LEVEL II SCOUR ANALYSIS FOR BRIDGE 2 (SOMMTH00010002) on TOWN HIGHWAY 1, crossing the RAKE BRANCH DEERFIELD RIVER, SOMERSET, VERMONT

Open-File Report 98-535

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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By RONDA L. BURNS

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 2 (SOMMTH00010002) ON TOWN HIGHWAY 1, CROSSING THE RAKE BRANCH DEERFIELD RIVER, SOMERSET, VERMONT

By **Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SOMMTH00010002 on Town Highway 1 crossing the Rake Branch Deerfield River, Somerset, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in southern Vermont. The 17.0-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, the Rake Branch Deerfield River has an incised, straight channel with a slope of approximately 0.008 ft/ft, an average channel top width of 55 ft and an average bank height of 3 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 106.2 mm (0.348 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 7, 1996, indicated that the reach was stable.

The Town Highway 1 crossing of the Rake Branch Deerfield River is a 45-ft-long, one-lane bridge consisting of one 38-foot steel-beam span (Vermont Agency of Transportation, written communication, September 28, 1995). The opening length of the structure parallel to the bridge face is 35.3 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is not skewed to the opening and the opening-skew-to-roadway is zero degrees.

The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the upstream left wingwall, downstream left and right wingwalls, and at the upstream end of the upstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.1 to 0.4 ft. The worst-case contraction scour occurred at the 100-year discharge. Abutment scour ranged from 9.0 to 15.6 ft. The worst-case abutment scour 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 Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number SOMMTH00010002 ***Stream*** Rake Branch Deerfield River

County Windham ***Road*** TH 1 ***District*** 1

Description of Bridge

Bridge length 45 ***ft*** ***Bridge width*** 14 ***ft*** ***Max span length*** 38 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/7/96

Description of stone fill Type-2, along the upstream left wingwall, the downstream left and right wingwalls, and at the upstream end of the upstream right wingwall.

Abutments and wingwalls are concrete. There are concrete filled bags along the left and right abutments and upstream wingwalls.

No 0

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

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	8/7/96	0	0
Level II	8/7/96	0	0

Potential for debris Moderate.

Describe any features near or at the bridge that may affect flow (include observation date) An overflow channel on the right bank diverts some water at high flows away from the bridge and through two culverts under the right road approach, observed on 8/7/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with narrow flood plains.

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

Date of inspection 8/7/96

DS left: Moderately sloped overbank and steep valley wall

DS right: Narrow flood plain

US left: Moderately sloped overbank and steep valley wall

US right: Narrow flood plain

Description of the Channel

Average top width 55 *ft* ***Average depth*** 3 *ft*

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

Perennial, straight and stable with non-alluvial channel boundaries and narrow point bars.

8/7/96

Vegetative co Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right: Trees and brush

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

None noted on 8/7/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 17.0 ***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.

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 3,250 ***ft³/s*** ***Q500*** 4,700 ***ft³/s***

The 100- and 500-year discharges are the median values from a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left abutment (elev. 508.22 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the right abutment (elev. 507.77 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	-39	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APTEM	52	1	Approach section as surveyed (Used as a template)
APPRO	58	2	Modelled Approach section (Templated from APTEM)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.050 to 0.060, and overbank "n" values ranged from 0.080 to 0.090.

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 0.0077 ft/ft, which was estimated from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0230 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Culvert routines provided with WSPRO are not fully integrated. Therefore, it was necessary to develop individual ratings for the culvert and bridge to model this multiple-opening situation. The ratings were combined to determine the quantity of the total discharge diverted from the bridge through the culverts. The combined ratings indicate the culverts divert 5.5% of the total peak discharge on average. Each modelled discharge was reduced by the flow through the culverts for the model provided in appendices A and B.

Bridge Hydraulics Summary

Average bridge embankment elevation 509.7 ***ft***
Average low steel elevation 508.1 ***ft***

100-year discharge 3,250 ***ft^3/s***
Water-surface elevation in bridge opening 503.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 220 ***ft^3/s***
Area of flow in bridge opening 223 ***ft^2***
Average velocity in bridge opening 12.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.8 ***ft/s***

Water-surface elevation at Approach section with bridge 506.9
Water-surface elevation at Approach section without bridge 504.3
Amount of backwater caused by bridge 2.6 ***ft***

500-year discharge 4,700 ***ft^3/s***
Water-surface elevation in bridge opening 504.6 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,080 ***ft^3/s***
Area of flow in bridge opening 275 ***ft^2***
Average velocity in bridge opening 12.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.9 ***ft/s***

Water-surface elevation at Approach section with bridge 508.1
Water-surface elevation at Approach section without bridge 505.2
Amount of backwater caused by bridge 2.9 ***ft***

Incipient overtopping discharge 2,580 ***ft^3/s***
Water-surface elevation in bridge opening 502.5 ***ft***
Area of flow in bridge opening 204 ***ft^2***
Average velocity in bridge opening 11.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.5 ***ft/s***

Water-surface elevation at Approach section with bridge 505.9
Water-surface elevation at Approach section without bridge 503.8
Amount of backwater caused by bridge 2.1 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year, 500-year, and incipient roadway-overtopping discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.4	0.1	0.1
Depth to armoring	16.7	11.2	12.2
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	11.2	14.1	9.0
Right abutment	13.5	15.6	12.3
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.6	3.2	2.4
Right abutment	2.6	3.2	2.4
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

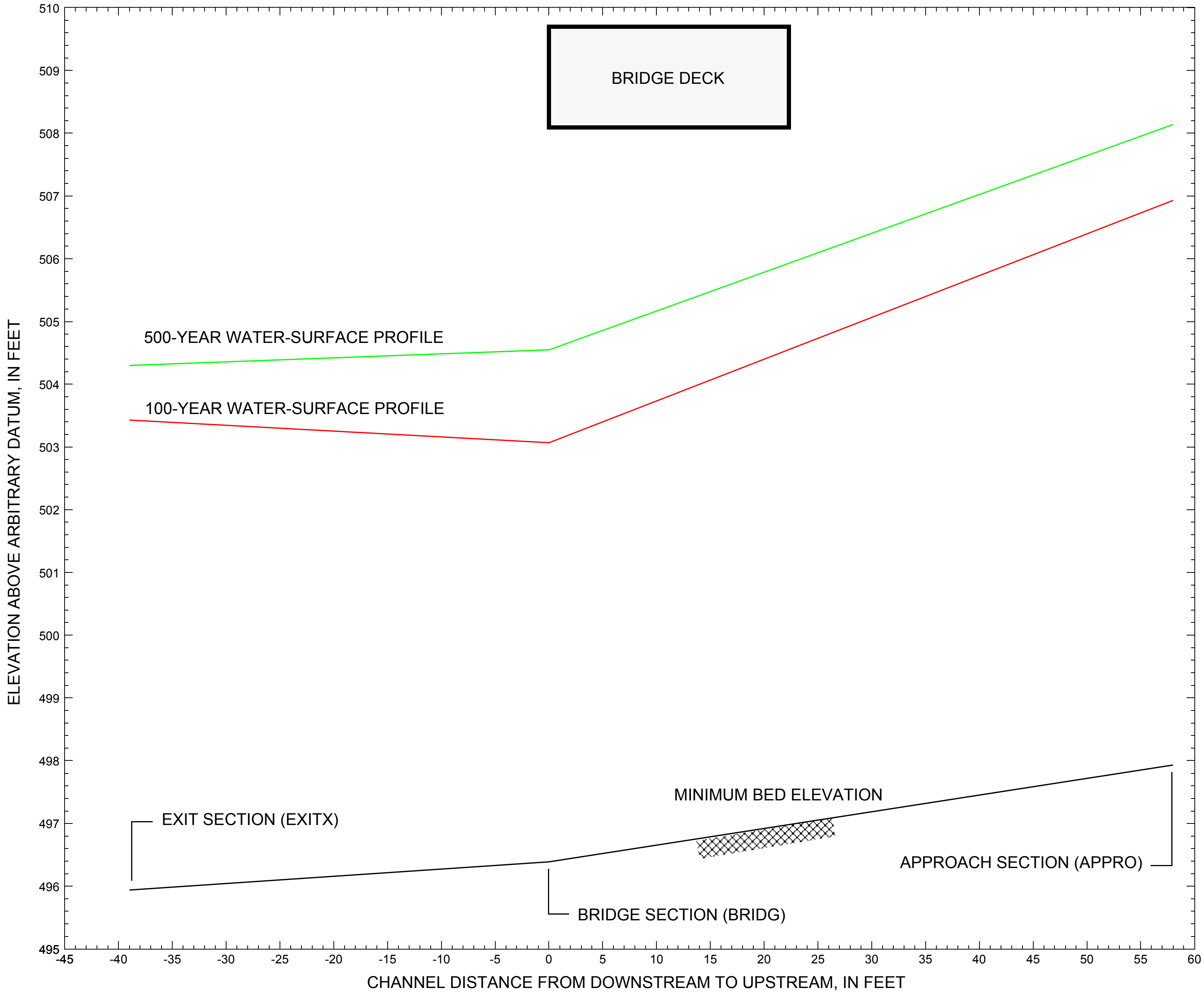

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure SOMMTH00010002 on Town Highway 1, crossing the Rake Branch Deerfield River, Somerset, Vermont.

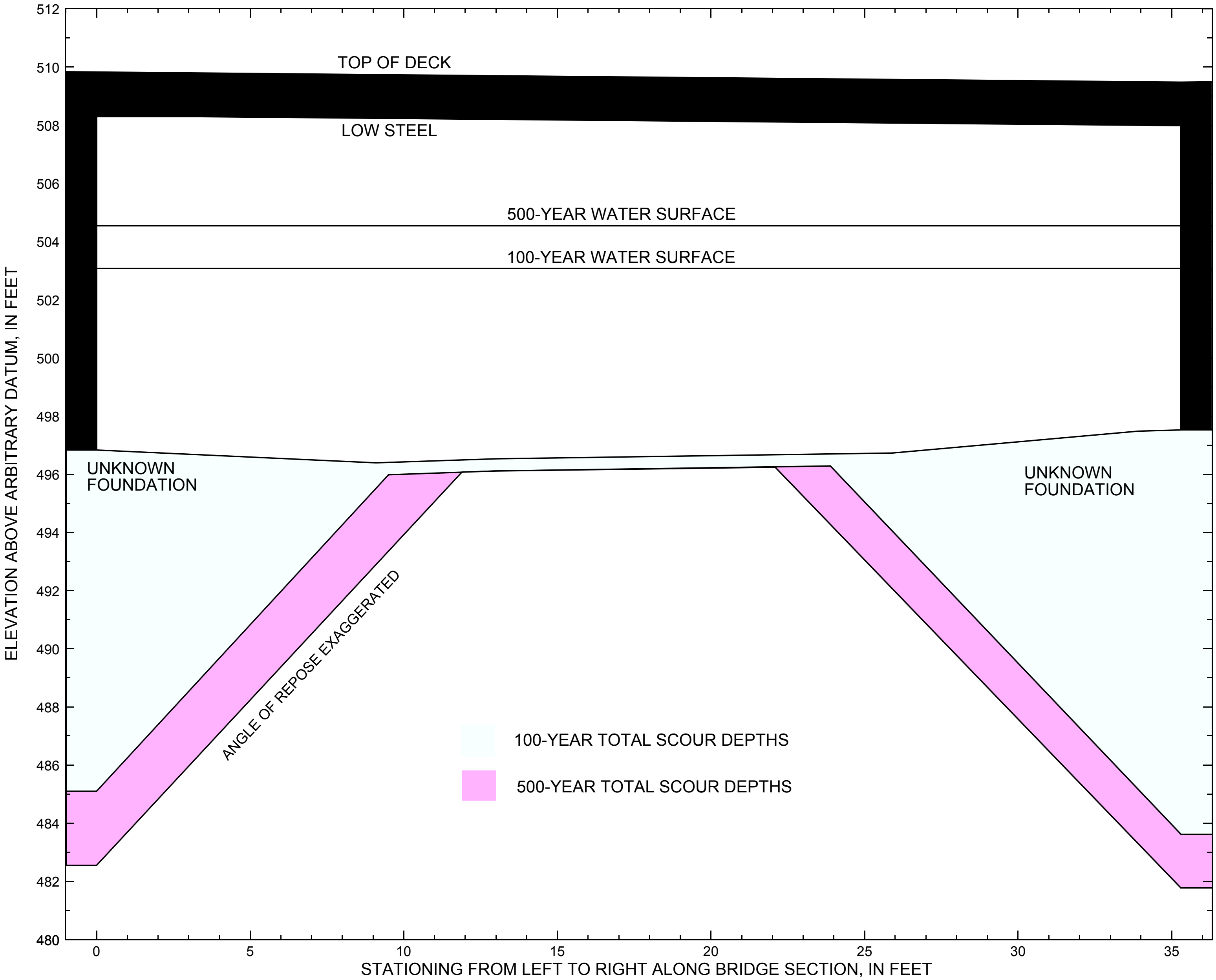

Figure 8. Scour elevations for the 100- and 500-year discharges at structure SOMMTH00010002 on Town Highway 1, crossing the Rake Branch Deerfield River, Somerset, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SOMMTH00010002 on Town Highway 1, crossing the Rake Branch Deerfield River, Somerset, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 3,250 cubic-feet per second											
Left abutment	0.0	--	508.3	--	496.8	0.4	11.2	--	11.6	485.2	--
Right abutment	35.3	--	508.0	--	497.5	0.4	13.5	--	13.9	483.6	--

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 SOMMTH00010002 on Town Highway 1, crossing the Rake Branch Deerfield River, Somerset, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 4,700 cubic-feet per second											
Left abutment	0.0	--	508.3	--	496.8	0.1	14.1	--	14.2	482.6	--
Right abutment	35.3	--	508.0	--	497.5	0.1	15.6	--	15.7	481.8	--

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, 1986, Mount Snow, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File somm002.wsp
T2        Hydraulic analysis for structure SOMMTH00010002   Date: 13-NOV-97
T3        TH 1 CROSSING RAKE BRANCH DEERFIELD RIVER IN SOMERSET, VT       RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3060.0  4510.0  2410.0
WS          503.43  504.30  502.96
*
XS   EXITX    -39           0.
GR         -142.0, 510.35    -85.2, 508.37    -33.5, 501.61     -7.0, 500.97
GR            0.0, 498.83      9.5, 497.01     10.9, 496.16     14.3, 496.63
GR           18.1, 495.94     20.5, 496.07     25.1, 496.25     30.3, 497.22
GR           42.1, 501.86     64.4, 502.88    114.6, 500.88    119.6, 498.33
GR          140.8, 498.52    148.1, 500.60    158.5, 500.78    167.6, 499.45
GR          187.7, 498.73    192.4, 502.59    230.9, 502.31    240.0, 504.89
*
N           0.090        0.055        0.090
SA                   -7.0         42.1
*
XS   FULLV      0  * * *   0.0174
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    508.13       0.0
GR            0.0, 508.30      0.0, 496.83      2.1, 496.74
GR            9.1, 496.39     13.0, 496.53     18.4, 496.60     25.9, 496.73
GR           33.9, 497.48     35.3, 497.52     35.3, 507.96      0.0, 508.30
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      22.5      2.3    509.7     44.2
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      14.0     2
GR          -99.6, 509.80    -67.7, 509.65      0.0, 509.83     35.9, 509.48
GR          131.9, 507.30    181.5, 506.43    238.9, 505.74    266.4, 506.45
GR          295.2, 509.78    345.2, 515.55
*
XT   APTEM     52           0.
GR          -94.6, 522.10    -63.8, 504.24     -9.4, 503.18      0.0, 499.59
GR           11.4, 498.92     13.7, 498.20     17.4, 498.30     21.3, 497.79
GR           25.2, 498.26     31.2, 498.36     36.9, 498.81     43.1, 499.19
GR           50.3, 501.27     67.8, 503.30    119.7, 502.30    158.6, 502.23
GR          173.5, 500.28    186.9, 500.30    188.6, 502.92    196.8, 504.66
GR          266.4, 506.45    295.2, 509.78    345.2, 515.55
*
AS   APPRO     58  * * *   0.0230
GT
N           0.080        0.060        0.085
SA                   -9.4         50.3
*
HP 1 BRIDG  503.07 1 503.07
HP 2 BRIDG  503.07 * * 2840
HP 2 RDWAY  506.79 * * 220
HP 1 APPRO  506.93 1 506.93
HP 2 APPRO  506.93 * * 3250
*
HP 1 BRIDG  504.55 1 504.55
HP 2 BRIDG  504.55 * * 3430
HP 2 RDWAY  507.81 * * 1080
HP 1 APPRO  508.14 1 508.14
HP 2 APPRO  508.14 * * 4700
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File somm002.wsp
      Hydraulic analysis for structure SOMMTH00010002   Date: 13-NOV-97
      TH 1 CROSSING RAKE BRANCH DEERFIELD RIVER IN SOMERSET, VT       RLB
         *** RUN DATE & TIME: 04-09-98  11:13

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

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     223.  18754.    35.    47.                        3185.
  503.07          223.  18754.    35.    47.  1.00     0.    35.   3185.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      503.07     0.0    35.3   223.2   18754.    2840.  12.72

X STA.        0.0        4.4        5.8        7.2        8.6       10.0
  A(I)           27.9        9.0        9.3        9.2        9.1
  V(I)           5.08      15.79      15.34      15.42      15.65

X STA.       10.0       11.4       12.8       14.2       15.7       17.1
  A(I)            9.2        9.4        9.2        9.4        9.4
  V(I)          15.38      15.04      15.38      15.06      15.11

X STA.       17.1       18.5       20.0       21.5       22.9       24.4
  A(I)            9.4        9.3        9.4        9.3        9.4
  V(I)          15.15      15.21      15.09      15.27      15.03

X STA.       24.4       25.9       27.3       28.9       30.5       35.3
  A(I)            9.4        9.3        9.6        9.7       27.1
  V(I)          15.19      15.29      14.76      14.59       5.23

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      506.79   161.0   269.3    63.8     741.     220.   3.45

X STA.      161.0      198.6      204.1      208.6      212.7      216.2
  A(I)           11.6        3.3        3.0        2.9        2.7
  V(I)           0.95       3.30       3.72       3.82       4.08

X STA.      216.2      219.5      222.5      225.4      228.1      230.2
  A(I)            2.6        2.5        2.5        2.4        2.0
  V(I)           4.28       4.36       4.36       4.54       5.48

X STA.      230.2      232.5      235.2      237.7      240.1      242.7
  A(I)            2.2        2.6        2.6        2.5        2.5
  V(I)           4.92       4.21       4.29       4.43       4.32

X STA.      242.7      245.5      248.6      252.3      257.0      269.3
  A(I)            2.6        2.7        2.7        3.0        4.9
  V(I)           4.28       4.14       4.05       3.63       2.26

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     173.   6582.    59.    59.                        1688.
            2     449.  42219.    60.    61.                        6983.
            3     752.  29813.   219.   221.                        7903.
  506.93         1374.  78614.   338.   341.  1.67   -68.   269.  12169.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

        WSEL     LEW     REW    AREA        K        Q    VEL
      506.93   -68.2   269.4  1373.9   78614.    3250.   2.37

X STA.      -68.2      -27.6       -3.8        3.0        8.4       13.5
  A(I)          110.8       88.6       46.5       40.6       40.9
  V(I)           1.47       1.83       3.49       4.01       3.97

X STA.       13.5       17.9       22.2       26.6       31.1       35.8
  A(I)           37.2       38.3       37.7       38.5       38.7
  V(I)           4.37       4.25       4.32       4.22       4.20

X STA.       35.8       40.9       46.8       59.3       84.4      106.5
  A(I)           40.1       43.3       66.0       94.3       88.8
  V(I)           4.05       3.75       2.46       1.72       1.83

X STA.      106.5      125.3      143.4      161.6      174.0      269.4
  A(I)           83.2       81.7       83.3       71.6      203.8
  V(I)           1.95       1.99       1.95       2.27       0.80
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        U.S. Geological Survey WSPRO Input File somm002.wsp
        Hydraulic analysis for structure SOMMTH00010002   Date: 13-NOV-97
        TH 1 CROSSING RAKE BRANCH DEERFIELD RIVER IN SOMERSET, VT       RLB
           *** RUN DATE & TIME: 04-09-98  11:13

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     275.   25568.    35.    50.                        4366.
   504.55          275.   25568.    35.    50.  1.00     0.    35.   4366.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       504.55     0.0    35.3   275.4   25568.    3430.  12.45

 X STA.         0.0        4.8        6.1        7.5        8.9       10.2
   A(I)            37.4       10.9       11.2       10.8       11.2
   V(I)            4.58      15.78      15.37      15.93      15.32

 X STA.        10.2       11.6       13.0       14.4       15.8       17.2
   A(I)            11.1       11.2       11.2       11.4       11.4
   V(I)           15.49      15.37      15.35      15.03      15.06

 X STA.        17.2       18.7       20.1       21.5       22.9       24.4
   A(I)            11.4       11.3       11.1       11.2       11.4
   V(I)           15.07      15.11      15.52      15.32      15.08

 X STA.        24.4       25.8       27.2       28.7       30.3       35.3
   A(I)            11.3       11.2       11.3       11.4       36.3
   V(I)           15.22      15.27      15.18      15.02       4.73

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       507.81   109.4   278.2   206.8    3919.    1080.   5.22

 X STA.       109.4      171.8      179.9      186.7      192.9      198.5
   A(I)            40.0       10.4        9.5        9.2        8.6
   V(I)            1.35       5.18       5.66       5.85       6.26

 X STA.       198.5      203.9      208.9      213.6      218.1      221.4
   A(I)             8.7        8.5        8.1        8.1        6.0
   V(I)            6.22       6.35       6.65       6.69       8.93

 X STA.       221.4      225.1      229.6      233.9      238.0      242.1
   A(I)             7.0        8.6        8.5        8.5        8.2
   V(I)            7.74       6.25       6.35       6.39       6.57

 X STA.       242.1      246.3      251.1      256.3      262.0      278.2
   A(I)             8.3        8.6        8.7        8.8       14.3
   V(I)            6.52       6.25       6.18       6.11       3.78

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     246.   11470.    61.    62.                        2801.
             2     521.   54142.    60.    61.                        8735.
             3    1023.   48307.   230.   231.                       12259.
   508.14         1790.  113919.   350.   354.  1.55   -70.   280.  18421.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

         WSEL     LEW     REW    AREA        K        Q    VEL
       508.14   -70.3   279.8  1790.0  113919.    4700.   2.63

 X STA.       -70.3      -34.3      -10.1        1.0        7.3       13.2
   A(I)           131.8      110.7       73.6       54.7       53.7
   V(I)            1.78       2.12       3.19       4.30       4.37

 X STA.        13.2       18.3       23.3       28.5       33.8       39.5
   A(I)            50.1       49.8       50.7       51.2       52.3
   V(I)            4.69       4.72       4.64       4.59       4.49

 X STA.        39.5       45.8       57.8       79.8      101.0      119.8
   A(I)            54.7       80.4      110.9      108.6      103.9
   V(I)            4.29       2.92       2.12       2.16       2.26

 X STA.       119.8      137.8      155.5      170.3      181.7      279.8
   A(I)           103.2      101.6       94.5       87.2      266.0
   V(I)            2.28       2.31       2.49       2.69       0.88
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        U.S. Geological Survey WSPRO Input File somm002.wsp
        Hydraulic analysis for structure SOMMTH00010002   Date: 13-NOV-97
        TH 1 CROSSING RAKE BRANCH DEERFIELD RIVER IN SOMERSET, VT       RLB
           *** RUN DATE & TIME: 04-09-98  11:13

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     204.   16413.    35.    46.                       2786.
   502.53          204.   16413.    35.    46.  1.00     0.    35.   2786.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.53     0.0    35.3   204.1   16413.    2410.  11.81

X STA.        0.0        4.3        5.7        7.1        8.5        9.9
  A(I)           24.7        8.3        8.5        8.5        8.6
  V(I)           4.88      14.54      14.12      14.17      14.02

X STA.        9.9       11.3       12.7       14.1       15.6       17.0
  A(I)            8.5        8.4        8.6        8.8        8.7
  V(I)          14.18      14.32      14.05      13.77      13.81

X STA.       17.0       18.5       20.0       21.4       22.9       24.4
  A(I)            8.7        8.6        8.7        8.6        8.7
  V(I)          13.89      13.94      13.84      14.01      13.80

X STA.       24.4       25.9       27.4       29.0       30.7       35.3
  A(I)            8.6        8.8        8.6        9.3       23.9
  V(I)          13.95      13.64      14.03      13.02       5.04

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     114.    3335.    57.    57.                        910.
             2     387.   33026.    60.    61.                       5598.
             3     538.   18791.   189.   191.                       5145.
   505.90         1039.   55151.   306.   310.  1.71   -66.   240.   8304.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      58.

         WSEL     LEW     REW    AREA        K        Q    VEL
       505.90   -66.4   239.6  1038.9   55151.    2580.   2.48

X STA.      -66.4      -16.4        0.2        5.3       10.0       14.3
  A(I)           96.0       59.9       32.2       31.5       30.1
  V(I)           1.34       2.15       4.00       4.10       4.28

X STA.       14.3       18.2       21.9       25.6       29.5       33.6
  A(I)           29.5       28.6       28.9       29.3       29.8
  V(I)           4.38       4.51       4.47       4.41       4.33

X STA.       33.6       37.9       42.5       48.6       65.6       95.7
  A(I)           30.4       31.0       35.7       63.2       81.9
  V(I)           4.24       4.16       3.61       2.04       1.58

X STA.       95.7      118.2      138.2      157.6      171.6      239.6
  A(I)           72.3       69.6       68.1       60.6      130.2
  V(I)           1.78       1.85       1.90       2.13       0.99
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        U.S. Geological Survey WSPRO Input File somm002.wsp
        Hydraulic analysis for structure SOMMTH00010002   Date: 13-NOV-97
        TH 1 CROSSING RAKE BRANCH DEERFIELD RIVER IN SOMERSET, VT       RLB
           *** RUN DATE & TIME: 04-09-98  11:13

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

EXITX:XS   ******   -47.     793.  0.47 *****  503.90  501.86   3060.  503.43
      -39. ******   235.   37024.  2.01 ***** *******    0.58    3.86

FULLV:FV      39.   -44.     665.  0.69  0.33  504.34 *******   3060.  503.65
        0.    39.   233.   29531.  2.10  0.11    0.00    0.76    4.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      58.   -61.     604.  0.67  0.64  504.99 *******   3060.  504.33
       58.    58.   195.   28853.  1.67  0.00    0.01    0.75    5.07
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   507.65       0.00     502.92     505.74

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

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

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

BRIDG:BR      39.     0.     223.  3.04  0.49  506.11  502.61   2840.  503.07
        0.    39.    35.   18759.  1.21  1.73    0.00    0.98   12.72

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   4.  0.910 ******  508.13 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    44.  0.07  0.13  506.99    0.00    220.  506.79

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.   117.  -100.    17.   3.0   2.9   9.6   9.4   4.3   3.1
   RT:   220.   108.   161.   269.   1.0   0.6   3.8   3.5   0.8   2.9

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

APPRO:AS      36.   -68.    1374.  0.13  0.29  507.06  503.77   3060.  506.93
       58.    49.   269.   78647.  1.67  0.66    0.01    0.25    2.23

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.862  0.638   28335.    14.    49. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -39.   -47.   235.   3060.   37024.     793.    3.86  503.43
   FULLV:FV       0.   -44.   233.   3060.   29531.     665.    4.60  503.65
   BRIDG:BR       0.     0.    35.   2840.   18759.     223.   12.72  503.07
   RDWAY:RG      11.*******     0.    220.       0.*********    2.00  506.79
   APPRO:AS      58.   -68.   269.   3060.   78647.    1374.    2.23  506.93

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      14.    49.   28335.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    501.86    0.58  495.94  510.35************  0.47  503.90  503.43
   FULLV:FV  ********    0.76  496.62  511.03  0.33  0.11  0.69  504.34  503.65
   BRIDG:BR    502.61    0.98  496.39  508.30  0.49  1.73  3.04  506.11  503.07
   RDWAY:RG  ****************  505.74  515.55  0.07******  0.13  506.99  506.79
   APPRO:AS    503.77    0.25  497.93  522.24  0.29  0.66  0.13  507.06  506.93
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File somm002.wsp
        Hydraulic analysis for structure SOMMTH00010002   Date: 13-NOV-97
        TH 1 CROSSING RAKE BRANCH DEERFIELD RIVER IN SOMERSET, VT       RLB
           *** RUN DATE & TIME: 04-09-98  11:13

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

EXITX:XS   ******   -54.    1043.  0.54 *****  504.84  503.25   4510.  504.30
      -39. ******   238.   53540.  1.87 ***** *******    0.55    4.33

FULLV:FV      39.   -51.     915.  0.73  0.33  505.27 *******   4510.  504.54
        0.    39.   236.   44774.  1.94  0.09    0.00    0.68    4.93
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      58.   -65.     822.  0.79  0.63  505.94 *******   4510.  505.15
       58.    58.   211.   41707.  1.68  0.03    0.01    0.73    5.49
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   510.67       0.00     504.73     505.74

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

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

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

BRIDG:BR      39.     0.     276.  3.01  0.45  507.56  503.39   3430.  504.55
        0.    39.    35.   25579.  1.25  2.27    0.00    0.88   12.45

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   4.  0.895 ******  508.13 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    44.  0.07  0.15  508.23    0.00   1080.  507.81

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.   117.  -100.    17.   3.0   2.9   9.6   9.4   4.3   3.1
   RT:   1080.   169.   109.   278.   2.1   1.2   5.9   5.2   1.6   3.0

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

APPRO:AS      36.   -70.    1789.  0.15  0.26  508.29  504.53   4510.  508.14
       58.    48.   280.  113848.  1.55  0.47    0.00    0.25    2.52

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.872  0.694   34884.    15.    51. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -39.   -54.   238.   4510.   53540.    1043.    4.33  504.30
   FULLV:FV       0.   -51.   236.   4510.   44774.     915.    4.93  504.54
   BRIDG:BR       0.     0.    35.   3430.   25579.     276.   12.45  504.55
   RDWAY:RG      11.*******     0.   1080.        0.*********    2.00  507.81
   APPRO:AS      58.   -70.   280.   4510.  113848.    1789.    2.52  508.14

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      15.    51.   34884.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS     503.25    0.55  495.94  510.35************  0.54   504.84  504.30
   FULLV:FV   ********    0.68  496.62  511.03  0.33  0.09  0.73   505.27  504.54
   BRIDG:BR     503.39    0.88  496.39  508.30  0.45  2.27  3.01   507.56  504.55
   RDWAY:RG   ****************  505.74  515.55  0.07******  0.15   508.23  507.81
   APPRO:AS     504.53    0.25  497.93  522.24  0.26  0.47  0.15   508.29  508.14
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File somm002.wsp
        Hydraulic analysis for structure SOMMTH00010002   Date: 13-NOV-97
        TH 1 CROSSING RAKE BRANCH DEERFIELD RIVER IN SOMERSET, VT       RLB
           *** RUN DATE & TIME: 04-09-98  11:13

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

EXITX:XS   ******   -44.     661.  0.43 *****  503.39  501.46   2410.  502.96
      -39. ******   233.   29345.  2.10 ***** *******    0.60    3.64

FULLV:FV      39.   -40.     543.  0.62  0.33  503.81 *******   2410.  503.19
        0.    39.   232.   23710.  2.01  0.09    0.00    0.75    4.44
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      58.   -35.     482.  0.64  0.64  504.46 *******   2410.  503.82
       58.    58.   192.   22216.  1.65  0.01    0.00    0.78    5.00
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   505.90       0.00     502.53     505.74

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

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

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

BRIDG:BR      39.     0.     204.  2.54  0.47  505.07  502.01   2410.  502.53
        0.    39.    35.   16428.  1.17  1.20    0.00    0.94   11.80

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   4.  0.924 ******  508.13 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      36.   -66.    1039.  0.14  0.31  506.04  503.21   2410.  505.90
       58.    47.   240.   55134.  1.71  0.67    0.02    0.29    2.32

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.845  0.578   23133.    12.    47. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K      AREA     VEL    WSEL
   EXITX:XS     -39.   -44.   233.   2410.   29345.     661.    3.64  502.96
   FULLV:FV       0.   -40.   232.   2410.   23710.     543.    4.44  503.19
   BRIDG:BR       0.     0.    35.   2410.   16428.     204.   11.80  502.53
   RDWAY:RG      11.**************      0.       0.       0.    2.00********
   APPRO:AS      58.   -66.   240.   2410.   55134.    1039.    2.32  505.90

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      12.    47.   23133.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    501.46    0.60  495.94  510.35************  0.43  503.39  502.96
   FULLV:FV  ********    0.75  496.62  511.03  0.33  0.09  0.62  503.81  503.19
   BRIDG:BR    502.01    0.94  496.39  508.30  0.47  1.20  2.54  505.07  502.53
   RDWAY:RG  ***************  505.74  515.55  0.08******  0.14  505.96********
   APPRO:AS    503.21    0.29  497.93  522.24  0.31  0.67  0.14  506.04  505.90
```
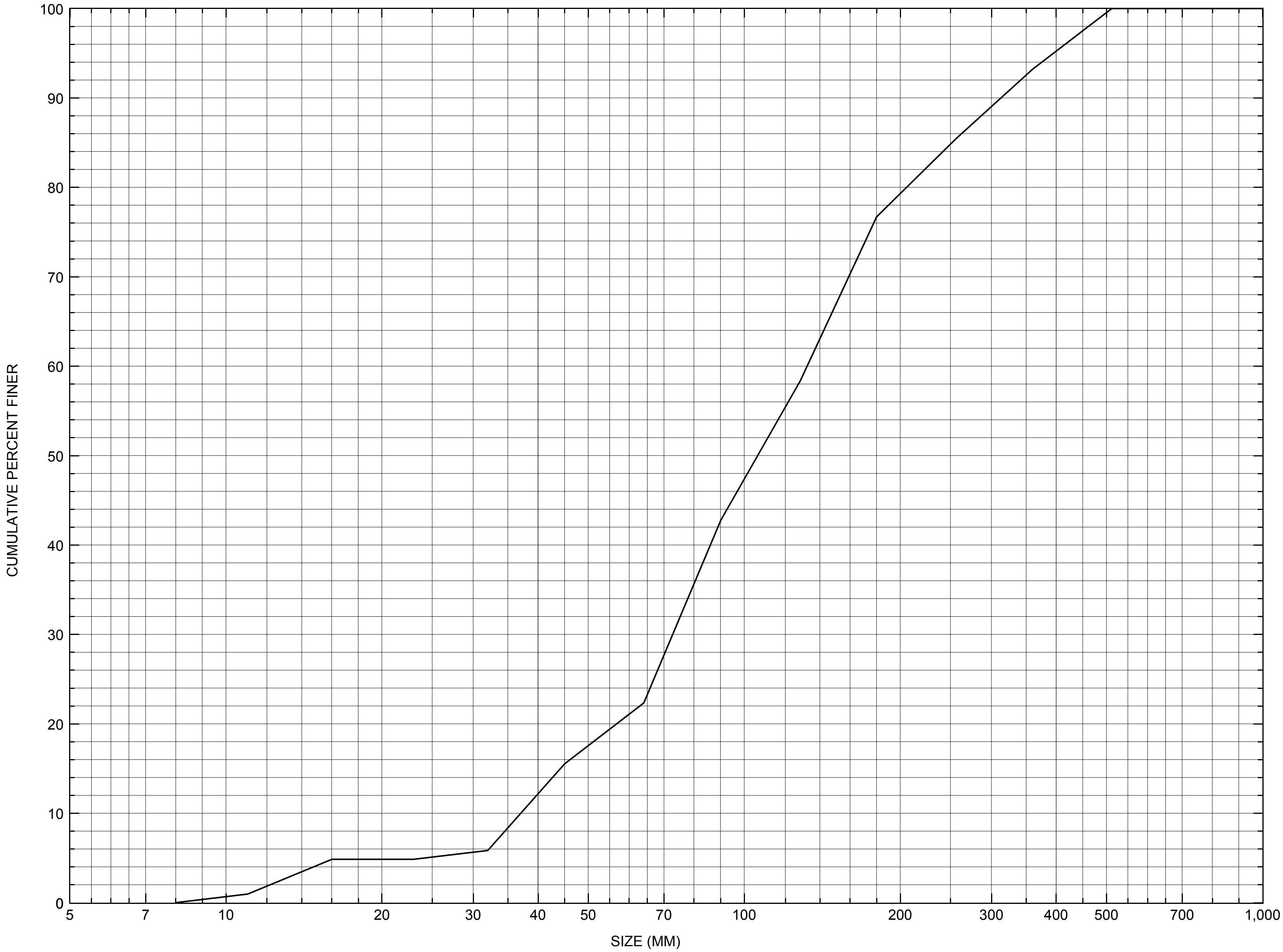

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure SOMMTH00010002, in Somerset, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SOMMTH00010002

General Location Descriptive

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

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

Highway District Number (I - 2; nn) 01

County (FIPS county code; I - 3; nnn) 025

Town (FIPS place code; I - 4; nnnnn) 65762

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

Waterway (I - 6) RAKE BRANCH DEERFIELD RIVER

Road Name (I - 7): -

Route Number C3001

Vicinity (I - 9) 4.9 MI TO JCT W VT9

Topographic Map Mount Snow

Hydrologic Unit Code: 01080203

Latitude (I - 16; nnnn.n) 42566

Longitude (i - 17; nnnnn.n) 72589

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10131500021315

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0038

Year built (I - 27; YYYY) 1919

Structure length (I - 49; nnnnnn) 000045

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

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

Year of ADT (I - 30; YY) 93

Channel & Protection (I - 61; n) 5

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

Waterway adequacy (I - 71; n) 6

Operational status (I - 41; X) A

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

Structure type (I - 43; nnn) 302

Year Reconstructed (I - 106) 0000

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

Clear span (nnn.n ft) 29

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 11.33

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

Waterway of full opening (nnn.n ft^2) 328.5

Comments:

According to the structural inspection report dated 9/10/93, the deck is a concrete filled steel grid with an asphalt overlay. The abutments, wingwalls, and backwalls are concrete. Dirt, gravel and vegetation were reported on the abutments around the fascia beams. Concrete filled bags have been placed along the bottoms of the abutments to correct an undermining/spalling problem. Stone and boulder fill is present around the ends of the wingwalls. There are boulders showing along the US and DS channel embankments. Minor cracks are noted at the abutments, wingwalls, and backwalls. No undermining is noted. Channel scour is noted as 1-1.5 ft deep at the abutments. Minor gravel bars and debris are noted. Hydraulic adequacy is noted as appearing adequate but narrow. **(Continued, p. 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -
-

Streambed material: -

Discharge Data (*cfs*): $Q_{2.33}$ - Q_{10} - Q_{25} -
Q_{50} - Q_{100} - Q_{500} -

Record flood date (*MM / DD / YY*): - / - / - Water surface elevation (*ft*): -

Estimated Discharge (*cfs*): - Velocity at Q - (*ft/s*): -

Ice conditions (*Heavy, Moderate, Light*) : - Debris (*Heavy, Moderate, Light*): -

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

Are there other structures nearby? (*Yes, No, Unknown*): - *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:

A letter dated 8/17/89 from VTAOT to the town of Somerset notes that the abutments are in poor condition. The streambed at the US half of both abutments is approximately 1 ft below the bottom of the abutment, and in some areas, undermining goes in under the abutment as much as 4 ft. The recommendation was to create a concrete subfooting and add riprap for protection. This work was noted as completed on 9/26/90.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **16.96** mi^2 Lake/pond/swamp area **0.388** mi^2

Watershed storage *(ST)* **2.29** %

Bridge site elevation **1872** ft Headwater elevation **3331** ft

Main channel length **8.017** mi

10% channel length elevation **2008** ft 85% channel length elevation **2360** ft

Main channel slope *(S)* **58.58** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS

Cross-sectional Data

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

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

Comments: **This cross section is the upstream face. The low chord elevations are from the survey log done for this report on 8/7/96. The low chord to bed length data come from the sketch attached to a bridge inspection report dated 9/10/93.**

Station	0	5	11	20	30	35	-	-	-	-	-
Feature	LAB	-	-	-	-	RAB	-	-	-	-	-
Low chord elevation	508.3	508.3	508.2	508.1	508.0	508.0	-	-	-	-	-
Bed elevation	497.6	496.1	496.2	497.2	496.5	497.7	-	-	-	-	-
Low chord to bed	10.7	12.2	12.0	10.9	11.5	10.3	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments:

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

U. S. Geological Survey
Bridge Field Data Collection and Processing Form

Qa/Qc Check by: EW Date: 10/10/96
Computerized by: EW Date: 10/10/96
Reviewd by: RB Date: 3/13/98

Structure Number SOMMTH00010002

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. BURNS Date *(MM/DD/YY)* 08 / 07 / 1996

2. Highway District Number 01 Mile marker 000000

County WINDHAM (025) Town SOMERSET (65762)

Waterway *(I - 6)* RAKE BRANCH DEERFIELD R. Road Name -

Route Number C3001 Hydrologic Unit Code: 01080203

3. Descriptive comments:

The bridge is located 4.9 miles from the junction with VT 9. It has a concrete filled steel grid deck with an asphalt overlay. There are concrete filled bags along the bottom of the abutments.

B. Bridge Deck Observations

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

5. Ambient water surface... US 2 UB 2 DS 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 45 *(feet)* Span length 38 *(feet)* Bridge width 14 *(feet)*

Road approach to bridge:

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

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

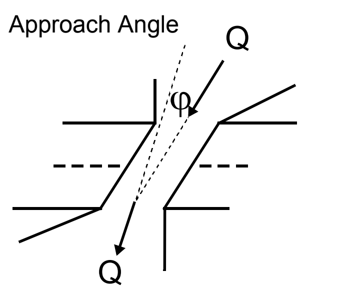
10. Embankment slope (*run / rise in feet / foot*):
US left 2.4:1 US right 2.3:1

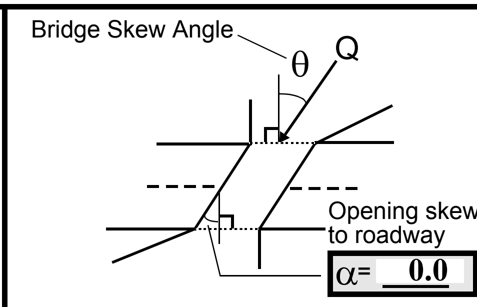
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	1

*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: 0 16. Bridge skew: 0





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

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

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

18. Bridge Type: **4**

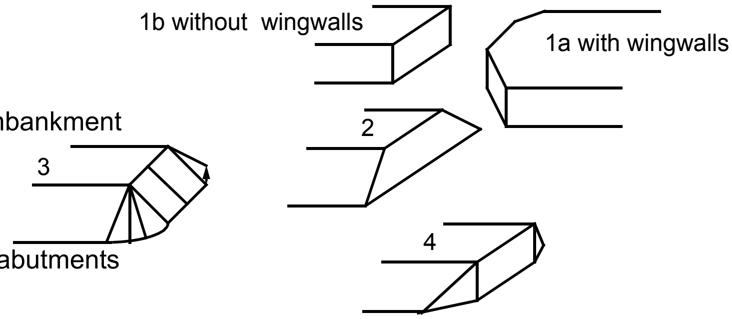
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#4: On the RBDS there is a break in the forest at approximately 50 feet downstream where there are shrubs and brush.
#7: Values are from the VTAOT database. Measured bridge length is 45 feet; width is 14.3 feet; span is 35.5 feet between the insides of the abutments and span is 39.5 feet between the insides of the backwalls.
#9: The road approaches are gravel and the bridge deck is paved.
#11: There are two culverts under the road on the right bank. On the DSRB a gully at the bottom of the road embankment runs into the stream at the downstream end of the DSRWW.
#15: This is a very straight reach of the channel.
#18: Wingwalls slope down below low chord, but not all the way down to the stream bed.

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
38.0	3.5			2.0	4	4	435	435	0	0

23. Bank width **20.0** 24. Channel width **15.0** 25. Thalweg depth **60.0** 29. Bed Material **435**

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.):
There are natural stones along the banks.
The banks are shallow and low.
There is a wide strip of grass on the right bank before the tree line.

About 300 feet upstream, on the right bank, there is a swath of grass through the trees where the water is diverted to the culverts under the road, during high flows.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **20** 35. Mid-bar width: **12**

36. Point bar extent: **55** feet **US** *(US, UB)* to **10** feet **US** *(US, UB, DS)* positioned **0** %LB to **30** %RB

37. Material: **435**

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

This side bar is vegetated with grass.

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

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
43.0		**1.0**		**2**	**7**	**7**	**-**

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

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

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

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

435

At the upstream bridge face, there is a riffle caused by boulders in the center of the channel. At the present water level, flow is directed towards both abutments from this riffle.

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

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

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

70. Debris and Ice Comments:

1

-

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	-	-	90.0
RABUT	1	5	90			2	0	35.5

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

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

-

-

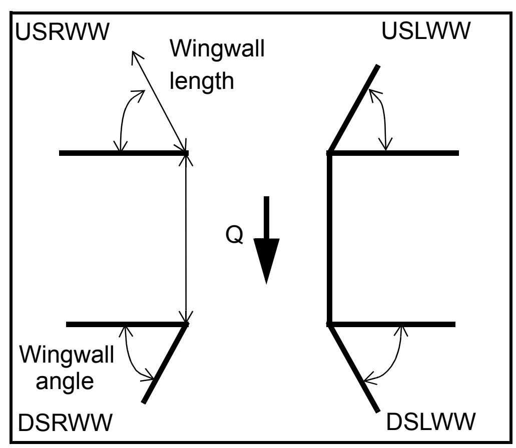
1

The abutments are protected with bags of concrete along the upstream three-quarters of the abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						35.5	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	22.5	
DSRWW:	1		0		-	22.5	

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

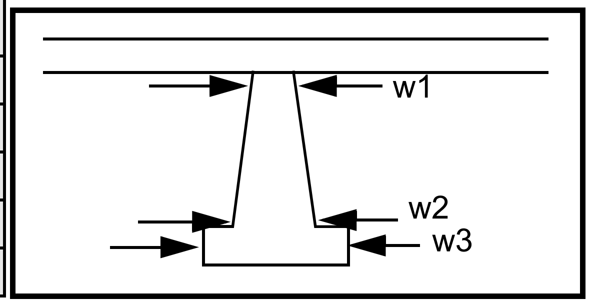
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
1
2
1
1

Piers:

84. Are there piers? **Th** (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				**45.0**	**10.0**	**45.0**
Pier 2				**10.0**	**45.0**	**10.0**
Pier 3			-	**45.0**	**10.0**	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
NO PIERS

4
3

101. Is a drop structure present? 45 *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

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

105. Drop structure comments (eg. downstream scour depth):
453
0
1
453
0
0

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

Point bar extent: e are feet a (US, UB, DS) to lot of feet nat (US, UB, DS) positioned ura %LB to l %RB

Material: sto

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

nes on the bank.

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

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

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

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

N

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

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

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

RE

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

Confluence 1: Distance Y Enters on 10 (LB or RB) Type 8 (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance 0 Enters on DS (LB or RB) Type 45 (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

DS
80

F. Geomorphic Channel Assessment

107. Stage of reach evolution 100

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)*:

453

-

Y

RB

80

70

DS

90

DS

1

109. G. Plan View Sketch

\- T

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: SOMMTH00010002 Town: SOMERSET
Road Number: TH 1 County: WINDHAM
Stream: RAKE BRANCH DEERFIELD RIVER

Initials RLB Date: 2/24/98 Checked: EMB

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3250	4700	2580
Main Channel Area, ft2	449	521	387
Left overbank area, ft2	173	246	114
Right overbank area, ft2	752	1023	538
Top width main channel, ft	60	60	60
Top width L overbank, ft	59	61	57
Top width R overbank, ft	219	230	189
D50 of channel, ft	0.3483	0.3483	0.3483
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.5	8.7	6.5
y1, average depth, LOB, ft	2.9	4.0	2.0
y1, average depth, ROB, ft	3.4	4.4	2.8
Total conveyance, approach	78614	113919	55151
Conveyance, main channel	42219	54142	33026
Conveyance, LOB	6582	11470	3335
Conveyance, ROB	29813	48307	18791
Percent discrepancy, conveyance	0.0000	0.0000	-0.0018
Qm, discharge, MC, cfs	1745.4	2233.8	1545.0
Ql, discharge, LOB, cfs	272.1	473.2	156.0
Qr, discharge, ROB, cfs	1232.5	1993.0	879.1
Vm, mean velocity MC, ft/s	3.9	4.3	4.0
Vl, mean velocity, LOB, ft/s	1.6	1.9	1.4
Vr, mean velocity, ROB, ft/s	1.6	1.9	1.6
Vc-m, crit. velocity, MC, ft/s	11.0	11.3	10.8
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	3250	4700	2580
(Q) discharge thru bridge, cfs	2840	3430	2410
Main channel conveyance	18754	25568	16413
Total conveyance	18754	25568	16413
Q2, bridge MC discharge,cfs	2840	3430	2410
Main channel area, ft2	223	275	204
Main channel width (normal), ft	35.3	35.3	35.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	35.3	35.3	35.3
y_bridge (avg. depth at br.), ft	6.32	7.80	5.78
Dm, median (1.25*D50), ft	0.435375	0.435375	0.435375
y2, depth in contraction,ft	6.75	7.93	5.86
ys, scour depth (y2-ybridge), ft	0.42	0.13	0.08

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2840	3430	2410
Main channel area (DS), ft2	223.2	275.4	204.1
Main channel width (normal), ft	35.3	35.3	35.3
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	35.3	35.3	35.3
D90, ft	1.0262	1.0262	1.0262
D95, ft	1.2963	1.2963	1.2963
Dc, critical grain size, ft	0.8746	0.7621	0.7853
Pc, Decimal percent coarser than Dc	0.136	0.170	0.162
Depth to armoring, ft	16.67	11.16	12.19

Abutment Scour

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

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	3250	4700	2580	3250	4700	2580
a', abut.length blocking flow, ft	68.2	70.3	66.4	32.5	32.5	32.5
Ae, area of blocked flow ft2	225.39	309.47	155.18	185.45	224.05	154.27
Qe, discharge blocked abut.,cfs	415.81	683.83	256.45	--	--	--
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.84	2.21	1.65	1.91	2.19	1.96
ya, depth of f/p flow, ft	3.30	4.40	2.34	5.71	6.89	4.75
--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	0.179	0.186	0.191	0.176	0.178	0.197
ys, scour depth, ft	11.22	14.06	9.01	13.48	15.62	12.25

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	68.2	70.3	66.4	32.5	32.5	32.5
y1 (depth f/p flow, ft)	3.30	4.40	2.34	5.71	6.89	4.75
a'/y1	20.64	15.97	28.41	5.70	4.71	6.85
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.18	0.19	0.19	0.18	0.18	0.20
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	9.83	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	8.06	ERR	ERR	ERR
spill-through	ERR	ERR	5.41	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.98	0.88	0.94	0.98	0.88	0.94
y, depth of flow in bridge, ft	6.32	7.80	5.78	6.32	7.80	5.78
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.63	3.15	2.38	2.63	3.15	2.38