LEVEL II SCOUR ANALYSIS FOR BRIDGE 26 (PUTNTH00010026) on TOWN HIGHWAY 1 (FAS 129), crossing SACKETTS BROOK, PUTNEY, VERMONT

U.S. Geological Survey
Open-File Report 97-183

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

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By MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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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 26 (PUTNTH00010026) ON TOWN HIGHWAY 1 (FAS 129), CROSSING SACKETTS BROOK, PUTNEY, VERMONT

By **Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure PUTNTH00010026 on Town Highway 1 crossing Sacketts Brook, Putney, 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 New England Upland section of the New England physiographic province in southern Vermont. The 10.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream and downstream of the bridge while the immediate banks have dense woody vegetation.

In the study area, Sacketts Brook has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 35 ft and an average bank height of 5 ft. The channel bed material is predominantly cobble with a median grain size (D_{50}) of 68.3 mm (0.224 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 20, 1996, indicated that the reach was stable.

The Town Highway 1 crossing of Sacketts Brook is a 49-ft-long, two-lane bridge consisting of one 46-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March 30, 1995). The bridge is supported by vertical, concrete abutments. The channel is skewed approximately 35 degrees to the opening while the opening-skew-to-roadway is 45 degrees.

The scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) at the upstream end of the left abutment and along the entire base length of the right abutment. There was also a vertical stone wall along the upstream left bank. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for modelled flows ranged from 0.0 to 2.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 7.9 to 9.9 ft. with the worst-case occurring at the 100-year discharge. Right abutment scour ranged from 12.6 to 17.0 ft. with the worst-case occurring at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Newfane and Townshend, VT. Quadrangle, 1:25,000, 1984

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 PUTNTH00010026 ***Stream*** Sacketts Brook

County Windham ***Road*** TH 1 ***District*** 2

Description of Bridge

Bridge length 49 ***ft*** ***Bridge width*** 23.3 ***ft*** ***Max span length*** 46 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 08/20/96

Description of stone fill

Type-2, around the upstream end of the left abutment and along the entire base length of the right abutment. There is also a stone wall along the upstream right bank.

Brief description of piers/abutments Abutments are concrete. The left abutment footing is exposed one vertical foot.

Is bridge skewed to flood flow according to Yes ***survey?*** ***Angle*** 35

Is bridge located on a bend in channel? No ***If so, describe (mild, moderate, severe)***

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	08/20/96	0	0
Level II	08/20/96	0	0

Potential for debris Moderate. There are some trees leaning over the channel upstream.

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

There is a side bar at the downstream bridge face extending along the downstream left bank as of 08/20/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with steep valley walls on both sides.

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

Date of inspection 08/20/96

DS left: Moderately sloped channel bank to a narrow flood plain.

DS right: Moderately sloped channel bank to a narrow flood plain.

US left: Vertical stone wall to narrow flood plain.

US right: Steep channel bank to a narrow flood plain.

Description of the Channel

Average top width 35 ft ***Average depth*** 5 ft

Predominant bed material Cobbles ***Bank material*** Sand and Gravel

Straight and stable with semi-alluvial channel boundaries and a narrow flood plain.

08/20/96

Vegetative co Trees and brush with field grasses on flood plain.

DS left: Trees and brush with field grasses on flood plain.

DS right: Trees and brush with field grasses on flood plain.

US left: Trees and brush with field grasses on flood plain.

US right:

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

The assessment of 08/20/96 noted a side bar at the downstream bridge face extending along the left bank.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 10.1 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/New England Upland	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None

Is there a USGS gage on the stream of interest? Yes, discontinued 1974

USGS gage description Sacketts Brook near Putney, VT.

USGS gage number 01155200

Gage drainage area 10.0 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 2,780 ***ft³/s*** ***Q500*** 4,100 ***ft³/s***

The 100-year discharge is based on a drainage area relationship [(10.08/14.79)exp 0.7] with bridge number 25 in Putney. Bridge number 25 crosses Sacketts Brook downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 25 is 14.79 square miles. The 500-year discharge was extrapolated from a flood frequency curve based on the above drainage area relationship. The discharge values fell within a range of empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Peak during gaging period was 903 cfs.

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

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

Datum tie between USGS survey and VTAOT plans Subtract 301 ft from the USGS survey to obtain VTAOT plans' datum to the nearest foot.

Description of reference marks used to determine USGS datum. RM1 is a USGS brass tablet on top of the downstream end of the left abutment (elev. 499.34 ft, arbitrary survey datum). RM2 is Vermont bridge tablet on top of the upstream left end of the road curb (elev. 500.42 ft, arbitrary survey datum). RM3 is a USGS brass tablet near a stream gage 60 ft upstream of the bridge on the left bank wall (elev 489.96 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	-40	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	18	1	Road Grade section
APPRO	65	2	Modelled Approach section (Templated from APTEM)
APTEM	75	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.060, and overbank "n" values ranged from 0.035 to 0.050.

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 the topographic map (U.S. Geological Survey, 1984).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.021 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.2 ***ft***
Average low steel elevation 495.8 ***ft***

100-year discharge 2,780 ***ft^3/s***
Water-surface elevation in bridge opening 496.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 405 ***ft^3/s***
Area of flow in bridge opening 236 ***ft^2***
Average velocity in bridge opening 10.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.1 ***ft/s***

Water-surface elevation at Approach section with bridge 499.4
Water-surface elevation at Approach section without bridge 496.0
Amount of backwater caused by bridge 3.4 ***ft***

500-year discharge 4,100 ***ft^3/s***
Water-surface elevation in bridge opening 496.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,236 ***ft^3/s***
Area of flow in bridge opening 236 ***ft^2***
Average velocity in bridge opening 12.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.7 ***ft/s***

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 497.5
Amount of backwater caused by bridge 2.6

Incipient overtopping discharge 2,170 ***ft^3/s***
Water-surface elevation in bridge opening 496.1 ***ft***
Area of flow in bridge opening 236 ***ft^2***
Average velocity in bridge opening 9.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.0 ***ft/s***

Water-surface elevation at Approach section with bridge 498.3
Water-surface elevation at Approach section without bridge 495.1
Amount of backwater caused by bridge 3.2 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

The 100-year and incipient road-overflow discharges resulted in unsubmerged orifice flow. The 500-year discharge resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 100-year, 500-year and incipient road-overflow discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146) The results of Laursen's clear-water contraction scour for these events were also computed and can be found in appendix F. In this case, the 500-year discharge resulted in the worst case contraction scour with a scour depth of 2.7 ft.

Abutment scour for the left abutment 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 at the right abutment for all discharges was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

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	0.9	2.7	0.0
Depth to armoring	5.2 15.6	2.9	--
Left overbank	--	--	--
Right overbank	--	--	9.9

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour	7.9	9.3	14.8
Left abutment	17.0	12.6	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	2.7
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(D_{50} in feet)		
Abutments:	3.2	2.2	2.7
Left abutment	3.2	2.2	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	
Pier 2			

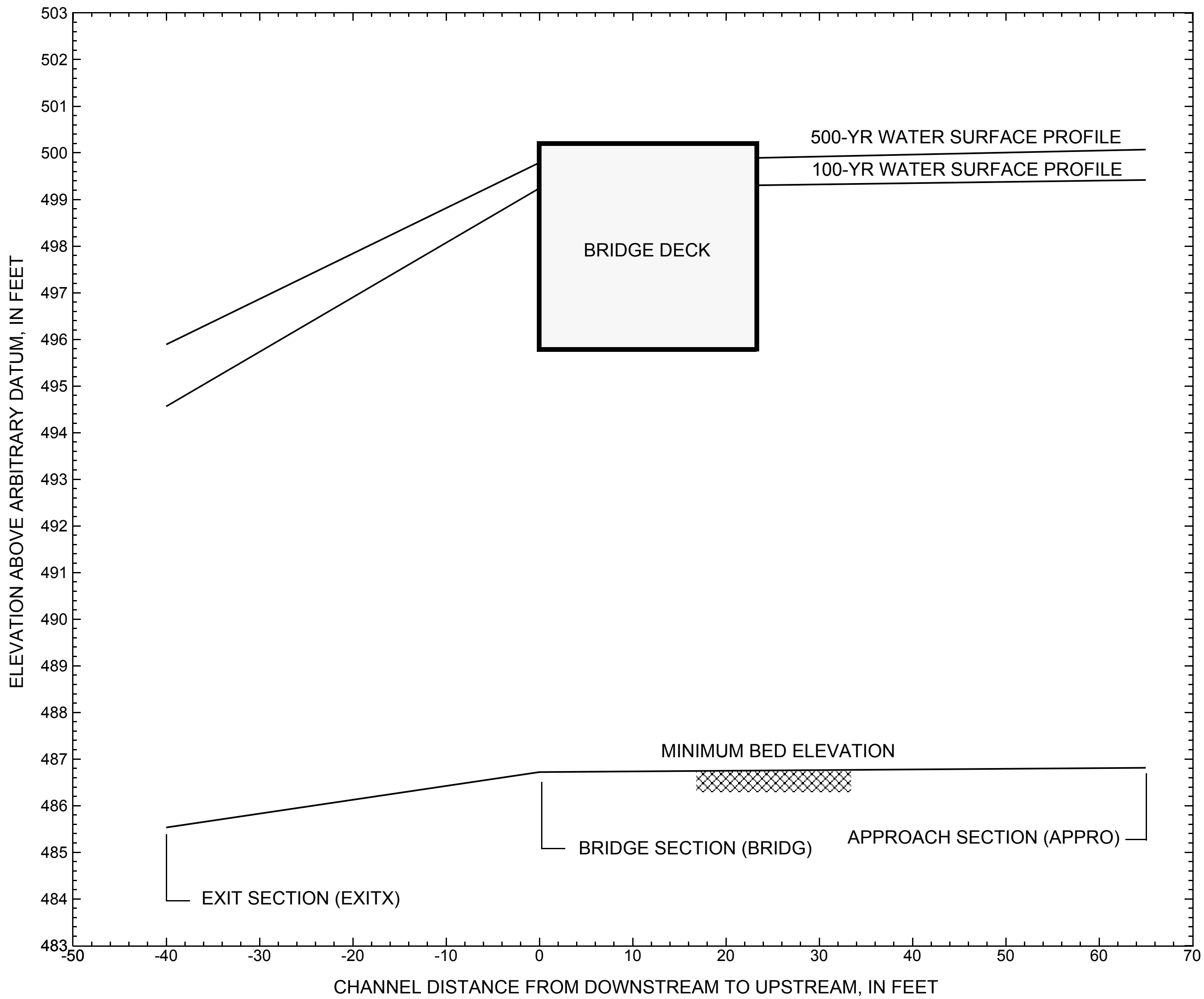

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure PUTNTH00010026 on Town Highway 1, crossing Sacketts Brook, Putney, Vermont.

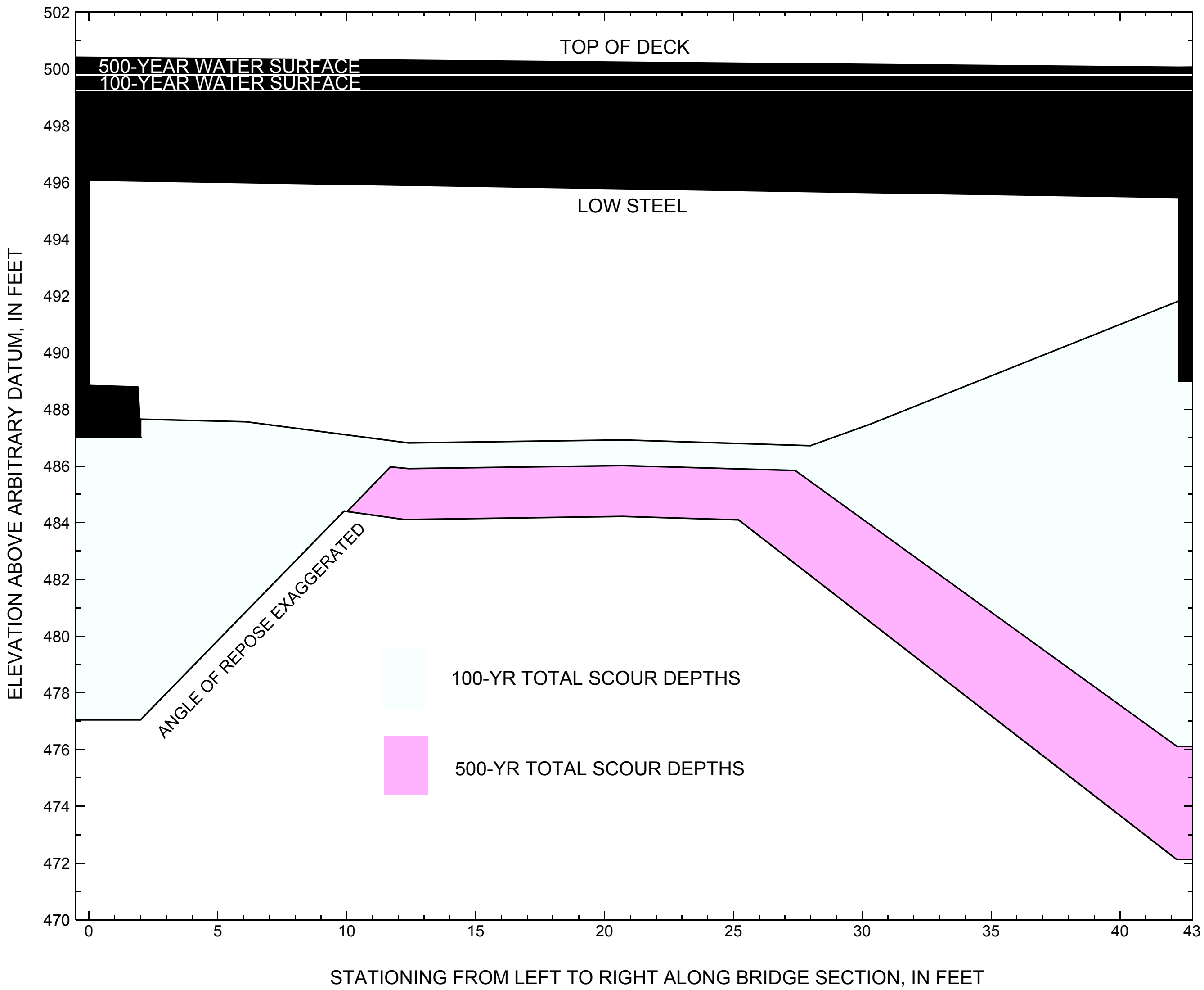

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure PUTNTH00010026 on Town Highway 1, crossing Sacketts Brook, Putney, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure PUTNTH00010026 on Town Highway 1, crossing Sacketts Brook, Putney, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,780 cubic-feet per second											
Left abutment	0.0	194.5	496.1	487	487.6	0.9	9.9	--	10.8	476.8	-10
Right abutment	42.3	194.2	495.5	489	491.8	0.9	14.8	--	15.7	476.1	-13

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 PUTNTH00010026 on Town Highway 1, crossing Sacketts Brook, Putney, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 4,100 cubic-feet per second											
Left abutment	0.0	194.5	496.1	487	487.6	2.7	7.9	--	10.6	477.0	-10
Right abutment	42.3	194.2	495.5	489	491.8	2.7	17.0	--	19.7	472.1	-17

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, 1984, Townshend, Vermont 7.5 X 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File putn026.wsp
T2        Hydraulic analysis for structure PUTNTH00010026   Date: 27-JAN-97
T3        Bridge # 26 on FAS 129 over Sacketts Brook in Putney, VT  by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
Q           2780.0   4100.0  2170.0
SK          0.0077   0.0077  0.0077
*
XS   EXITX    -40
GR         -386.5, 515.23   -369.3, 512.10   -360.5, 505.57   -331.4, 505.67
GR         -281.0, 502.57   -230.0, 498.31    -99.3, 498.31    -13.8, 493.31
GR            0.0, 491.83      7.6, 487.57      9.0, 487.28     21.2, 485.53
GR           29.5, 486.64     31.9, 487.28     38.7, 489.40     43.9, 490.34
GR           64.4, 498.51    199.4, 498.30    545.4, 502.08    587.2, 502.68
GR          598.8, 508.09
N           0.038        0.055        0.050
SA                   0.0          38.7
*
XS   FULLV       0  * * *   0.0054
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    495.78      45.0
GR            0.0, 496.08      0.1, 488.84      1.9, 488.79      2.0, 487.65
GR            6.1, 487.56     12.4, 486.81     20.7, 486.92     28.0, 486.72
GR           30.3, 487.47     42.3, 491.82     42.3, 495.47      0.0, 496.08
*        BRTYPE  BRWDTH
CD            1      35.9
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     18      23.3     1
GR         -305.7, 515.76   -292.1, 511.94   -269.2, 504.22   -245.0, 503.64
GR         -118.4, 500.73     -4.2, 499.81     -4.0, 500.37      0.0, 500.41
GR           43.2, 500.06     44.7, 500.04     44.9, 499.39    233.2, 498.30
GR          580.0, 502.08    625.6, 502.68    650.5, 508.09
*
XT   APTEM     75
GR         -284.1, 515.82   -240.1, 501.69   -192.3, 500.08    -60.4, 500.08
GR          -14.8, 499.71      0.0, 495.93      1.2, 488.46      1.3, 488.24
GR            9.1, 487.76     13.3, 487.58     15.9, 488.34     16.4, 487.02
GR           18.3, 487.43     21.4, 488.49     30.5, 492.94     75.9, 492.38
GR          155.8, 494.10    319.5, 494.86    559.4, 498.77    571.4, 501.69
GR          613.1, 502.58    622.3, 506.59
*
AS   APPRO     65
GT             -0.21
N           0.035        0.060        0.043
SA                   0.0          30.5
*
HP 1 BRIDG   496.08 1 496.08
HP 2 BRIDG   496.08 * * 2384
HP 2 RDWAY   499.24 * * 405
HP 1 APPRO   499.42 1 499.42
HP 2 APPRO   499.42 * * 2780
HP 1 BRIDG   496.08 1 496.08
HP 2 BRIDG   496.08 * * 2906
HP 2 RDWAY   499.79 * * 1236
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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       U.S. Geological Survey WSPRO Input File putn026.wsp
       Hydraulic analysis for structure PUTNTH00010026   Date: 27-JAN-97
       Bridge # 26 on FAS 129 over Sacketts Brook in Putney, VT  by MAI
          *** RUN DATE & TIME: 02-07-97  15:49

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      236     17112      0     73                            0
   496.08           236     17112      0     73  1.00      0     42        0


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.08     0.0    42.3   236.2   17112.    2384.  10.09

X STA.         0.0         3.8         5.9         7.8         9.6        11.3
  A(I)            20.5        12.9        11.6        10.9        10.6
  V(I)            5.83        9.21       10.31       10.90       11.25

X STA.        11.3        12.9        14.5        16.0        17.6        19.2
  A(I)            10.3        10.1         9.9        10.1        10.0
  V(I)           11.60       11.82       12.07       11.85       11.90

X STA.        19.2        20.8        22.4        24.0        25.7        27.3
  A(I)            10.0        10.0        10.1        10.5        10.4
  V(I)           11.93       11.94       11.77       11.36       11.46

X STA.        27.3        29.0        31.0        33.3        36.4        42.3
  A(I)            10.5        11.9        12.2        14.1        19.7
  V(I)           11.32       10.04        9.74        8.45        6.05

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      18.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.24    70.8   319.4   116.9    2105.     405.   3.47

X STA.        70.8       134.1       153.1       166.3       176.8       185.8
  A(I)            11.6         8.0         6.8         6.1         5.8
  V(I)            1.75        2.53        2.98        3.30        3.51

X STA.       185.8       193.7       200.5       206.8       212.6       218.1
  A(I)             5.4         5.0         4.9         4.7         4.6
  V(I)            3.77        4.03        4.17        4.34        4.44

X STA.       218.1       223.3       228.1       232.9       237.8       243.1
  A(I)             4.5         4.4         4.4         4.5         4.5
  V(I)            4.50        4.63        4.62        4.48        4.46

X STA.       243.1       249.0       256.2       264.9       277.5       319.4
  A(I)             4.7         5.2         5.6         6.6         9.6
  V(I)            4.27        3.89        3.59        3.07        2.11

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      65.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       27      1684     14     15                          207
             2      328     33548     31     39                         6109
             3     2347    218580    532    533                        27960
   499.42          2702    253812    577    587  1.01    -13    563    33066

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      65.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.42   -14.5   562.9  2701.9  253812.    2780.   1.03

X STA.       -14.5        10.9        20.0        34.0        49.1        63.8
  A(I)           148.9       108.9       120.6       103.3       102.8
  V(I)            0.93        1.28        1.15        1.35        1.35

X STA.        63.8        78.2        92.9       109.3       127.4       147.9
  A(I)           103.9       103.5       109.5       114.8       121.6
  V(I)            1.34        1.34        1.27        1.21        1.14

X STA.       147.9       170.8       194.4       219.7       246.2       273.7
  A(I)           126.8       127.7       133.5       137.0       138.8
  V(I)            1.10        1.09        1.04        1.01        1.00

X STA.       273.7       302.7       334.8       373.6       428.4       562.9
  A(I)           142.6       152.0       163.1       188.5       254.1
  V(I)            0.97        0.91        0.85        0.74        0.55
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     U.S. Geological Survey WSPRO Input File putn026.wsp
     Hydraulic analysis for structure PUTNTH00010026   Date: 27-JAN-97
     Bridge # 26 on FAS 129 over Sacketts Brook in Putney, VT  by MAI
        *** RUN DATE & TIME: 02-07-97  15:49

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      236     17112      0     73                            0
 496.08          236     17112      0     73  1.00      0     42        0

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.08     0.0    42.3   236.2   17112.    2906.  12.30

X STA.        0.0        3.8        5.9        7.8        9.6       11.3
  A(I)            20.5       12.9       11.6       10.9       10.6
  V(I)            7.10      11.22      12.57      13.29      13.72

X STA.       11.3       12.9       14.5       16.0       17.6       19.2
  A(I)            10.3       10.1        9.9       10.1       10.0
  V(I)           14.15      14.41      14.71      14.44      14.51

X STA.       19.2       20.8       22.4       24.0       25.7       27.3
  A(I)            10.0       10.0       10.1       10.5       10.4
  V(I)           14.54      14.56      14.35      13.85      13.97

X STA.       27.3       29.0       31.0       33.3       36.4       42.3
  A(I)            10.5       11.9       12.2       14.1       19.7
  V(I)           13.80      12.24      11.87      10.30       7.37

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      18.

      WSEL     LEW     REW    AREA        K        Q    VEL
    499.79    44.8   369.9   279.8    7540.    1236.   4.42

X STA.       44.8       83.8      108.1      126.5      142.0      155.5
  A(I)            20.0       16.9       15.0       14.2       13.5
  V(I)            3.10       3.65       4.12       4.34       4.58

X STA.      155.5      167.3      178.2      187.9      197.2      205.9
  A(I)            12.7       12.4       11.7       11.6       11.4
  V(I)            4.87       4.99       5.28       5.31       5.42

X STA.      205.9      214.2      222.3      230.0      237.6      246.1
  A(I)            11.3       11.3       11.2       11.3       11.8
  V(I)            5.49       5.48       5.54       5.46       5.22

X STA.      246.1      255.6      267.1      281.2      301.4      369.9
  A(I)            12.3       13.6       14.7       17.3       25.6
  V(I)            5.01       4.55       4.19       3.58       2.41

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      65.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1       81      1893    198    199                          293
          2      348     36993     31     39                         6671
          3     2694    274106    535    535                        34298
 500.07         3123    312992    764    773  1.04   -197    566    35204

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      65.

      WSEL     LEW     REW    AREA        K        Q    VEL
    500.07  -198.2   565.6  3122.8  312992.    4100.   1.31

X STA.     -198.2       11.9       22.5       38.8       54.6       70.1
  A(I)           223.4      130.9      135.9      119.4      119.6
  V(I)            0.92       1.57       1.51       1.72       1.71

X STA.       70.1       85.1      101.6      119.4      139.2      161.7
  A(I)           117.6      123.8      127.7      133.7      141.6
  V(I)            1.74       1.66       1.61       1.53       1.45

X STA.      161.7      185.4      209.9      235.2      261.8      289.8
  A(I)           144.8      146.7      148.4      152.9      157.6
  V(I)            1.42       1.40       1.38       1.34       1.30

X STA.      289.8      319.4      352.2      393.9      448.8      565.6
  A(I)           162.3      168.8      189.7      206.7      271.2
  V(I)            1.26       1.21       1.08       0.99       0.76
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        U.S. Geological Survey WSPRO Input File putn026.wsp
        Hydraulic analysis for structure PUTNTH00010026   Date: 27-JAN-97
        Bridge # 26 on FAS 129 over Sacketts Brook in Putney, VT  by MAI
           *** RUN DATE & TIME: 02-07-97  15:49
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      236     17112      0     73                            0
   496.08           236     17112      0     73  1.00      0     42        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.08     0.0    42.3   236.2   17112.    2170.   9.19

X STA.         0.0        3.8        5.9        7.8        9.6       11.3
  A(I)            20.5       12.9       11.6       10.9       10.6
  V(I)            5.31       8.38       9.39       9.92      10.24

X STA.        11.3       12.9       14.5       16.0       17.6       19.2
  A(I)            10.3       10.1        9.9       10.1       10.0
  V(I)           10.56      10.76      10.99      10.78      10.84

X STA.        19.2       20.8       22.4       24.0       25.7       27.3
  A(I)            10.0       10.0       10.1       10.5       10.4
  V(I)           10.86      10.87      10.72      10.34      10.43

X STA.        27.3       29.0       31.0       33.3       36.4       42.3
  A(I)            10.5       11.9       12.2       14.1       19.7
  V(I)           10.31       9.14       8.87       7.69       5.50

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      65.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       13       617     10     10                           81
             2      293     27740     31     39                         5148
             3     1735    135841    510    511                        18144
   498.26          2040    164198    551    560  1.02     -9    541    22071

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      65.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.26    -9.9   541.0  2040.0  164198.    2170.   1.06

X STA.        -9.9        9.5       16.7       24.1       38.2       51.5
  A(I)           107.6       77.3       75.2       88.1       76.0
  V(I)            1.01       1.40       1.44       1.23       1.43

X STA.        51.5       64.6       77.0       90.5      105.0      121.3
  A(I)            76.9       74.8       80.0       81.2       86.6
  V(I)            1.41       1.45       1.36       1.34       1.25

X STA.       121.3      139.9      161.7      185.1      210.1      237.3
  A(I)            91.4       97.7      100.5      104.3      110.2
  V(I)            1.19       1.11       1.08       1.04       0.98

X STA.       237.3      265.4      297.0      331.5      378.7      541.0
  A(I)           110.5      119.5      124.5      143.2      214.6
  V(I)            0.98       0.91       0.87       0.76       0.51
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       U.S. Geological Survey WSPRO Input File putn026.wsp
       Hydraulic analysis for structure PUTNTH00010026   Date: 27-JAN-97
       Bridge # 26 on FAS 129 over Sacketts Brook in Putney, VT  by MAI
          *** RUN DATE & TIME: 02-07-97  15:49

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

EXITX:XS   ******    -34      365  1.03 *****  495.59  492.93    2780  494.56
       -39 ******     54    31659  1.14 ***** *******    0.71    7.62

FULLV:FV       40    -37      380  0.95  0.29  495.90 *******    2780  494.95
         0     40     55    33292  1.15  0.00    0.01    0.68    7.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  1.76

APPRO:AS       65      0      966  0.14  0.26  496.15 *******    2780  496.01
        65     65    403    58433  1.09  0.00   -0.01    0.34    2.88
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   498.69       0.00     494.34     498.30

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.30     498.53     498.64     495.78

 ===245 ATTEMPTING FLOW CLASS 2 (5) 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       40      0      236  1.58 *****  497.66  493.70    2384  496.08
         0 ******     42    17112  1.00 ***** *******    0.75   10.09

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.498  0.000  495.78 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       18.    42.  0.01  0.02  499.43    0.00    405.  499.24

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.    76.   -70.    20.   0.5   0.2   3.7   6.7   0.6   3.0
   RT:   405.   250.    70.   320.   0.9   0.5   3.7   3.4   0.7   3.0

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

APPRO:AS       29    -13     2702  0.02  0.08  499.44  494.75    2780  499.42
        65     50    563   253868  1.01  0.84    0.00    0.08    1.03

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS      -40.   -35.    54.   2780.   31659.     365.    7.62  494.56
   FULLV:FV        0.   -38.    55.   2780.   33292.     380.    7.31  494.95
   BRIDG:BR        0.     0.    42.   2384.   17112.     236.   10.09  496.08
   RDWAY:RG       18.*******     0.    405.       0.*********    1.00  499.24
   APPRO:AS       65.   -14.   563.   2780.  253868.    2702.    1.03  499.42

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS     492.93    0.71  485.53  515.23************  1.03  495.59  494.56
   FULLV:FV   ********    0.68  485.75  515.45  0.29  0.00  0.95  495.90  494.95
   BRIDG:BR     493.70    0.75  486.72  496.08************  1.58  497.66  496.08
   RDWAY:RG   ****************  498.30  515.76  0.01******  0.02  499.43  499.24
   APPRO:AS     494.75    0.08  486.81  515.61  0.08  0.84  0.02  499.44  499.42
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        U.S. Geological Survey WSPRO Input File putn026.wsp
        Hydraulic analysis for structure PUTNTH00010026   Date: 27-JAN-97
        Bridge # 26 on FAS 129 over Sacketts Brook in Putney, VT  by MAI
           *** RUN DATE & TIME: 02-07-97  15:49

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

EXITX:XS   ******    -57      502  1.22 *****  497.11  494.64    4100  495.89
       -39 ******     58    46680  1.17 ***** *******    0.75    8.17

FULLV:FV       40    -60      524  1.12  0.29  497.41 *******    4100  496.30
         0     40     58    49215  1.17  0.00    0.01    0.71    7.83
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  2.46

APPRO:AS       65     -6     1638  0.10  0.18  497.60 *******    4100  497.50
        65     65    494   121223  1.03  0.00    0.00    0.25    2.50
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                         WS3N,LSEL =   496.30     495.78

            <<<<<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       40      0      236  2.35 *****  498.43  494.52    2906  496.08
         0 ******     42    17112  1.00 ***** *******    0.92   12.30

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  495.78 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      18.    42.  0.01  0.03  500.09    0.01   1236.  499.79

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    13.   -17.    -4.   0.1   0.1   2.8  13.1   0.4   3.0
   RT:   1236.   325.    45.   370.   1.5   0.9   4.9   4.4   1.2   3.0

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

APPRO:AS       29   -197     3121  0.03  0.13  500.10  495.15    4100  500.07
        65     57    566   312799  1.04  0.84    0.01    0.12    1.31

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -40.   -58.    58.   4100.   46680.     502.    8.17  495.89
   FULLV:FV       0.   -61.    58.   4100.   49215.     524.    7.83  496.30
   BRIDG:BR       0.     0.    42.   2906.   17112.     236.   12.30  496.08
   RDWAY:RG      18.*******     0.   1236.       0.*********    1.00  499.79
   APPRO:AS      65.  -198.   566.   4100.  312799.    3121.    1.31  500.07

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF     HO   VHD     EGL    WSEL
   EXITX:XS     494.64    0.75  485.53  515.23************  1.22  497.11  495.89
   FULLV:FV   ********    0.71  485.75  515.45  0.29  0.00  1.12  497.41  496.30
   BRIDG:BR     494.52    0.92  486.72  496.08************  2.35  498.43  496.08
   RDWAY:RG   ****************  498.30  515.76  0.01******  0.03  500.09  499.79
   APPRO:AS     495.15    0.12  486.81  515.61  0.13  0.84  0.03  500.10  500.07
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File putn026.wsp
        Hydraulic analysis for structure PUTNTH00010026   Date: 27-JAN-97
        Bridge # 26 on FAS 129 over Sacketts Brook in Putney, VT  by MAI
           *** RUN DATE & TIME: 02-07-97  15:49

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

EXITX:XS   ******    -20      299  0.91 *****  494.66  492.02    2170  493.75
       -39 ******     52    24710  1.11 ***** *******    0.67    7.26

FULLV:FV       40    -23      310  0.85  0.29  494.97 *******    2170  494.12
         0     40     53    25916  1.12  0.00    0.01    0.65    6.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       65      0      623  0.24  0.36  495.33 *******    2170  495.10
        65     65    347    32474  1.25  0.00    0.00    0.51    3.48
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.34     497.05     497.18     495.78

 ===245 ATTEMPTING FLOW CLASS 2 (5) 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       40      0      236  1.26 *****  497.34  493.27    2127  496.08
         0 ******     42    17112  1.00 ***** *******    0.67    9.01

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.492  0.000  495.78 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      18.        <<<<<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       29     -9     2039  0.02  0.07  498.28  493.89    2170  498.26
        65     42    541   164119  1.02  0.83   -0.02    0.10    1.06

  FIRST USER DEFINED TABLE.

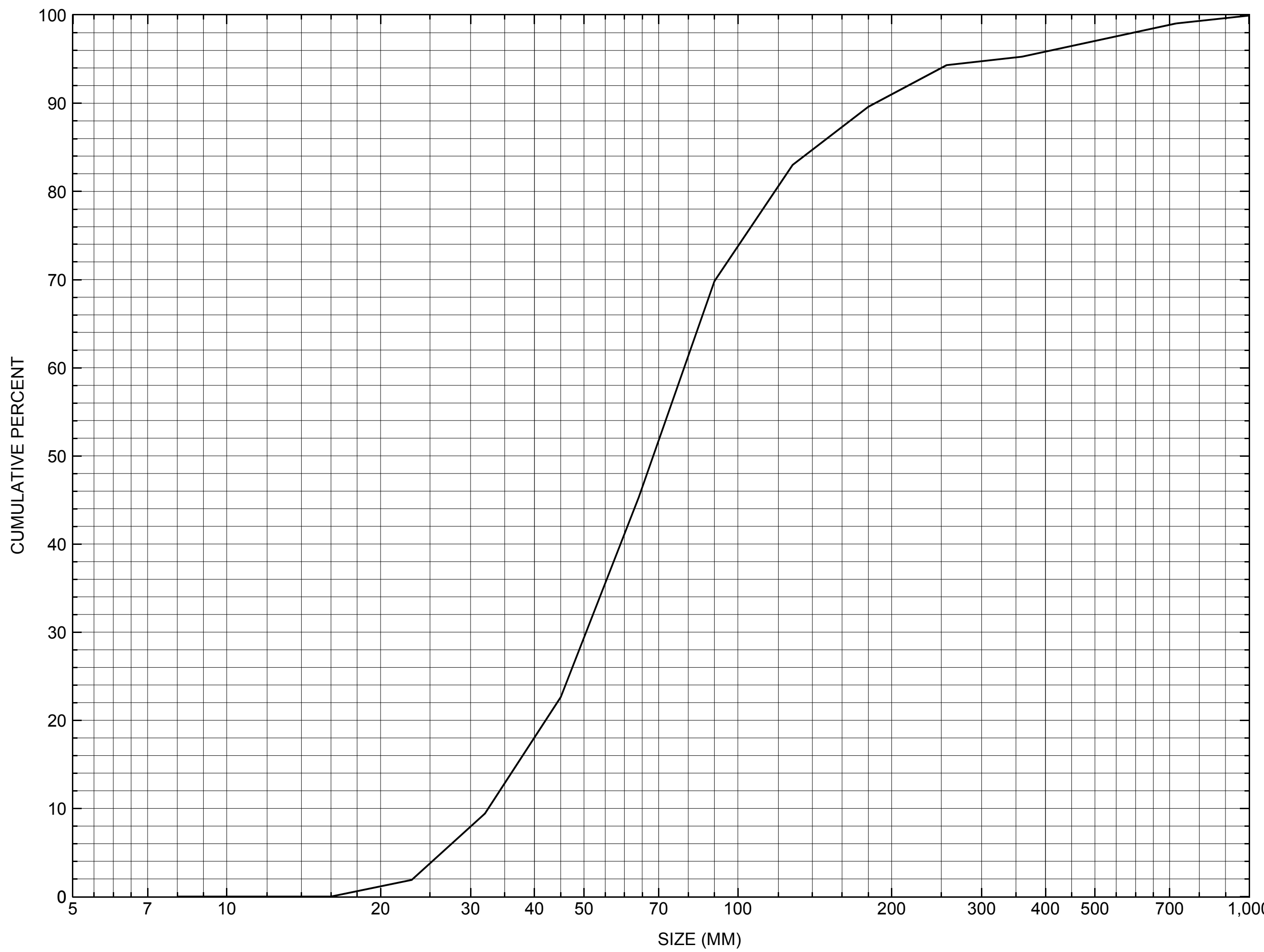
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -40.   -21.    52.   2170.   24710.     299.    7.26  493.75
   FULLV:FV       0.   -24.    53.   2170.   25916.     310.    6.99  494.12
   BRIDG:BR       0.     0.    42.   2127.   17112.     236.    9.01  496.08
   RDWAY:RG      18.**************       0.******************   1.00********
   APPRO:AS      65.   -10.   541.   2170.  164119.    2039.    1.06  498.26

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF     HO  VHD      EGL    WSEL
   EXITX:XS    492.02    0.67  485.53  515.23************  0.91  494.66  493.75
   FULLV:FV  ********    0.65  485.75  515.45  0.29  0.00  0.85  494.97  494.12
   BRIDG:BR    493.27    0.67  486.72  496.08************  1.26  497.34  496.08
   RDWAY:RG  ****************  498.30  515.76************  0.01  500.74********
   APPRO:AS    493.89    0.10  486.81  515.61  0.07  0.83  0.02  498.28  498.26
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure PUTNTH00010026, in Putney, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number PUTNTH00010026

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 30 / 95

Highway District Number *(I - 2; nn)* 02

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

Town *(FIPS place code; I - 4; nnnnn)* 57700

Mile marker *(I - 11; nnn.nnn)* 001860

Waterway *(I - 6)* SACKETS BROOK

Road Name *(I - 7):* -

Route Number TH001

Vicinity *(I - 9)* 1.9 MI W JCT. U.S.5

Topographic Map Newfane

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 43000

Longitude *(i - 17; nnnnn.n)* 72320

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20012900261313

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

Maximum span length *(I - 48; nnnn)* 0046

Year built *(I - 27; YYYY)* 1934

Structure length *(I - 49; nnnnnn)* 000049

Average daily traffic, ADT *(I - 29; nnnnnn)* 001140

Deck Width *(I - 52; nn.n)* 233

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

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

Opening skew to Roadway *(I - 34; nn)* 45

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

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

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

Structure type *(I - 43; nnn)* 104

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*) 008.0

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

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

Comments:

The structural inspection report of 6/28/94 indicates a concrete T-beam type bridge. The bridge is part of the Federal Aid System and is listed by the route number FAS 129. The abutment walls are concrete, which reportedly are in good condition. The right abutment footing is not exposed, but the downstream end of the left abutment is exposed up to 1 foot but not undermined. The waterway roughly proceeds straight through the bridge. There is stone fill protection along both abutment walls. There is a log across the stream that is acting like a drop structure just upstream from the end of the left abutment. **(Continued, page 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*): 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:

Downstream of the log the streambed drops about a foot. The streambed consists of stone and gravel. The primary channel scour noted is along the left abutment footing at the downstream end. There was no evidence of bank erosion, point bar development, and debris accumulation at this site.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **10.08** mi^2 Lake and pond area **0.04** mi^2

Watershed storage *(ST)* **0.3** %

Bridge site elevation **433** ft Headwater elevation **1673** ft

Main channel length **4.99** mi

10% channel length elevation **492** ft 85% channel length elevation **1148** ft

Main channel slope *(S)* **175.51** ft / mi

Watershed Precipitation Data

Average site precipitation _______ in Average headwater precipitation _______ in

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

Average seasonal snowfall *(Sn)* _______ ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 07 / 1934

Project Number SA66 “odd bridges” (1934) Minimum channel bed elevation: 186.5

Low superstructure elevation: USLAB 194.61 DSLAB 194.50 USRAB 194.31 DSRAB 194.21

Benchmark location description:

BM#2, Spot on sill of house, about 90 feet left bankward from the left abutment on downstream side of the roadway, elevation 202.96.

