LEVEL II SCOUR ANALYSIS FOR BRIDGE 17 (NEWHTH00200017) on TOWN HIGHWAY 20, crossing LITTLE OTTER CREEK, NEW HAVEN, VERMONT

Open-File Report 98-015

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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By EMILY C. WILD and RONDA L. BURNS

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Pembroke, New Hampshire

1998

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	Max	Maximum
D_{50}	median diameter of bed material	MC	main channel
DS	downstream	RAB	right abutment
elev.	elevation	RABUT	face of right abutment
f/p	flood plain	RB	right bank
ft^2	square feet	ROB	right overbank
ft/ft	feet per foot	RWW	right wingwall
FHWA	Federal Highway Administration	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
		yr	year

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 17 (NEWHTH00200017) ON TOWN HIGHWAY 20, CROSSING LITTLE OTTER CREEK, NEW HAVEN, VERMONT

By **Emily C. Wild and Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure NEWHTH00200017 on Town Highway 20 crossing Little Otter Creek, New Haven, 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 Champlain section of the St. Lawrence Valley physiographic province in west-central Vermont. The 10.8-mi^2 drainage area is in a predominantly rural and wetland basin. In the vicinity of the study site, the surface cover is shrubland on the downstream right overbank. The surface cover of the downstream left overbank, the upstream right overbank and the upstream left overbank is wetland and pasture.

In the study area, Little Otter Creek has a meandering channel with a slope of approximately 0.0007 ft/ft, an average channel top width of 97 ft and an average bank height of 5 ft. The channel bed material ranges from silt and clay to cobble. Medium sized silt and clay is the channel material upstream of the approach cross-section and downstream of the exit cross-section. The median grain size (D50) of the silt and clay channel bed material is 1.52 mm (0.005 ft), which was used for contraction and abutment scour computations. From the approach cross-section, under the bridge, and to the exit cross-section, stone fill is the channel bed material. The median grain size (D_{50}) of the stone fill channel bed material is 95.7 mm (0.314 ft). The stone fill median grain size was used solely for armoring computations. The geomorphic assessment at the time of the Level I and Level II site visit on June 11, 1996, indicated that the reach was stable.

The Town Highway 20 crossing of Little Otter Creek is a 32-ft-long, two-lane bridge consisting of a 28-ft steel-beam span (Vermont Agency of Transportation, written communication, December 15, 1995). The opening length of the structure parallel to the bridge face is 24.9 ft. The bridge is supported by almost vertical, concrete abutments. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is zero degrees.

The scour countermeasures at the site consisted of type-1 stone fill (less than 12 inches diameter) along the left and right abutments, as well as along the upstream left and right banks. Type-2 stone fill (less than 36 inches diameter) was present along the downstream right bank. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 9.7 to 13.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 6.9 to 7.9 ft. Right abutment scour ranged from 10.5 to 11.8 ft. The worst-case left and right abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 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.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number NEWHTH00200017 ***Stream*** Little Otter Creek

County Addison ***Road*** TH20 ***District*** 5

Description of Bridge

Bridge length 32 ***ft*** ***Bridge width*** 24.5 ***ft*** ***Max span length*** 28 ***ft***

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

Abutment type Concrete ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 6/11/96

Description of stone fill Type-1, along the left and right abutments.

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

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

There is a moderate channel bend in the upstream and downstream reach.

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	6/11/96	0	0
Level II	6/11/96	0	0

Potential for debris Low.

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

None, (6/11/96).

Description of the Geomorphic Setting

General topography The channel is located within a wide, slightly irregular flood plain with moderately sloped valley walls on both sides.

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

Date of inspection 6/11/96

DS left: Wide flood plain.

DS right: Narrow flood plain to a vertical quarry wall.

US left: Wide flood plain.

US right: Moderately sloped overbank

Description of the Channel

Average top width 97 ***ft*** ***Average depth*** 5 ***ft***

Predominant bed material Silt / Cobbles ***Bank material*** Silt/Bedrock

Meandering but stable with semi-alluvial channel boundaries and a wide flood plain.

6/11/96

Vegetative co Wetland and pasture

DS left: Shrubland

DS right: Wetland and pasture

US left: Wetland and pasture

US right: Yes

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

None, 6/11/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 10.8 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
St. Lawrence Valley/Champlain	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***:

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

USGS gage description Little Otter Creek at Ferrisburg, VT

USGS gage number 04282650

Gage drainage area 57.1 ***mi²***

Is there a lake/p No However, there is a significant wetland area in the vicinity of Little Otter Creek.

Calculated Discharges

Q100 1,120 ***ft³/s*** ***Q500*** 1,500 ***ft³/s***

The 100-year discharge is from the FHWA empirical relationship curve, and the 500-year discharge is based on values extrapolated from the FHWA empirical relationship curve (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). The FHWA curve values were within a range of curves of other empirical methods.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left abutment (elev. 499.66 feet, arbitrary survey datum). RM2 is a chiseled X on top of a boulder located 45 feet bankward of the right abutment and 35 feet downstream of the roadway (elev. 501.67 feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	*Section Reference Distance (SRD) in feet*	*[2]Cross-section development*	*Comments*
EXITX	-23	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	55	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 0.040 to 0.050, and overbank "n" values ranged from 0.040 to 0.065.

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 0.0007 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1963).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 499.8 *ft*
Average low steel elevation 497.7 *ft*

100-year discharge 1,120 *ft^3/s*
Water-surface elevation in bridge opening 497.7 *ft*
Road overtopping? Y *Discharge over road* 290 *ft^3/s*
Area of flow in bridge opening 96 *ft^2*
Average velocity in bridge opening 8.6 *ft/s*
Maximum WSPRO tube velocity at bridge 11.1 *ft/s*

Water-surface elevation at Approach section with bridge 500.4
Water-surface elevation at Approach section without bridge 497.5
Amount of backwater caused by bridge 2.9 *ft*

500-year discharge 1,500 *ft^3/s*
Water-surface elevation in bridge opening 497.7 *ft*
Road overtopping? Y *Discharge over road* 507 *ft^3/s*
Area of flow in bridge opening 96 *ft^2*
Average velocity in bridge opening 10.4 *ft/s*
Maximum WSPRO tube velocity at bridge 13.3 */s*

Water-surface elevation at Approach section with bridge 500.6
Water-surface elevation at Approach section without bridge 497.9
Amount of backwater caused by bridge 2.7 *ft*

Incipient overtopping discharge 750 *ft^3/s*
Water-surface elevation in bridge opening 497.7 *ft*
Area of flow in bridge opening 96 *ft^2*
Average velocity in bridge opening 7.8 *ft/s*
Maximum WSPRO tube velocity at bridge 10.0 *ft/s*

Water-surface elevation at Approach section with bridge 499.7
Water-surface elevation at Approach section without bridge 497.0
Amount of backwater caused by bridge 2.7 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

At this site, the modelled discharges resulted in 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 these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The results of the scour analysis are presented in tables 1 and 2 and the scour depths are presented graphically in
figure 8.

For comparison, estimates of contraction scour were also computed for the discharges resulting in orifice flow by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). The results are presented in appendix F. For the 100-year and incipient roadway-overtopping discharges, which resulted in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are also provided in appendix F.

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

Scour at the left abutment was computed by use of the HIRE equation (Richardson and Davis, 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	10.9	13.8	9.7
Depth to armoring	N/A N/–	A N/–	A–
Left overbank	--–	---	---
Right overbank	--–	--–	--–
Local scour:			
Abutment scour	7.5 7.9	6.9	11.1
Left abutment	11.8–	10.5-	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	1.5
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:	1.6	1.3	1.5
Left abutment	1.6	1.3	--
Right abutment	--–	---	---
Piers:	--	--	--
Pier 1	--–	--–	–
Pier 2			

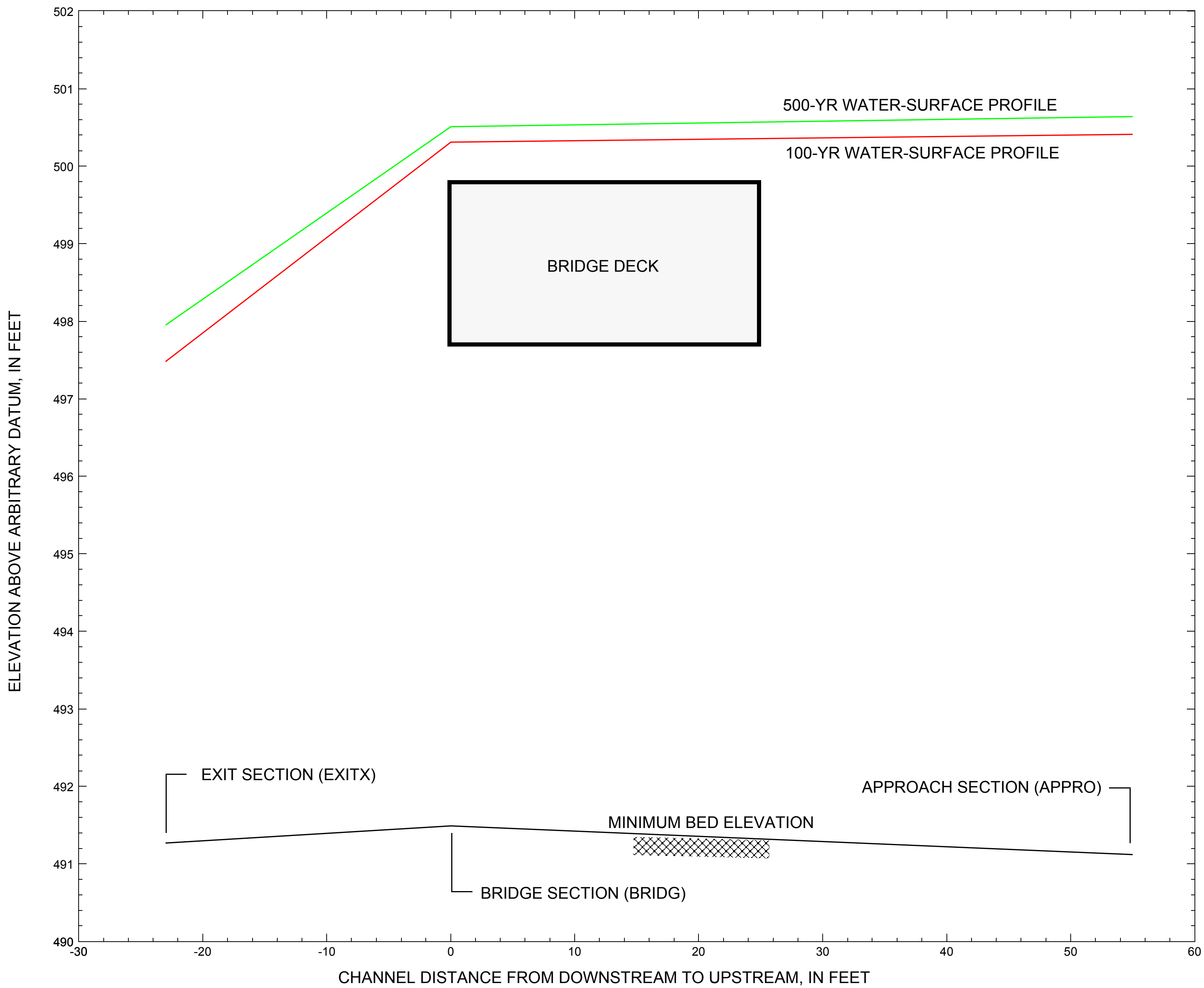

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure NEWHTH00200017 on Town Highway 20, crossing Little Otter Creek, New Haven, Vermont.

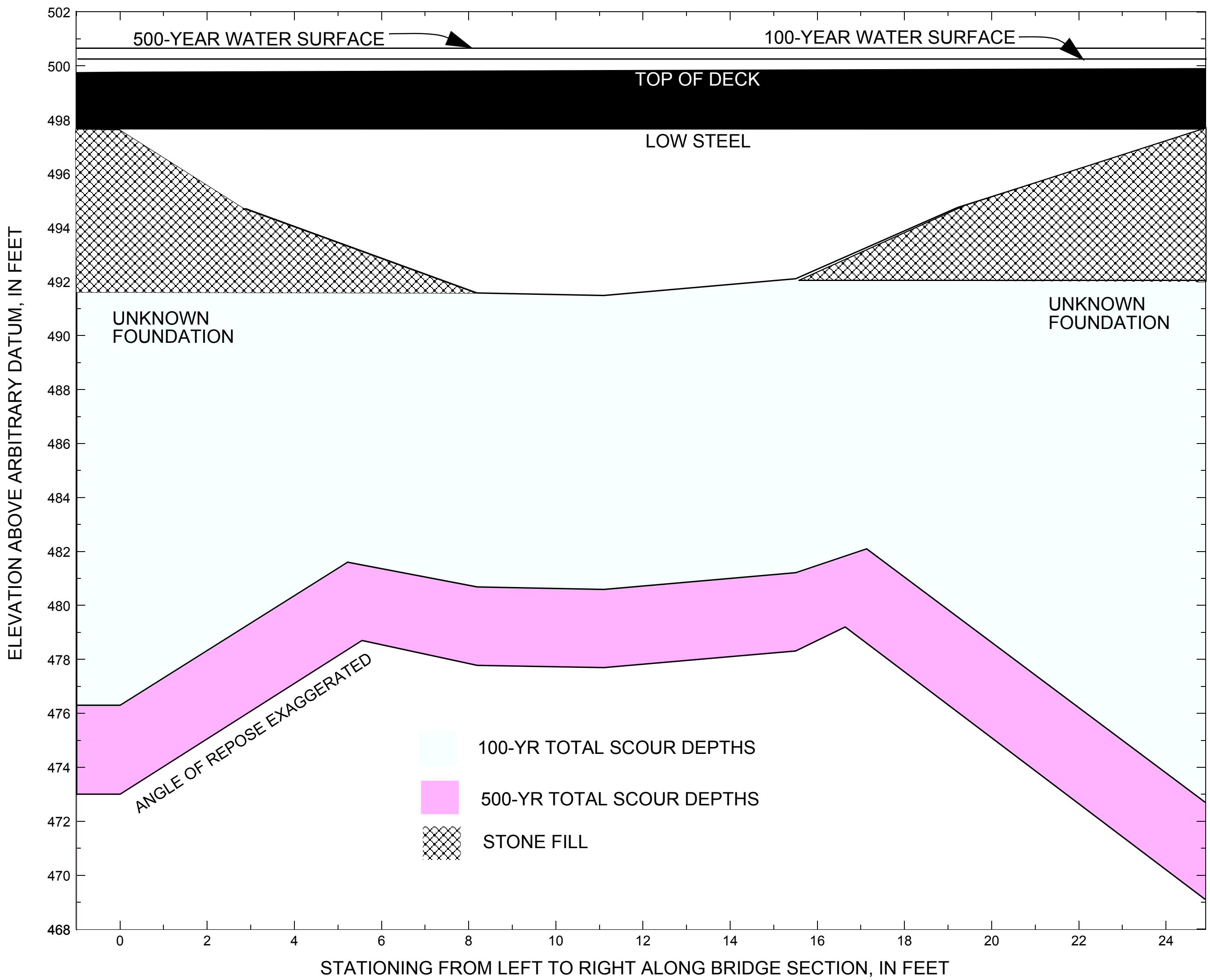

Figure 8. Scour elevations for the 100- and 500-yr discharges at structure NEWHTH00200017 on Town Highway 20, crossing Little Otter Creek, New Haven, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure NEWHTH00200017 on Town Highway 20, crossing Little Otter Creek, New Haven, 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 1,120 cubic-feet per second											
Left abutment	0.0	--	497.7	--	494.7	10.9	7.5	--	18.4	476.3	--
Right abutment	24.9	--	497.7	--	494.7	10.9	11.1	--	22.0	472.7	--

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-yr discharge at structure NEWHTH00200017 on Town Highway 20, crossing Little Otter Creek, New Haven, 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 1,500 cubic-feet per second											
Left abutment	0.0	--	497.7	--	494.7	13.8	7.9	--	21.7	473.0	--
Right abutment	24.9	--	497.7	--	494.7	13.8	11.8	--	25.6	469.1	--

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, 1963, Monkton Boro, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Photorevised 1972, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File newh017.wsp
T2        Hydraulic analysis for structure NEWHTH00200017   Date: 18-JUN-97
T3        Town Highway 20, Little Otter Creek, Bridge 17, New Haven, VT     ECW
*
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1120.0   1500.0     750.0
SK          0.0007   0.0007    0.0007
*
XS   EXITX    -23           0.
GR         -500.3, 514.38   -415.4, 496.90   -267.6, 495.94   -130.3, 495.88
GR          -20.7, 495.41    -13.8, 494.43     -7.8, 493.18      0.0, 492.02
GR            3.1, 491.43      7.4, 491.27     12.6, 491.32     23.1, 491.42
GR           33.7, 492.42     40.5, 494.76     46.5, 497.48     51.6, 498.36
GR           86.0, 499.30    131.6, 499.23
*
N           0.065        0.050        0.055
SA                 -20.7         46.5
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.67       0.0
GR            0.0, 497.68      2.9, 494.70      8.2, 491.58     11.1, 491.49
GR           15.5, 492.11     19.2, 494.74     24.9, 497.65      0.0, 497.68
*
*         BRTYPE  BRWDTH
CD           1      25.3
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      24.5     2
GR         -441.7, 512.92   -310.5, 504.17   -189.9, 500.51   -109.8, 499.67
GR            0.0, 499.76     29.3, 499.92     68.6, 500.24    139.0, 501.62
GR          218.7, 505.27    390.1, 519.41
*
AS   APPRO     55           0.
GR         -296.3, 506.78   -222.9, 501.01   -138.6, 498.10    -66.7, 498.51
GR          -18.4, 495.18     -9.0, 494.54      0.0, 491.66      6.5, 491.12
GR           10.3, 491.26     17.3, 492.73     35.7, 493.22     40.5, 493.52
GR           42.4, 494.59     44.9, 496.28     53.3, 499.96     68.2, 501.76
*
N           0.040        0.045        0.055
SA                 -66.7         53.3
*
HP 1 BRIDG 497.68 1 497.68
HP 2 BRIDG 497.68 * * 826
HP 1 BRIDG 497.50 1 497.50
HP 2 RDWAY 500.31 * * 290
HP 1 APPRO 500.41 1 500.41
HP 2 APPRO 500.41 * * 1120
*
HP 1 BRIDG 497.68 1 497.68
HP 2 BRIDG 497.68 * * 995
HP 2 RDWAY 500.51 * * 507
HP 1 APPRO 500.64 1 500.64
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File newh017.wsp
        Hydraulic analysis for structure NEWHTH00200017   Date: 18-JUN-97
        Town Highway 20, Little Otter Creek, Bridge 17, New Haven, VT     ECW
           *** RUN DATE & TIME: 11-14-97  13:32
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       96      5273      0     53                            0
   497.68            96      5273      0     53  1.00      0     25        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.68     0.0    24.9    95.9    5273.     826.   8.61

X STA.         0.0         4.1         5.4         6.4         7.3         8.0
  A(I)            8.2         5.5         4.9         4.4         4.1
  V(I)           5.01        7.55        8.49        9.28        9.99

X STA.         8.0         8.7         9.3         9.9        10.5        11.1
  A(I)            4.0         3.8         3.8         3.7         3.7
  V(I)          10.36       10.85       10.96       11.05       11.02

X STA.        11.1        11.7        12.4        13.0        13.7        14.4
  A(I)            3.8         3.8         3.9         4.0         4.2
  V(I)          10.92       10.74       10.57       10.41        9.90

X STA.        14.4        15.2        16.1        17.2        18.9        24.9
  A(I)            4.3         4.8         5.2         6.4         9.3
  V(I)           9.56        8.53        7.99        6.48        4.43

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       92      7550     24     28                         1010
   497.50            92      7550     24     28  1.00      0     25     1010

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.31  -170.8    72.2   107.8    1615.     290.   2.69

X STA.      -170.8      -127.6      -114.9      -105.6       -97.0       -88.7
  A(I)            9.8         6.6         5.8         5.4         5.2
  V(I)           1.48        2.20        2.48        2.68        2.79

X STA.       -88.7       -80.3       -71.9       -63.5       -55.0       -46.5
  A(I)            5.2         5.2         5.0         5.1         5.0
  V(I)           2.78        2.80        2.88        2.84        2.88

X STA.       -46.5       -37.7       -28.9       -20.0       -12.9        -5.5
  A(I)            5.1         5.1         5.1         4.0         4.1
  V(I)           2.82        2.85        2.86        3.63        3.53

X STA.        -5.5         2.1        10.5        20.5        33.2        72.2
  A(I)            4.2         4.4         4.6         5.1         7.7
  V(I)           3.47        3.32        3.14        2.83        1.89

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      229     11876    139    139                         1665
             2      657     66720    120    122                         8725
             3        1         8      4      4                            2
   500.41           887     78604    263    265  1.17   -205     57     8564

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.41  -205.5    57.0   886.5   78604.    1120.   1.26

X STA.      -205.5      -132.4      -101.8       -67.6       -42.4       -29.4
  A(I)           91.6        66.9        68.6        68.3        52.3
  V(I)           0.61        0.84        0.82        0.82        1.07

X STA.       -29.4       -19.9       -12.0        -5.6        -1.1         2.5
  A(I)           45.5        42.6        38.9        34.8        32.0
  V(I)           1.23        1.31        1.44        1.61        1.75

X STA.         2.5         5.9         9.2        12.5        16.3        20.5
  A(I)           30.6        30.1        30.2        31.1        32.3
  V(I)           1.83        1.86        1.86        1.80        1.74

X STA.        20.5        24.8        29.3        34.0        39.1        57.0
  A(I)           32.8        33.4        34.1        36.7        54.0
  V(I)           1.71        1.68        1.64        1.53        1.04
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File newh017.wsp
        Hydraulic analysis for structure NEWHTH00200017   Date: 18-JUN-97
        Town Highway 20, Little Otter Creek, Bridge 17, New Haven, VT     ECW
           *** RUN DATE & TIME: 11-14-97  13:32
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       96      5273      0     53                            0
   497.68            96      5273      0     53  1.00      0     25        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.68     0.0    24.9    95.9    5273.     995.  10.37

X STA.         0.0         4.1         5.4         6.4         7.3         8.0
  A(I)             8.2         5.5         4.9         4.4         4.1
  V(I)            6.04        9.09       10.23       11.18       12.03

X STA.         8.0         8.7         9.3         9.9        10.5        11.1
  A(I)             4.0         3.8         3.8         3.7         3.7
  V(I)           12.48       13.07       13.20       13.31       13.27

X STA.        11.1        11.7        12.4        13.0        13.7        14.4
  A(I)             3.8         3.8         3.9         4.0         4.2
  V(I)           13.15       12.93       12.73       12.54       11.93

X STA.        14.4        15.2        16.1        17.2        18.9        24.9
  A(I)             4.3         4.8         5.2         6.4         9.3
  V(I)           11.52       10.27        9.62        7.81        5.34

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.51  -189.9    82.4   159.3    2869.     507.   3.18

X STA.      -189.9      -135.8      -120.2      -108.9       -99.1       -89.6
  A(I)            15.3        10.2         8.9         8.2         7.9
  V(I)            1.65        2.49        2.86        3.08        3.23

X STA.       -89.6       -80.2       -70.8       -61.6       -52.1       -42.6
  A(I)             7.7         7.6         7.5         7.6         7.5
  V(I)            3.30        3.32        3.40        3.36        3.39

X STA.       -42.6       -32.9       -23.2       -15.0        -7.2         0.5
  A(I)             7.6         7.5         6.3         5.9         5.8
  V(I)            3.34        3.38        4.04        4.32        4.35

X STA.         0.5         9.0        18.2        29.2        42.8        82.4
  A(I)             6.1         6.3         6.8         7.3        11.5
  V(I)            4.14        4.05        3.74        3.46        2.20

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      261     14382    145    146                         1988
             2      685     71456    120    122                         9280
             3        2        25      6      6                            6
   500.64           948     85864    271    274  1.17   -211     59     9312

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.64  -212.2    58.9   947.9   85864.    1500.   1.58

X STA.      -212.2      -137.1      -107.9       -78.0       -48.8       -33.9
  A(I)            97.3        71.5        68.1        73.5        57.8
  V(I)            0.77        1.05        1.10        1.02        1.30

X STA.       -33.9       -23.4       -14.9        -7.8        -2.5         1.4
  A(I)            49.8        46.2        42.6        38.4        34.4
  V(I)            1.50        1.62        1.76        1.96        2.18

X STA.         1.4         5.0         8.4        11.9        15.7        20.0
  A(I)            33.5        32.2        32.0        33.3        34.0
  V(I)            2.24        2.33        2.35        2.25        2.20

X STA.        20.0        24.5        29.0        33.8        39.2        58.9
  A(I)            35.1        34.7        36.3        39.1        58.2
  V(I)            2.14        2.16        2.07        1.92        1.29
```

```
         U.S. Geological Survey WSPRO Input File newh017.wsp
         Hydraulic analysis for structure NEWHTH00200017   Date: 18-JUN-97
         Town Highway 20, Little Otter Creek, Bridge 17, New Haven, VT     ECW
            *** RUN DATE & TIME: 11-14-97  13:32
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       96      5273      0     53                            0
    497.68            96      5273      0     53  1.00      0     25        0

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        497.68     0.0    24.9    95.9    5273.     750.   7.82

 X STA.        0.0        4.1        5.4        6.4        7.3        8.0
  A(I)            8.2        5.5        4.9        4.4        4.1
  V(I)           4.55       6.85       7.71       8.43       9.07

 X STA.        8.0        8.7        9.3        9.9       10.5       11.1
  A(I)            4.0        3.8        3.8        3.7        3.7
  V(I)           9.41       9.85       9.95      10.03      10.00

 X STA.       11.1       11.7       12.4       13.0       13.7       14.4
  A(I)            3.8        3.8        3.9        4.0        4.2
  V(I)           9.91       9.75       9.60       9.46       8.99

 X STA.       14.4       15.2       16.1       17.2       18.9       24.9
  A(I)            4.3        4.8        5.2        6.4        9.3
  V(I)           8.68       7.74       7.25       5.88       4.02

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       78      6100     23     26                          826
    496.93            78      6100     23     26  1.00      1     23      826

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      133      5371    117    117                          801
              2      567     52425    119    122                         7017
    499.66           700     57795    236    239  1.16   -183     53     6348

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

          WSEL     LEW     REW    AREA        K        Q    VEL
        499.66  -183.8    52.6   699.8   57795.     750.   1.07

 X STA.     -183.8     -111.1      -58.0      -36.5      -24.8      -16.1
  A(I)           76.0       69.3       53.7       42.3       37.7
  V(I)           0.49       0.54       0.70       0.89       0.99

 X STA.      -16.1       -9.0       -3.8        0.0        3.1        6.1
  A(I)           34.7       30.9       28.0       25.6       24.8
  V(I)           1.08       1.21       1.34       1.46       1.51

 X STA.        6.1        8.9       11.8       15.0       18.6       22.3
  A(I)           24.0       24.3       24.1       25.5       25.6
  V(I)           1.56       1.54       1.55       1.47       1.47

 X STA.       22.3       26.1       30.2       34.4       39.0       52.6
  A(I)           25.9       26.9       27.4       29.5       43.6
  V(I)           1.45       1.40       1.37       1.27       0.86
```

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        U.S. Geological Survey WSPRO Input File newh017.wsp
        Hydraulic analysis for structure NEWHTH00200017   Date: 18-JUN-97
        Town Highway 20, Little Otter Creek, Bridge 17, New Haven, VT     ECW
           *** RUN DATE & TIME: 11-14-97  13:32

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

EXITX:XS   ******   -417      886  0.05 *****  497.53  494.59    1120  497.48
       -22 ******     46    42306  1.92 ***** *******    0.22    1.26

FULLV:FV       23   -417      893  0.05  0.02  497.54 *******    1120  497.50
         0     23     47    42761  1.91  0.00    0.00    0.22    1.25
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.54

APPRO:AS       55    -51      321  0.19  0.07  497.68 *******    1120  497.49
        55     55     48    22948  1.00  0.07    0.00    0.34    3.49
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===210 QUESTIONABLE CRITICAL-FLOW SOLUTION.
                   SECID "BRIDG"     Q,CRWS =  1120.00     497.66

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   500.54       0.00     497.66     499.67

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   497.62     499.94     500.01     497.67

 ===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       23      0       96  1.15 *****  498.83  496.94     826  497.68
         0 ******     25     5273  1.00 ***** *******    0.77    8.61

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.500  0.000  497.67 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG      13.    31.  0.01  0.03  500.43    0.00    290.  500.31

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    247.   182.  -170.    11.   0.6   0.5   3.3   2.7   0.6   2.8
   RT:     43.    61.    11.    72.   0.5   0.3   2.6   2.5   0.4   2.7

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

APPRO:AS       30   -205      887  0.03  0.08  500.44  495.14    1120  500.41
        55     33     57    78607  1.17  0.45    0.00    0.13    1.26

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K      AREA     VEL    WSEL
   EXITX:XS     -23.  -418.    46.   1120.   42306.     886.    1.26  497.48
   FULLV:FV      0.  -418.    47.   1120.   42761.     893.    1.25  497.50
   BRIDG:BR      0.     0.    25.    826.    5273.      96.    8.61  497.68
   RDWAY:RG     13.*******   247.    290.******************    2.00  500.31
   APPRO:AS     55.  -206.    57.   1120.   78607.     887.    1.26  500.41

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    494.59    0.22  491.27  514.38************  0.05  497.53  497.48
   FULLV:FV  ********    0.22  491.27  514.38  0.02  0.00  0.05  497.54  497.50
   BRIDG:BR    496.94    0.77  491.49  497.68************  1.15  498.83  497.68
   RDWAY:RG  ***************  499.67  519.41  0.01******  0.03  500.43  500.31
   APPRO:AS    495.14    0.13  491.12  506.78  0.08  0.45  0.03  500.44  500.41
```

```
        U.S. Geological Survey WSPRO Input File newh017.wsp
        Hydraulic analysis for structure NEWHTH00200017   Date: 18-JUN-97
        Town Highway 20, Little Otter Creek, Bridge 17, New Haven, VT     ECW
           *** RUN DATE & TIME: 11-14-97  13:32

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

EXITX:XS   ******   -419     1104  0.05 *****  498.00  495.16    1500  497.95
       -22 ******     49    56667  1.75 ***** *******    0.21    1.36

FULLV:FV       23   -420     1112  0.05  0.02  498.01 *******    1500  497.96
         0     23     49    57240  1.74  0.00    0.00    0.20    1.35
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  0.48

APPRO:AS       55    -57      367  0.26  0.08  498.19 *******    1500  497.93
        55     55     49    27308  1.00  0.11    0.00    0.39    4.09
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                     WS3N,LSEL =    497.96     497.67

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                QRD,QRDMAX,RATIO =     507.       487.    1.04

            <<<<<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       23      0       96  1.67 *****  499.35  497.46     995  497.68
         0 ******     25     5273  1.00 ***** *******    0.93   10.37

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.67 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    31.  0.01  0.05  500.68    0.00    507.  500.51

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    416.   201.  -190.    11.   0.8   0.6   3.8   3.2   0.8   2.8
   RT:     92.    71.    11.    82.   0.7   0.4   3.3   3.0   0.6   2.8

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

APPRO:AS       30   -211      948  0.05  0.11  500.69  495.71    1500  500.64
        55     33     59    85907  1.17  0.45    0.00    0.16    1.58

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -23.  -420.    49.   1500.   56667.    1104.    1.36  497.95
   FULLV:FV       0.  -421.    49.   1500.   57240.    1112.    1.35  497.96
   BRIDG:BR       0.     0.    25.    995.    5273.      96.   10.37  497.68
   RDWAY:RG      13.*******   416.    507.*****************    2.00  500.51
   APPRO:AS      55.  -212.    59.   1500.   85907.     948.    1.58  500.64

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    495.16    0.21  491.27  514.38************  0.05  498.00  497.95
   FULLV:FV  ********    0.20  491.27  514.38  0.02  0.00  0.05  498.01  497.96
   BRIDG:BR    497.46    0.93  491.49  497.68************  1.67  499.35  497.68
   RDWAY:RG  ****************  499.67  519.41  0.01******  0.05  500.68  500.51
   APPRO:AS    495.71    0.16  491.12  506.78  0.11  0.45  0.05  500.69  500.64
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File newh017.wsp
        Hydraulic analysis for structure NEWHTH00200017   Date: 18-JUN-97
        Town Highway 20, Little Otter Creek, Bridge 17, New Haven, VT     ECW
           *** RUN DATE & TIME: 11-14-97  13:32

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

 EXITX:XS   ******   -414      625  0.05 *****  496.96  493.96     750  496.92
       -22 ******     45    28324  2.14 ***** *******    0.27    1.20

 FULLV:FV       23   -415      633  0.05  0.02  496.98 *******     750  496.93
          0     23     45    28707  2.14  0.00    0.00    0.26    1.18
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.64

 APPRO:AS       55    -43      270  0.12  0.06  497.07 *******     750  496.95
         55     55     46    18320  1.00  0.04    0.00    0.28    2.78
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.68     498.76     498.85     497.67

  ===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       23      0       96  0.95 *****  498.63  496.68     750  497.68
          0 ******     25     5273  1.00 ***** *******    0.70    7.82

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   2.  0.495  0.000  497.67 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      13.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPRO:AS       30   -183      701  0.02  0.06  499.68  494.48     750  499.66
         55     33     53    57865  1.16  0.47    0.00    0.12    1.07

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      ****** ****** ******** ****** ******   499.66

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
    EXITX:XS     -23.  -415.    45.    750.   28324.     625.    1.20  496.92
    FULLV:FV       0.  -416.    45.    750.   28707.     633.    1.18  496.93
    BRIDG:BR       0.     0.    25.    750.    5273.      96.    7.82  497.68
    RDWAY:RG      13.**************      0.******************    2.00********
    APPRO:AS      55.  -184.    53.    750.   57865.     701.    1.07  499.66

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS  ***********************

  SECOND USER DEFINED TABLE.

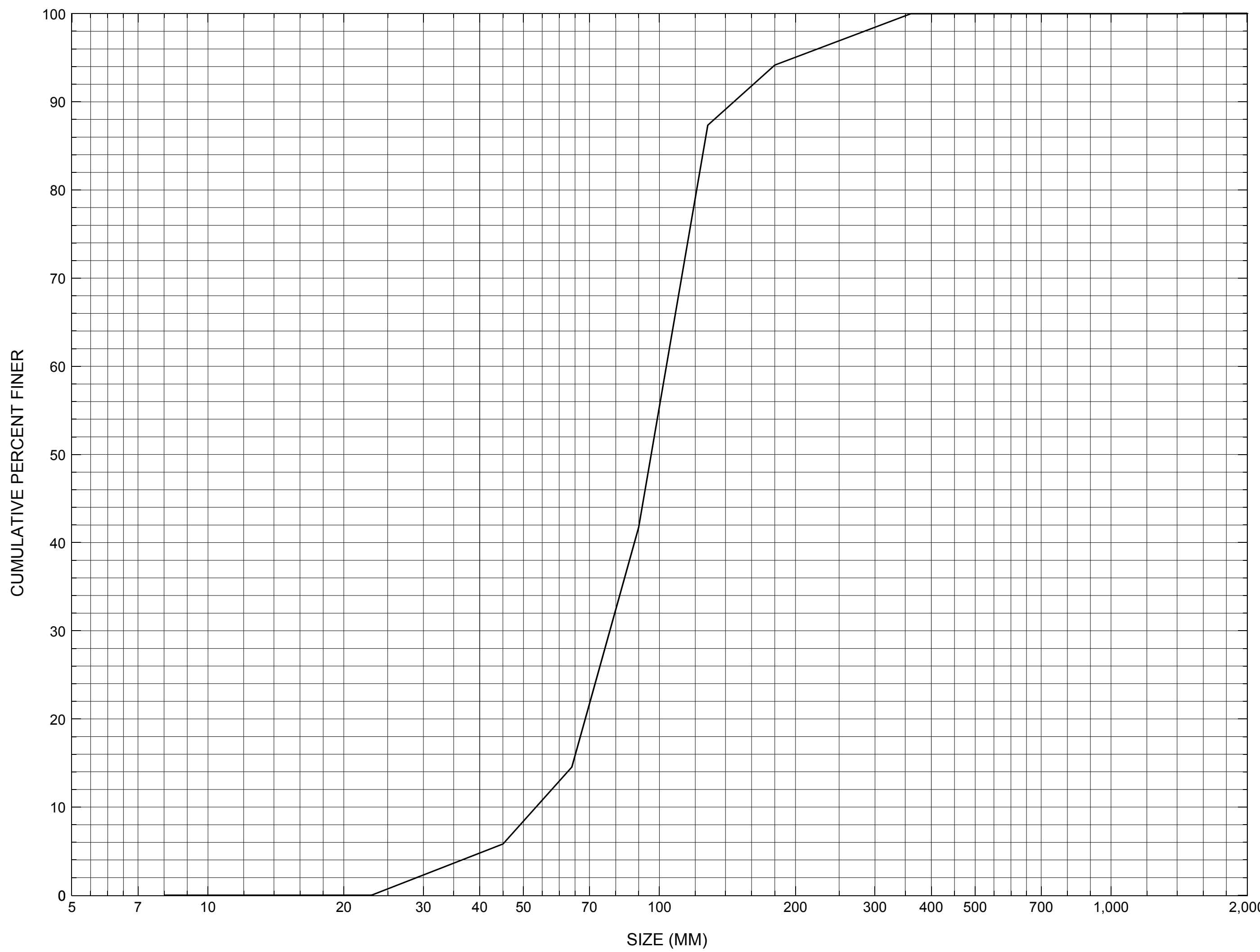
     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    EXITX:XS    493.96    0.27  491.27  514.38************  0.05  496.96  496.92
    FULLV:FV  ********    0.26  491.27  514.38  0.02  0.00  0.05  496.98  496.93
    BRIDG:BR    496.68    0.70  491.49  497.68************  0.95  498.63  497.68
    RDWAY:RG  ****************  499.67  519.41************  0.02  499.96********
    APPRO:AS    494.48    0.12  491.12  506.78  0.06  0.47  0.02  499.68  499.66
      END OF FILE ON PRIMARY INPUT UNIT  55


NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

STONE FILL MATERIAL

PARTICLE-SIZE DISTRIBUTION



Appendix C. Stone fill material particle-size distribution for a pebble count at the downstream bridge face of structure NEWHTH00200017, in New Haven, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number NEWHTH00200017

General Location Descriptive

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

Date *(MM/DD/YY)* 12 / 15 / 95

Highway District Number *(I - 2; nn)* 05

County *(FIPS county code; I - 3; nnn)* 001

Town *(FIPS place code; I - 4; nnnnn)* 48700

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

Waterway *(I - 6)* BR LITTLE OTTER CREEK

Road Name *(I - 7):* -

Route Number C3020

Vicinity *(I - 9)* 0.2 MI TO JCT C3 TH 8

Topographic Map Monkton Boro

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 44088

Longitude *(i - 17; nnnnn.n)* 73108

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011300170113

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

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

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

Structure length *(I - 49; nnnnnn)* 000032

Average daily traffic, ADT *(I - 29; nnnnnn)* 000070

Deck Width *(I - 52; nn.n)* 245

Year of ADT *(I - 30; YY)* 92

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 1988

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

Clear span (*nnn.n ft*) 25

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

Vertical clearance from streambed (*nnn.n ft*) 4.4

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

Waterway of full opening (*nnn.n* ft^2) 110.4

Comments:

According to the structural inspection report dated 12/8/94, the bridge deck is concrete with a gravel wearing surface. The abutments and backwalls are concrete. Voided sections are present along the entire bottom of the RABUT and along the bottom right half of the LABUT. The left half of each abutment appears to have been poured on a uniform layer of stones and boulders, some of which are starting to wash away at the RABUT side. The upstream half of the RABUT may be partially resting on ledge. There is spalling along the bottoms of both abutments and the right half of the faces. Some stone and boulder stone fill has been placed on the embankments at the ends of each abutment.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 10.81 mi^2 Lake/pond/swamp area 0.378 mi^2

Watershed storage *(ST)* 3.5 %

Bridge site elevation 270 ft Headwater elevation 470 ft

Main channel length 7.07 mi

10% channel length elevation 270 ft 85% channel length elevation 330 ft

Main channel slope *(S)* 11.32 ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION AVAILABLE

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION INFORMATION AVAILABLE

Comments:

NO PLANS AVAILABLE

Cross-sectional Data

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

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

Comments: **This is a cross-section of the upstream face. The low chord elevation is from the survey log done for this report on 06/11/96. The low cord to bed length data is from the sketch attached to a bridge inspection report dated 12/08/92. The sketch was done on 11/24/92.**

Station	0	6.3	12.6	18.7	25	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	497.7	497.7	497.7	497.7	497.7	-	-	-	-	-	-
Bed elevation	496.1	492.7	491.9	493.1	497.2	-	-	-	-	-	-
Low chord to bed	1.6	5	5.8	4.6	0.5	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments:

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 7/11/96

Computerized by: EW Date: 1/20/96

Reviewd by: EW Date: 11/21/97

Structure Number NEWHTH00200017

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. BURNS   Date *(MM/DD/YY)* 06 / 11 / 1996

2. Highway District Number 05   Mile marker 000000

County Addison (001)   Town New Haven (48700)

Waterway *(I - 6)* Little Otter Creek   Road Name Quarry Road

Route Number TH020   Hydrologic Unit Code: 02010002

3. Descriptive comments:

Located 0.2 miles from junction between TH20 and TH8. The bridge has a concrete deck and concrete abutments, with stone fill along the roadway embankments.

B. Bridge Deck Observations

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

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

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

7. Bridge length 32 *(feet)*   Span length 28 *(feet)*   Bridge width 24.5 *(feet)*

Road approach to bridge:

8. LB 0 RB 2 *(**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 47.6:1   US right --

	Protection: 11.Type	Protection: 12.Cond.	13.Erosion	14.Severity
LBUS	1	1	2	1
RBUS	1	1	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*

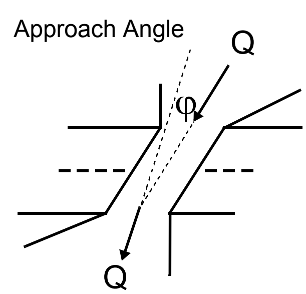
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

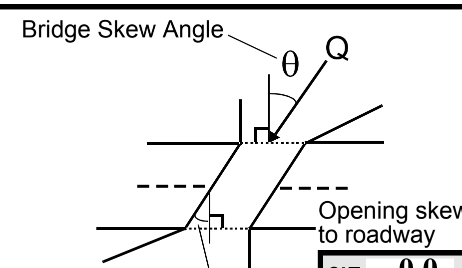
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 15   16. Bridge skew: 15





α = 0.0

17. Channel impact zone 1:   Exist? Y *(Y or N)*

Where? LB *(LB, RB)*   Severity 2

Range? 28 feet US *(US, UB, DS)* to 8 feet US

Channel impact zone 2:   Exist? Y *(Y or N)*

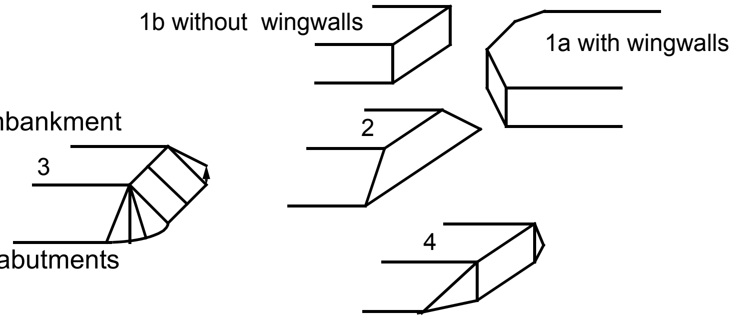
Where? RB *(LB, RB)*   Severity 1

Range? 12 feet DS *(US, UB, DS)* to 26 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 parallel to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

#4: The LBUS, RBUS, and LBDS are very low and marshy areas where pasture fields exist beyond. The RBDS is vegetated with shrubs and trees; a quarried wall of bedrock is beyond the brushland.
#7: Measured bridge length = 31.6 feet; bridge span = 29 feet; bridge width = 24.7 feet.
#11: The upstream bank protection also acts as road embankment protection.

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
35.0	3.5			9.5	1	1	123	123	1	0

23. Bank width **20.0** 24. Channel width **15.0** 25. Thalweg depth **95.5** 29. Bed Material **132**

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

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

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

#28: The stream makes a sharp bend before the bridge.
#30: Bank protection on the left bank extends 30 feet upstream.
Bank protection on right bank extends 36 feet upstream.

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

36. Point bar extent: - feet - *(US, UB)* to - feet - *(US, UB, DS)* positioned - %LB to - %RB

37. Material: -

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

NO POINT BARS

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

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

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

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

NO CUT BANKS

45. Is channel scour present? Y *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: 34 US

47. Scour dimensions: Length 8 Width 2 Depth : 0.5 Position 5 %LB to 15 %RB

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

Channel scour is present where the stream bends.

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
51.5		3.5		2	7	7	-

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

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

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

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

41

The bed material under the bridge is mostly stone fill.

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

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

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

70. Debris and Ice Comments:

2

#68: Capture efficiency is moderate because of low bridge clearance.
#69: Ice blockage potential is moderate because of low bridge clearance.

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		**-**	**80**	**2**	**0**	**-**	**-**	**90.0**
RABUT	**1**	**10**	**80**			**2**	**0**	**25.0**

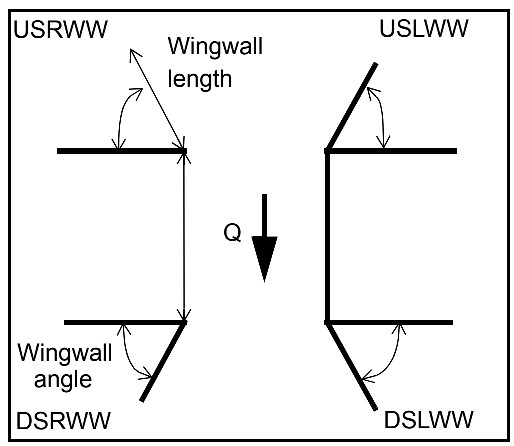
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1*- Concrete; *2*- Stone masonry or drywall; *3*- steel or metal; *4*- wood

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

-
-
1
The concrete abutment walls are at a slight angle. The protection dumped in front of the abutments is at about a 60 degree slope angle and it extends about six feet from the front of the concrete abutments.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**25.0**	
USRWW:	**N**		**-**		**-**	**3.0**	
DSLWW:	**-**		**-**		**N**	**25.5**	
DSRWW:	**-**		**-**		**-**	**25.5**	



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

82. **Bank / Bridge Protection**:

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

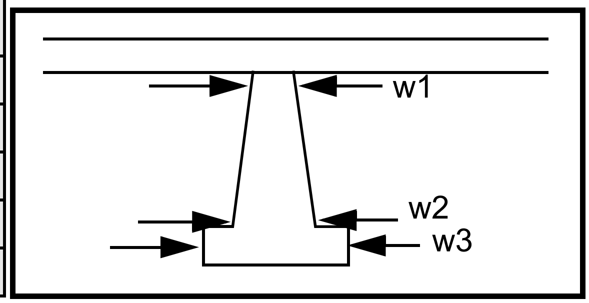
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? _____ *(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)		-	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		-	-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material		-	-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		-	-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		-	-	-	*Y- yes; N- no*
91. Attack ∠ (BF)		-	-	-	
92. Pushed		-	-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		-	-	-	
95. Cross-members		-	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition		-	-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**N**	-	-	-	
98. Exposure depth	-	-	-	-	

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
-	-			-	-	NO	PIE	RS		

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

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

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

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

1
1
12
123
0
1
14
0
2
-
1
Right bank protection extends from 4 feet US to 75 feet DS. There is a break in the protection where the DS cut-bank exists from 20 feet DS to 30 feet DS.

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

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

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

banks have type 1 protection, which extends from the DS bridge face to 4 feet DS.

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

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

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **70** feet **DS** *(US, UB, DS)* to **4** feet **60** *(US, UB, DS)*

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

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

75
DS
20
30

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

Scour dimensions: Length **chan** Width **nel** Depth: **bar** Positioned **is** %LB to **cov** %RB

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

ered with grass.

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

Confluence 1: Distance **30** Enters on **DS** *(LB or RB)* Type **20** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **DS** Enters on **32** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

1
Very slight damage from eddying.

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
-
-
-
-
-
-
NO CHANNEL SCOUR

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: NEWHTH00200017 Town: NEW HAVEN
Road Number: TH20 County: ADDISON
Stream: LITTLE OTTER CREEK

Initials ECW Date: 12/29/97 Checked: EMB

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1120	1500	750
Main Channel Area, ft2	657	685	567
Left overbank area, ft2	229	261	133
Right overbank area, ft2	1	2	0
Top width main channel, ft	120	120	119
Top width L overbank, ft	139	145	117
Top width R overbank, ft	4	6	0
D50 of channel, ft	0.005	0.005	0.005
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.5	5.7	4.8
y1, average depth, LOB, ft	1.6	1.8	1.1
y1, average depth, ROB, ft	0.3	0.3	ERR
Total conveyance, approach	78604	85864	57795
Conveyance, main channel	66720	71456	52425
Conveyance, LOB	11876	14382	5371
Conveyance, ROB	8	25	0
Percent discrepancy, conveyance	0.0000	0.0012	-0.0017
Qm, discharge, MC, cfs	950.7	1248.3	680.3
Ql, discharge, LOB, cfs	169.2	251.2	69.7
Qr, discharge, ROB, cfs	0.1	0.4	0.0
Vm, mean velocity MC, ft/s	1.4	1.8	1.2
Vl, mean velocity, LOB, ft/s	0.7	1.0	0.5
Vr, mean velocity, ROB, ft/s	0.1	0.2	ERR
Vc-m, crit. velocity, MC, ft/s	2.5	2.6	2.5
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1120	1500	750
(Q) discharge thru bridge, cfs	826	995	750
Main channel conveyance	5273	5273	5273
Total conveyance	5273	5273	5273
Q2, bridge MC discharge,cfs	826	995	750
Main channel area, ft2	96	96	96
Main channel width (normal), ft	24.9	24.9	24.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.9	24.9	24.9
y_bridge (avg. depth at br.), ft	3.86	3.86	3.86
Dm, median (1.25*D50), ft	0.00625	0.00625	0.00625
y2, depth in contraction,ft	10.61	12.45	9.77
ys, scour depth (y2-ybridge), ft	6.76	8.59	5.92

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	826	995	750
Main channel area (DS), ft2	92	96	78
Main channel width (normal), ft	24.9	24.9	24.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	24.9	24.9	24.9
D90, ft	0.4790	0.4790	0.4790
D95, ft	0.6525	0.6525	0.6525
Dc, critical grain size, ft	0.3935	0.5148	0.4860
Pc, Decimal percent coarser than Dc	0.211	0.086	0.971
Depth to armoring, ft	4.43	16.50	0.04

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc Cf=1.5*Fr^0.43 (<=1) Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1120	1500	750
Q, thru bridge MC, cfs	826	995	750
Vc, critical velocity, ft/s	2.54	2.56	2.49
Va, velocity MC approach, ft/s	1.45	1.82	1.20
Main channel width (normal), ft	24.9	24.9	24.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.9	24.9	24.9
qbr, unit discharge, ft2/s	33.2	40.0	30.1
Area of full opening, ft2	96.0	96.0	96.0
Hb, depth of full opening, ft	3.86	3.86	3.86
Fr, Froude number, bridge MC	0.77	0.93	0.7
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	92	N/A	78
**Hb, depth at downstream face, ft	3.69	N/A	3.13
**Fr, Froude number at DS face	0.82	ERR	0.96
**Cf, for downstream face (<=1.0)	1.00	N/A	1.00
Elevation of Low Steel, ft	497.67	497.67	497.67
Elevation of Bed, ft	493.81	493.81	493.81
Elevation of Approach, ft	500.41	500.64	499.66
Friction loss, approach, ft	0.08	0.11	0.06
Elevation of WS immediately US, ft	500.33	500.53	499.60
ya, depth immediately US, ft	6.52	6.72	5.79
Mean elevation of deck, ft	499.8	499.8	499.8
w, depth of overflow, ft (>=0)	0.53	0.73	0.00
Cc, vert contrac correction (<=1.0)	0.88	0.88	0.89
**Cc, for downstream face (<=1.0)	0.865694	ERR	0.79
Ys, scour w/Chang equation, ft	10.93	13.83	9.71
Ys, scour w/Umbrell equation, ft	1.00	1.77	0.25

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

**Ys, scour w/Chang equation, ft	11.36	N/A	12.20

**Ys, scour w/Umbrell equation, ft	1.16	N/A	0.98

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	10.61	12.45	9.77
WSEL at downstream face, ft	497.50	--	496.93
Depth at downstream face, ft	3.69	N/A	3.13
Ys, depth of scour (Laursen), ft	6.92	N/A	6.64

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	1120	1500	750	1120	1500	750
a', abut.length blocking flow, ft	205.5	212.2	183.8	32.1	34	27.7
Ae, area of blocked flow ft2	434.54	446.13	372.6	149.43	150.58	135.58
Qe, discharge blocked abut.,cfs	--	--	300	--	--	161.84
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.00	1.27	0.81	1.41	1.78	1.19
ya, depth of f/p flow, ft	2.11	2.10	2.03	4.66	4.43	4.89
--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	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.111	0.137	0.100	0.113	0.142	0.095
ys, scour depth, ft	11.10	12.43	9.86	11.07	11.77	10.47

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)	205.5	212.2	183.8	32.1	34	27.7
y1 (depth f/p flow, ft)	2.11	2.10	2.03	4.66	4.43	4.89
a'/y1	97.18	100.93	90.67	6.90	7.68	5.66
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.11	0.14	0.10	0.11	0.14	0.10
Ys w/ corr. factor K1/0.55:						
vertical	7.45	7.93	6.89	ERR	ERR	ERR
vertical w/ ww's	6.10	6.51	5.65	ERR	ERR	ERR
spill-through	4.09	4.36	3.79	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.82	0.93	0.96	0.82	0.93	0.96
y, depth of flow in bridge, ft	3.69	3.86	3.13	3.69	3.86	3.13
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	1.46	1.58	1.29	1.46	1.58	1.29