LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (LINCTH00010013) on TOWN HIGHWAY 1, crossing COTA BROOK, LINCOLN, VERMONT

Open-File Report 98-157

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (LINCTH00010013) on TOWN HIGHWAY 1, crossing COTA BROOK, LINCOLN, VERMONT

By EMILY C. WILD

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Pembroke, New Hampshire

1998

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (LINCTH00010013) ON TOWN HIGHWAY 1, CROSSING THE COTA BROOK, LINCOLN, VERMONT

By **Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure LINCTH00010013 on Town Highway 1 crossing Cota Brook, Lincoln, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in west-central Vermont. The 3.0-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest along the upstream right bank and brushland along the upstream left bank. Downstream of the bridge, the surface cover is pasture along the left and right banks.

In the study area, Cota Brook has an sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 30 ft and an average bank height of 2 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 34.7 mm (0.114 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 10, 1996, indicated that the reach was laterally unstable due to cut-banks and wide, vegetated point bars upstream and downstream of the bridge.

The Town Highway 1 crossing of Cota Brook is a 38-ft-long, two-lane bridge consisting of a 36-foot steel-stringer span (Vermont Agency of Transportation, written communication, December 14, 1995). The opening length of the structure parallel to the bridge face is 34.4 ft. The bridge is supported by vertical, concrete abutments. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 2.0 ft deeper than the mean thalweg depth was observed along the upstream right bank during the Level I assessment. Along the right abutment, it is 0.25 ft deeper than the mean thalweg depth. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the upstream right bank and type-2 stone fill (less than 36 inches diameter) along the left and right abutments and along the downstream left 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. 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 1.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 9.1 to 11.3 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number LINCTH00010013 ***Stream*** Cota Brook

County Addison ***Road*** TH 1 ***District*** 5

Description of Bridge

Bridge length 38 ***ft*** ***Bridge width*** 23.3 ***ft*** ***Max span length*** 36 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 6/10/96

Description of stone fill Type-2, along the left and right abutments.

Abutments are concrete. There is a 0.25 foot deep scour hole in front of the right abutment.

Yes 15

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

There is a moderate bend in the channel in the upstream reach. There is a scour hole along the upstream right bank, where the flow impacts the bank.

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	6/10/96	0	0
Level II	6/10/96	0	0

Potential for debris High. There is some debris caught within the trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None, 6/10/96.

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 6/10/96

DS left: Narrow flood plain

DS right: Little flood plain to a steep valley wall

US left: Moderately sloped overbank

US right: Steep valley wall

Description of the Channel

Average top width 30 *ft* ***Average depth*** 2 *ft*

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

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

6/10/96

Vegetative co Pasture

DS left: Pasture

DS right: Shrubs and brush

US left: Trees

US right:

Do banks appear stable? No

It was noted (6/10/96) that the banks are laterally unstable; evidence of the instability is apparent in the cut-banks and wide, vegetated point bars upstream and downstream of the bridge.

date of observation.

Describe any obstructions in channel and date of observation.

On 6/10/96, a concrete step was observed in the channel 22 feet downstream of the bridge. The step extends 6 feet into the channel and diverts flow into the right bank.

Hydrology

Drainage area 3.0 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 790 ***ft³/s*** ***Q500*** 1,180 ***ft³/s***

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

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 499.86 ft, arbitrary survey datum). RM2 is a chiseled X on the roadway, 22 feet from the downstream end of the left abutment (elev. 499.75 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	-29	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	64	1	Approach section

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.060, and overbank "n" values ranged from 0.035 to 0.070.

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 0.0109 ft/ft, determined from surveyed thalweg points downstream of the structure .

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 500.1 ***ft***
Average low steel elevation 497.1 ***ft***

100-year discharge 790 ***ft³/s***
Water-surface elevation in bridge opening 497.3 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 136 ***ft²***
Average velocity in bridge opening 5.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 7.0 ***ft/s***

Water-surface elevation at Approach section with bridge 498.0
Water-surface elevation at Approach section without bridge 497.1
Amount of backwater caused by bridge 0.9 ***ft***

500-year discharge 1,180 ***ft³/s***
Water-surface elevation in bridge opening 497.3 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 136 ***ft²***
Average velocity in bridge opening 8.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.4 ***ft/s***

Water-surface elevation at Approach section with bridge 500.0
Water-surface elevation at Approach section without bridge 497.8
Amount of backwater caused by bridge 2.2 ***ft***

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

At this site, the 100-year and 500-year 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 for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison, contraction scour was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Furthermore, 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 Davis, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	1.7	--
Depth to armoring	N/A	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	9.4	11.2	--
Right abutment	9.1	11.3	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge (D50 in feet)	Incipient overtopping discharge
Abutments:			
Left abutment	1.1	1.4	--
Right abutment	1.1	1.4	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

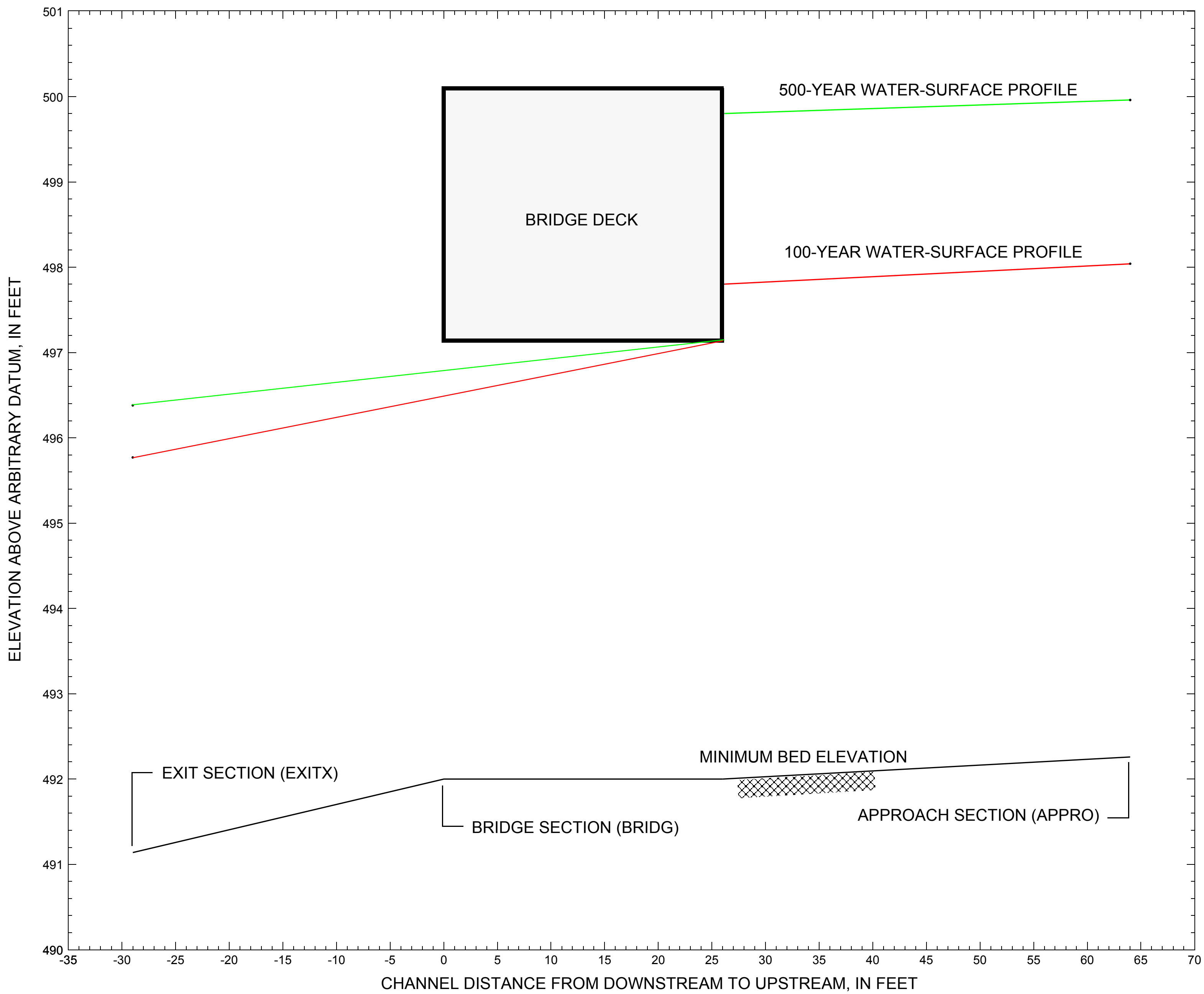

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure LINCTH00010013 on Town Highway 1, crossing Cota Brook, Lincoln, Vermont.

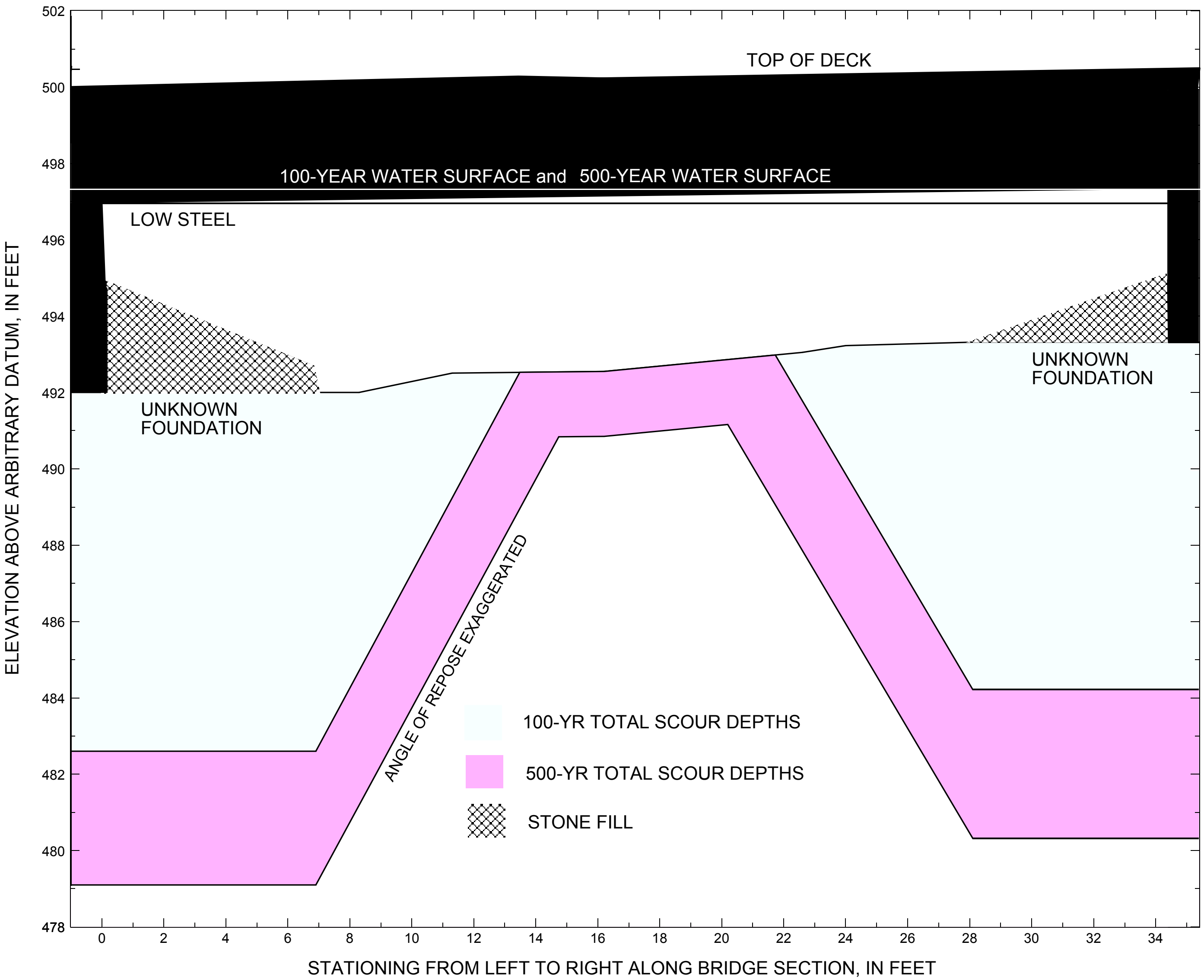

Figure 8. Scour elevations for the 100- and 500-year discharges at structure LINCTH00010013 on Town Highway 1, crossing Cota Brook, Lincoln, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure LINCTH00010013 on Town Highway 1, crossing Cota Brook, Lincoln, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 790 cubic-feet per second											
Left abutment	0.0	--	497.0	--	492.0	0.0	9.4	--	9.4	482.6	--
Right abutment	34.4	--	497.3	--	493.3	0.0	9.1	--	9.1	484.2	--

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 LINCTH00010013 on Town Highway 1, crossing Cota Brook, Lincoln, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 1,180 cubic-feet per second											
Left abutment	0.0	--	497.0	--	492.0	1.7	11.2	--	12.9	479.1	--
Right abutment	34.4	--	497.3	--	493.3	1.7	11.3	--	13.0	480.3	--

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, 1970, Lincoln, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File linc013.wsp
T2        Hydraulic analysis for structure LINCTH00010013   Date: 16-JUL-97
T3        Town Highway 1, Cota Brook, Lincoln, Vermont               ECW
*
J1         * * 0.01
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q            790.0   1180.0
SK          0.0109   0.0109
*
XS   EXITX    -29           0.
GR          -17.4, 498.02      0.0, 496.64      1.9, 496.16      7.9, 491.99
GR            8.2, 491.95      9.1, 491.36     10.9, 491.14     16.4, 491.27
GR           18.4, 491.49     21.0, 491.95     23.9, 492.93     34.3, 494.55
GR           65.9, 494.50     77.7, 499.73    114.1, 501.66    146.2, 502.31
GR          164.9, 505.07    182.9, 513.53
*
N           0.045        0.060        0.035
SA                   0.0          23.9
*
*
XS   FULLV      0  * * *   0.0169
*
*             SRD     LSEL    XSSKEW
BR   BRIDG      0    497.14       0.0
GR            0.0, 496.96      0.1, 494.92      6.7, 492.74      6.9, 492.00
GR            8.3, 492.00     11.3, 492.51     16.2, 492.55     22.6, 493.05
GR           24.0, 493.23     28.1, 493.32     34.4, 494.95     34.4, 497.33
GR            0.0, 496.96
*
*         BRTYPE  BRWDTH
CD           1      25.8
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      23.3     1
GR         -274.3, 501.25   -201.1, 500.98   -120.8, 500.52      0.0, 499.92
GR           33.4, 500.21    114.1, 501.66    146.2, 502.31    164.9, 505.07
GR          182.9, 513.53
*
*
AS   APPRO     64           0.
GR         -274.3, 501.25   -201.1, 500.98   -120.8, 500.52    -87.2, 500.05
GR          -43.5, 499.60    -36.5, 497.27    -29.9, 495.64    -16.2, 494.55
GR           -7.6, 495.54      0.0, 495.04      2.0, 493.25      6.3, 492.74
GR            9.5, 492.77     14.6, 492.26     18.1, 492.45     24.2, 493.27
GR           38.5, 494.73     61.9, 495.82     65.7, 497.86    114.1, 501.66
GR          146.2, 502.31    164.9, 505.07    182.9, 513.53
*
N           0.055        0.060      0.070
SA                -43.5        65.7
*
HP 1 BRIDG 497.33 1 497.33
HP 2 BRIDG 497.33 * * 790
HP 1 BRIDG 496.08 1 496.08
HP 1 APPRO 498.04 1 498.04
HP 2 APPRO 498.04 * * 790
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File linc013.wsp
      Hydraulic analysis for structure LINCTH00010013   Date: 16-JUL-97
      Town Highway 1, Cota Brook, Lincoln, Vermont               ECW
         *** RUN DATE & TIME: 02-12-98  12:59
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     136.    6711.     0.    74.                          0.
 497.33          136.    6711.     0.    74.  1.00     0.    34.      0.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     497.33     0.0    34.4   135.7    6711.     790.   5.82

X STA.        0.0         4.5         6.3         7.6         8.8         9.9
  A(I)           12.3         6.8         6.5         5.7         5.7
  V(I)           3.21        5.82        6.04        6.95        6.96

X STA.        9.9        11.2        12.5        13.8        15.1        16.4
  A(I)            5.9         5.9         6.0         5.9         5.9
  V(I)           6.67        6.64        6.58        6.66        6.65

X STA.       16.4        17.7        19.1        20.5        22.0        23.4
  A(I)            6.1         5.9         6.1         6.3         6.1
  V(I)           6.52        6.65        6.48        6.30        6.43

X STA.       23.4        25.1        26.7        28.3        30.2        34.4
  A(I)            6.5         6.4         6.4         6.9        12.3
  V(I)           6.08        6.20        6.15        5.73        3.22

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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1      99.    6236.    34.    38.                        955.
 496.08           99.    6236.    34.    38.  1.00     0.    34.    955.

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           2     351.   19362.   105.   106.                       3657.
           3       0.       1.     2.     2.                          0.
 498.04          352.   19363.   107.   109.  1.00   -39.    68.   3619.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.04   -38.8    68.0   351.7   19363.     790.   2.25

X STA.      -38.8       -21.4       -16.0       -10.1        -1.8         3.0
  A(I)           34.7        17.6        18.6        22.1        18.1
  V(I)           1.14        2.24        2.13        1.79        2.18

X STA.        3.0         5.7         8.3        10.9        13.3        15.7
  A(I)           13.5        13.6        13.8        13.7        13.3
  V(I)           2.92        2.91        2.86        2.89        2.96

X STA.       15.7        18.1        20.6        23.4        26.6        29.9
  A(I)           13.6        13.9        14.1        14.8        14.6
  V(I)           2.90        2.84        2.80        2.67        2.71

X STA.       29.9        33.9        38.7        44.4        51.2        68.0
  A(I)           15.9        16.9        18.2        19.6        31.1
  V(I)           2.48        2.34        2.18        2.02        1.27
```

```
       U.S. Geological Survey WSPRO Input File linc013.wsp
       Hydraulic analysis for structure LINCTH00010013   Date: 16-JUL-97
       Town Highway 1, Cota Brook, Lincoln, Vermont               ECW
          *** RUN DATE & TIME: 02-12-98  12:59
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     136.   6711.     0.    74.                            0.
  497.33          136.   6711.     0.    74.  1.00     0.    34.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.33     0.0    34.4   135.7    6711.    1180.   8.70

X STA.         0.0         4.5         6.3         7.6         8.8         9.9
  A(I)             12.3         6.8         6.5         5.7         5.7
  V(I)             4.79        8.70        9.02       10.39       10.40

X STA.         9.9        11.2        12.5        13.8        15.1        16.4
  A(I)              5.9         5.9         6.0         5.9         5.9
  V(I)             9.96        9.92        9.84        9.94        9.94

X STA.        16.4        17.7        19.1        20.5        22.0        23.4
  A(I)              6.1         5.9         6.1         6.3         6.1
  V(I)             9.73        9.93        9.68        9.41        9.60

X STA.        23.4        25.1        26.7        28.3        30.2        34.4
  A(I)              6.5         6.4         6.4         6.9        12.3
  V(I)             9.08        9.26        9.19        8.55        4.82

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     120.   8371.    34.    39.                         1267.
  496.68          120.   8371.    34.    39.  1.00     0.    34.   1267.

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1       6.      54.    35.    35.                           15.
            2     557.   40525.   109.   111.                         7147.
            3      28.     616.    27.    27.                          163.
  499.96          592.   41195.   171.   173.  1.07   -78.    92.   6029.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.96   -78.5    92.4   591.8   41195.    1180.   1.99

X STA.       -78.5       -24.9       -19.2       -14.0        -7.9        -1.1
  A(I)             62.5        28.5        27.6        29.2        31.1
  V(I)             0.94        2.07        2.14        2.02        1.90

X STA.        -1.1         3.6         6.9        10.0        13.1        16.0
  A(I)             27.8        23.5        22.7        22.9        22.3
  V(I)             2.12        2.51        2.60        2.57        2.65

X STA.        16.0        19.1        22.4        26.0        29.9        34.4
  A(I)             23.0        24.0        24.1        24.7        26.1
  V(I)             2.57        2.46        2.45        2.39        2.26

X STA.        34.4        39.3        45.0        51.0        57.8        92.4
  A(I)             26.5        28.6        28.8        30.8        57.2
  V(I)             2.22        2.06        2.05        1.92        1.03
```

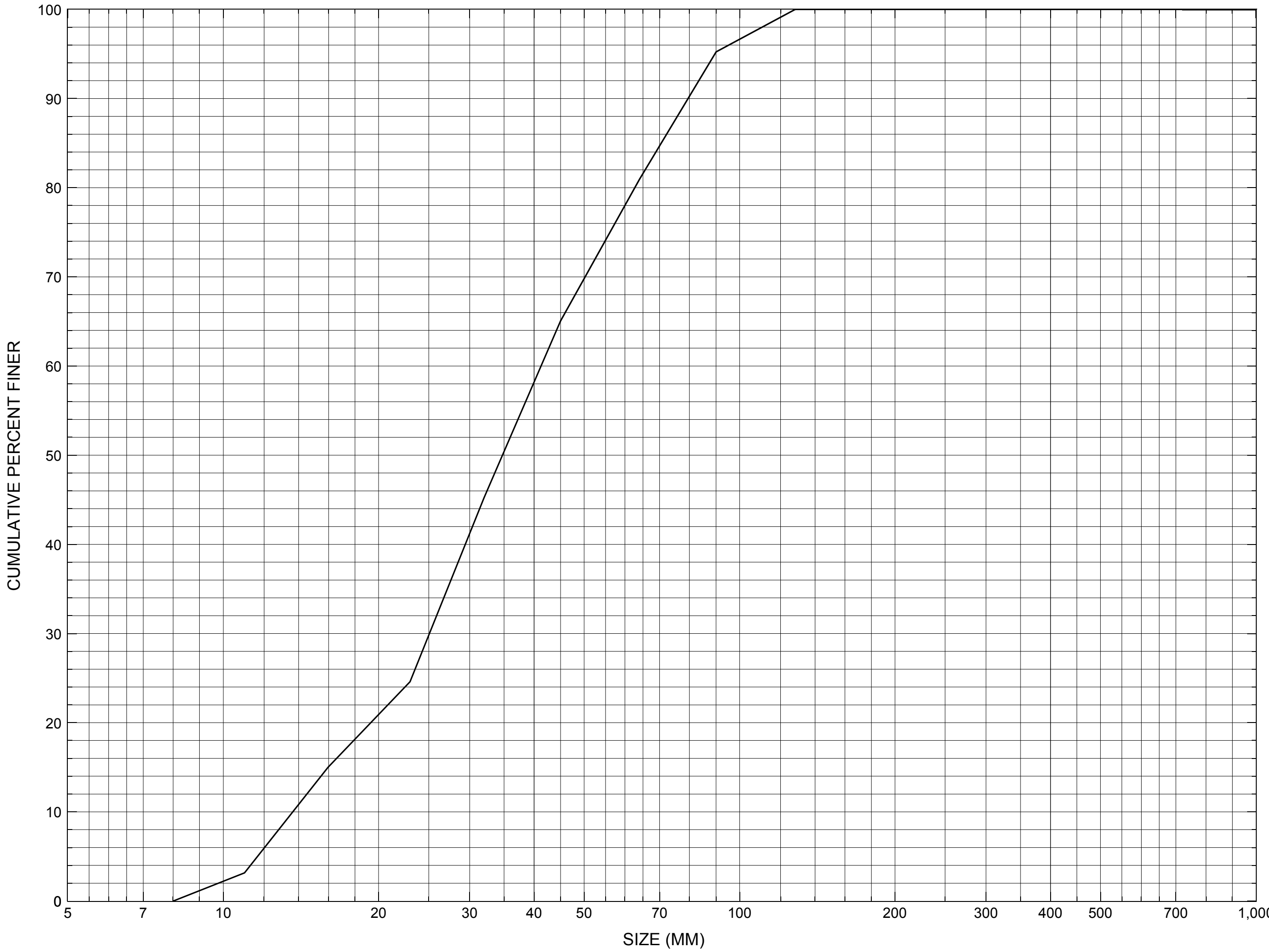
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File linc013.wsp
        Hydraulic analysis for structure LINCTH00010013   Date: 16-JUL-97
        Town Highway 1, Cota Brook, Lincoln, Vermont               ECW
           *** RUN DATE & TIME: 02-12-98  12:59

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

EXITX:XS   ******     2.     139.  0.50 *****  496.27  495.35    790.  495.77
      -29. ******    69.    7560.  1.00 ***** *******    0.69    5.67

FULLV:FV      29.     3.     128.  0.60  0.36  496.68 *******    790.  496.08
        0.    29.    68.    6597.  1.01  0.05    0.00    0.79    6.20
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  1.73

APPRO:AS      64.   -36.     251.  0.15  0.53  497.21 *******    790.  497.06
       64.    64.    64.   11398.  1.00  0.00    0.00    0.35    3.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.75     497.53     497.81     497.14
 ===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      29.     0.     136.  0.52 *****  497.85  495.73    787.  497.33
        0. ******    34.    6711.  1.00 ***** *******    0.52    5.80
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.436  0.000  497.14 ****** ****** ******

    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      38.   -39.     351.  0.08  0.20  498.12  495.68    790.  498.04
       64.    41.    68.   19330.  1.00  0.61    0.00    0.22    2.25

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   497.97
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -29.     2.    69.    790.    7560.     139.    5.67  495.77
   FULLV:FV       0.     3.    68.    790.    6597.     128.    6.20  496.08
   BRIDG:BR       0.     0.    34.    787.    6711.     136.    5.80  497.33
   RDWAY:RG      13.**************      0.******************    1.00********
   APPRO:AS      64.   -39.    68.    790.   19330.     351.    2.25  498.04

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

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.35    0.69  491.14  513.53************  0.50  496.27  495.77
   FULLV:FV  ********    0.79  491.63  514.02  0.36  0.05  0.60  496.68  496.08
   BRIDG:BR    495.73    0.52  492.00  497.33************  0.52  497.85  497.33
   RDWAY:RG  ****************  499.92  513.53************  0.02  501.25********
   APPRO:AS    495.68    0.22  492.26  513.53  0.20  0.61  0.08  498.12  498.04
```

```
        U.S. Geological Survey WSPRO Input File linc013.wsp
        Hydraulic analysis for structure LINCTH00010013   Date: 16-JUL-97
        Town Highway 1, Cota Brook, Lincoln, Vermont               ECW
           *** RUN DATE & TIME: 02-12-98  12:59
 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******     1.     181.  0.67 *****  497.05  495.82   1180.  496.38
      -29. ******    70.   11295.  1.01 ***** *******    0.72    6.53

FULLV:FV      29.     2.     168.  0.77  0.35  497.45 *******   1180.  496.68
        0.    29.    70.   10108.  1.00  0.05    0.00    0.79    7.03
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  1.68

APPRO:AS      64.   -38.     324.  0.21  0.52  497.98 *******   1180.  497.77
       64.    64.    66.   16989.  1.00  0.00    0.01    0.36    3.65
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.52     498.67     498.93     497.14
 ===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      29.     0.     136.  1.16 *****  498.49  496.50   1171.  497.33
        0. ******    34.    6711.  1.00 ***** *******    0.77    8.63
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.499  0.000  497.14 ****** ****** ******

    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      38.   -78.     591.  0.07  0.21  500.02  496.13   1180.  499.96
       64.    41.    92.   41153.  1.07  0.59   -0.01    0.20    2.00

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.92
                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -29.     1.    70.   1180.   11295.     181.    6.53  496.38
   FULLV:FV       0.     2.    70.   1180.   10108.     168.    7.03  496.68
   BRIDG:BR       0.     0.    34.   1171.    6711.     136.    8.63  497.33
   RDWAY:RG      13.**************      0.       0.       0.    1.00********
   APPRO:AS      64.   -78.    92.   1180.   41153.     591.    2.00  499.96

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

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO  VHD      EGL    WSEL
   EXITX:XS    495.82    0.72  491.14  513.53************  0.67  497.05  496.38
   FULLV:FV  ********    0.79  491.63  514.02  0.35  0.05  0.77  497.45  496.68
   BRIDG:BR    496.50    0.77  492.00  497.33************  1.16  498.49  497.33
   RDWAY:RG  ****************  499.92  513.53************  0.07  499.99********
   APPRO:AS    496.13    0.20  492.26  513.53  0.21  0.59  0.07  500.02  499.96
  ER
NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure LINCTH00010013, in Lincoln, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number LINCTH00010013

General Location Descriptive

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

Date *(MM/DD/YY)* 12 / 14 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 40075

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

Waterway *(I - 6)* COTA BROOK

Road Name *(I - 7):* -

Route Number C2001

Vicinity *(I - 9)* 0.5 MI TO JCT W CL2 TH2

Topographic Map Lincoln

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 44054

Longitude *(i - 17; nnnnn.n)* 72588

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011000130110

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

Maximum span length *(I - 48; nnnn)* 0036

Year built *(I - 27; YYYY)* 1939

Structure length *(I - 49; nnnnnn)* 000038

Average daily traffic, ADT *(I - 29; nnnnnn)* 000400

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

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)* 5

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 35.58

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

Vertical clearance from streambed (*nnn.n ft*) 3.84

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

Waterway of full opening (*nnn.n* ft^2) 136.7

Comments:

According to the structural inspection report dated 11/13/94, the structure has a concrete bridge deck. The abutments and backwalls are concrete and have minor cracks and leaks. Boulder riprap has been placed in front of and around their ends. A vegetated gravel bar in the upstream channel on the left side blocks much of the channel, and pushes the flow toward the US end of the RABUT. Some erosion is noted at the US end of the RABUT.

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area (*mi²*): -

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} (*ft³/ 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 (*ft²*): -

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)* **3.00** mi^2 Lake/pond/swamp area **0** mi^2
Watershed storage *(ST)* **0** %
Bridge site elevation **1060** ft Headwater elevation **3261** ft
Main channel length **3.54** mi
10% channel length elevation **1190** ft 85% channel length elevation **2540** ft
Main channel slope *(S)* **508.48** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

-
-
-
-

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

Is boring information available? - *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:

Foundation type is unknown.

-
-
-
-
-

Comments:

-
-
-
-
-
-

Cross-sectional Data

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

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

Comments: **This cross section is the upstream face. The low chord elevations are from the survey log done for this report on 6/10/96. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 11/13/94. The sketch was done on 10/16/92.**

Station	0	13.8	26.3	30.6	35.6	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	497.0	497.1	497.2	497.2	497.3	-	-	-	-	-	-
Bed elevation	494.7	493.1	491.4	493.0	494.9	-	-	-	-	-	-
Low chord to bed	2.3	4.0	5.8	4.2	2.4	-	-	-	-	-	-

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: ECW Date: 10/8/96
Computerized by: ECW Date: 1/20/97
Reviewd by: ECW Date: 2/17/98

Structure Number LINCTH00010013

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. BURNS Date *(MM/DD/YY)* 06 / 10 / 1996

2. Highway District Number 05 Mile marker 000000

County ADDISON (001) Town LINCOLN (40075)

Waterway *(I - 6)* COTA BROOK Road Name -

Route Number TH001 Hydrologic Unit Code: 02010002

3. Descriptive comments:

The bridge is located 0.5 miles to junction with CL2 TH2.
The bridge deck and abutments are concrete. The disk on the bridge says No. 81.

B. Bridge Deck Observations

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

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

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

7. Bridge length 38 *(feet)* Span length 36 *(feet)* Bridge width 23.3 *(feet)*

Road approach to bridge:

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

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

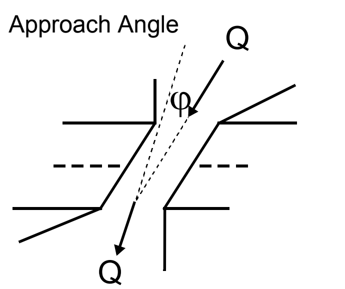
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

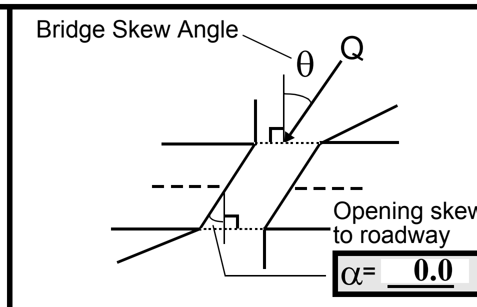
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	1	3	2	2
RBDS	0	-	2	1
LBDS	0	-	0	-

*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: 20 16. Bridge skew: 15





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 30 feet US *(US, UB, DS)* to 10 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 0 feet DS *(US, UB, DS)* to 10 feet DS

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

18. Bridge Type: **1b**

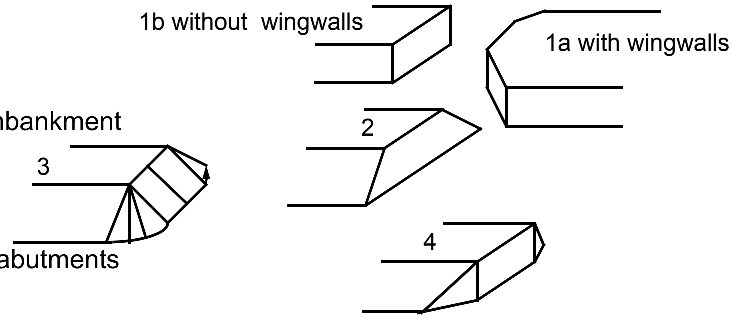
1a- Vertical abutments with wingwalls

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: A house and lawn are on the left bank downstream. Small trees and shrubs are on the left bank upstream, beyond is pasture. Along the right bank upstream, forest is along the bank with pasture on top of the hill. Some small trees are along the downstream right bank.

7: Measured lengths are the same as the historical form.

18: The wingwalls are three feet long and flush with the abutment face. They angle down like type 2, but not below low steel because they are so short. Therefore, bridge is considered type 1b.

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
39.0	**1.5**			**1.5**	**3**	**4**	**23**	**23**	**0**	**2**

23. Bank width **-** 24. Channel width **5.0** 25. Thalweg depth **38.5** 29. Bed Material **324**

30 .Bank protection type: LB **0** RB **1** 31. Bank protection condition: LB **-** RB **2**

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

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

30: The right bank protection extends from 14 feet upstream to 6 feet upstream. Also, two large boulders are present at the upstream end of the USRWW.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **36** 35. Mid-bar width: **22**

36. Point bar extent: **84** feet **US** (US, UB) to **8** feet **UB** (US, UB, DS) positioned **0** %LB to **60** %RB

37. Material: **23**

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

Point bar is substantially vegetated with shrubs and brush.

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

41. Mid-bank distance: **20** 42. Cut bank extent: **42** feet **US** (US, UB) to **14** feet **US** (US, UB, DS)

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

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

Bank erosion continues upstream for an additional 50 feet. There are many small trees leaning into the channel.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **12 US**

47. Scour dimensions: Length **32** Width **8** Depth : **2.5** Position **80** %LB to **100** %RB

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

The scour depth assumes the thalweg is 0.5 feet.
The scour extends from 24 feet upstream to 8 feet 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):

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
22.0		1.0		2	7	7	-

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

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

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

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

32
The point bar from the LBUS extends 8 feet along the LABUT.
The scour hole on the RBUS extends 8 feet along the RABUT.

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

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

70. Debris and Ice Comments:

2

66: Debris is caught in the trees leaning upstream and along the road embankment on the right bank and on the point bar upstream.

68: Capture efficiency is high 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		10	90	2	0	-	-	90.0
RABUT	1	0	90			2	1	34.5

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.):

0.25

-

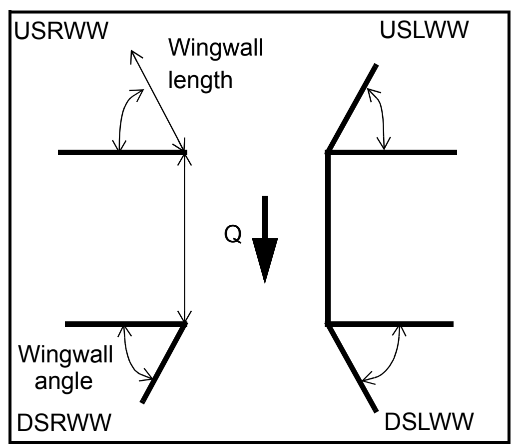
1

72: Protection is piled at a 60 degree angle up to the abutment.

74: Scour along the RABUT is a continuation of the upstream scour hole.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						34.5	
USRWW:	N		-		-	1.0	
DSLWW:	-		-		N	26.0	
DSRWW:	-		-		-	26.0	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	2	2	-

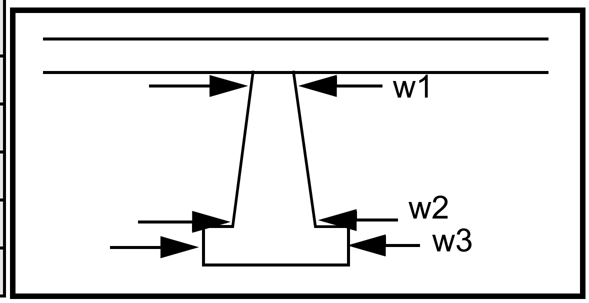
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? Th (Y or if N type ctrl-n pr)

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	ere is a	LABU	ream		LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	retai	T.	end		1- Solid pier, 2- column, 3- bent
88. Material	ning	Ther	of		1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	wall	e are	the	N	1- Round; 2- Square; 3- Pointed
90. Inclined?	at	large	RAB	-	Y- yes; N- no
91. Attack ∠ (BF)	the	type	UT.	-	
92. Pushed	dow	3		-	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	nstre	boul-		-	
95. Cross-members	am	ders		-	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	end	at		-	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	of	the		-	
98. Exposure depth	the	upst		-	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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):
-
-

NO PIERS

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 **1** *(US, UB, DS)* positioned **1** %LB to **2** %RB

Material: **2**

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

0
1
432
2

Is a cut-bank present? **0** *(Y or if N type ctrl-n cb)* Where? **2** *(LB or RB)* Mid-bank distance: **-**

Cut bank extent: **The** feet **left** *(US, UB, DS)* to **bank** feet **pro** *(US, UB, DS)*

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

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

tion extends from the downstream bridge face to 60 feet downstream.

There is a concrete step in the channel 22 feet downstream. The step extends 6 feet into the channel and diverts flow into the right bank.

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

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

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

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

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

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

Confluence comments (eg. confluence name):

RE

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)*:

Y
4
6
6
UB
14
US
70
100
342

109. G. Plan View Sketch

Po

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: LINCTH00010013 Town: LINCOLN
Road Number: TH1 County: ADDISON
Stream: COTA BROOK

Initials ECW Date: 2-12-98 Checked: RLB

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	790	1180	0
Main Channel Area, ft2	351	557	0
Left overbank area, ft2	0	6	0
Right overbank area, ft2	0	28	0
Top width main channel, ft	105	109	0
Top width L overbank, ft	0	35	0
Top width R overbank, ft	0	27	0
D50 of channel, ft	0.1139	0.1139	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	3.3	5.1	ERR
y1, average depth, LOB, ft	ERR	0.2	ERR
y1, average depth, ROB, ft	ERR	1.0	ERR
Total conveyance, approach	19363	41195	0
Conveyance, main channel	19362	40525	0
Conveyance, LOB	0	54	0
Conveyance, ROB	0	616	0
Percent discrepancy, conveyance	0.0052	0.0000	ERR
Qm, discharge, MC, cfs	790.0	1160.8	ERR
Ql, discharge, LOB, cfs	0.0	1.5	ERR
Qr, discharge, ROB, cfs	0.0	17.6	ERR
Vm, mean velocity MC, ft/s	2.3	2.1	ERR
Vl, mean velocity, LOB, ft/s	ERR	0.3	ERR
Vr, mean velocity, ROB, ft/s	ERR	0.6	ERR
Vc-m, crit. velocity, MC, ft/s	6.6	7.1	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	790	1180	0
(Q) discharge thru bridge, cfs	790	1180	0
Main channel conveyance	6711	6711	0
Total conveyance	6711	6711	0
Q2, bridge MC discharge,cfs	790	1180	ERR
Main channel area, ft2	136	136	0
Main channel width (normal), ft	34.4	34.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.4	34.4	0
y_bridge (avg. depth at br.), ft	3.95	3.95	ERR
Dm, median (1.25*D50), ft	0.142375	0.142375	0
y2, depth in contraction,ft	3.17	4.47	ERR
ys, scour depth (y2-ybridge), ft	-0.78	0.52	N/A

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

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	790	1180	N/A
Main channel area (DS), ft2	99	120	0
Main channel width (normal), ft	34.4	34.4	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	34.4	34.4	0.0
D90, ft	0.2606	0.2606	0.0000
D95, ft	0.2936	0.2936	0.0000
Dc, critical grain size, ft	0.2671	0.3755	ERR
Pc, Decimal percent coarser than Dc	0.090	0.015	0.000
Depth to armoring, ft	N/A	N/A	ERR

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 Davis, 1995, p. 144-146)
```

	Q100	Q500	OtherQ
Q, total, cfs	790	1180	0
Q, thru bridge MC, cfs	790	1180	N/A
Vc, critical velocity, ft/s	6.64	7.13	N/A
Va, velocity MC approach, ft/s	2.25	2.08	N/A
Main channel width (normal), ft	34.4	34.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.4	34.4	0.0
qbr, unit discharge, ft2/s	23.0	34.3	ERR
Area of full opening, ft2	136.0	136.0	0.0
Hb, depth of full opening, ft	3.95	3.95	ERR
Fr, Froude number, bridge MC	0.52	0.77	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	99	120	N/A
**Hb, depth at downstream face, ft	2.88	3.49	ERR
**Fr, Froude number at DS face	0.83	0.93	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	497.14	497.14	0
Elevation of Bed, ft	493.19	493.19	N/A
Elevation of Approach, ft	498.04	499.96	0
Friction loss, approach, ft	0.2	0.21	0
Elevation of WS immediately US, ft	497.84	499.75	0.00
ya, depth immediately US, ft	4.65	6.56	N/A
Mean elevation of deck, ft	500.07	500.07	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.96	0.86	ERR
**Cc, for downstream face (<=1.0)	0.866447	0.79	ERR
Ys, scour w/Chang equation, ft	-0.35	1.67	N/A
Ys, scour w/Umbrell equation, ft	-1.28	-0.51	N/A

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

**Ys, scour w/Chang equation, ft	1.11	2.60	N/A

**Ys, scour w/Umbrell equation, ft	-0.21	-0.04	ERR

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	3.17	4.47	0.00
WSEL at downstream face, ft	496.08	496.68	--
Depth at downstream face, ft	2.88	3.49	N/A
Ys, depth of scour (Laursen), ft	0.29	0.98	N/A

Abutment Scour

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

	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	790	1180	0	790	1180	0
a', abut.length blocking flow, ft	38.8	78.5	0	33.6	58	0
Ae, area of blocked flow ft2	99.79	185.41	0	84.04	171.9	0
Qe, discharge blocked abut.,cfs	172.81	308.81	0	153.89	295	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.73	1.67	ERR	1.83	1.72	ERR
ya, depth of f/p flow, ft	2.57	2.36	ERR	2.50	2.96	ERR
--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	0.190	0.191	ERR	0.204	0.176	ERR
ys, scour depth, ft	9.39	11.17	N/A	9.08	11.33	N/A

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

a'(abut length blocked, ft)	38.8	78.5	0	33.6	58	0
y1 (depth f/p flow, ft)	2.57	2.36	ERR	2.50	2.96	ERR
a'/y1	15.09	33.24	ERR	13.43	19.57	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.19	0.19	N/A	0.20	0.18	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	9.95	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	8.16	ERR	ERR	ERR	ERR
spill-through	ERR	5.47	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 Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.83	0.93	0	0.83	0.93	0
y, depth of flow in bridge, ft	2.88	3.49	0.00	2.88	3.49	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	1.14	1.43	ERR	1.14	1.43	ERR