LEVEL II SCOUR ANALYSIS FOR BRIDGE 38 (RANDTH00640038) on TOWN HIGHWAY 64, crossing the SECOND BRANCH of the WHITE RIVER, RANDOLPH, VERMONT

U.S. Geological Survey
Open-File Report 96-587

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

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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 38 (RANDTH00640038) ON TOWN HIGHWAY 64, CROSSING THE SECOND BRANCH OF THE 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 RANDTH00640038 on town highway 64 crossing the Second Branch of the 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 46.5-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the The upstream left bank is forested, the upstream right bank is covered primarily by brush, the surface cover is pasture on the downstream left and row crops on the downstream right.

In the study area, the Second Branch of the White River has an incised, sinuous channel with a slope of approximately 0.0015 ft/ft, an average channel top width of 71 ft and an average channel depth of 8 ft. The predominant channel bed material is gravel with a median grain size (D_{50}) of 32.0 mm (0.105 ft). The geomorphic assessment at the time of the Level I site visits on August 10, 1994 and December 5, 1994 indicated that the reach was laterally unstable.

The town highway 64 crossing of the Second Branch of the White River is a 43-ft-long, one-lane covered bridge consisting of one 35-foot steel-beam span (Vermont Agency of Transportation, written communication, August 1, 1994). The bridge is supported by vertical, stone abutments with upstream wingwalls. The channel bends sharply at it's approach to the bridge, however, at the bridge face, the channel is skewed approximately 0 degrees to the opening. The opening-skew-to-roadway is also 0 degrees.

A scour hole 2 ft deeper than the mean thalweg depth was observed upstream of the bridge along the outside of the channel bend. Other scour problems at this site included undermining of the right abutment at it’s upstream and downstream ends. 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 1.7 to 2.6 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 7.2 to 24.2 ft. The worst-case abutment scour also occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and 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 RANDTH00640038 ***Stream*** Second Branch of the White River

County Orange ***Road*** TH64 ***District*** 4

Description of Bridge

Bridge length 43 ***ft*** ***Bridge width*** 14.0 ***ft*** ***Max span length*** 35 ***ft***

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

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

Stone fill on abutment? Yes, left ***Date of inspection*** 11/08/94

Description of stone fill There is type-2 stone fill (less than 36 inches diameter) along the left abutment extending 20 ft. upstream on the left bank.

Brief description of piers/abutments Abutments are stone. The upstream and downstream ends on the right abutment are undermined by 1.5 and 2.0 feet, respectively.

Is bridge skewed to flood flow according to Y ***survey?*** N ***Angle*** 0

There is a severe bend upstream of the bridge impacting the upstream left bank. However, as the channel reaches the upstream face it aligns with the abutments.

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	8/10/94 and 12/5/94	0	0
Level II	8/10/94	0	0

Potential for debris Moderate.

Describe any features near or at the bridge that may affect flow (include observation date) August 10, 1994 and December 5, 1994. The channel bends sharply as it approaches the bridge. At higher discharges, flow will overtop the right road approach allowing some relief to the bridge opening.

Description of the Geomorphic Setting

General topography Upstream of the structure is a natural constriction and the valley is narrow (see Figure 1). Downstream, the valley is wide and irregular with steep valley walls

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

Date of inspection 8/10/94 and 12/5/94

DS left: Flood plain to steep valley wall.

DS right: Flood plain to steep valley wall.

US left: Narrow flood plain to steep valley wall.

US right: Narrow flood plain to steep valley wall.

Description of the Channel

Average top width 71 ***ft*** ***Average depth*** 8 ***ft***

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

Sinuous, incised channel with alluvial boundaries

8/10/94 and 12/5/94

Vegetative co Pasture with trees and brush on immediate channel bank.

DS left: Pasture.

DS right: Trees and brush.

US left: Field grasses and gravel roadway.

US right: N

Do banks appear stable? August 10, 1994 and December 5, 1994. The channel is laterally unstable. Cut banks exist in the reach, the most severe is on the downstream right bank.

date of observation.

August 10, 1994 and December 5, 1994. None.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 46.5 ***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***: None. Much of the basin is forested, the remainder is agricultural land.

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 7,100 ***ft³/s*** ***Q500*** 10,000 ***ft³/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 Subtract 401 feet from USGS survey to obtain VTAOT plans' datum to the nearest foot.

Description of reference marks used to determine USGS datum. RM1 is a chiseled square in concrete on top of the downstream right corner of the right abutment (elev. 502.48 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT	0	1	Exit section
FV	55	2	Downstream Full-valley section (Templated from EXIT)
BRDG	55	1	Bridge section
RDWAY	62	1	Road Grade section
APPRO	103	2	Modelled Approach section (Templated from APTEM)
APTEM	143	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 0.035 to 0.045, and overbank "n" values ranged from 0.035 to 0.075.

Normal depth at the exit section (EXIT) 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 0.0015 ft/ft which was the bed slope measured from the Flood Insurance Study profile plot (Federal Emergency Management Agency, 1991).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0132 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 503.4 *ft*
Average low steel elevation 501.1 *ft*

100-year discharge 7,100 *ft^3/s*
Water-surface elevation in bridge opening 501.7 *ft*
Road overtopping? Y *Discharge over road* 3,680 *s*
Area of flow in bridge opening 371 *ft^2*
Average velocity in bridge opening 9.2 *ft/s*
Maximum WSPRO tube velocity at bridge 11.3 *ft/s*

Water-surface elevation at Approach section with bridge 503.6
Water-surface elevation at Approach section without bridge 501.7
Amount of backwater caused by bridge 1.9 *t*

500-year discharge 10,000 *ft^3/s*
Water-surface elevation in bridge opening 501.7 *ft*
Road overtopping? Y *Discharge over road* 6,550
Area of flow in bridge opening 371 *ft^2*
Average velocity in bridge opening 9.3 *ft/s*
Maximum WSPRO tube velocity at bridge 11.4 */s*

Water-surface elevation at Approach section with bridge 505.3
Water-surface elevation at Approach section without bridge 503.4
Amount of backwater caused by bridge 1.9

Incipient overtopping discharge 2,050 *ft^3/s*
Water-surface elevation in bridge opening 496.2 *ft*
Area of flow in bridge opening 220 *ft^2*
Average velocity in bridge opening 9.3 *ft/s*
Maximum WSPRO tube velocity at bridge 11.7 *ft/s*

Water-surface elevation at Approach section with bridge 497.5
Water-surface elevation at Approach section without bridge 496.8
Amount of backwater caused by bridge 0.7 *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.

Contraction scour for the 100- and 500-year events was computed by use of the Chang pressure-flow scour equation (Richardson and others, 1995, p. 145-146). For the 100- and 500-year discharges, there was submerged orifice flow at the bridge. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996) . The results of Laursen's clear-water contraction scour for these discharges were also computed and can be found in appendix F. Contraction scour for the incipient road-overflow discharge was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20).

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.3	2.6	1.7
Depth to armoring	2.7	2.9	5.3
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	17.7	20.3	7.2
Right abutment	22.4	24.2	15.2
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	1.6	1.6	1.8
Right abutment	1.6	1.6	1.8
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

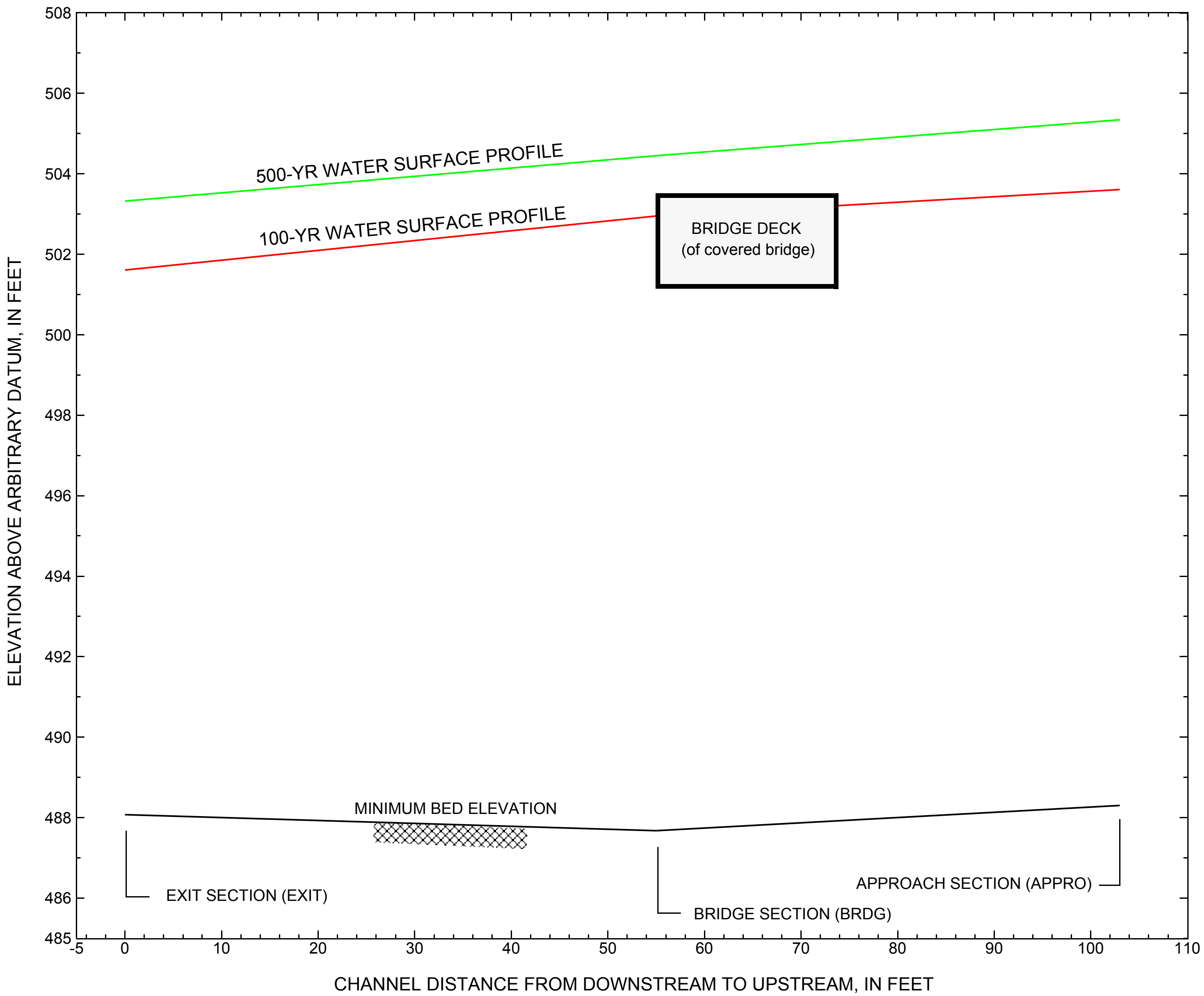

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RANDTH00640038 on town highway 64, crossing Second Branch of the White River, Randolph, Vermont.

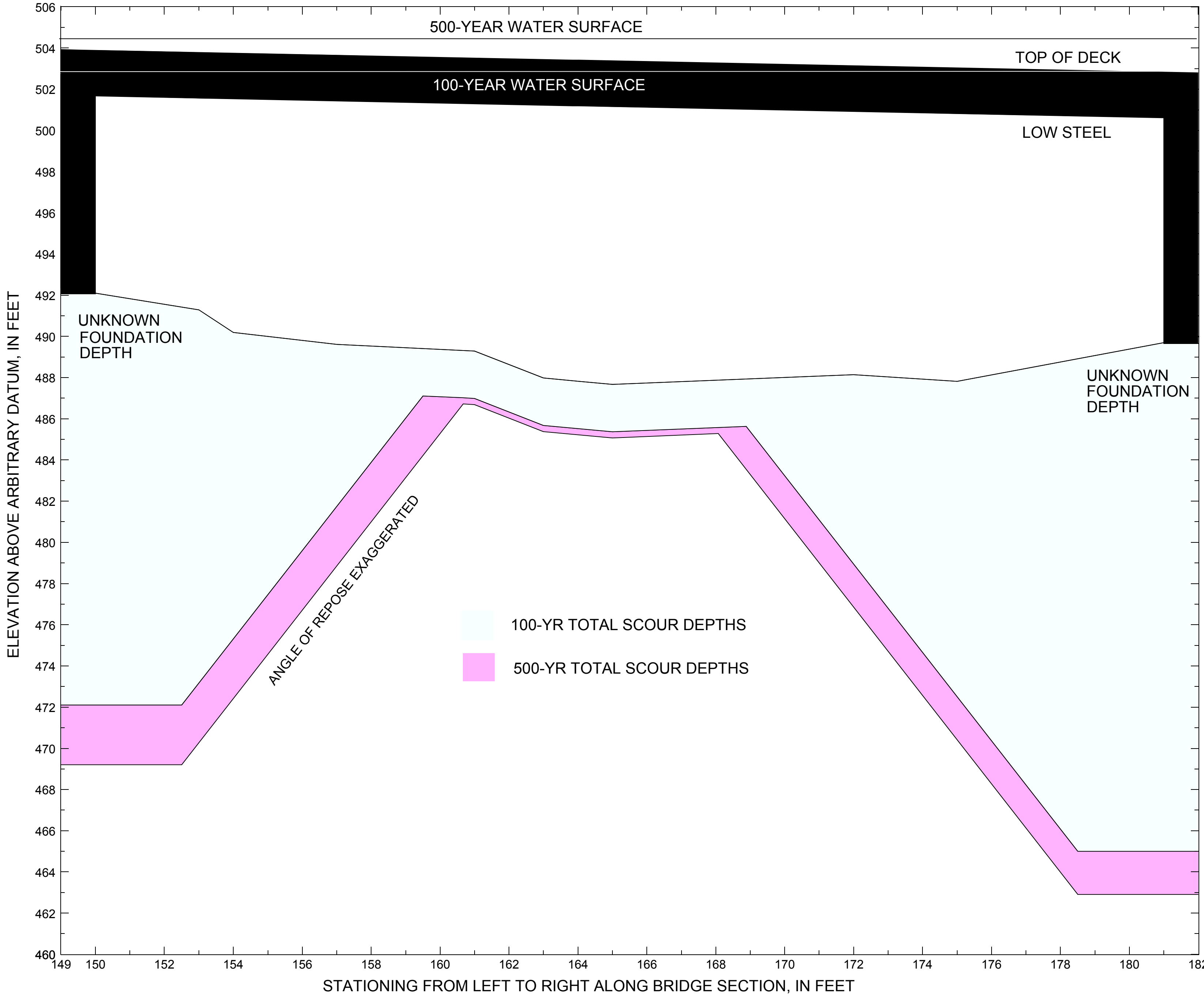

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RANDTH00640038 on town highway 64, crossing Second Branch of the White River, Randolph, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RANDTH00640038 on Town Highway 64, crossing Second Branch of the White River, Randolph, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT bridge seat 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	150	100.0	501.7	--	492.1	2.3	17.7	--	20.0	472.1	--
Right abutment	181	101.1	500.6	--	489.7	2.3	22.4	--	24.7	465.0	--

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 RANDTH00640038 on Town Highway 64, crossing Second Branch of the White River, Randolph, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT bridge seat 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	150	100.0	501.7	--	492.1	2.6	20.3	--	22.9	469.2	--
Right abutment	181	101.1	500.6	--	489.7	2.6	24.2	--	26.8	462.9	--

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158

Federal Emergency Management Agency, 1991, Flood Insurance Study, Town of Randolph, Orange County, Vermont: Washington, D.C., July 16, 1991.

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

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            HYDRAULIC ANALYSIS
T2            Randolph, VT  BRIDGE #038
T3            USGS  BOW,NH   06/05/96
*
J1         * * 0.001
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q             7100 10000 2050
SK            0.0015 0.0015 0.0015
*
XS   EXIT     0
GR           -11., 513.99      36., 506.13      92., 502.67     120., 502.04
GR           127., 496.63     136., 494.62     139., 491.01     150., 490.27
GR           154., 489.53     158., 489.51     159., 490.60     170., 489.55
GR           173., 489.18     183., 488.07     194., 489.11     198., 491.98
GR           203., 493.45     213., 494.65     253., 496.83     267., 497.72
GR           292., 498.61     333., 502.37     380., 506.79     403., 512.05
N               0.050        0.045        0.035
SA                    120.         203.
*
XS   FV        55
*
BR   BRDG      55 501.1
GR           150., 501.67     150., 492.07     153., 491.29     154., 490.19
GR           157., 489.61     161., 489.29     163., 487.98     165., 487.67
GR           172., 488.14     175., 487.82     180., 489.65     181., 500.61
GR           150., 501.67
N                0.035
CD             1 17.8 * * 15 3.9
*
XR   RDWAY     62 14 2
GR            54., 512.63      68., 509.74     108., 506.33     150., 504.02
GR           150., 514.00     186., 514.00     186., 502.72     201., 501.69
GR           226., 499.16     252., 498.07     292., 499.43     299., 499.66
GR           331., 502.71     372., 506.37     408., 514.07
BP            150
*
XT   APTEM    143
GR            88., 506.75      99., 499.70     108., 496.66     145., 495.59
GR           150., 494.21     154., 492.83     156., 491.33     157., 489.38
GR           163., 488.83     171., 489.22     190., 489.90     192., 490.68
GR           200., 495.57     208., 498.69     252., 498.07     292., 499.43
GR           299., 499.66     331., 502.71     372., 506.37     408., 514.07
*
AS   APPRO    103
GT           -0.53
N               0.075        0.040        0.035
SA                     145.         208.
BP           145 208 40 95
*
HP 1 BRDG  501.67 1 501.67
HP 2 BRDG  501.67 * * 3418
HP 2 RDWAY 502.95 * * 3676
HP 1 APPRO 503.61 1 503.61
HP 2 APPRO 503.61 * * 7100
HP 1 BRDG  501.67 1 501.67
HP 2 BRDG  501.67 * * 3447
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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          HYDRAULIC ANALYSIS
          Randolph, VT  BRIDGE #038
          USGS  BOW,NH   06/05/96
         *** RUN DATE & TIME: 06-06-96  08:01
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRDG ;  SRD =      55.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     371.   42851.     0.    83.                           0.
  501.67          371.   42851.     0.    83.  1.00   150.   181.      0.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRDG ;  SRD =      55.
        WSEL     LEW     REW    AREA        K        Q    VEL
      501.67   150.0   181.0   371.1   42851.    3418.   9.21
X STA.      150.0      153.3      155.2      156.8      158.3      159.7
  A(I)           32.9       21.7       18.5       17.7       17.0
  V(I)           5.19       7.88       9.22       9.65      10.04

X STA.      159.7      161.1      162.4      163.6      164.8      165.9
  A(I)           16.5       16.4       15.8       15.4       15.4
  V(I)          10.35      10.41      10.79      11.12      11.08

X STA.      165.9      167.1      168.2      169.4      170.6      171.8
  A(I)           15.2       15.1       15.7       15.7       15.7
  V(I)          11.24      11.33      10.92      10.90      10.87

X STA.      171.8      173.1      174.5      175.9      177.6      181.0
  A(I)           16.6       17.2       18.0       21.3       33.2
  V(I)          10.31       9.93       9.50       8.02       5.14

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      62.
        WSEL     LEW     REW    AREA        K        Q    VEL
      502.95   186.0   333.7   435.6   39543.    3676.   8.44
X STA.      186.0      214.6      222.1      227.8      232.7      237.1
  A(I)           37.6       22.6       21.1       19.4       18.4
  V(I)           4.89       8.13       8.72       9.46       9.98

X STA.      237.1      241.4      245.4      249.1      252.7      256.3
  A(I)           18.6       17.9       17.6       17.3       17.2
  V(I)           9.91      10.27      10.44      10.60      10.68

X STA.      256.3      260.1      264.2      268.4      273.0      278.0
  A(I)           17.8       18.4       18.7       19.4       20.4
  V(I)          10.34      10.00       9.81       9.49       9.01

X STA.      278.0      283.3      289.2      296.0      304.7      333.7
  A(I)           20.6       21.9       23.9       27.2       39.7
  V(I)           8.94       8.38       7.70       6.76       4.63

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     103.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     366.   25755.    53.    55.                        5452.
            2     787.  150967.    63.    67.                       15773.
            3     607.   68994.   139.   139.                        7201.
  503.61         1759.  245716.   255.   261.  1.37    92.   347.  22385.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     103.
        WSEL     LEW     REW    AREA        K        Q    VEL
      503.61    92.1   347.0  1759.4  245716.    7100.   4.04
X STA.       92.1      123.9      143.4      152.2      158.1      161.9
  A(I)          191.8      160.5       81.9       74.0       57.1
  V(I)           1.85       2.21       4.33       4.80       6.21

X STA.      161.9      165.6      169.3      173.0      176.8      180.7
  A(I)           56.1       56.3       55.9       55.8       57.0
  V(I)           6.33       6.31       6.35       6.36       6.22

X STA.      180.7      184.6      188.8      193.5      201.5      218.7
  A(I)           57.0       60.0       64.4       80.5      102.9
  V(I)           6.23       5.91       5.52       4.41       3.45

X STA.      218.7      234.7      250.5      267.5      288.5      347.0
  A(I)           91.6       93.9       98.8      109.2      154.6
  V(I)           3.88       3.78       3.59       3.25       2.30
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          HYDRAULIC ANALYSIS
          Randolph, VT  BRIDGE #038
          USGS  BOW,NH   06/05/96
         *** RUN DATE & TIME: 06-06-96  08:01
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRDG ;  SRD =      55.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     371.   42851.     0.    83.                          0.
  501.67          371.   42851.     0.    83.  1.00   150.   181.      0.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRDG ;  SRD =      55.
       WSEL     LEW     REW    AREA        K        Q    VEL
     501.67   150.0   181.0   371.1   42851.    3447.   9.29
X STA.       150.0      153.3      155.2      156.8      158.3      159.7
  A(I)            32.9       21.7       18.5       17.7       17.0
  V(I)            5.24       7.95       9.30       9.73      10.13

X STA.       159.7      161.1      162.4      163.6      164.8      165.9
  A(I)            16.5       16.4       15.8       15.4       15.4
  V(I)           10.44      10.49      10.88      11.22      11.17

X STA.       165.9      167.1      168.2      169.4      170.6      171.8
  A(I)            15.2       15.1       15.7       15.7       15.7
  V(I)           11.33      11.43      11.01      11.00      10.96

X STA.       171.8      173.1      174.5      175.9      177.6      181.0
  A(I)            16.6       17.2       18.0       21.3       33.2
  V(I)           10.40      10.01       9.58       8.09       5.19

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      62.
       WSEL     LEW     REW    AREA        K        Q    VEL
     504.45   142.2   350.5   671.5   72352.    6554.   9.76
X STA.       142.2      209.2      217.5      223.9      229.4      234.5
  A(I)            61.3       33.4       30.4       29.0       28.2
  V(I)            5.35       9.83      10.77      11.30      11.63

X STA.       234.5      239.2      243.8      248.1      252.3      256.5
  A(I)            27.2       27.3       26.2       26.6       26.6
  V(I)           12.04      12.00      12.53      12.32      12.33

X STA.       256.5      261.0      265.6      270.5      275.8      281.5
  A(I)            27.6       27.7       28.8       29.9       31.0
  V(I)           11.89      11.82      11.38      10.96      10.58

X STA.       281.5      287.6      294.4      302.0      313.0      350.5
  A(I)            32.0       34.4       36.5       43.9       63.6
  V(I)           10.25       9.53       8.97       7.46       5.16

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     103.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     459.   36296.    56.    58.                       7493.
            2     896.  187415.    63.    67.                      19162.
            3     864.  113929.   158.   159.                      11460.
  505.34         2220.  337640.   277.   284.  1.33    89.   366.  30883.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     103.
       WSEL     LEW     REW    AREA        K        Q    VEL
     505.34    89.4   366.4  2219.6  337640.   10000.   4.51
X STA.        89.4      122.8      142.0      151.9      158.4      162.7
  A(I)           238.0      190.8      108.6       92.3       73.3
  V(I)            2.10       2.62       4.60       5.42       6.82

X STA.       162.7      167.0      171.2      175.5      179.8      184.3
  A(I)            71.5       70.5       71.6       71.5       73.0
  V(I)            6.99       7.10       6.98       7.00       6.85

X STA.       184.3      188.9      194.3      203.9      219.1      233.8
  A(I)            73.7       81.5      106.3      113.5      109.3
  V(I)            6.78       6.14       4.70       4.41       4.57

X STA.       233.8      248.3      263.1      279.4      300.3      366.4
  A(I)           110.8      113.0      116.8      135.7      198.1
  V(I)            4.51       4.43       4.28       3.69       2.52
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            HYDRAULIC ANALYSIS
            Randolph, VT  BRIDGE #038
            USGS  BOW,NH   06/05/96
           *** RUN DATE & TIME: 06-06-96  08:01
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRDG ;  SRD =      55.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1      220.   28103.    31.    42.                      3341.
    496.23           220.   28103.    31.    42.  1.00   150.   181.   3341.

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRDG ;  SRD =      55.
          WSEL     LEW     REW    AREA        K        Q    VEL
        496.23   150.0   180.6   219.7   28103.    2050.   9.33
 X STA.       150.0      154.2      156.2      157.9      159.5      161.0
   A(I)            20.2       12.9       11.3       10.6       10.0
   V(I)            5.08       7.97       9.05       9.66      10.23

 X STA.       161.0      162.4      163.6      164.6      165.6      166.7
   A(I)            10.5        9.6        8.8        8.8        8.8
   V(I)            9.72      10.71      11.64      11.62      11.69

 X STA.       166.7      167.7      168.8      169.9      171.0      172.1
   A(I)             8.9        8.8        8.8        9.0        9.3
   V(I)           11.55      11.65      11.61      11.33      11.03

 X STA.       172.1      173.3      174.5      175.8      177.3      180.6
   A(I)             9.4       10.1       10.6       12.4       20.8
   V(I)           10.85      10.14       9.65       8.26       4.93
1      CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     103.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1       74.    2190.    41.    41.                       569.
              2      404.   50619.    61.    66.                      5884.
    497.53           479.   52808.   103.   107.  1.24   104.   206.   5273.

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     103.
          WSEL     LEW     REW    AREA        K        Q    VEL
        497.53   103.9   206.4   478.6   52808.    2050.   4.28
 X STA.       103.9      147.4      154.3      157.9      160.1      162.2
   A(I)            81.3       28.8       25.7       19.9       18.3
   V(I)            1.26       3.56       3.99       5.16       5.60

 X STA.       162.2      164.1      166.0      168.0      169.9      171.9
   A(I)            18.2       17.2       17.9       17.5       17.3
   V(I)            5.63       5.97       5.74       5.87       5.93

 X STA.       171.9      173.9      175.9      178.1      180.2      182.4
   A(I)            17.8       17.6       18.3       18.3       18.8
   V(I)            5.77       5.82       5.60       5.59       5.44

 X STA.       182.4      184.7      187.2      189.9      193.2      206.4
   A(I)            19.4       20.3       21.9       25.0       39.1
   V(I)            5.29       5.04       4.68       4.10       2.62
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WSPRO OUTPUT FILE (continued)

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          HYDRAULIC ANALYSIS
          Randolph, VT  BRIDGE #038
          USGS  BOW,NH   06/05/96
         *** RUN DATE & TIME: 06-06-96  08:01

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

EXIT :XS   ******   121.    1356.  0.45 *****  502.06  497.36   7100.  501.61
        0. ******   325.  183171.  1.06 ***** *******    0.37    5.24

FV   :FV      55.   120.    1377.  0.44  0.08  502.15 *******   7100.  501.72
       55.    55.   326.  187175.  1.06  0.00    0.01    0.36    5.16
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      48.    95.    1288.  0.68  0.08  502.35 *******   7100.  501.67
      103.    48.   326.  161763.  1.44  0.12   -0.01    0.49    5.51
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   501.72     501.10

          <<<<<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

BRDG :BR      55.   150.     371.  1.32 *****  502.99  496.35   3418.  501.67
       55. ******   181.   42851.  1.00 ***** *******    0.47    9.21

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    6.  0.800  0.000  501.10 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      62.    34.  0.03  0.35  503.93    0.00   3676.  502.95

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    38.   112.   150.   2.1   1.1   7.3  12.3   2.7   3.0
   RT:   3676.   148.   186.   334.   4.9   3.0   9.5   8.4   3.9   3.2

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

APPRO:AS      30.    92.    1759.  0.35  0.18  503.96  499.24   7100.  503.61
      103.    69.   347.  245686.  1.37  0.00    0.00    0.32    4.04

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT :XS       0.   121.   325.   7100.  183171.    1356.    5.24  501.61
   FV   :FV      55.   120.   326.   7100.  187175.    1377.    5.16  501.72
   BRDG :BR      55.   150.   181.   3418.   42851.     371.    9.21  501.67
   RDWAY:RG      62.*******     0.   3676.       0.*********    2.00  502.95
   APPRO:AS     103.    92.   347.   7100.  245686.    1759.    4.04  503.61

  SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT :XS    497.36    0.37  488.07  513.99************  0.45  502.06  501.61
   FV   :FV  ********    0.36  488.07  513.99  0.08  0.00  0.44  502.15  501.72
   BRDG :BR    496.35    0.47  487.67  501.67************  1.32  502.99  501.67
   RDWAY:RG  ****************  498.07  514.07  0.03******  0.35  503.93  502.95
   APPRO:AS    499.24    0.32  488.30  513.54  0.18  0.00  0.35  503.96  503.61
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WSPRO OUTPUT FILE (continued)

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           HYDRAULIC ANALYSIS
           Randolph, VT  BRIDGE #038
           USGS  BOW,NH   06/05/96
          *** RUN DATE & TIME: 06-06-96  08:01

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

EXIT :XS   ******    82.    1751.  0.54 *****  503.86  498.94  10000.  503.32
        0. ******   343.  257972.  1.07 ***** *******    0.40    5.71

FV   :FV      55.    80.    1779.  0.53  0.08  503.95 *******  10000.  503.43
       55.    55.   344.  263339.  1.08  0.00    0.01    0.40    5.62
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      48.    92.    1704.  0.74  0.08  504.13 *******  10000.  503.39
      103.    48.   345.  235326.  1.38  0.10   -0.01    0.47    5.87
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   503.43     501.10

           <<<<<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

BRDG :BR      55.   150.     371.  1.34 *****  503.01  496.40   3447.  501.67
       55. ******   181.   42851.  1.00 ***** *******    0.47    9.29

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  501.10 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG      62.    34.  0.03  0.42  505.73    0.00   6554.  504.45

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     42.     8.   142.   150.   0.4   0.2   5.3  24.6   1.5   2.9
   RT:   6513.   165.   186.   351.   6.4   4.1  11.1   9.7   5.3   3.2

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

APPRO:AS      30.    89.    2219.  0.42  0.24  505.76  500.44  10000.  505.34
      103.    76.   366.  337458.  1.33  0.00    0.00    0.32    4.51

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXIT :XS       0.    82.   343.  10000.  257972.    1751.    5.71  503.32
   FV   :FV      55.    80.   344.  10000.  263339.    1779.    5.62  503.43
   BRDG :BR      55.   150.   181.   3447.   42851.     371.    9.29  501.67
   RDWAY:RG      62.*******    42.   6554.       0.*********    2.00  504.45
   APPRO:AS     103.    89.   366.  10000.  337458.    2219.    4.51  505.34

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXIT :XS    498.94    0.40  488.07  513.99************  0.54  503.86  503.32
   FV   :FV  ********    0.40  488.07  513.99  0.08  0.00  0.53  503.95  503.43
   BRDG :BR    496.40    0.47  487.67  501.67************  1.34  503.01  501.67
   RDWAY:RG  ****************  498.07  514.07  0.03******  0.42  505.73  504.45
   APPRO:AS    500.44    0.32  488.30  513.54  0.24  0.00  0.42  505.76  505.34
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           HYDRAULIC ANALYSIS
           Randolph, VT  BRIDGE #038
           USGS  BOW,NH   06/05/96
          *** RUN DATE & TIME: 06-06-96  08:01

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

EXIT :XS   ******   127.     529.  0.25 *****  496.99  492.99   2050.  496.74
        0. ******   251.   52885.  1.08 ***** *******    0.34    3.87

FV   :FV      55.   127.     542.  0.24  0.08  497.08 *******   2050.  496.83
       55.    55.   253.   54496.  1.09  0.00    0.01    0.34    3.78
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      48.   106.     405.  0.47  0.08  497.27 *******   2050.  496.80
      103.    48.   205.   43603.  1.18  0.11    0.00    0.48    5.06
        <<<<<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

BRDG :BR      55.   150.     220.  1.41  0.16  497.63  494.23   2050.  496.23
       55.    55.   181.   28088.  1.04  0.49    0.00    0.63    9.33

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.982 ******  501.10 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      62.        <<<<<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      30.   104.     479.  0.35  0.16  497.89  493.56   2050.  497.53
      103.    56.   206.   52855.  1.24  0.09    0.01    0.39    4.28

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.689  0.222   41037.   156.   186.   497.48

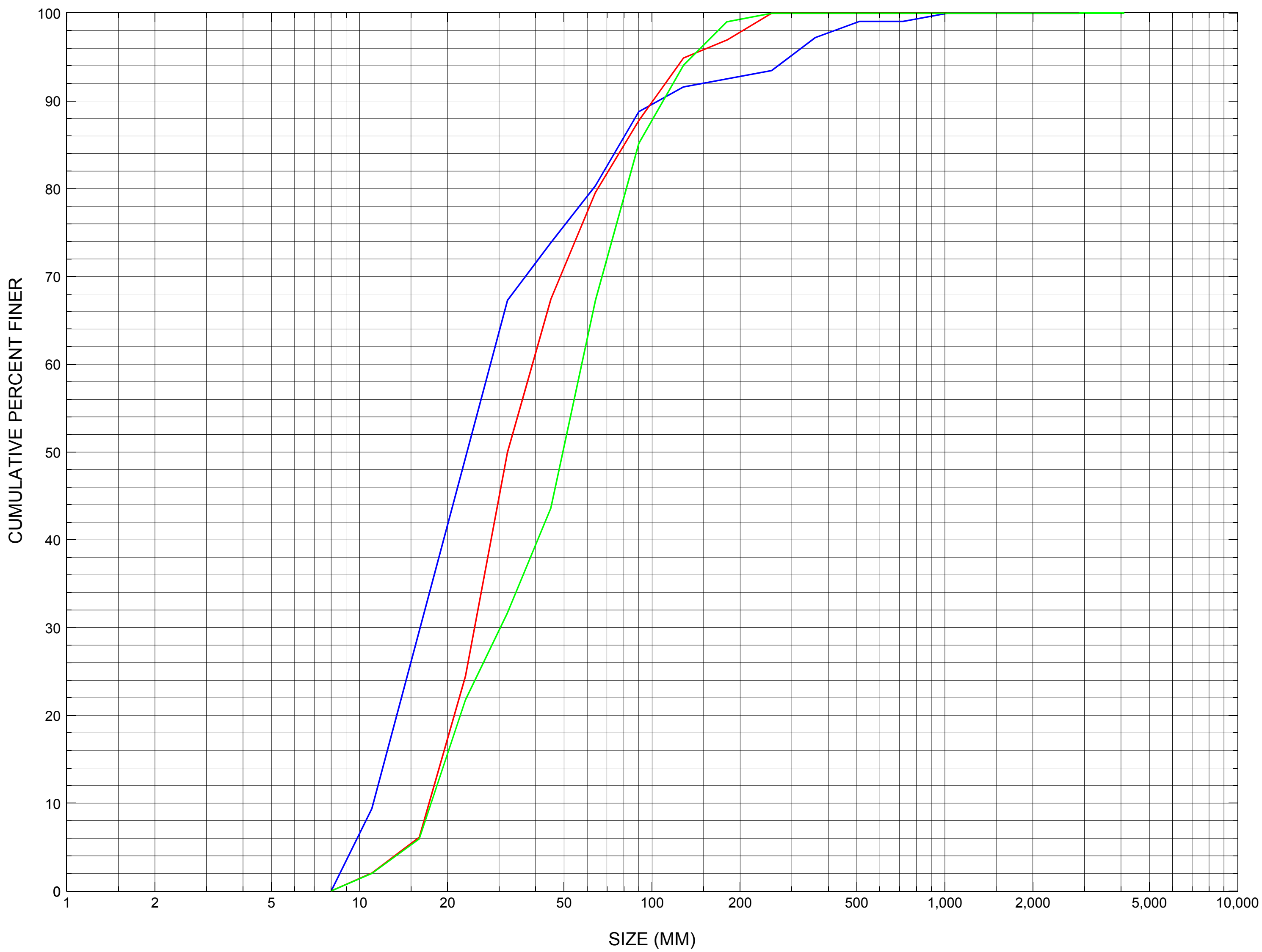
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT :XS       0.   127.   251.   2050.   52885.     529.    3.87  496.74
   FV   :FV      55.   127.   253.   2050.   54496.     542.    3.78  496.83
   BRDG :BR      55.   150.   181.   2050.   28088.     220.    9.33  496.23
   RDWAY:RG      62.**************      0.******************    2.00********
   APPRO:AS     103.   104.   206.   2050.   52855.     479.    4.28  497.53

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     156.   186.   41037.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT :XS    492.99    0.34  488.07  513.99************  0.25  496.99  496.74
   FV   :FV  ********    0.34  488.07  513.99  0.08  0.00  0.24  497.08  496.83
   BRDG :BR    494.23    0.63  487.67  501.67  0.16  0.49  1.41  497.63  496.23
   RDWAY:RG  ****************  498.07  514.07**********************************
   APPRO:AS    493.56    0.39  488.30  513.54  0.16  0.09  0.35  497.89  497.53
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure RANDTH00640038, in Randolph, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number RANDTH00640038

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 01 / 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 TH064

Vicinity *(I - 9)* 0.1 MI JCT TH 64 + VT 14

Topographic Map Randolph.Center

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43558

Longitude *(i - 17; nnnnn.n)* 72333

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10090900380909

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

Maximum span length *(I - 48; nnnn)* 0035

Year built *(I - 27; YYYY)* 1904

Structure length *(I - 49; nnnnnn)* 000043

Average daily traffic, ADT *(I - 29; nnnnnn)* 000020

Deck Width *(I - 52; nn.n)* 140

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

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

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

Waterway adequacy *(I - 71; n)* 5

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 012.5

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

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

Comments:

Structural inspection report of 8/23/93 indicated voids present in the stonework of the left abutment with settlement cracks in stones above the voids. The report also indicated minor scour along the left abutment and a sharp channel bend from upstream through the bridge. Stone fill was noted as in fair condition. Road wash was indicated at all four corners of 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: **Sand, coarse gravel & some small boulders**

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*): **Moderate**

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)* **46.53** 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 **14.46** mi

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

Main channel slope *(S)* **17.52** 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)*: **08** / **1976**

Project Number **TH 64 BRIDGE 38** Minimum channel bed elevation: **-**

Low superstructure elevation: USLAB **100.0** DSLAB **100.0** USRAB **101.1** DSRAB **101.1**

Benchmark location description:

NONE

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

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

If 1: Footing Thickness **-** Footing bottom elevation: **-**

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

If 3: Footing bottom elevation: **-**

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

Plans refer to rehabilitation of original structure built in 1904. Not very detailed. Elevation of low chord was described as to be set in field. Current elevation is unknown. Abutments consist of laid up stone.

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: **DLS** Date: **2/9/95**
Computerized by: **MAI** Date: **3/20/95**
Reviewd by: **SAO** Date: **8/12/96**

Structure Number **RANDTH00640038**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **8** / **10** / 19**94**

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 **TH064**
Hydrologic Unit Code: **01080105**

3. Descriptive comments:
0.1 miles to the junction to TH 64 and VT 14.
Covered bridge in a low, narrow valley.
Additional Level I data also collected by M. Ivanoff on 12/5/95.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **4** LBDS **4** RBDS **3** 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 **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **43** *(feet)* Span length **35** *(feet)* Bridge width **14** *(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)*

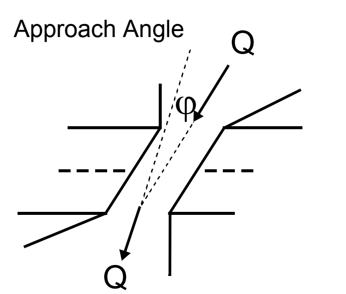
10. Embankment slope (*run / rise in feet / foot*):
US left **0.0:1** US right **0.0:1**

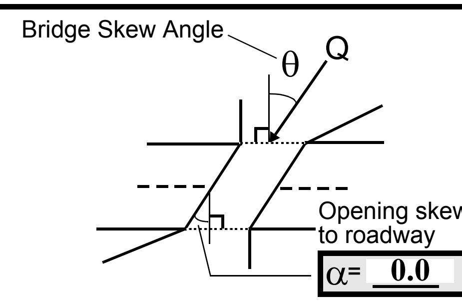
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	2
RBUS	0	-	1	2
RBDS	0	-	3	2
LBDS	0	-	2	1

*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: **90** 16. Bridge skew: **0**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **3**
Range? **20** feet **US** *(US, UB, DS)* to **0** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **3**
Range? **20** feet **US** *(US, UB, DS)* to **60** feet **US**

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

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

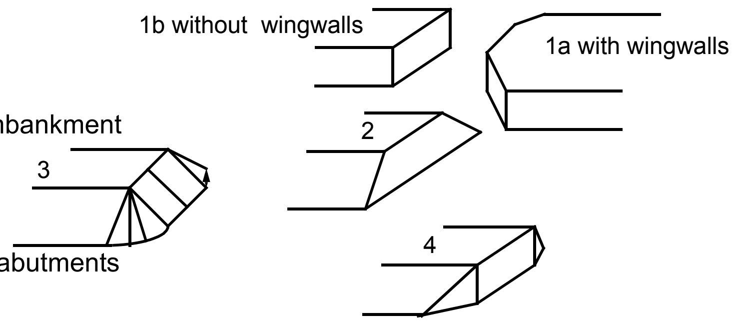
1a- Vertical abutments with wingwalls

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: 43, span: 35, and width: 14.5 feet.

16. The skew angle is variable due to complex flow patterns at this site. The channel makes a sharp bend at the approach to the bridge. However, at the upstream face the average angle is close to 0 degrees.

17. Another impact zone exists 40 to 80 feet downstream with a severity of 3.

19. Road approach (right) overflow width 16 ft.

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
89.9	**5.0**			**8.0**	**3**	**1**	**132**	**231**	**2**	**2**

23. Bank width **35.0** 24. Channel width **25.0** 25. Thalweg depth **58.0** 29. Bed Material **324**

30 .Bank protection type: LB **2** RB **0** 31. Bank protection condition: LB **2** 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.):

28. LB: cut bank erosion downstream of the left bank protection (30). Some slumping has occurred. Protection appears to be in good condition near cut. Bank is over-steepened from the cutting.

30. LB: protection extends 20 ft. from the bridge.

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: **20** 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.):

Exposed tree roots and minor slumping evident locally, otherwise bank is fairly well vegetated.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **20**

47. Scour dimensions: Length **34** Width **20** Depth : **2** Position **20** %LB to **50** %RB

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

Scour hole is at the outside of the bend as the channel approaches the bridge.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
32.5		1.0		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.):

234

61. Abutment is drywall (stone) capped with concrete.

63. Bed material is sand and gravel and some cobble.

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

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

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

70. Debris and Ice Comments:

2

67. No debris accumulation near the bridge the channel is laterally unstable and sinuous with some cut banks.

68. Moderate channel gradient and the span length is 60% 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		0	90	2	0	0	0	90.0
RABUT	2	0	90			2	3	30.0

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

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

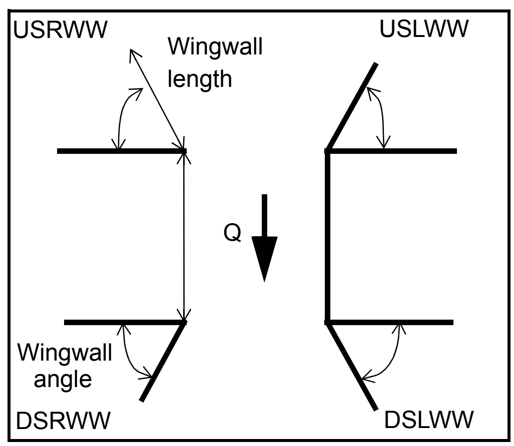
1.8
0
2

71. LABUT: attack angle is assumed to be slight. Although the channel makes a sharp bend as it approaches the bridge, the flow is likely to align with the abutments at bank full flow. The right abutment may experience slight impact as well due to the redirection of flow by the sharp channel bend upstream (see sketch).

75. Erosion under the RABUT corners up and downstream; 1.5 to 2.0 ft. depth.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						23.0	
USRWW:	Y		2		0	2.0	
DSLWW:	-		-		Y	14.5	
DSRWW:	2		1		1.5	19.0	



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

82. **Bank / Bridge Protection**:

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

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

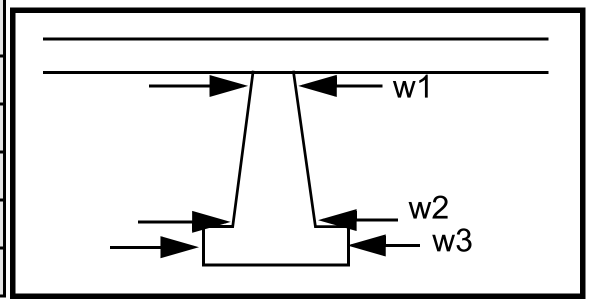
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
0
-
-

Piers:

84. Are there piers? **82.** *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	**15**	**15**	**-**	**3**	**5**	**-**
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**LAB**	**near**		**-**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**UT:**	**the**		**-**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**upst**	**brid**		**-**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**ream**	**ge as**		**-**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**left**	**note**		**-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**bank**	**d in**		**-**	
92. Pushed	**is**	**the**		**-**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**pro-**	**pre-**		**-**	
95. Cross-members	**tecte**	**vious**		**-**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**d by**	**sec-**	**N**	**-**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**stone**	**tion.**	**-**	**-**	
98. Exposure depth	**fill**		**-**	**-**	

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.):

-
-
-
-
-
-
-
-
-
-
-
-
-

NO PIERS

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

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

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

106. Point/Side bar present? **2** (Y or N. if N type ctrl-n pb) Mid-bar distance: **1** Mid-bar width: **432**

Point bar extent: **321** feet **1** (US, UB, DS) to **2** feet **32** (US, UB, DS) positioned **0** %LB to **0** %RB

Material: **-**

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

-
Grasses and weeds along the right bank offers limited bank stability.
Channel widens downstream of the bridge.
Bank material LB: cobble and gravel and some sand. RB: gravel and sand and some silt/ clay.