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

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

If 1: Footing Thickness 2.0 Footing bottom elevation: 187.55

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:

The bottom of footing elevation shown above is that given for the right abutment. The bottom of the left abutment footing is given as 186.28.

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: EW Date: 10/1/96
Computerized by: EW Date: 10/2/96
Reviewd by: MAI Date: 2/12/97

Structure Number PUTNTH00010026

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 08 / 20 / 1996
2. Highway District Number 02 Mile marker 001860
County WINDHAM (025) Town PUTNEY (57700)
Waterway *(I - 6)* SACKETTS BROOK Road Name -
Route Number TH 1 Hydrologic Unit Code: 01080104
3. Descriptive comments:

This concrete t-beam bridge is located 1.9 miles west of junction with us 5.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 LBDS 4 RBDS 4 Overall 4
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 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 49 *(feet)* Span length 46 *(feet)* Bridge width 23.3 *(feet)*

Road approach to bridge:

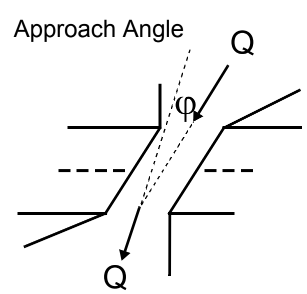
8. LB 2 RB 2 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left ________ US right ________

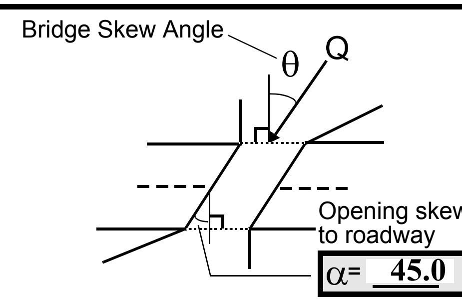
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	1

*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: 5 16. Bridge skew: 35





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 30 feet US *(US, UB, DS)* to 0 feet DS
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 30 feet DS *(US, UB, DS)* to 50 feet DS

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

18. Bridge Type: **1b**

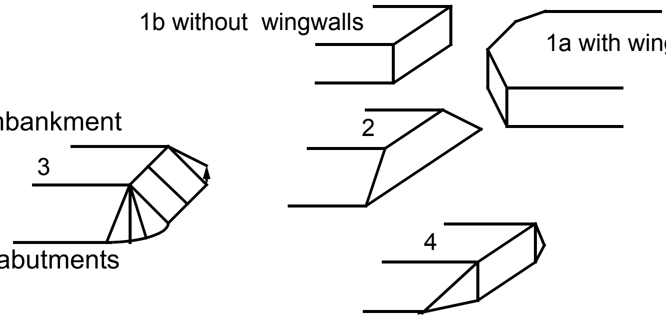
1a- Vertical abutments with wingwalls

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: There is a house on the downstream left bank, as well as the upstream right bank. The immediate banks have dense woody vegetation.

#7: The values are from the VTAOT database. The measured values were the same.

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
43.5	**7.5**			**4.5**	**3**	**2**	**234**	**234**	**1**	**1**

23. Bank width **80.0** 24. Channel width **25.0** 25. Thalweg depth **30.5** 29. Bed Material **432**

30 .Bank protection type: LB **7** RB **0** 31. Bank protection condition: LB **1** 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.):

#30: Left bank protection is a stone wall extending from 60 feet upstream to 15 feet upstream (at the upstream end of the left abutment).

The bridge is skewed to flow; the distance measurements are taken from the center of the channel.

There is a log imbedded across the stream bed, acting like a drop structure at 32 feet upstream. The water surface drops 1 foot at this point in the stream.

There is a discontinued USGS gaging station at 55 feet upstream. A survey mark, outside reference gage and a crest stage pipe remain.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **80** 35. Mid-bar width: **5**

36. Point bar extent: **95** feet **US** (US, UB) to **75** feet **US** (US, UB, DS) positioned **0** %LB to **10** %RB

37. Material: **32**

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

The side bar is located under the cut-bank at the upstream end.

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: **75** 42. Cut bank extent: **85** feet **US** (US, UB) to **70** feet **US** (US, UB, DS)

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

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

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
20.5		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.):

432

The bed material is coarser from the upstream left bank to downstream right bank.

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

70. Debris and Ice Comments:

2

Ice scaring is evident on trees. Some trees are leaning into the upstream channel.

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**	**2**	**0**	**1**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**0**	**29.5**

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.):

-

-

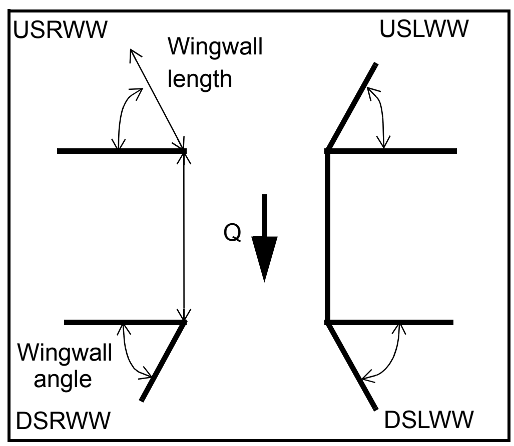
1

The upstream end of the left abutment has some bank material in front of it. The left abutment scour condition reflects the downstream end of the abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**29.5**	
USRWW:	**N**		**-**		**-**	**0.5**	
DSLWW:	**-**		**-**		**N**	**36.0**	
DSRWW:	**-**		**-**		**-**	**36.0**	

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	**-**	**-**	**N**	**-**	**-**	**-**	**3**	**1**
Condition	**N**	**-**	**-**	**-**	**-**	**-**	**2**	**1**
Extent	**-**	**-**	**-**	**-**	**-**	**2**	**2**	**-**

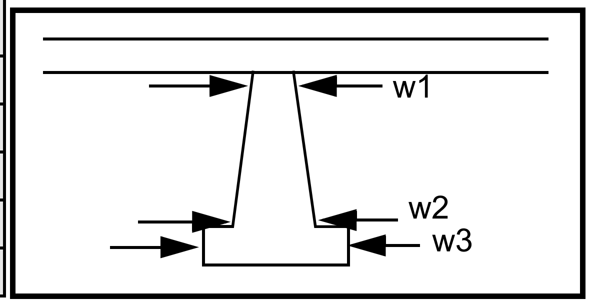
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

2
3
342
32
1

106. Point/Side bar present? 1 (Y or N. if N type ctrl-n pb) Mid-bar distance: 432 Mid-bar width: 0

Point bar extent: 0 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.):

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: N (1- eroded and/or creep; 2- slip failure; 3- block failure)

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

-

NO DROP STRUCTURE

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

Scour dimensions: Length ______ Width Y Depth: 0 Positioned 6 %LB to 0 %RB

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

UB

30

DS

0

Are there major confluences? 20 (Y or if N type ctrl-n mc) How many? 234

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

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

Confluence comments (eg. confluence name):

sens from upstream to downstream.

There are additional narrow point bars. The left bank bar extends from 80 feet downstream to 105 feet down-

F. Geomorphic Channel Assessment

107. Stage of reach evolution str

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)*:

eam. The right bank bar extends from 75 feet downstream to 105 feet downstream.

Y
LB
30
25
DS
40
DS
1

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: PUTNTH00010026　　Town: Putney
Road Number: TH 1(FAS 129)　　County: Windham
Stream: Sacketts Brook

Initials MAI　　Date: 02/07/97 Checked: SAO

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	2780	4100	2170
Main Channel Area, ft2	328	384	293
Left overbank area, ft2	27	81	13
Right overbank area, ft2	2347	2694	1735
Top width main channel, ft	31	31	31
Top width L overbank, ft	14	198	10
Top width R overbank, ft	532	535	510
D50 of channel, ft	0.224	0.224	0.224
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.6	12.4	9.5
y1, average depth, LOB, ft	1.9	0.4	1.3
y1, average depth, ROB, ft	4.4	5.0	3.4
Total conveyance, approach	253812	312992	164198
Conveyance, main channel	33548	36993	27740
Conveyance, LOB	1684	1893	617
Conveyance, ROB	218580	274106	135841
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	367.5	484.6	366.6
Ql, discharge, LOB, cfs	18.4	24.8	8.2
Qr, discharge, ROB, cfs	2394.1	3590.6	1795.2
Vm, mean velocity MC, ft/s	1.1	1.3	1.3
Vl, mean velocity, LOB, ft/s	0.7	0.3	0.6
Vr, mean velocity, ROB, ft/s	1.0	1.3	1.0
Vc-m, crit. velocity, MC, ft/s	10.1	10.4	9.9
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

ARMORING

D90	0.607	0.607	0.607

	Q100	Q500	Qother
D95	1.066	1.066	1.066
Critical grain size,Dc, ft	0.4009	0.5956	0.3321
Decimal-percent coarser than Dc	0.187	0.103	0.258
Depth to armoring,ft	5.23	15.56	2.87

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	328	384	293
Main channel width, ft	31	31	31
y1, main channel depth, ft	10.58	12.39	9.45

Bridge Section			
(Q) total discharge, cfs	2780	4100	2170
(Q) discharge thru bridge, cfs	2384	2906	2170
Main channel conveyance	17112	17112	17112
Total conveyance	17112	17112	17112
Q2, bridge MC discharge,cfs	2384	2906	2170
Main channel area, ft2	236	236	236
Main channel width (skewed), ft	29.9	29.9	29.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.9	29.9	29.9
y_bridge (avg. depth at br.), ft	7.89	7.89	7.89
Dm, median (1.25*D50), ft	0.28	0.28	0.28
y2, depth in contraction,ft	7.59	9.00	7.01
ys, scour depth (y2-ybridge), ft	-0.30	1.11	-0.89

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	2780	4100	2170
Q, thru bridge, cfs	2384	2906	2170
Total Conveyance, bridge	17112	17112	17112
Main channel(MC) conveyance, bridge	17112	17112	17112
Q, thru bridge MC, cfs	2384	2906	2170
Vc, critical velocity, ft/s	10.09	10.36	9.90
Vc, critical velocity, m/s	3.07	3.16	3.02
Main channel width (skewed), ft	29.9	29.9	29.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.9	29.9	29.9
qbr, unit discharge, ft2/s	79.7	97.2	72.6
qbr, unit discharge, m2/s	7.4	9.0	6.7
Area of full opening, ft2	236.0	236.0	236.0
Hb, depth of full opening, ft	7.89	7.89	7.89
Hb, depth of full opening, m	2.41	2.41	2.41
Fr, Froude number, bridge MC	0.75	0.92	0.67

Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	495.78	495.78	495.78
Elevation of Bed, ft	487.89	487.89	487.89
Elevation of Approach, ft	499.42	500.07	498.26
Friction loss, approach, ft	0.08	0.13	0.07
Elevation of WS immediately US, ft	499.34	499.94	498.19
ya, depth immediately US, ft	11.45	12.05	10.30
ya, depth immediately US, m	3.49	3.67	3.14
Mean elevation of deck, ft	500.24	500.24	500.24
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.90	0.89	0.93
Ys, depth of scour, ft	0.85	2.68	-0.04

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

y2, from Laursen's equation, ft	7.59	8.99	7.01
Full valley WSEL, ft	494.95	0	494.12
Full valley depth, ft	7.06	-487.887	6.23
Ys, depth of scour (y2-yfullv), ft	0.532	N/A	0.774

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	2780	4100	2170	2780	4100	2170
a', abut.length blocking flow, ft	20.7	204.4	16.1	526.8	529.5	504.9
Ae, area of blocked flow ft2	121.4	217.3	89.3	2192.2	2375.2	1705.2
Qe, discharge blocked abut.,cfs	113.3	199.4	90	--	--	1752.2
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	0.93	0.92	1.01	1.01	1.33	1.03
ya, depth of f/p flow, ft	5.86	1.06	5.55	4.16	4.49	3.38
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	45	45	45	135	135	135
K2	0.91	0.91	0.91	1.05	1.05	1.05
Fr, froude number f/p flow	0.068	0.157	0.075	0.085	0.104	0.099
ys, scour depth, ft	9.92	7.90	9.31	21.91	25.48	20.31

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)	20.7	204.4	16.1	526.8	529.5	504.9
y1 (depth f/p flow, ft)	5.86	1.06	5.55	4.16	4.49	3.38
a'/y1	3.53	192.27	2.90	126.59	118.04	149.50
Skew correction (p. 49, fig. 16)	0.80	0.80	0.80	1.10	1.10	1.10
Froude no. f/p flow	0.07	0.16	0.08	0.09	0.10	0.10
Ys w/ corr. factor K1/0.55:						
vertical	ERR	3.36	ERR	14.76	17.00	12.58
vertical w/ ww's	ERR	2.75	ERR	12.10	13.94	10.31
spill-through	ERR	1.85	ERR	8.12	9.35	6.92

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother	Q100	Q500	Qother
Fr, Froude Number	0.75	0.92	0.67	0.75	0.92	0.67
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	7.89	7.89	7.89	7.89	7.89	7.89
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.74	ERR	2.19	2.74	ERR	2.19
Fr>0.8 (vertical abut.)	ERR	3.22	ERR	ERR	3.22	ERR