ (BF)	wing	stric-	abut	N	
92. Pushed	walls	tion	ment	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	is	of	s.	-	
95. Cross-members	due	the		-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	to	strea		-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	the	m by		-	
98. Exposure depth	ero-	the		-	

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

-
-
-
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width (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):

-
-
-
-

NO PIERS

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 **3** %RB

Material: **1**

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

21
21
1
3

Is a cut-bank present? **34** *(Y or if N type ctrl-n cb)* Where? **2** *(LB or RB)* Mid-bank distance: **0**

Cut bank extent: **0** feet **-** *(US, UB, DS)* to **-** feet **Ba** *(US, UB, DS)*

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

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

material: sand and silt/clay
Bed material: gravel and cobble and some sand.
Note: A beaver dam is 20 ft. downstream of mid-span of the bridge deck; height of the dam is 3.5 ft.

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

Scour dimensions: Length ______ Width ______ Depth: _____ Positioned ____ %LB to ____ %RB

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

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

Confluence 1: Distance **NO** Enters on **DR** *(LB or RB)* Type **OP** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

RE

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

1- *Constructed*
2- *Stable*
3- *Aggraded*
4- *Degraded*
5- *Laterally unstable*
6- *Vertically and laterally unstable*

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

N
-
-
-
-
-
-
-
-
-

109. G. Plan View Sketch

N

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: RANDTH00650035 Town: Randolph
Road Number: TH65 County: Orange
Stream: 2nd Branch White River

Initials SAO Date: 7/9/96 Checked: EMB 7/22/96

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	7100	10000	1230
Main Channel Area, ft2	551	598	287
Left overbank area, ft2	327	421	0
Right overbank area, ft2	166	257	0
Top width main channel, ft	53	53	49
Top width L overbank, ft	101	113	6
Top width R overbank, ft	96	111	0
D50 of channel, ft	0.0045	0.0045	0.0045
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.4	11.3	5.9
y1, average depth, LOB, ft	3.2	3.7	0.0
y1, average depth, ROB, ft	1.7	2.3	ERR
Total conveyance, approach	126550	158665	32313
Conveyance, main channel	91077	104227	32311
Conveyance, LOB	26634	37644	2
Conveyance, ROB	8839	16794	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	5109.8	6569.0	1229.9
Ql, discharge, LOB, cfs	1494.3	2372.5	0.1
Qr, discharge, ROB, cfs	495.9	1058.5	0.0
Vm, mean velocity MC, ft/s	9.3	11.0	4.3
Vl, mean velocity, LOB, ft/s	4.6	5.6	ERR
Vr, mean velocity, ROB, ft/s	3.0	4.1	ERR
Vc-m, crit. velocity, MC, ft/s	2.7	2.8	2.5
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	1	1	1
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

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	7100	10000	1230	7100	10000	1230
Total conveyance	126550	158665	32313	--	--	--
Main channel conveyance	91077	104227	32311	--	--	--
Main channel discharge	5110	6569	1230	1300	1202	1230
Area - main channel, ft2	551	598	287	260	260	165
(W1) channel width, ft	53	53	49	25.6	25.6	25.4
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	53	53	49	25.6	25.6	25.4
D50, ft	0.0045	0.0045	0.0045			
w, fall velocity, ft/s (p. 32)	0.53	0.53	0.53			
y, ave. depth flow, ft	10.40	11.28	5.86	10.16	10.16	6.50
S1, slope EGL	0.0005	0.0005	0.002			
P, wetted perimeter, MC, ft	59	59	55			
R, hydraulic Radius, ft	9.339	10.136	5.218			
V*, shear velocity, ft/s	0.388	0.404	0.580			
V*/w	0.732	0.762	1.094			
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	0.64	0.64	0.64			
y2,depth in contraction, ft	5.12	4.19	8.92			
ys, scour depth, ft (y2-y_bridge)	-5.03	-5.96	2.42			

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	551	598	287
Main channel width, ft	53	53	49
y1, main channel depth, ft	10.40	11.28	5.86

Bridge Section			
(Q) total discharge, cfs	7100	10000	1230
(Q) discharge thru bridge, cfs	1300	1202	1230
Main channel conveyance	29137	29137	20882
Total conveyance	29137	29137	20882

Q2, bridge MC discharge,cfs	1300	1202	1230
Main channel area, ft2	260	260	165
Main channel width (skewed), ft	25.6	25.6	25.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	25.6	25.6	25.4
y_bridge (avg. depth at br.), ft	10.16	10.16	6.50
Dm, median (1.25*D50), ft	0.2295	0.2295	0.2295
y2, depth in contraction,ft	5.46	5.11	5.24
ys, scour depth (y2-ybridge), ft	-4.70	-5.05	-1.25

ARMORING

D90	0.433	0.433	0.433
D95	0.547	0.547	0.547
Critical grain size,Dc, ft	0.0788	0.0674	0.2065
Decimal-percent coarser than Dc	0.834	0.875	0.432
Depth to armoring,ft	0.05	0.03	0.81

PRESSURE FLOW SCOUR COMPUTATION

Structure Number: RANDTH00650035 Town: Randolph
Road Number: TH 65 County: Orange
Stream: Second Branch White River
Intial: EMB Date: 10/10/96 Checked:
Pressure Flow Scour (contraction scour for orifice flow condtions)

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

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	1300	1202	0
Vc, critical velocity, ft/s	2.7	2.8	2.5
Vc, critical velocity, m/s	0.82292	0.853398	0.761963
Main channel width (skewed), ft	25.6	25.6	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	25.6	25.6	0
qbr, unit discharge, ft^2/s	50.78125	46.95313	ERR
qbr, unit discharge, m^2/s	4.717272	4.361662	N/A
Area of full opening, ft^2	260.3	260.3	0
Hb, depth of full opening, ft	10.16797	10.16797	ERR
Hb, depth of full opening, m	3.099046	3.099046	N/A
Fr, Froude number MC	0.28	0.26	1
Cf, Fr correction factor (<=1.0)	0.867699	0.840485	1.5
Elevation of Low Steel, ft	499.62	499.62	0
Elevation of Bed, ft	489.452	489.452	N/A
Elevation of approach WS, ft	501.63	502.51	0
HF, bridge to approach, ft	0.02	0.02	0
Elevation of WS immediately US, ft	501.61	502.49	0
ya, depth immediately US, ft	12.15797	13.03797	N/A
ya, depth immediately US, m	3.778113	4.051575	N/A
Mean elev. of deck, ft	501.28	501.28	0
w, depth of overflow, ft (>=0)	0.33	1.21	0
Cc, vert contrac correction (<=1.0)	0.963105	0.963105	ERR
Ys, depth of scour (chang), ft	12.33794	10.54789	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	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	7100	10000	1230	7100	10000	1230
a', abut.length blocking flow, ft	112	124.2	17.4	43.9	43.9	12.1
Ae, area of blocked flow ft2	412.6	505	29.1	154.1	177.3	61.8
Qe, discharge blocked abut.,cfs	543.7	--	61.2	--	--	222.1
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	1.32	1.54	2.10	1.68	1.88	3.59
ya, depth of f/p flow, ft	3.68	4.07	1.67	3.51	4.04	5.11
--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	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.121	0.133	0.287	0.138	0.136	0.280
ys, scour depth, ft	12.06	13.88	5.73	9.16	10.10	11.30

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)	112	124.2	17.4	43.9	43.9	12.1
y1 (depth f/p flow, ft)	3.68	4.07	1.67	3.51	4.04	5.11
a'/y1	30.40	30.55	10.40	12.51	10.87	2.37
Skew correction (p. 49, fig. 16)	1.05	1.05	1.05	0.92	0.92	0.92
Froude no. f/p flow	0.12	0.13	0.29	0.14	0.14	0.28
Ys w/ corr. factor K1/0.55:						
vertical	14.01	15.96	ERR	ERR	ERR	ERR
vertical w/ ww's	11.49	13.08	ERR	ERR	ERR	ERR
spill-through	7.71	8.78	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	0.28	0.26	0.52	0.28	0.26	0.52
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	10.16	10.16	6.5	10.16	10.16	6.5
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	0.49	0.42	1.09	0.49	0.42	1.09
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR