LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (LONDTH00410029) on TOWN HIGHWAY 41, crossing COOK BROOK, LONDONDERRY, VERMONT

U.S. Geological Survey
Open-File Report 97-403

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (LONDTH00410029) on TOWN HIGHWAY 41, crossing COOK BROOK, LONDONDERRY, VERMONT

By LORA K. STRIKER AND EMILY C. WILD

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U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	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 29 (LONDTH00410029) ON TOWN HIGHWAY 41, CROSSING COOK BROOK, LONDONDERRY, VERMONT

By **Lora K. Striker and Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure LONDTH00410029 on Town Highway 41 crossing Cook Brook, Londonderry, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in south-central Vermont. The 6.48-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is shrub on the left bank upstream and downstream of the bridge while the right bank is forest upstream and downstream of the bridge.

In the study area, Cook Brook has a straight incised channel with a slope of approximately 0.02 ft/ft, an average channel top width of 80 ft and an average bank height of 8 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 70.9 mm (0.233 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 7, 1996, indicated that the reach was stable.

The Town Highway 41 crossing of Cook Brook is a 25-ft-long, one-lane bridge consisting of one 22-foot steel-beam span (Vermont Agency of Transportation, written communication, April 6, 1995). The opening length of the structure parallel to the bridge face is 20.4 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 5 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the upstream left wingwall and left abutment during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches) along the downstream end of the left abutment and upstream end of the downstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 1.5. Abutment scour ranged from 8.4 to 15.1 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number LONDTH00410029 ***Stream*** Cook Brook

County Windham ***Road*** TH41 ***District*** 2

Description of Bridge

Bridge length 25 ***ft*** ***Bridge width*** 12.6 ***ft*** ***Max span length*** 22 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** Sloping; near vertical

Stone fill on abutment? Yes ***Date of inspection*** 08/07/96

Description of stone fill Type-2, along the downstream end of the left abutment and upstream end of the DSRWW.

The abutments and wingwalls are concrete. There is a one foot deep scour hole in front of the upstream left wingwall and left abutment.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 5

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	08/07/96	0	0
Level II	08/07/96	0	0

Potential for debris Moderate. There is some debris caught on both the left and right upstream wingwalls. There are also trees leaning into the channel US.

Describe any features near or at the bridge that may affect flow (include observation date) None, 08/07/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley.

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

Date of inspection 08/07/96

DS left: Steep channel bank to moderately sloped overbank

DS right: Moderately sloped overbank

US left: Steep channel bank to moderately sloped overbank

US right: Moderately sloped overbank

Description of the Channel

Average top width 80 ***ft*** ***Average depth*** 8 ***ft***

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

Straight and stable with semi-alluvial boundaries.

08/07/96

Vegetative co Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: Trees. and brush.

US right:

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

None 08/07/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 6.48 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p ... No

Calculated Discharges

Q100 1650 ***ft³/s*** ***Q500*** 2350 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(6.48/5.60)exp 0.67] with bridge number 4 in Winhall. Bridge number 4 crosses Cook Brook upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 4 is 5.6 square miles. These values are within a range defined by several empirical flood frequency curves.(Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887)

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 at the downstream shoreward corner of a chiseled square at the upstream end of the left abutment (elev. 499.43 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 499.79 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	-23	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APTEM	36	1	Approach section as surveyed (Used as a template)
APPRO	42	2	Modelled Approach section (Templated from APTEM)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.055 to 0.065, and overbank "n" values ranged from 0.060 to 0.080.

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 0.0164 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0313 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.9 *ft*
Average low steel elevation 498.4 *ft*

100-year discharge 1,650 *ft³/s*
Water-surface elevation in bridge opening 498.5 *ft*
Road overtopping? Y *Discharge over road* 83 *ft³/s*
Area of flow in bridge opening 167 *ft²*
Average velocity in bridge opening 9.4 *ft/s*
Maximum WSPRO tube velocity at bridge 11.5 *ft/s*

Water-surface elevation at Approach section with bridge 500.6
Water-surface elevation at Approach section without bridge 497.7
Amount of backwater caused by bridge 2.9 *ft*

500-year discharge 2,350 *ft³/s*
Water-surface elevation in bridge opening 498.5 *ft*
Road overtopping? Y *Discharge over road* 548 *ft³/s*
Area of flow in bridge opening 167 *ft²*
Average velocity in bridge opening 10.8 *ft/s*
Maximum WSPRO tube velocity at bridge 13.2 *ft/s*

Water-surface elevation at Approach section with bridge 501.7
Water-surface elevation at Approach section without bridge 498.6
Amount of backwater caused by bridge 3.1 *ft*

Incipient overtopping discharge 1,390 *ft³/s*
Water-surface elevation in bridge opening 498.5 *ft*
Area of flow in bridge opening 167 *ft²*
Average velocity in bridge opening 8.3 *ft/s*
Maximum WSPRO tube velocity at bridge 10.2 *ft/s*

Water-surface elevation at Approach section with bridge 499.9
Water-surface elevation at Approach section without bridge 497.3
Amount of backwater caused by bridge 2.6 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site all discharges resulted in unsubmerged 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 was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For all discharges resulting in orifice flow, estimates of contraction scour were also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, for those discharges resulting 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 provided in Appendix F.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.5 1.5	0.0	6.4 5.8
Depth to armoring	5.3	--	--
Left overbank	--	--	--
Right overbank	--	8.6 8.7	8.4

Local scour:			
Abutment scour	14.1	15.1	13.3
Left abutment	---	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	2.3	2.3	2.1
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	2.3	2.3	2.1
Left abutment	--	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1			
Pier 2			

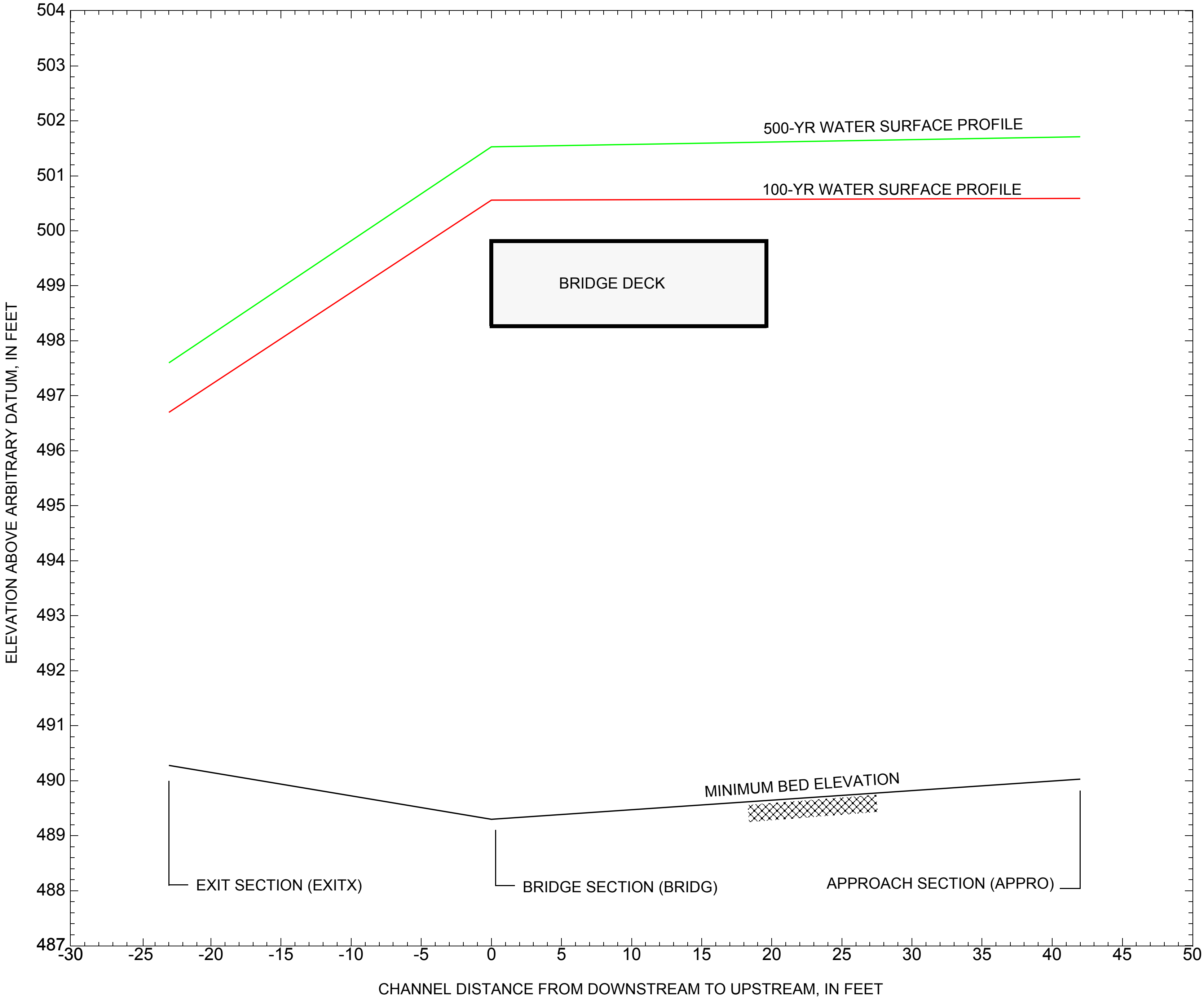

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure LONDTH00410029 on Town Highway 41, crossing Cook Brook, Londonderry, Vermont.

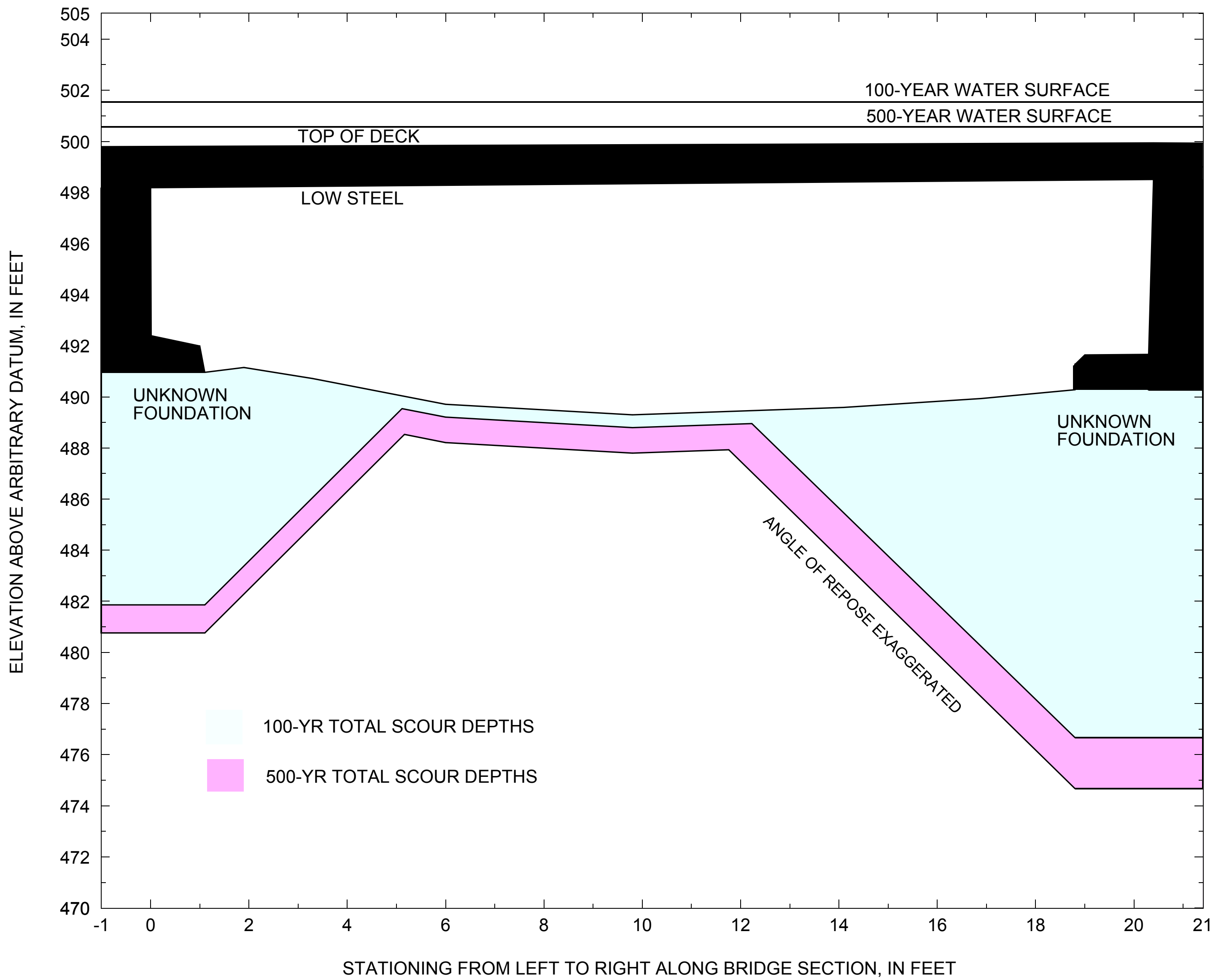

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure LONDTH00410029 on Town Highway 41, crossing Cook Brook, Londonderry, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure LONDTH00410029 on Town Highway 41, crossing Cook Brook, Londonderry, 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 1650 cubic-feet per second											
Left abutment	0.0	--	498.2	--	491.0	0.5	8.6	--	9.1	481.9	--
Right abutment	20.4	--	498.5	--	490.3	0.5	14.1	--	14.6	475.7	--

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-year discharge at structure LONDTH00410029 on Town Highway 41, crossing Cook Brook, Londonderry, 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 2350 cubic-feet per second											
Left abutment	0.0	--	498.2	--	491.0	1.5	8.7	--	10.2	480.8	--
Right abutment	20.4	--	498.5	--	490.3	1.5	15.1	--	16.6	473.7	--

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

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

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File lond029.wsp
T2        Hydraulic analysis for structure LONDTH00410029   Date: 06-MAY-97
T3        TH 041 over Cook Brook located 0.1 miles of junction with TH 39
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1650.0   2350.0   1390.0
SK          0.0164   0.0164   0.0164
*
XS   EXITX    -23
GR         -186.6, 509.01   -169.9, 503.32    -35.6, 500.39    -20.6, 499.99
GR           -7.6, 494.48      0.0, 493.11      1.7, 491.42      3.4, 491.14
GR            7.1, 490.28     12.1, 490.33     18.3, 490.39     22.8, 490.57
GR           22.8, 491.18     23.2, 491.85     28.5, 493.14     42.0, 494.58
GR           51.8, 496.43     88.0, 498.06    101.6, 501.42    154.7, 504.87
GR          172.1, 510.41
*
N           0.060        0.065        0.080
SA                 -20.6          51.8
*
XS   FULLV      0  * * *   0.0020
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.35       0.0
GR            0.0, 498.19      0.1, 492.39      1.0, 491.99      1.1, 490.96
GR            1.9, 491.15      3.3, 490.72      6.0, 489.71      9.8, 489.30
GR           14.1, 489.59     16.9, 489.94     18.8, 490.28     18.8, 491.27
GR           19.0, 491.64     20.3, 491.66     20.4, 498.51      0.0, 498.19
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      28.4 * *     34.7     10.3
N           0.055
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      12.6     2
GR         -252.1, 522.61   -139.3, 506.67    -84.6, 502.93    -35.9, 501.13
GR            0.0, 499.80     21.5, 499.94    101.0, 502.39    139.0, 508.73
*
*           EXPECTED SRD =   42 AT ONE BR. LENGTH BUT COMPUTED SRD =   36
*
XT   APTEM     36
GR         -212.1, 517.30   -169.4, 511.33    -69.9, 502.64    -35.1, 501.47
GR          -14.3, 498.08     -9.7, 495.85     -8.1, 494.86      0.0, 492.96
GR            1.0, 491.70      2.6, 491.15      4.0, 490.34      6.8, 490.07
GR           10.6, 489.84     15.1, 490.18     18.9, 491.16     21.6, 492.00
GR           37.3, 494.63     49.2, 496.46     51.6, 497.94     77.4, 501.41
GR          131.9, 505.25    172.2, 510.65
*
AS   APPRO     42 * * * 0.0313
GT
N           0.060        0.065     0.08
SA                 -35.1      51.6
*
HP 1 BRIDG   498.51 1 498.51
HP 2 BRIDG   498.51 * * 1573
* fullvalley
HP 1 BRIDG   497.17 1 497.17
HP 2 RDWAY   500.56 * *   83
HP 1 APPRO   500.59 1 500.59
HP 2 APPRO   500.59 * * 1650
*
HP 1 BRIDG   498.51 1 498.51
HP 2 BRIDG   498.51 * * 1795
* fullvalley
HP 1 BRIDG   498.10 1 498.10
HP 2 RDWAY   501.53 * *  548
HP 1 APPRO   501.71   501.71
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File lond029.wsp
        Hydraulic analysis for structure LONDTH00410029   Date: 06-MAY-97
        TH 041 over Cook Brook located 0.1 miles of junction with TH 39
           *** RUN DATE & TIME: 06-02-97  13:32

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =        0.
       WSEL     LEW     REW    AREA        K        Q     VEL
     498.51     0.0    20.4   166.7    9366.    1573.   9.43
 X STA.         0.0         2.3         3.6         4.7         5.6         6.5
  A(I)             14.8         9.7         8.6         7.8         7.6
  V(I)             5.30        8.12        9.12       10.09       10.39

 X STA.         6.5         7.3         8.1         8.9         9.7        10.4
  A(I)              7.2         7.0         6.9         6.9         6.9
  V(I)            10.92       11.19       11.45       11.46       11.40

 X STA.        10.4        11.2        12.0        12.7        13.5        14.3
  A(I)              6.9         6.8         6.9         7.1         7.1
  V(I)            11.48       11.53       11.45       11.12       11.04

 X STA.        14.3        15.2        16.1        17.1        18.2        20.4
  A(I)              7.5         7.8         8.2         9.4        15.7
  V(I)            10.52       10.03        9.62        8.38        5.00

  * fullvalley
  HP 1 BRIDG   497.17 1 497.17
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      143     10243     20     33                         2143
   497.17           143     10243     20     33  1.00      0     20     2143

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       11.
        WSEL     LEW     REW    AREA        K        Q     VEL
      500.58   -21.1    42.3    30.1     423.      83.   2.76
 X STA.       -21.1        -9.3        -5.8        -3.3        -1.4         0.3
  A(I)              2.6         1.7         1.5         1.4         1.3
  V(I)             1.62        2.39        2.76        3.01        3.22

 X STA.         0.3         2.0         3.6         5.2         6.8         8.5
  A(I)              1.3         1.2         1.2         1.2         1.2
  V(I)             3.30        3.39        3.41        3.38        3.43

 X STA.         8.5        10.2        12.0        13.9        15.7        17.7
  A(I)              1.2         1.3         1.3         1.3         1.4
  V(I)             3.34        3.29        3.24        3.26        3.06

 X STA.        17.7        19.9        22.1        24.9        28.8        42.3
  A(I)              1.4         1.4         1.6         1.8         2.8
  V(I)             2.96        2.90        2.54        2.25        1.49

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      482     35547     80     83                         6698
             3       23       479     18     18                          142
   500.59           504     36026     98    102  1.05    -28     70     6305

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =       42.
       WSEL     LEW     REW    AREA        K        Q     VEL
     500.59   -28.5    69.9   504.1   36026.    1650.   3.27
 X STA.       -28.5        -6.4        -1.4         2.0         4.6         6.7
  A(I)             50.4        32.2        27.4        24.5        21.8
  V(I)             1.64        2.56        3.01        3.36        3.78

 X STA.         6.7         8.7        10.6        12.5        14.3        16.2
  A(I)             20.8        19.7        19.8        19.0        19.2
  V(I)             3.97        4.20        4.17        4.34        4.29

 X STA.        16.2        18.2        20.4        22.8        25.4        28.3
  A(I)             19.3        20.0        20.5        20.7        21.7
  V(I)             4.27        4.13        4.02        3.99        3.81

 X STA.        28.3        31.4        35.1        39.5        45.1        69.9
  A(I)             22.1        23.8        25.3        28.3        47.5
  V(I)             3.72        3.46        3.27        2.92        1.74
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        U.S. Geological Survey WSPRO Input File lond029.wsp
      Hydraulic analysis for structure LONDTH00410029   Date: 06-MAY-97
      TH 041 over Cook Brook located 0.1 miles of junction with TH 39
         *** RUN DATE & TIME: 06-02-97  13:32
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      167      9366     0     56                            0
   498.51           167      9366     0     56  1.00      0     20        0

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.51     0.0    20.4   166.7    9366.    1795.  10.77
X STA.         0.0        2.3        3.6        4.7        5.6        6.5
  A(I)             14.8        9.7        8.6        7.8        7.6
  V(I)             6.04       9.27      10.41      11.52      11.86

X STA.         6.5        7.3        8.1        8.9        9.7       10.4
  A(I)              7.2        7.0        6.9        6.9        6.9
  V(I)            12.46      12.77      13.06      13.08      13.01

X STA.        10.4       11.2       12.0       12.7       13.5       14.3
  A(I)              6.9        6.8        6.9        7.1        7.1
  V(I)            13.10      13.16      13.06      12.69      12.59

X STA.        14.3       15.2       16.1       17.1       18.2       20.4
  A(I)              7.5        7.8        8.2        9.4       15.7
  V(I)            12.01      11.44      10.98       9.56       5.70

  * fullvalley
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      162     12158    20     35                         2582
   498.10           162     12158    20     35  1.00      0     20     2582

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.53   -46.7    73.1   117.1    2979.     548.   4.68
X STA.       -46.7      -23.0      -16.3      -11.6       -7.7       -4.4
  A(I)             10.4        6.6        5.8        5.3        5.0
  V(I)             2.62       4.13       4.74       5.13       5.49

X STA.        -4.4       -1.4        1.3        4.1        6.8        9.6
  A(I)              4.8        4.7        4.7        4.6        4.7
  V(I)             5.72       5.79       5.89       5.91       5.79

X STA.         9.6       12.5       15.4       18.4       21.6       24.9
  A(I)              4.8        4.7        4.9        5.0        5.1
  V(I)             5.71       5.78       5.58       5.48       5.33

X STA.        24.9       28.6       33.0       38.3       45.6       73.1
  A(I)              5.3        5.7        6.1        7.0       11.7
  V(I)             5.17       4.79       4.51       3.91       2.35

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1        0         0     2      2                            0
             2      575     45413    87     90                         8406
             3       48      1281    27     28                          358
   501.71           623     46694   116    119  1.08    -36     79     7885


     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.71   -36.7    79.0   622.9   46694.    2350.   3.77

X STA.       -36.7       -8.6       -3.1        1.1        4.0        6.3
  A(I)             63.8       40.1       35.0       30.2       26.8
  V(I)             1.84       2.93       3.36       3.89       4.39

X STA.         6.3        8.6       10.7       12.7       14.8       16.9
  A(I)             25.5       24.5       23.6       23.8       23.2
  V(I)             4.60       4.79       4.98       4.93       5.06

X STA.        16.9       19.1       21.5       24.2       27.0       30.0
  A(I)             23.6       24.2       24.4       24.8       25.8
  V(I)             4.99       4.85       4.82       4.74       4.55

X STA.        30.0       33.6       37.4       42.0       47.7       79.0
  A(I)             27.5       27.7       30.1       32.4       65.9
  V(I)             4.27       4.24       3.90       3.63       1.78
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        U.S. Geological Survey WSPRO Input File lond029.wsp
       Hydraulic analysis for structure LONDTH00410029   Date: 06-MAY-97
       TH 041 over Cook Brook located 0.1 miles of junction with TH 39
          *** RUN DATE & TIME: 06-02-97  13:32
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      167      9366      0     56                           0
    498.51          167      9366      0     56  1.00      0     20        0

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        498.51     0.0    20.4   166.7    9366.    1390.   8.34
  X STA.        0.0        2.3        3.6        4.7        5.6        6.5
    A(I)            14.8        9.7        8.6        7.8        7.6
    V(I)            4.68       7.18       8.06       8.92       9.18

  X STA.        6.5        7.3        8.1        8.9        9.7       10.4
    A(I)             7.2        7.0        6.9        6.9        6.9
    V(I)            9.65       9.89      10.12      10.13      10.07

  X STA.       10.4       11.2       12.0       12.7       13.5       14.3
    A(I)             6.9        6.8        6.9        7.1        7.1
    V(I)           10.14      10.19      10.11       9.83       9.75

  X STA.       14.3       15.2       16.1       17.1       18.2       20.4
    A(I)             7.5        7.8        8.2        9.4       15.7
    V(I)            9.30       8.86       8.50       7.40       4.42

    * fullvalley
    HP 1 BRIDG   496.75 1 496.75
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      134      9401     20     32                        1954
    496.75          134      9401     20     32  1.00      0     20     1954

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      424     29852     76     79                        5696
             3       11       185     13     13                          58
    499.85          435     30037     88     92  1.03    -23     64     5384

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      42.
          WSEL     LEW     REW    AREA        K        Q    VEL
        499.85   -24.0    64.4   434.9   30037.    1390.   3.20

  X STA.      -24.0       -5.1       -0.6        2.5        4.7        6.7
    A(I)            42.2       27.3       23.6       20.3       18.9
    V(I)            1.65       2.54       2.94       3.42       3.68

  X STA.        6.7        8.6       10.3       12.1       13.8       15.6
    A(I)            18.0       17.0       17.2       16.5       16.8
    V(I)            3.86       4.08       4.04       4.21       4.14

  X STA.       15.6       17.4       19.4       21.7       24.1       26.9
    A(I)            16.7       17.4       17.8       18.4       19.2
    V(I)            4.16       4.00       3.90       3.78       3.63

  X STA.       26.9       29.9       33.4       37.8       43.4       64.4
    A(I)            20.1       20.8       23.0       25.6       38.0
    V(I)            3.45       3.34       3.02       2.72       1.83
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WSPRO OUTPUT FILE (continued)

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         U.S. Geological Survey WSPRO Input File lond029.wsp
        Hydraulic analysis for structure LONDTH00410029   Date: 06-MAY-97
        TH 041 over Cook Brook located 0.1 miles of junction with TH 39
          *** RUN DATE & TIME: 06-02-97  13:32
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******    -12      241  0.73 *****  497.43  495.54    1650  496.70
       -22 ******     58    12878  1.01 ***** *******    0.65    6.84

FULLV:FV       23    -13      273  0.58  0.32  497.75 *******    1650  497.17
         0     23     67    15294  1.03  0.00    0.00    0.59    6.04
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       42    -12      273  0.57  0.47  498.24 *******    1650  497.67
        42     42     51    16016  1.00  0.00    0.02    0.52    6.05
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   500.14       0.00     496.06     499.80
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   496.02     499.93     500.09     498.35
 ===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      167  1.38 *****  499.89  495.86    1573  498.51
         0 ******     20     9366  1.00 ***** *******    0.58    9.44

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.465  0.000  498.35 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    29.  0.06  0.18  500.71    0.00     83.  500.56

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     45.    31.   -20.    10.   0.8   0.5   3.4   2.9   0.6   2.8
   RT:     39.    31.    10.    41.   0.7   0.4   3.2   2.9   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       14    -28      504  0.18  0.12  500.77  495.86    1650  500.59
        42     15     70    36050  1.05  1.20    0.00    0.26    3.27

   FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -23.   -13.    58.   1650.   12878.     241.    6.84  496.70
   FULLV:FV       0.   -14.    67.   1650.   15294.     273.    6.04  497.17
   BRIDG:BR       0.     0.    20.   1573.    9366.     167.    9.44  498.51
   RDWAY:RG      11.*******    45.     83.******************    2.00  500.56
   APPRO:AS      42.   -29.    70.   1650.   36050.     504.    3.27  500.59

  SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.54    0.65  490.28  510.41************  0.73  497.43  496.70
   FULLV:FV  ********    0.59  490.33  510.46  0.32  0.00  0.58  497.75  497.17
   BRIDG:BR    495.86    0.58  489.30  498.51************  1.38  499.89  498.51
   RDWAY:RG  ****************  499.80  522.61  0.06******  0.18  500.71  500.56
   APPRO:AS    495.86    0.26  490.03  517.49  0.12  1.20  0.18  500.77  500.59
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         U.S. Geological Survey WSPRO Input File lond029.wsp
        Hydraulic analysis for structure LONDTH00410029   Date: 06-MAY-97
        TH 041 over Cook Brook located 0.1 miles of junction with TH 39
           *** RUN DATE & TIME: 06-02-97  13:32

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******    -14      315  0.93 *****  498.53  496.42    2350  497.60
       -22 ******     78    18349  1.07 ***** *******    0.74    7.46

FULLV:FV       23    -15      359  0.74  0.32  498.84 *******    2350  498.10
         0     23     88    21580  1.11  0.00   -0.01    0.65    6.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       42    -15      335  0.77  0.50  499.37 *******    2350  498.60
        42     42     55    21530  1.00  0.02    0.02    0.57    7.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   502.56       0.00     497.62     499.80
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   497.08     501.11     501.28     498.35
 ===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      167  1.80 *****  500.31  496.40    1795  498.51
         0 ******     20     9366  1.00 ***** *******    0.66   10.77

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.489  0.000  498.35 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    29.  0.07  0.24  501.88    0.00    548.  501.53

           Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    276.    57.   -47.    10.   1.7   1.0   5.3   4.8   1.4   3.0
   RT:    272.    63.    10.    73.   1.7   0.9   5.0   4.6   1.3   2.9

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS       14    -36      623  0.24  0.15  501.95  496.79    2350  501.71
        42     15     79    46744  1.08  1.14    0.00    0.30    3.77

   FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -23.   -15.    78.   2350.   18349.     315.    7.46  497.60
   FULLV:FV       0.   -16.    88.   2350.   21580.     359.    6.54  498.10
   BRIDG:BR       0.     0.    20.   1795.    9366.     167.   10.77  498.51
   RDWAY:RG      11.*******   276.    548.******************    2.00  501.53
   APPRO:AS      42.   -37.    79.   2350.   46744.     623.    3.77  501.71

   SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    496.42    0.74  490.28  510.41************  0.93  498.53  497.60
   FULLV:FV  ********    0.65  490.33  510.46  0.32  0.00  0.74  498.84  498.10
   BRIDG:BR    496.40    0.66  489.30  498.51************  1.80  500.31  498.51
   RDWAY:RG  ****************  499.80  522.61  0.07******  0.24  501.88  501.53
   APPRO:AS    496.79    0.30  490.03  517.49  0.15  1.14  0.24  501.95  501.71
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         U.S. Geological Survey WSPRO Input File lond029.wsp
        Hydraulic analysis for structure LONDTH00410029   Date: 06-MAY-97
        TH 041 over Cook Brook located 0.1 miles of junction with TH 39
          *** RUN DATE & TIME: 06-02-97  13:32

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******    -11      215  0.65 *****  496.95  495.16    1390  496.30
       -22 ******     51    10847  1.00 ***** *******    0.62    6.47

FULLV:FV       23    -12      242  0.52  0.32  497.27 *******    1390  496.75
         0     23     58    12904  1.01  0.00    0.00    0.55    5.75
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       42    -11      247  0.49  0.46  497.75 *******    1390  497.25
        42     42     50    13774  1.00  0.00    0.02    0.50    5.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.67     498.86     499.02     498.35

 ===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      167  1.06 *****  499.57  495.37    1376  498.51
         0 ******     20     9366  1.00 ***** *******    0.51    8.25

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.433  0.000  498.35 ****** ****** ******

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

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS       14    -23      435  0.16  0.10  500.01  495.46    1390  499.85
        42     15     64    30000  1.03  1.03   -0.01    0.26    3.20

  FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -23.   -12.    51.   1390.   10847.     215.    6.47  496.30
   FULLV:FV       0.   -13.    58.   1390.   12904.     242.    5.75  496.75
   BRIDG:BR       0.     0.    20.   1376.    9366.     167.    8.25  498.51
   RDWAY:RG      11.**************       0.       0.       0.    2.00********
   APPRO:AS      42.   -24.    64.   1390.   30000.     435.    3.20  499.85

  SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.16    0.62  490.28  510.41************  0.65  496.95  496.30
   FULLV:FV  ********    0.55  490.33  510.46  0.32  0.00  0.52  497.27  496.75
   BRIDG:BR    495.37    0.51  489.30  498.51************  1.06  499.57  498.51
   RDWAY:RG  ****************  499.80  522.61************  0.16  499.95********
   APPRO:AS    495.46    0.26  490.03  517.49  0.10  1.03  0.16  500.01  499.85
```
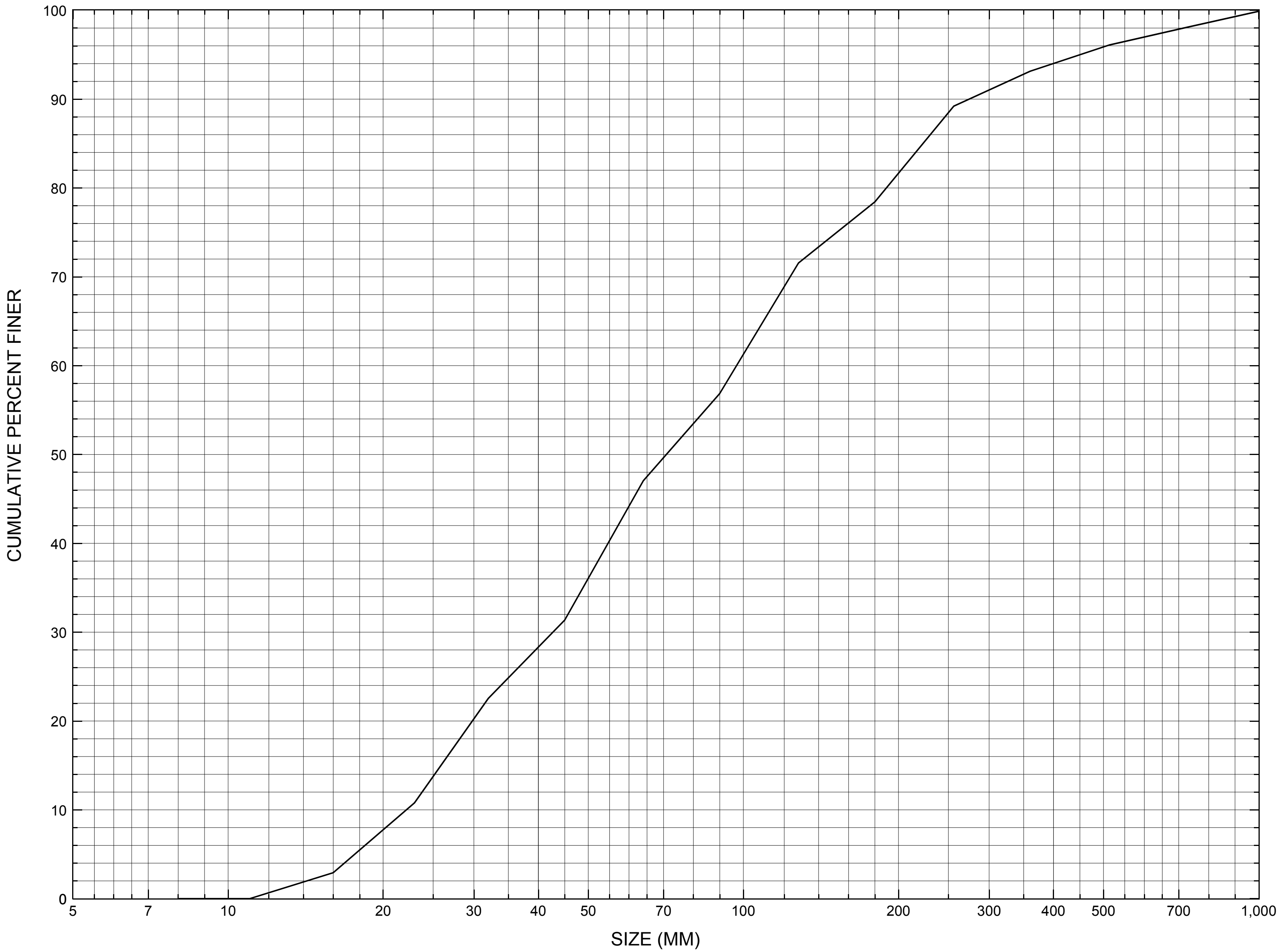

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure LONDTH00410029, in Londonderry, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number LONDTH00410029

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. IVANOFF

Date *(MM/DD/YY)* 04 / 06 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 40225

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

Waterway *(I - 6)* COOK BROOK

Road Name *(I - 7):* -

Route Number TH041

Vicinity *(I - 9)* 0.1 MI JCT TH 41 & TH 39

Topographic Map Londonderry

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43113

Longitude *(i - 17; nnnnn.n)* 72513

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10131000291310

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

Maximum span length *(I - 48; nnnn)* 0022

Year built *(I - 27; YYYY)* 1950

Structure length *(I - 49; nnnnnn)* 000025

Average daily traffic, ADT *(I - 29; nnnnnn)* 000030

Deck Width *(I - 52; nn.n)* 126

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

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)* P

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 008.0

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

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

Comments:

The structural inspection report of 09/15/93 indicates the structure is a steel beam type bridge with a timber deck. Both concrete abutment walls have only a couple of hairline cracks and stains reported. The report also states that the footings are exposed. The streambed along the right abutment is roughly 12 inches below the top of footing. At the left abutment the bed is 2 feet below the top of the footing, and there is some very shallow undermining beneath the footing. In a few locations, the range pole can be shoved up to 3 feet behind the front face of the footing. There are some random boulders in view beneath the footing. Overall, the abutment appears stable. The streambed consists of stone and gravel, with some silt deposits.

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:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **6.48** mi^2 Lake/pond/swamp area **0.02** mi^2
Watershed storage *(ST)* **0.3** %
Bridge site elevation **1043** ft Headwater elevation **3281** ft
Main channel length **5.63** mi
10% channel length elevation **1260** ft 85% channel length elevation **2126** ft
Main channel slope *(S)* **205.29** 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:

There is 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:

There is no foundation material information available.

Comments:

There are no bridge plans available.

Cross-sectional Data

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

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

Comments: **There is no cross-section information available.**

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: **There is no cross-section information available.**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 1/23/97
Computerized by: RB Date: 1/23/97
Reviewd by: LKS Date: 06/02/97

Structure Number LONDTH00410029

A. General Location Descriptive

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

2. Highway District Number 02 Mile marker 0000

County WINDHAM (025) Town LONDONDERRY (40225)

Waterway *(I - 6)* COOK BROOK Road Name SPRING HILL ROAD

Route Number TH041 Hydrologic Unit Code: 01080107

3. Descriptive comments:

The bridge is located 0.1 miles from the junction of TH41 and TH39, Livermore Rd.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 6 LBDS 5 RBDS 6 Overall 5

*(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 25 *(feet)* Span length 22 *(feet)* Bridge width 12.6 *(feet)*

Road approach to bridge:

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

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

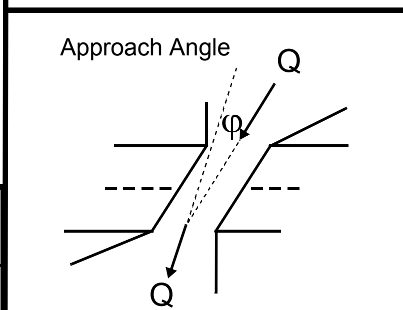
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

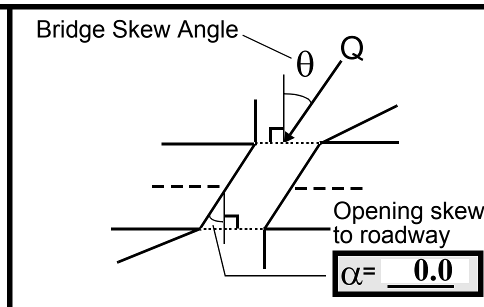
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	0	-	2	1
LBDS	0	-	2	1

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*
*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 5





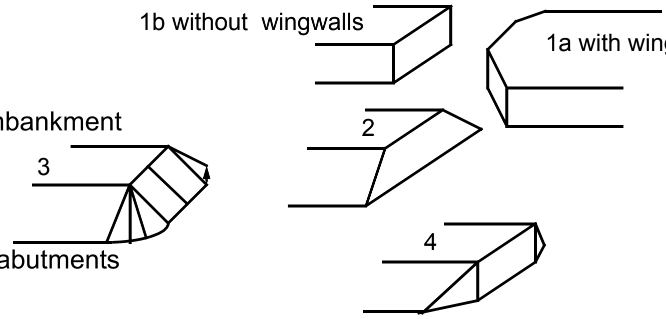
17. Channel impact zone 1: Exist? N *(Y or N)*
Where? - *(LB, RB)* Severity -
Range? - feet - *(US, UB, DS)* to - feet -

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

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

18. Bridge Type: 1a

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

4. On the left bank US is TH 41 and a small home on the hillside. The left bank DS surface cover has a few trees, many bushes and a small clearing where tall grass and small bushes are growing.
7. Bridge dimensions are from the VT AOT. The measured bridge length is 23.5 ft., bridge span is 21.3 ft., and the bridge width is 12.6 ft.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
24.0	11.0			6.0	2	3	425	425	2	2

23. Bank width 15.0 24. Channel width 10.0 25. Thalweg depth 87.0 29. Bed Material 4325

30 .Bank protection type: LB 0 RB 0 31. Bank protection condition: LB - RB -

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

32. Comments (bank material variation, minor inflows, protection extent, etc.):
The channel is straight, however, both banks have eroded extensively which has led to slumping. Vegetation on both banks has fallen down, covering the stream with a canopy of leaves. From 35 ft US to the bridge face, there is an opening in the vegetative canopy.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **12** 35. Mid-bar width: **6**

36. Point bar extent: **32** feet **US** (US, UB) to **7** feet **US** (US, UB, DS) positioned **60** %LB to **100** %RB

37. Material: **123**

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

There is an additional side bar comprised of silt, clay and sand from 3.5 ft. US to 3 ft. DS. The mid-bar distance is 8 ft under the bridge. At this point the bar is 7 ft wide. The bar is positioned from 50% LB to 100% RB.

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.):

There are no cut-banks present.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **5**

47. Scour dimensions: Length **18.5** Width **5** Depth : **1** Position **10** %LB to **50** %RB

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

The scour is deepest at the corner of the US end of the left abutment and the US left wingwall. The thalweg was measured out of the scour hole and is assumed to be 1.1 ft. The scour extends from 8.5 ft US to 10 ft. under the bridge.

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

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

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

54. Confluence comments (eg. confluence name):

There are no major confluences.

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
18.0		**1.5**		**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.):

1234

63. The right side of the channel bed is silt, clay, sand and gravel from the side bar. The center of the channel is cobble. The left side of the channel is comprised of boulders protecting the DS end of the left abutment.

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

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

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

70. Debris and Ice Comments:

2

65. There is debris caught on both US wingwalls.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**2**	**3**	**0**	**2.1**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**2**	**20.5**

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.):

0

1.1

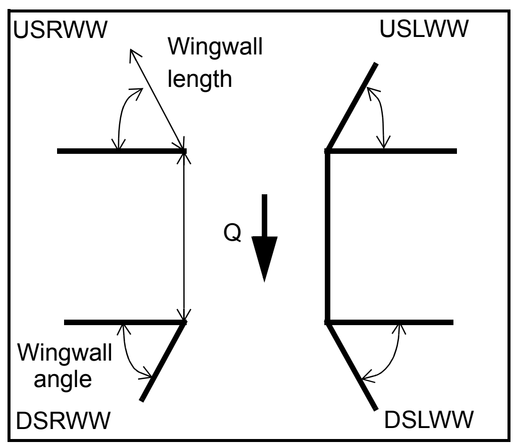
1

76. The water depth in front of the left abutment footing is 1.1 ft. The entire footing of the left abutment is exposed. The exposure of the footing is more pronounced at the US end where there is no protection.

75. The left abutment footing is undermined. A rod can penetrate 2 ft. underneath the footing.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**20.5**	
USRWW:	**Y**		**1**		**2**	**2.0**	
DSLWW:	**0**		**1.3**		**Y**	**21.5**	
DSRWW:	**1**		**0**		**-**	**21.0**	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**0**	**Y**	**0**	**-**	**-**	**1**	**-**
Condition	**Y**	**-**	**1**	**0.6**	**-**	**-**	**3**	**-**
Extent	**1**	**-**	**2**	**0**	**0**	**2**	**0**	**-**

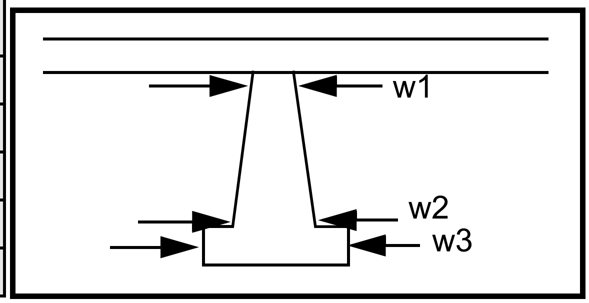
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
2
1
2

Piers:

84. Are there piers? **80.** *(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				**30.0**	**13.0**	**35.0**
Pier 2				**12.0**	**25.0**	**10.0**
Pier 3			**-**	**25.0**	**10.0**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



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

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

3
3
234

106. Point/Side bar present? 23 (Y or N. if N type ctrl-n pb) Mid-bar distance: 4 Mid-bar width: 2

Point bar extent: 2 feet 234 (US, UB, DS) to 5 feet 0 (US, UB, DS) positioned 0 %LB to - %RB

Material: -

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

There is a log holding up the bank from 12 ft DS to 36 ft DS. The log was protecting the bank from erosion as of 08/07/96.

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

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

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

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

N

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

Scour dimensions: Length e is Width no Depth: dro Positioned p %LB to stru %RB

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

cture at the site.

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

Confluence 1: Distance Y Enters on 27 (LB or RB) Type 6.5 (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance 20 Enters on DS (LB or RB) Type 33.4 (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

DS

0

F. Geomorphic Channel Assessment

107. Stage of reach evolution 25

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)*:

325

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N

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109. G. Plan View Sketch

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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: LONDTH00410029 Town: LONDONDERRY
Road Number: TH 041 County: WINDHAM
Stream: COOK BROOK

Initials LKS Date: 05/09/97 Checked: MAI

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1650	2350	1390
Main Channel Area, ft2	482	575	424
Left overbank area, ft2	0	0	0
Right overbank area, ft2	23	48	11
Top width main channel, ft	80	87	76
Top width L overbank, ft	0	0	0
Top width R overbank, ft	18	27	13
D50 of channel, ft	0.232586	0.232586	0.232586
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.0	6.6	5.6
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	1.3	1.8	0.8
Total conveyance, approach	36026	46694	30037
Conveyance, main channel	35547	45413	29852
Conveyance, LOB	0	0	0
Conveyance, ROB	479	1281	185
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1628.1	2285.5	1381.4
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	21.9	64.5	8.6
Vm, mean velocity MC, ft/s	3.4	4.0	3.3
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	1.0	1.3	0.8
Vc-m, crit. velocity, MC, ft/s	9.3	9.4	9.2
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	1650	2350	1390
(Q) discharge thru bridge, cfs	1573	1795	1390
Main channel conveyance	9366	9366	9366
Total conveyance	9366	9366	9366
Q2, bridge MC discharge,cfs	1573	1795	1390
Main channel area, ft2	167	167	167
Main channel width (normal), ft	20.4	20.4	20.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.4	20.4	20.4
y_bridge (avg. depth at br.), ft	8.19	8.19	8.19
Dm, median (1.25*D50), ft	0.290733	0.290733	0.290733
y2, depth in contraction,ft	7.30	8.18	6.57
ys, scour depth (y2-ybridge), ft	-0.89	-0.01	-1.62

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	1573	1795	1390
Main channel area (DS), ft2	143	162	134
Main channel width (normal), ft	20.4	20.4	20.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	20.4	20.4	20.4
D90, ft	0.8992	0.8992	0.8992
D95, ft	1.4763	1.4763	1.4763
Dc, critical grain size, ft	0.5879	0.5652	0.5381
Pc, Decimal percent coarser than Dc	0.217	0.225	0.234
Depth to armoring, ft	6.36	5.84	5.27

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	1650	2350	1390
Q, thru bridge MC, cfs	1573	1795	1390
Vc, critical velocity, ft/s	9.30	9.44	9.18
Va, velocity MC approach, ft/s	3.38	3.97	3.26
Main channel width (normal), ft	20.4	20.4	20.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.4	20.4	20.4
qbr, unit discharge, ft2/s	77.1	88.0	68.1
Area of full opening, ft2	167.0	167.0	167.0
Hb, depth of full opening, ft	8.19	8.19	8.19
Fr, Froude number, bridge MC	0.58	0.66	0.51
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	143	162	134
**Hb, depth at downstream face, ft	7.01	7.94	6.57
**Fr, Froude number at DS face	0.73	0.69	0.71
**Cf, for downstream face (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	498.35	498.35	498.35
Elevation of Bed, ft	490.16	490.16	490.16
Elevation of Approach, ft	500.59	501.71	499.85
Friction loss, approach, ft	0.12	0.15	0.1
Elevation of WS immediately US, ft	500.47	501.56	499.75
ya, depth immediately US, ft	10.31	11.40	9.59
Mean elevation of deck, ft	499.87	499.87	499.87
w, depth of overflow, ft (>=0)	0.60	1.69	0.00
Cc, vert contrac correction (<=1.0)	0.96	0.96	0.96
**Cc, for downstream face (<=1.0)	0.917355	0.95067	0.901898
Ys, scour w/Chang equation, ft	0.47	1.54	-0.47
Ys, scour w/Umbrell equation, ft	-2.24	-1.42	-2.53

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

**Ys, scour w/Chang equation, ft	2.03	1.86	1.66

**Ys, scour w/Umbrell equation, ft	-1.06	-1.18	-0.91

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	7.30	8.18	6.57
WSEL at downstream face, ft	497.17	498.10	496.75
Depth at downstream face, ft	7.01	7.94	6.57
Ys, depth of scour (Laursen), ft	0.29	0.23	-0.00

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	1650	2350	1390	1650	2350	1390
a', abut.length blocking flow, ft	28.5	36.7	24	49.5	58.6	44
Ae, area of blocked flow ft2	85.6	94.5	74.1	202.6	226.9	175.2
Qe, discharge blocked abut.,cfs	--	--	152.5	--	--	525.8
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.12	2.48	2.06	3.14	3.69	3.00
ya, depth of f/p flow, ft	3.00	2.57	3.09	4.09	3.87	3.98
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.206	0.232	0.206	0.269	0.303	0.265
ys, scour depth, ft	8.62	8.74	8.39	14.08	15.06	13.25

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)	28.5	36.7	24	49.5	58.6	44
y1 (depth f/p flow, ft)	3.00	2.57	3.09	4.09	3.87	3.98
a'/y1	9.49	14.25	7.77	12.09	15.13	11.05
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.21	0.23	0.21	0.27	0.30	0.27
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.73	0.69	0.71	0.73	0.69	0.71
y, depth of flow in bridge, ft	7.01	7.94	6.57	7.01	7.94	6.57
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.31	2.34	2.05	2.31	2.34	2.05
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	2.01	2.04	1.79	2.01	2.04	1.79
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR