LEVEL II SCOUR ANALYSIS FOR BRIDGE 10 (WFIETH00170010) on TOWN HIGHWAY 17, crossing TAFT BROOK, WESTFIELD, VERMONT

U.S. Geological Survey
Open-File Report 97-344

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

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 10 (WFIETH00170010) ON TOWN HIGHWAY 17, CROSSING TAFT BROOK, WESTFIELD, 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 WFIETH00170010 on Town Highway 17 crossing Taft Brook, Westfield, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in northern Vermont. The 2.39-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the immediate channel banks have thick woody vegetation while the overbanks are grass or pasture.

In the study area, Taft Brook has an incised, sinuous channel with a slope of approximately 0.04 ft/ft, an average channel top width of 38 ft and an average bank height of 6 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 85.3 mm (0.280 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 26, 1995, indicated that the reach was stable.

The Town Highway 17 crossing of Taft Brook is a 26-ft-long, two-lane bridge consisting of one 24-foot concrete span (Vermont Agency of Transportation, written communication, March 7, 1995). The opening length of the structure parallel to the bridge face is 23.1 ft.The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is 25 degrees.

There is 0.1 ft (vertical) undermining of both abutments and 0.8 feet of undermining at the downstream right wingwall. Scour countermeasures at the site include sparsely placed type-2 stone fill (less than 36 inches diameter) at the ends of each wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). 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 500-year discharge. Abutment scour at the left abutment ranged from 6.1 to 7.7 ft. Abutment scour at the right abutment ranged from 4.3 to 5.4 ft.The worst-case abutment scour occurred at the 500-year discharge for both abutments. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Lowell, VT. Quadrangle, 1:24,000, 1986

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 WFIETH00170010 ***Stream*** Taft Brook

County Orleans ***Road*** TH17 ***District*** 9

Description of Bridge

Bridge length 26 ***ft*** ***Bridge width*** 24.3 ***ft*** ***Max span length*** 24 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 6/26/95

Description of stone fill There is some type-2 stone-fill at the ends of each wingwall.

Abutments and wingwalls are concrete. Both abutments are undermined up to 0.1 ft. The downstream right wingwall is undermined as much as 0.8 ft.

Y

Is bridge skewed to flood flow according to ***survey?*** ***Angle*** 15 N

6/26/95

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***
	0	0	6/26/
Level I	95	0	0
Level II			

Moderate. There is some debris--logs and branches--blocking the entire channel about 80 feet upstream.

Potential for debris

June 26, 1995. The upstream debris could get caught at bridge in a future event.

Describe any features near or at the bridge that may affect flow (include observation date)

Description of the Geomorphic Setting

General topography The channel is located within moderate relief, non-alluvial valley with no flood plains. Left of the bridge is a 350 ft wide, flat, terrace-like feature.

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

Date of inspection 6/26/95

DS left: Steep channel bank to a wide terrace-like feature.

DS right: Steep channel bank to moderately sloped overbank.

US left: Steep channel bank to a wide terrace-like feature.

US right: Steep channel bank to moderately sloped overbank.

Description of the Channel

Average top width 38 ***ft*** ***Average depth*** 6 ***ft***

Predominant bed material Cobbles ***Bank material*** Cobbles

Straight and stable with non-alluvial channel boundaries.

6/26/95

Vegetative co Trees and brush with field grasses on the overbank.

DS left: Trees and brush with lawn and trees on the overbank.

DS right: Trees and brush with lawn on the overbank.

US left: Trees and brush with lawn and trees on the overbank.

US right:

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

Describe any obstructions in channel and date of observation. The assessment of 6/26/95 noted debris blocking the entire channel about 80 feet upstream of the bridge.

Hydrology

Drainage area 2.39 ***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 625 ***ft³/s*** ***Q500*** 940 ***ft³/s***

The 100- and 500-year discharges were computed using methods described in "Peak rates of runoff in the New England Hill and Lowland area" (Potter, 1957 b) and graphically extrapolated to the 500-year discharge. These results were chosen due to their central tendency among other empirical techniques (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Talbot, 1887). For example, the Q100 result was the median and within 3 per cent of the average.

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 downstream end of the right abutment (elev. 499.49 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the left abutment (elev. 499.46 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	-36	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APPRO	53	1	Approach section

[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 0.045 to 0.065, and overbank "n" values ranged from 0.045 to 0.075.

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 0.0365 ft/ft which was determined from surveyed thalweg points downstream of the bridge. For the 500-year discharge, 940 cfs, this slope resulted in a normal depth that was supercritical. However, the computed normal depth was only 0.14 ft below critical depth and thus, the use of the critical water surface to start the 500-year model was considered appropriate.

The approach section (APPRO) was surveyed one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the 100- and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.7 ***ft***
Average low steel elevation 498.5 ***ft***

100-year discharge 625 ***ft³/s***
Water-surface elevation in bridge opening 494.2 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 63 ***ft²***
Average velocity in bridge opening 10.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.9 ***ft/s***

Water-surface elevation at Approach section with bridge 496.6
Water-surface elevation at Approach section without bridge 495.3
Amount of backwater caused by bridge 1.3 ***ft***

500-year discharge 940 ***ft³/s***
Water-surface elevation in bridge opening 495.2 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 83 ***ft²***
Average velocity in bridge opening 11.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.8 ***ft/s***

Water-surface elevation at Approach section with bridge 497.9
Water-surface elevation at Approach section without bridge 496.0
Amount of backwater caused by bridge 1.9 ***ft***

Incipient overtopping discharge -- ***ft³/s***
Water-surface elevation in bridge opening -- ***ft***
Area of flow in bridge opening -- ***ft²***
Average velocity in bridge opening -- ***ft/s***
Maximum WSPRO tube velocity at bridge -- ***ft/s***

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). Results of this analysis are presented in figure 8 and tables 1 and 2. For the 100-year event, the streambed armoring depths computed suggest that armoring will not limit the depth contraction scour. For the 500-year discharge, less than five percent of the bed material was larger than the critical grain size (incipient motion size), thus, armoring is not probable for this event.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.1	0.4	--
Depth to armoring	17.9	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	6.1	7.7	--
Right abutment	4.3	5.4	--
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	1.3	1.7	--
Right abutment	1.3	1.7	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

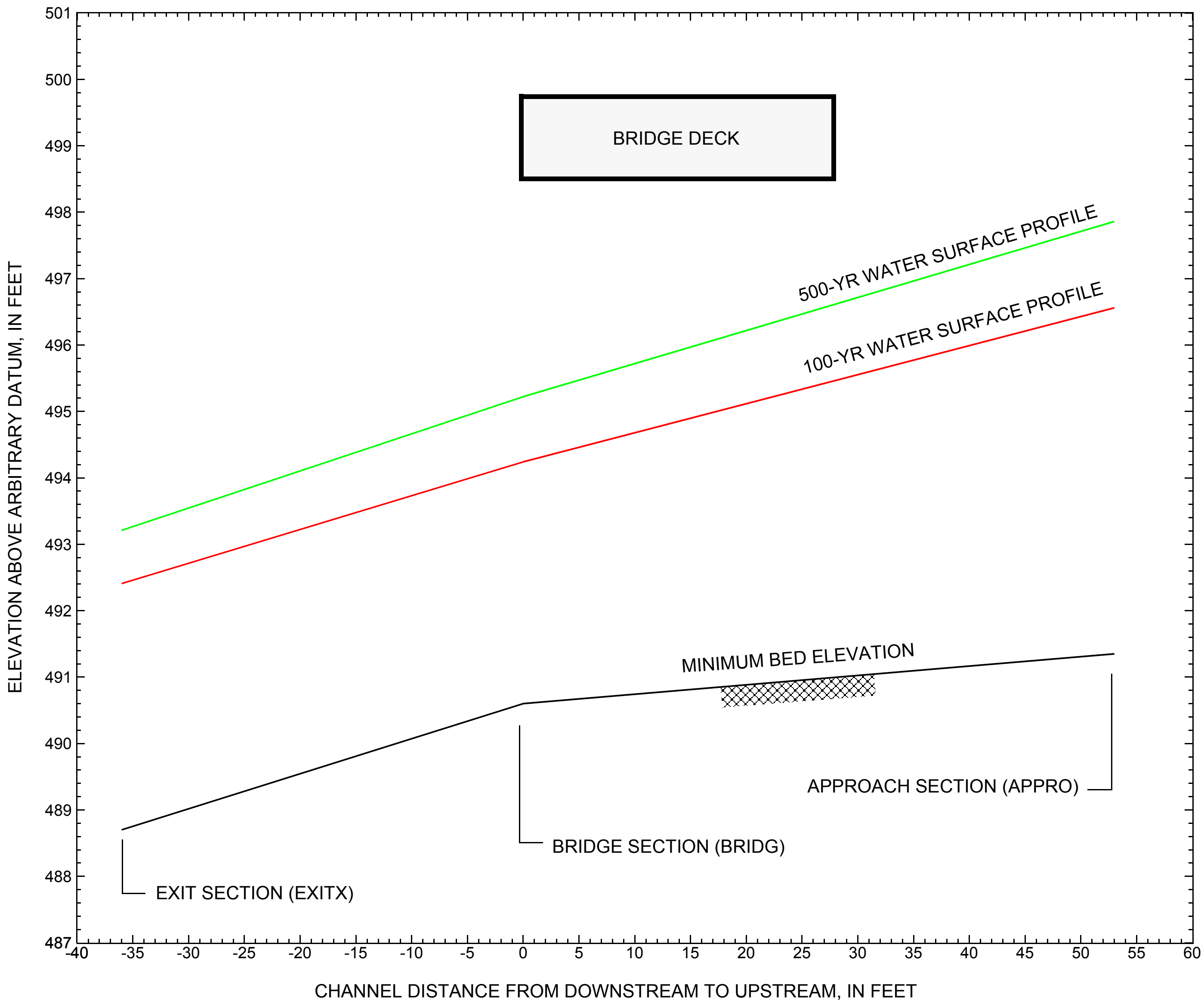

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WFIETH00170010 on Town Highway 17, crossing Taft Brook, Westfield, Vermont.

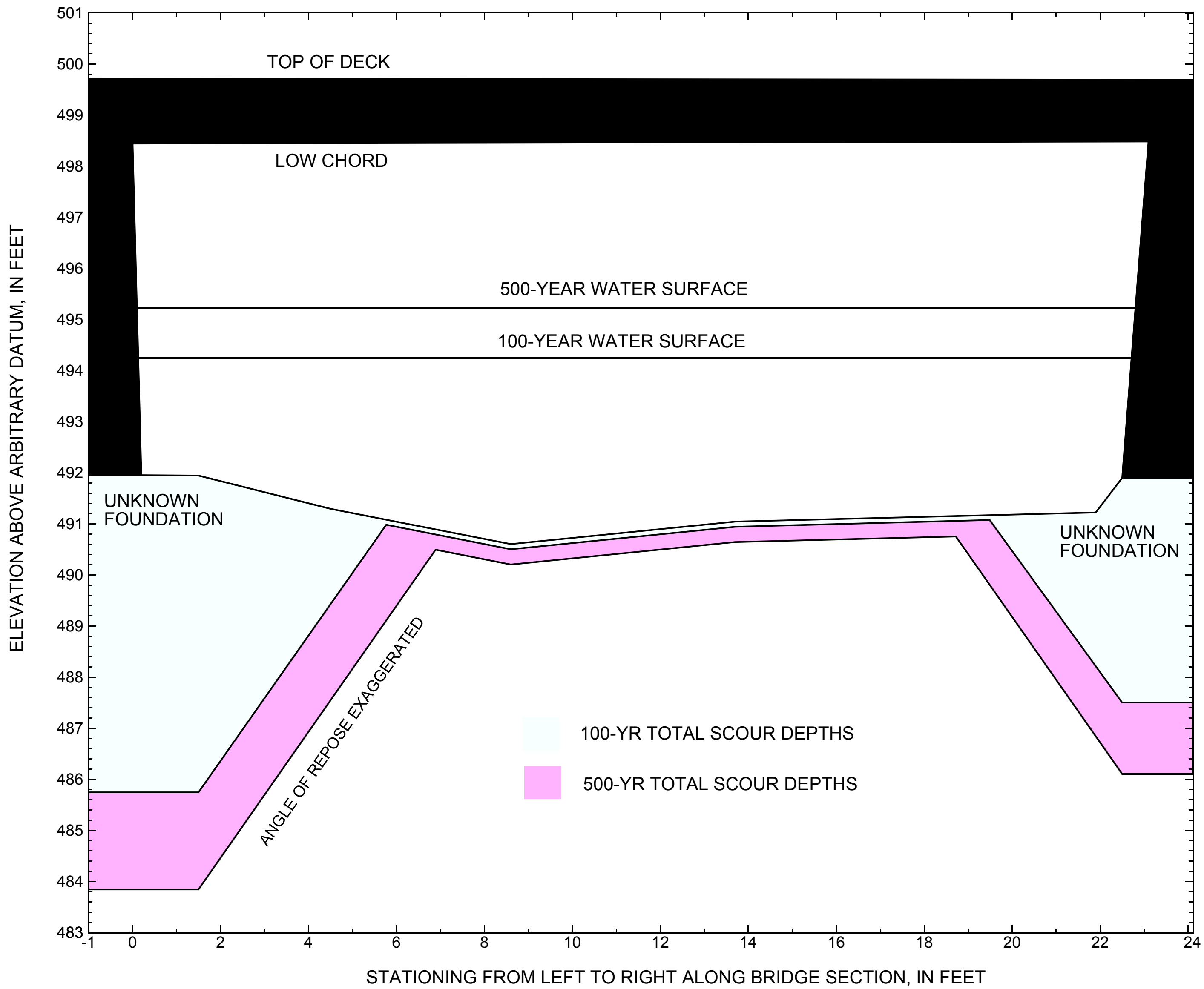

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WFIETH00170010 on Town Highway 17, crossing Taft Brook, Westfield, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WFIETH00170010 on Town Highway 17, crossing Taft Brook, Westfield, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 625 cubic-feet per second											
Left abutment	0.0	--	498.4	--	491.9	0.1	6.1	--	6.2	485.7	--
Right abutment	23.1	--	498.5	--	491.9	0.1	4.3	--	4.4	487.5	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure WFIETH00170010 on Town Highway 17, crossing Taft Brook, Westfield, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 940 cubic-feet per second											
Left abutment	0.0	--	498.4	--	491.9	0.4	7.7	--	8.1	483.8	--
Right abutment	23.1	--	498.5	--	491.9	0.4	5.4	--	5.8	486.1	--

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, Lowell, 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 wfie010.wsp
T2        Hydraulic analysis for structure wfieth00170010   Date: 09-APR-97
T3        Westfield bridge 10 over Taft Brook   SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           625  940
SK          0.0365  0.0365
*
XS   EXITX    -36
GR         -111.2, 497.78    -82.8, 497.03    -49.1, 496.57    -29.4, 492.79
GR          -17.4, 493.58     -9.2, 495.75      0.0, 491.91      5.4, 489.29
GR           13.4, 488.70     22.1, 489.41     29.5, 492.23     51.5, 492.59
GR           65.1, 495.93     91.0, 498.17
N           0.075        0.065        0.070
SA                  -9.2         29.5
*
XS   FULLV      0  * * *   0.030
*
BR   BRIDG     0 498.46 25
GR            0.0, 498.44      0.2, 491.95      1.5, 491.94      4.5, 491.29
GR            8.6, 490.60     13.7, 491.04     21.9, 491.22     22.5, 491.90
GR           23.1, 498.48      0.0, 498.44
N            0.045
CD           1 35 * * 75 2
*
XR   RDWAY     14 24 2
GR         -111.3, 501.13    -60.8, 500.49      0.0, 499.71     24.4, 499.69
GR           83.6, 498.45    143.4, 499.45    199.9, 502.61
*
AS   APPRO     53
GR         -112.8, 501.42    -75.9, 501.21    -17.9, 502.83     -8.7, 501.03
GR           -4.2, 495.62      0.0, 491.82      3.5, 491.35     10.3, 491.96
GR           17.6, 492.39     21.3, 495.47     28.9, 499.38     74.0, 500.86
N           0.045        0.065        0.055
SA                  -8.7         28.9
*
HP 1 BRIDG    494.24 1 494.24
HP 2 BRIDG    494.24 * * 625
HP 1 APPRO    496.56 1 496.56
HP 2 APPRO    496.56 * * 625
*
HP 1 BRIDG    495.22 1 495.22
HP 2 BRIDG    495.22 * * 940
HP 1 APPRO    497.86 1 497.86
HP 2 APPRO    497.86 * * 940
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File wfie010.wsp
     Hydraulic analysis for structure wfieth00170010   Date: 09-APR-97
     Westfield bridge 10 over Taft Brook   SAO

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1      63.    3804.    20.    25.                         624.
 494.24          63.    3804.    20.    25.  1.00     0.    23.    624.

 VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL     LEW     REW    AREA        K        Q    VEL
    494.24     0.1    22.7    62.8    3804.     625.   9.96
X STA.         0.1         2.7         4.1         5.3         6.4         7.3
  A(I)              5.3         3.6         3.2         3.1         2.8
  V(I)             5.86        8.56        9.80       10.22       11.22

X STA.         7.3         8.2         9.0         9.8        10.6        11.5
  A(I)              2.8         2.6         2.7         2.6         2.7
  V(I)            11.14       11.90       11.73       11.88       11.76

X STA.        11.5        12.4        13.3        14.3        15.2        16.2
  A(I)              2.7         2.8         2.7         2.8         2.8
  V(I)            11.75       11.30       11.37       11.35       11.02

X STA.        16.2        17.2        18.3        19.4        20.6        22.7
  A(I)              2.8         3.0         3.1         3.5         5.2
  V(I)            10.97       10.49       10.09        9.04        5.98

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          2     106.    5424.    28.    32.                        1161.
 496.56         106.    5424.    28.    32.  1.00    -5.    23.   1161.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
      WSEL     LEW     REW    AREA        K        Q    VEL
    496.56    -5.0    23.4   106.0    5424.     625.   5.90
X STA.        -5.0        -0.7         0.6         1.6         2.6         3.5
  A(I)              9.3         5.8         5.1         4.9         4.5
  V(I)             3.36        5.38        6.10        6.41        6.90

X STA.         3.5         4.3         5.2         6.1         7.0         7.8
  A(I)              4.4         4.3         4.4         4.4         4.3
  V(I)             7.10        7.22        7.14        7.09        7.20

X STA.         7.8         8.8         9.7        10.7        11.7        12.8
  A(I)              4.4         4.5         4.6         4.6         4.8
  V(I)             7.03        6.94        6.85        6.74        6.53

X STA.        12.8        13.9        15.1        16.4        17.9        23.4
  A(I)              4.9         5.2         5.4         6.2         9.7
  V(I)             6.33        6.01        5.76        5.02        3.21
```

```
        U.S. Geological Survey WSPRO Input File wfie010.wsp
        Hydraulic analysis for structure wfieth00170010   Date: 09-APR-97
        Westfield bridge 10 over Taft Brook   SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      83.    5753.    21.    27.                        944.
   495.22           83.    5753.    21.    27.  1.00     0.    23.    944.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.22     0.1    22.8    82.9    5753.     940.  11.34
X STA.         0.1        2.6        4.0        5.2        6.3        7.2
  A(I)             7.4        4.9        4.2        3.9        3.7
  V(I)            6.39       9.68      11.32      11.91      12.58

X STA.         7.2        8.1        8.9        9.8       10.6       11.5
  A(I)             3.6        3.4        3.4        3.5        3.4
  V(I)           12.94      13.67      13.70      13.60      13.83

X STA.        11.5       12.4       13.3       14.2       15.1       16.1
  A(I)             3.5        3.5        3.6        3.6        3.7
  V(I)           13.37      13.61      13.21      13.16      12.75

X STA.        16.1       17.1       18.2       19.3       20.5       22.8
  A(I)             3.7        3.9        4.0        4.7        7.4
  V(I)           12.68      12.10      11.62      10.05       6.37

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     145.    8391.    32.    36.                       1755.
   497.86          145.    8391.    32.    36.  1.00    -6.    26.   1755.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.
         WSEL     LEW     REW    AREA        K        Q    VEL
       497.86    -6.1    25.9   145.2    8391.     940.   6.47
X STA.        -6.1       -1.2        0.3        1.4        2.4        3.4
  A(I)            12.9        8.3        6.9        6.4        6.2
  V(I)            3.65       5.64       6.78       7.35       7.52

X STA.         3.4        4.3        5.3        6.2        7.1        8.1
  A(I)             5.9        6.0        5.9        5.8        5.9
  V(I)            7.94       7.80       8.03       8.08       7.94

X STA.         8.1        9.1       10.1       11.1       12.2       13.3
  A(I)             5.9        6.0        6.1        6.4        6.3
  V(I)            7.94       7.81       7.68       7.38       7.42

X STA.        13.3       14.5       15.7       17.1       18.8       25.9
  A(I)             6.7        7.0        7.4        9.0       14.0
  V(I)            7.04       6.67       6.36       5.21       3.36
```

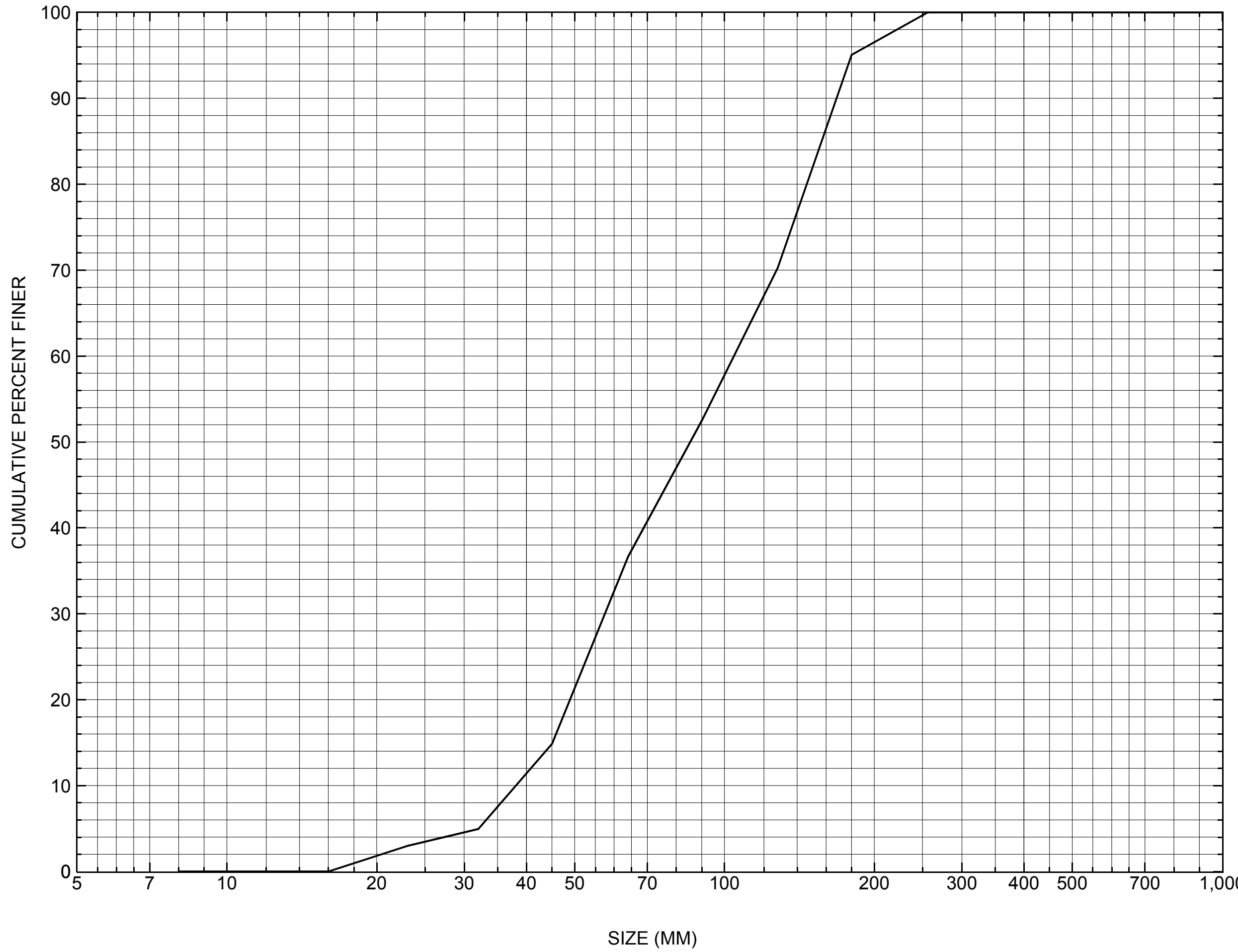
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wfie010.wsp
        Hydraulic analysis for structure wfieth00170010   Date: 09-APR-97
        Westfield bridge 10 over Taft Brook   SAO

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

EXITX:XS   ******    -1.      79.  0.99 *****  493.40  492.19    625.  492.41
      -36. ******    41.    3270.  1.02 ***** *******    1.02    7.88

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.96     493.74     493.27
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.91     499.25    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.91     499.25     493.27

FULLV:FV      36.    -2.      92.  0.79  1.13  494.53  493.27    625.  493.74
        0.    36.    52.    3814.  1.09  0.00    0.01    0.96    6.83
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.90     495.28     495.07
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.24     502.83    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.24     502.83     495.07

APPRO:AS      53.    -4.      72.  1.17  1.73  496.46  495.07    625.  495.28
       53.    53.    21.    3145.  1.00  0.19    0.01    0.90    8.68
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =      625.      494.24

            <<<<<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      36.     0.      63.  1.54 *****  495.78  494.24    625.  494.24
        0.    36.    23.    3809.  1.00 ***** *******    1.00    9.95

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.46 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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      18.    -5.     106.  0.54  0.37  497.10  495.07    625.  496.56
       53.    20.    23.    5427.  1.00  0.94   -0.01    0.54    5.90

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.096  0.000    5780.    -4.    19.   496.18

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -36.    -1.    41.    625.    3270.      79.    7.88  492.41
   FULLV:FV       0.    -2.    52.    625.    3814.      92.    6.83  493.74
   BRIDG:BR       0.     0.    23.    625.    3809.      63.    9.95  494.24
   RDWAY:RG      14.**************      0.*****************    2.00********
   APPRO:AS      53.    -5.    23.    625.    5427.     106.    5.90  496.56

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -4.    19.    5780.

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    492.19    1.02  488.70  498.17************  0.99  493.40  492.41
   FULLV:FV    493.27    0.96  489.78  499.25  1.13  0.00  0.79  494.53  493.74
   BRIDG:BR    494.24    1.00  490.60  498.48************  1.54  495.78  494.24
   RDWAY:RG  ****************  498.45  502.61**********************************
   APPRO:AS    495.07    0.54  491.35  502.83  0.37  0.94  0.54  497.10  496.56
```

```
        U.S. Geological Survey WSPRO Input File wfie010.wsp
        Hydraulic analysis for structure wfieth00170010   Date: 09-APR-97
        Westfield bridge 10 over Taft Brook   SAO

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                           WSI,CRWS =   493.07     493.21

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

EXITX:XS   ******   -32.     124.  1.06 *****  494.27  493.21    940.  493.21
      -36. ******    54.    5332.  1.19 ***** *******    1.06    7.58

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.01     494.38     494.29
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.71     499.25    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.71     499.25     494.29

FULLV:FV      36.   -32.     127.  1.01  1.09  495.35  494.29    940.  494.34
        0.    36.    54.    5493.  1.19  0.00    0.00    1.03    7.38
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.01     495.98     496.00
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.84     502.83    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.84     502.83     496.00
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   496.00     502.83     496.00

APPRO:AS      53.    -5.      91.  1.67 *****  497.68  496.00    940.  496.00
       53.    53.    22.    4357.  1.00 ***** *******    1.00   10.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =      940.     495.22

            <<<<<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      36.     0.      83.  2.00 *****  497.22  495.22    940.  495.22
        0.    36.    23.    5754.  1.00 ***** *******    1.00   11.34

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.46 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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      18.    -6.     145.  0.65  0.35  498.51  496.00    940.  497.86
       53.    19.    26.    8397.  1.00  0.93   -0.02    0.54    6.47

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.159  0.000    8983.    -4.    19.  497.50

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -36.   -32.    54.    940.    5332.     124.    7.58  493.21
   FULLV:FV       0.   -32.    54.    940.    5493.     127.    7.38  494.34
   BRIDG:BR       0.     0.    23.    940.    5754.      83.   11.34  495.22
   RDWAY:RG      14.**************      0.******************    2.00********
   APPRO:AS      53.    -6.    26.    940.    8397.     145.    6.47  497.86

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -4.    19.    8983.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.21    1.06  488.70  498.17************  1.06  494.27  493.21
   FULLV:FV    494.29    1.03  489.78  499.25  1.09  0.00  1.01  495.35  494.34
   BRIDG:BR    495.22    1.00  490.60  498.48************  2.00  497.22  495.22
   RDWAY:RG  ***************  498.45  502.61**********************************
   APPRO:AS    496.00    0.54  491.35  502.83  0.35  0.93  0.65  498.51  497.86
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WFIETH00170010, in Westfield, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WFIETH00170010

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 07 / 95

Highway District Number *(I - 2; nn)* 09

County *(FIPS county code; I - 3; nnn)* 019

Town *(FIPS place code; I - 4; nnnnn)* 80200

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

Waterway *(I - 6)* TAFT BROOK

Road Name *(I - 7)*: -

Route Number TH017

Vicinity *(I - 9)* 0.01 MI TO JCT W C3 TH18

Topographic Map Lowell

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44518

Longitude *(i - 17; nnnnn.n)* 72272

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10101800101018

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

Maximum span length *(I - 48; nnnn)* 0024

Year built *(I - 27; YYYY)* 1968

Structure length *(I - 49; nnnnnn)* 000026

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

Deck Width *(I - 52; nn.n)* 243

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

Channel & Protection *(I - 61; n)* 5

Opening skew to Roadway *(I - 34; nn)* 25

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

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

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

Structure type *(I - 43; nnn)* 501

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*) 7.0

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

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

Comments:

The structural inspection report of 7/1/93 indicates the structure is a prestressed voided concrete slab type bridge. Both concrete abutment walls are in like new condition, with the exception of some minor vertical concrete shrinkage cracks. The wingwalls also are in like new condition. The footings are exposed at both abutments. At the upstream end of each abutment the top of the footings are flush with the adjacent streambed. At the downstream end of each abutment the streambed level is about 1.5 feet below the top of the footings. In places, the concrete of the footings has eroded away. Some slight undermining of the downstream left wingwall is noted. The waterway proceeds straight through (Continued, page 31)

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: **Mountain stream**

Streambed material: **Stones and gravel, with 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)* : - Debris *(Heavy, Moderate, Light)*: -

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

the structure. The streambed consists of stones and gravel with some small boulders. There are numerous logs and debris across the channel reported near 100 feet upstream. The banks are well stabilized with trees and vegetation. No settlement is noted. Stone fill protection is noted as "little present".

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **2.39** mi^2 Lake and pond area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **1083** ft Headwater elevation **2871** ft

Main channel length **3.53** mi

10% channel length elevation **1181** ft 85% channel length elevation **1988** ft

Main channel slope *(S)* **304.85** 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:

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:

-

Comments:

While not expressed explicitly, the footings appear to be spread footing type on mainly regolith material.

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: **RB** Date: **3/26/96**
Computerized by: **RB** Date: **4/8/96**
Reviewd by: **SAO** Date: **5/6/97**

Structure Number **WFIETH00170010**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **D. SONG** Date *(MM/DD/YY)* **06** / **25** / 19**95**

2. Highway District Number **09** Mile marker **000**

County **ORLEANS (019)** Town **WESTFIELD (80200)**

Waterway *(I - 6)* **TAFT BROOK** Road Name **BALANCE ROCK ROAD**

Route Number **TH017** Hydrologic Unit Code: **02010007**

3. Descriptive comments:

Located 0.01 miles to the junction with C3 TH18.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **4** LBDS **6** RBDS **6** Overall **4**

*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

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

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

7. Bridge length **26** *(feet)* Span length **24** *(feet)* Bridge width **24.3** *(feet)*

Road approach to bridge:

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

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

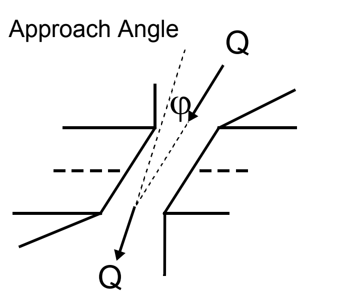
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

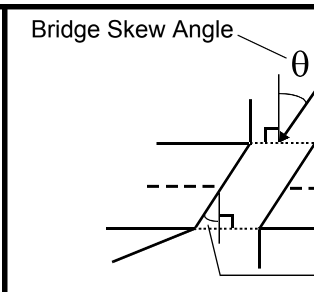
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	2	2	1
RBUS	1	1	0	-
RBDS	2	1	1	0
LBDS	2	2	2	1

*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: **15**





α= **25.0**

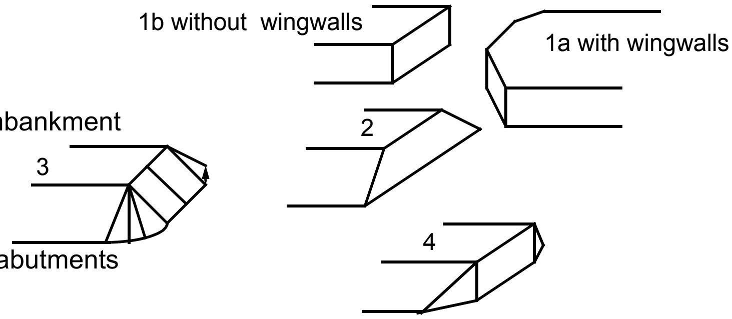
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **10** feet **US** *(US, UB, DS)* to **40** feet **US**

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: 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.)

4. On the right bank DS there are shrubs and pasture close to the bridge and forest beyond. On the left bank DS there is forest one bridge length away from the stream and a road and pasture beyond.
7. Values are from the VT AOT files.
18. The wingwalls are a combination of 1a and 4 but there is no embankment.

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
27.0	9.0			7.0	4	4	432	432	2	1

23. Bank width 35.0 24. Channel width 30.0 25. Thalweg depth 37.5 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 is a large debris accumulation across the channel at 80 feet US with the potential to clog the bridge opening.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **60** 35. Mid-bar width: **10**

36. Point bar extent: **40** feet **US** (US, UB) to **80** feet **US** (US, UB, DS) positioned **0** %LB to **50** %RB

37. Material: **4**

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

The side bar is established behind the major debris pile 80 feet US which pushes flow to the right bank.

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: **50** 42. Cut bank extent: **15** feet **US** (US, UB) to **80** feet **US** (US, UB, DS)

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

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

Tree roots are exposed and undermined and the bank material is slumping.

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) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
18.5		1.0		2	7	7	-

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

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

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

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

435

-

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

67. Debris Potential **1** ____ *(**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:

1

There is a large debris pile of logs and twigs 80 feet US that is already constricting flow. The bridge has a low vertical clearance from the streambed and has good potential to trap debris.

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		**5**	**90**	**2**	**3**	**0**	**1.5**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**3**	**21.0**

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.):

0

1.5

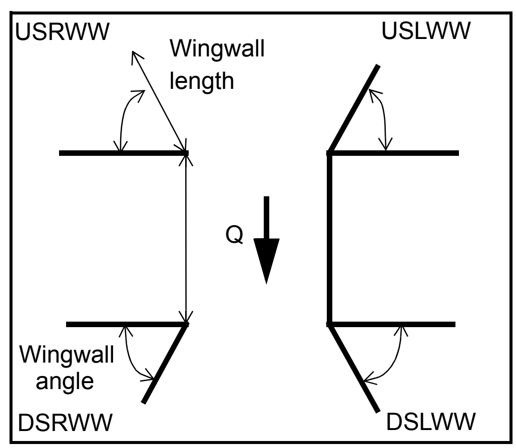
1

There is slight undermining and erosion of both abutments. Both the left and the right abutment footings are exposed 1.4 feet and undermined 0.1 foot.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**21.0**	
USRWW:	**Y**		**1**		**0**	**0.5**	
DSLWW:	**0**		**0**		**Y**	**28.0**	
DSRWW:	**1**		**2**		**0**	**28.0**	

*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	**0.8**	**3**	**Y**	**0**	**1**	**1**	**-**	**-**
Condition	**Y**	**0**	**1**	**2.3**	**2**	**2**	**-**	**-**
Extent	**1**	**1.2**	**3**	**2**	**2**	**0**	**0**	**-**

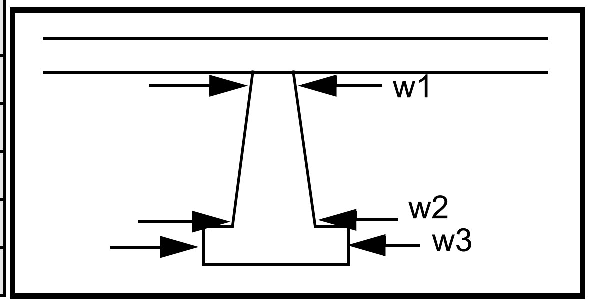
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
3
2
1
3

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		7.5	7.5	65.0	85.0	115.0
Pier 2	8.5	8.5	-	65.0	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e DS	foot of	sed 1.5		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	left	unde	feet		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	wing	rmin	with		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	wall	ing.	0.8		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	foot-	The	foot		*Y- yes; N- no*
91. Attack ∠ (BF)	ing is	DS	unde		
92. Pushed	expo	right	rmin		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	sed	wing	ing		
95. Cross-members	1.1	wall	at its	N	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	feet	foot-	US	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	with	ing is	end.	-	
98. Exposure depth	0.1	expo		-	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

106. Point/Side bar present? **-** ____ *(Y or N. if N type ctrl-n pb)* Mid-bar distance: **NO** ____ Mid-bar width: **PIE** ____

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

Material: _____

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

4

Is a cut-bank present? **3** ____ *(Y or if N type ctrl-n cb)* Where? **432** ____ *(LB or RB)* Mid-bank distance: **432** ____

Cut bank extent: **0** ____ feet **0** ____ *(US, UB, DS)* to **435** ____ feet **0** ____ *(US, UB, DS)*

Bank damage: **0** ____ *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

-

-

Bank erosion is not evident within 2 bridge lengths, but steep cutting of both banks exist further DS.

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

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

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

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

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

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

Confluence comments (eg. confluence name):

UCTURE

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N
-
-
-
-
-
-
-
-
-

109. G. Plan View Sketch

\- N

point bar (pb)	debris	flow (Q)	stone wall
cut-bank (cb)	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number:	WFIETH00170010	Town:	Westfield
Road Number:	TH17	County:	Orleans
Stream:	Taft Brook		

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

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	625	940	0
Main Channel Area, ft2	106	145	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	28	32	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.280	0.280	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	3.8	4.5	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	5424	8391	0
Conveyance, main channel	5424	8391	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	625.0	940.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	5.9	6.5	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.2	9.4	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	625	940	0
(Q) discharge thru bridge, cfs	625	940	0
Main channel conveyance	3804	5753	0
Total conveyance	3804	5753	0
Q2, bridge MC discharge,cfs	625	940	ERR
Main channel area, ft2	62.8	82.9	0
Main channel width (normal), ft	20.5	20.6	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.5	20.6	0
y_bridge (avg. depth at br.), ft	3.06	4.02	ERR
Dm, median (1.25*D50), ft	0.35	0.35	0
y2, depth in contraction,ft	3.13	4.42	ERR
ys, scour depth (y2-ybridge), ft	0.06	0.39	N/A

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	625	940	N/A
Main channel area (DS), ft2	62.8	82.9	0
Main channel width (normal), ft	20.5	20.6	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	20.5	20.6	0.0
D90, ft	0.5509	0.5509	0.0000
D95, ft	0.5901	0.5901	0.0000
Dc, critical grain size, ft	0.5614	0.6430	ERR
Pc, Decimal percent coarser than Dc	0.086	0.038	0.000

Depth to armoring, ft	17.90	N/A	ERR

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	625	940	0	625	940	0
a', abut.length blocking flow, ft	5	6.1	0	2.9	5.3	0
Ae, area of blocked flow ft2	12.4	19.5	0	5.1	10.5	0
Qe, discharge blocked abut.,cfs	48.1	84.6	0	16.5	35.1	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.88	4.34	ERR	3.24	3.34	ERR
ya, depth of f/p flow, ft	2.48	3.20	ERR	1.76	1.98	ERR
--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	65	65	65	115	115	115
K2	0.96	0.96	0.96	1.03	1.03	1.03
Fr, froude number f/p flow	0.434	0.428	ERR	0.430	0.419	ERR
ys, scour depth, ft	6.08	7.68	N/A	4.26	5.40	N/A

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

a'(abut length blocked, ft)	5	6.1	0	2.9	5.3	0
y1 (depth f/p flow, ft)	2.48	3.20	ERR	1.76	1.98	ERR
a'/y1	2.02	1.91	ERR	1.65	2.68	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.43	0.43	N/A	0.43	0.42	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	0	1	1	0
y, depth of flow in bridge, ft	3.06	4.02	0.00	3.06	4.02	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	1.28	1.68	ERR	1.28	1.68	ERR