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

Cut bank extent: **erial** feet **:** (US, UB, DS) to **grav** feet **el** (US, UB, DS)

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

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

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.):

N
-
NO DROP STRUCTURE

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

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

Confluence 2: Distance **Y** Enters on **50** (LB or RB) Type **30** (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

20
DS

F. Geomorphic Channel Assessment

107. Stage of reach evolution **200**

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

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

DS
20
50
423
Point bar is slightly vegetated.

Y
RB
70
15
DS

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:	RANDTH00640038	Town:	Randolph
Road Number:	TH64	County:	Orange
Stream:	2nd Branch White River		

Initials SAO Date: 6/6/96 Checked: EMB 07/24/96

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	2050
Main Channel Area, ft2	787	896	404
Left overbank area, ft2	366	459	74
Right overbank area, ft2	607	864	0
Top width main channel, ft	63	63	61
Top width L overbank, ft	53	56	41
Top width R overbank, ft	139	158	0
D50 of channel, ft	0.105	0.105	0.105
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	12.5	14.2	6.6
y1, average depth, LOB, ft	6.9	8.2	1.8
y1, average depth, ROB, ft	4.4	5.5	--
Total conveyance, approach	245716	337640	52808
Conveyance, main channel	150967	187415	50619
Conveyance, LOB	25755	36296	2190
Conveyance, ROB	68994	113929	0
Percent discrepancy, conveyance	0.0000	0.0000	-0.0019
Qm, discharge, MC, cfs	4362.2	5550.7	1965.0
Ql, discharge, LOB, cfs	744.2	1075.0	85.0
Qr, discharge, ROB, cfs	1993.6	3374.3	0.0
Vm, mean velocity MC, ft/s	5.5	6.2	4.9
Vl, mean velocity, LOB, ft/s	2.0	2.3	1.1
Vr, mean velocity, ROB, ft/s	3.3	3.9	--
Vc-m, crit. velocity, MC, ft/s	8.1	8.2	7.2
Vc-l, crit. velocity, LOB, ft/s	--	--	--
Vc-r, crit. velocity, ROB, ft/s	--	--	--

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

Main Channel	0	0	0
Left Overbank	--	--	--
Right Overbank	--	--	--

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	787	896	404
Main channel width, ft	63	63	61
y1, main channel depth, ft	12.49	14.22	6.62

Bridge Section			
(Q) total discharge, cfs	7100	10000	2050
(Q) discharge thru bridge, cfs	3418	3447	2050
Main channel conveyance	42851	42851	28103
Total conveyance	42851	42851	28103
Q2, bridge MC discharge,cfs	3418	3447	2050
Main channel area, ft2	371	371	220
Main channel width (skewed), ft	31.0	31.0	30.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	31	31	30.6
y_bridge (avg. depth at br.), ft	11.97	11.97	7.19
Dm, median (1.25*D50), ft	0.09425	0.09425	0.09425
y2, depth in contraction,ft	13.69	13.79	8.93
ys, scour depth (y2-ybridge), ft	1.72	1.82	1.74

ARMORING			
D90	0.345	0.345	0.345
D95	0.513	0.513	0.513
Critical grain size,Dc, ft	0.2341	0.2381	0.2855
Decimal-percent coarser than Dc	0.205339	0.19965	0.138746
Depth to armoring,ft	2.72	2.86	5.32

PRESSURE FLOW SCOUR COMPUTATION

Structure Number: RANDTH00640038 Town: Randolph
Road Number: TH 64 County: Orange
Stream: Second Branch White River
InItial: EMB Date: 10/10/96 Checked:
Pressure Flow Scour (contraction scour for orifice flow condItions)

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

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	3418	3447	0
Vc, critical velocity, ft/s	8.1	8.2	0
Vc, critical velocity, m/s	2.46876	2.499238	0
Main channel width (skewed), ft	31	31	0
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	31	31	0
qbr, unit discharge, ft^2/s	110.2581	111.1935	ERR
qbr, unit discharge, m^2/s	10.24231	10.32921	N/A
Area of full opening, ft^2	371.1	371.1	0
Hb, depth of full opening, ft	11.97097	11.97097	ERR
Hb, depth of full opening, m	3.648573	3.648573	N/A
Fr, Froude number MC	0.47	0.47	1
Cf, Fr correction factor (<=1.0)	1	1	1.5
Elevation of Low Steel, ft	501.1	501.1	0
Elevation of Bed, ft	489.129	489.129	N/A
Elevation of approach WS, ft	503.61	505.34	0
HF, bridge to approach, ft	0.18	0.24	0
Elevation of WS immediately US, ft	503.43	505.1	0
ya, depth immediately US, ft	14.30097	15.97097	N/A
ya, depth immediately US, m	4.444055	4.96301	N/A
Mean elev. of deck, ft	--	--	0
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	0.956455	0.927676	ERR
Ys, depth of scour (chang), ft	2.260858	2.646415	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	2050	7100	10000	2050
a', abut.length blocking flow, ft	57.9	60.6	46.1	27	27	25.4
Ae, area of blocked flow ft2	413.7	501.3	92.2	260.9	284.3	137.7
Qe, discharge blocked abut.,cfs	976.3	--	141.1	--	--	577.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	2.36	2.72	1.53	5.15	5.79	4.20
ya, depth of f/p flow, ft	7.15	8.27	2.00	9.66	10.53	5.42
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.156	0.164	0.191	0.274	0.285	0.318
ys, scour depth, ft	17.66	20.31	7.22	22.36	24.19	15.16

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)	57.9	60.6	46.1	27	27	25.4
y1 (depth f/p flow, ft)	7.15	8.27	2.00	9.66	10.53	5.42
a'/y1	8.10	7.33	23.05	2.79	2.56	4.69
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.16	0.16	0.19	0.27	0.29	0.32
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	0.47	0.47	0.63	0.47	0.47	0.63
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	12	12	7.2	12	12	7.2
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.64	1.64	1.77	1.64	1.64	1.77
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR