LEVEL II SCOUR ANALYSIS FOR BRIDGE 46 (LINCTH00060046) on TOWN HIGHWAY 6, crossing the NEW HAVEN RIVER, LINCOLN, VERMONT

Open-File Report 98-023

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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By EMILY C. WILD

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Pembroke, New Hampshire

1998

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

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

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	Max	maximum
D_{50}	median diameter of bed material	MC	main channel
DS	downstream	RAB	right abutment
elev.	elevation	RABUT	face of right abutment
f/p	flood plain	RB	right bank
ft^2	square feet	ROB	right overbank
ft/ft	feet per foot	RWW	right wingwall
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 46 (LINCTH00060046) ON TOWN HIGHWAY 6, CROSSING THE NEW HAVEN RIVER, 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 LINCTH00060046 on Town Highway 6 crossing the New Haven River, 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 45.9-mi^2 drainage area is in a predominantly suburban and forested basin. In the vicinity of the study site, the surface cover is forest upstream of the bridge. The downstream right overbank near the bridge is suburban with buildings, homes, lawns, and pavement (less than fifty percent). The downstream left overbank is brushland while the immediate banks have dense woody vegetation.

In the study area, the New Haven River has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 95 ft and an average bank height of 7 ft. The channel bed material ranges from sand to bedrock with a median grain size (D_{50}) of 120.7 mm (0.396 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 13, 1996, indicated that the reach was stable.

The Town Highway 34 crossing of the New Haven River is a 85-ft-long, two-lane bridge consisting of an 80-foot steel arch truss (Vermont Agency of Transportation, written communication, December 14, 1995). The opening length of the structure parallel to the bridge face is 69 feet. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway is 5 degrees.

A scour hole 2.0 ft deeper than the mean thalweg depth was observed in the downstream channel during the Level I assessment. Protection measures at the site include type-1 stone fill (less than 12 inches diameter) at the upstream left wingwall, type-2 stone fill (less than 36 inches diameter) at the downstream end of the downstream left wingwall, and type-3 stone fill (less than 48 inches diameter) at the upstream right wingwall and the downstream 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 Davis, 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 1.7 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge. Left abutment scour ranged from 12.9 to 17.8 ft. Right abutment scour ranged from 5.9 to 11.9 ft. The worst-case abutment scour occurred at the incipient roadway-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number LINCTH00060046 ***Stream*** New Haven River

County Addison ***Road*** TH6 ***District*** 5

Description of Bridge

Bridge length 85 ***ft*** ***Bridge width*** 21.2 ***ft*** ***Max span length*** 80 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 06/13/96

Description of stone fill Type-1 at the upstream left wingwall, type-2 at the downstream end of the downstream left wingwall, and type-3 at the upstream right wingwall and the downstream end of the downstream right wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a one to two foot deep scour hole in front of the right abutment.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 25

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	06/13/96	0	0
Level II	06/13/96	0	0

Potential for debris Moderate. Some debris has accumulated on upstream point bar, in front of upstream left wingwall and on downstream channel bar.

Describe any features near or at the bridge that may affect flow (include observation date) Under bridge channel is narrower at the incipient roadway-overtopping discharge than the 100-year and 500-year discharges. During the site visit on June 13, 1996, it was noted the left bridge seat is set back approximately 12 feet from the vertical left abutment.

Description of the Geomorphic Setting

General topography The channel is located within a 100 foot-wide, narrow valley with steep valley walls on both sides.

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

Date of inspection 06/13/96

DS left: Moderately sloped overbank

DS right: Steep valley wall

US left: Moderately sloped overbank

US right: Steep valley wall

Description of the Channel

Average top width 95 *ft* ***Average depth*** 7 *ft*

Predominant bed material Sand / Bedrock ***Bank material*** Sand/ Boulder

Sinuous but stable with alluvial channel boundaries and local anabranching downstream.

06/13/96

Vegetative co Trees and brush

DS left: None. (Town Highway 1)

DS right: Trees and brush

US left: None. (Town Highway 1)

US right:

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

Point bar through bridge along left bank (6/13/96).

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 45.9 ***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:*** There are a couple houses on the upstream left overbank area.

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 7,960 ***ft³/s*** ***Q500*** 11,000 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(45.87/48.87)exp 0.67] with bridge number 11 in Bristol. Bridge number 11 crosses the New Haven River downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 11 is 48.87 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 a chiseled X on top of the downstream left corner of the bridge (elev. 499.37 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream right corner of the bridge (elev. 497.67 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-75	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPR1	93	2	Modelled Approach section (Templated from APTEM)
APTEM	82	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

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

Normal depth at the exit section (EXIT1) 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 0.0121 ft/ft which was the 100-year discharge water surface slope downstream of the bridge in the Flood Insurance Study for Lincoln, VT (Federal Emergency Management Agency, August 19, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0199 ft/ft) to establish the modelled approach section (APPR1), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharges. After analyzing both the supercritical and subcritical models for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.1 ***ft***
Average low steel elevation 496.0 ***ft***

100-year discharge 7,960 ***ft³/s***
Water-surface elevation in bridge opening 496.7 ***ft***
Road overtopping? Y ***Discharge over road*** 411 ***ft³/s***
Area of flow in bridge opening 690 ***ft²***
Average velocity in bridge opening 10.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.3 ***ft/s***

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 494.4
Amount of backwater caused by bridge 4.9 ***ft***

500-year discharge 11,000 ***ft³/s***
Water-surface elevation in bridge opening 496.0 ***ft***
Road overtopping? Y ***Discharge over road*** 2200 ***ft³/s***
Area of flow in bridge opening 680 ***ft²***
Average velocity in bridge opening 13.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 18.0 ***ft/s***

Water-surface elevation at Approach section with bridge 501.2
Water-surface elevation at Approach section without bridge 495.8
Amount of backwater caused by bridge 5.4

Incipient overtopping discharge 7,310 ***ft³/s***
Water-surface elevation in bridge opening 492.2 ***ft***
Area of flow in bridge opening 455 ***ft²***
Average velocity in bridge opening 16.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 19.0 ***ft/s***

Water-surface elevation at Approach section with bridge 496.9
Water-surface elevation at Approach section without bridge 494.0
Amount of backwater caused by bridge 2.9 ***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 analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). 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). Therefore, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 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 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-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	1.2	1.7
Depth to armoring	29.3	22.1	31.5
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	12.9	14.0	17.8
Right abutment	10.1	5.9	11.9
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	3.0	3.6	3.4
Right abutment	3.0	3.6	3.4
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

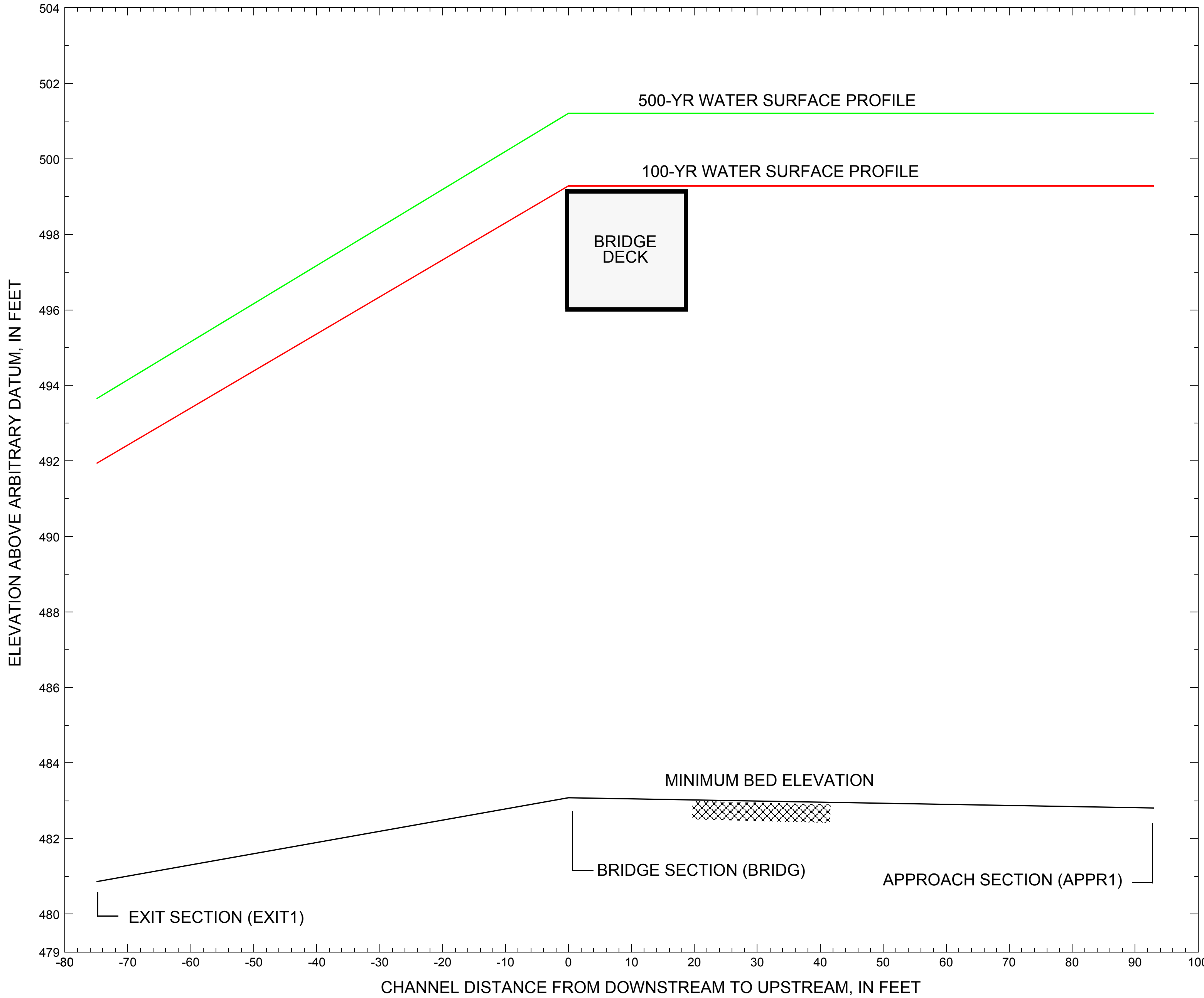

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure LINCTH00060046 on Town Highway 6, crossing the New Haven River, Lincoln, Vermont.

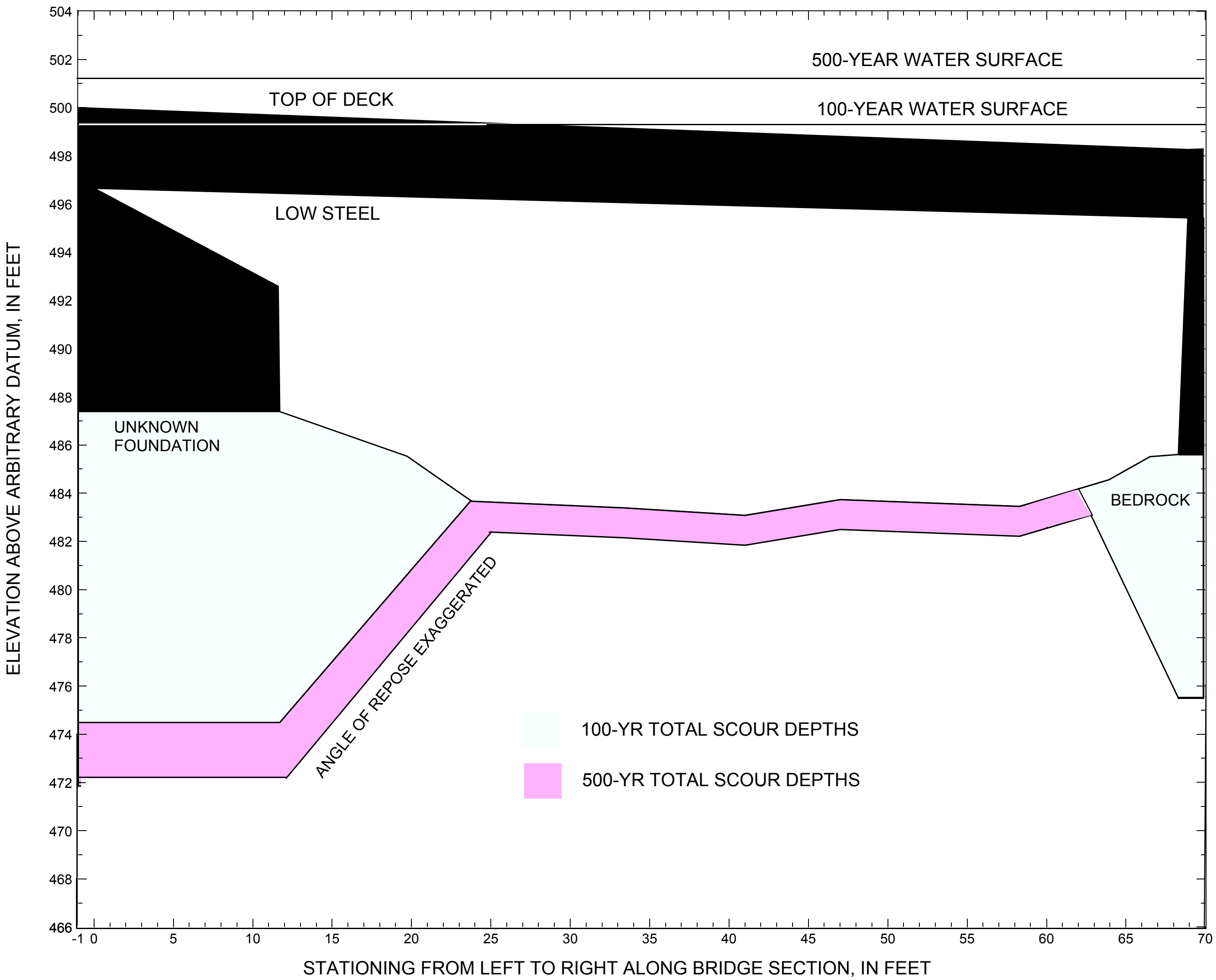

Figure 8. Scour elevations for the 100-yr discharge at structure LINCTH00060046 on Town Highway 6, crossing the New Haven River, Lincoln, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure LINCTH00060046 on Town Highway 6, crossing the New Haven River, 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 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 7,960 cubic-feet per second											
Left abutment	0.0	--	496.7	--	487.4	0.0	12.9	--	12.9	474.5	--
Right abutment	68.9	--	495.4	--	485.6	0.0	10.1	--	10.1	475.5	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure LINCTH00060046 on Town Highway 6, crossing the New Haven River, 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 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 11,000 cubic-feet per second											
Left abutment	0.0	--	496.7	--	487.4	1.2	14.0	--	15.2	472.2	--
Right abutment	68.9	--	495.4	--	485.6	1.2	5.9	--	7.1	478.5	--

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

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U.S. Geological Survey, 1963, South Mountain, 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 linc046.wsp
T2        Hydraulic analysis for structure LINCTH00060046   Date: 06-FEB-97
T3        TH006, NEW HAVEN RIVER, LINCOLN, VERMONT    ECW
*
J1         * * 0.0005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           7960.0  11000.0   7310.0
SK          0.0121   0.0121   0.0121
*
XS   EXIT1    -75
GR         -228.4, 513.18    -20.1, 504.46      0.0, 489.62      4.2, 485.68
GR           18.2, 485.03     33.2, 483.22     42.0, 483.90     48.0, 482.83
GR           59.0, 483.23     60.4, 480.86     68.8, 482.69     86.3, 483.68
GR           89.4, 484.98     94.2, 486.28    102.8, 493.23    108.9, 497.72
GR          117.6, 497.11    138.5, 497.34    166.7, 499.48    219.8, 506.87
*
N           0.075         0.060         0.065
SA                  0.0        108.9
*
*
XS   FULLV      0  * * *   0.0248
*
*            SRD     LSEL    XSSKEW
BR   BRIDG    0    496.04       5.0
GR           0.0, 496.65      11.6, 492.58      11.7 487.39     19.7, 485.54
GR           23.8, 483.66     33.4, 483.39     41.0, 483.08     47.0, 483.73
GR           58.3, 483.45     63.9, 484.55     66.5, 485.51     68.3, 485.61
GR           68.9, 495.42      0.0, 496.65
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD            1      37.1 * *     54.4      7.5
N           0.055
*
             SRD    EMBWID   IPAVE
XR   RDWAY     12      21.2     1
GR         -332.2, 524.63   -218.6, 513.79   -149.5, 510.98   -106.2, 508.21
GR          -40.6, 504.46      0.0, 499.97     83.0, 498.26    119.9, 497.99
GR          139.7, 509.53
*
XT   APTEM     82
GR         -182.9, 510.94   -100.2, 509.82    -19.7, 506.33     -7.0, 496.03
GR           -3.2, 493.93      0.0, 489.52     16.4, 486.17     17.2, 484.26
GR           18.7, 484.35     18.8, 483.90     22.3, 482.84     26.1, 483.91
GR           27.6, 482.59     39.1, 483.90     44.0, 483.76     53.7, 484.95
GR           57.6, 485.60     60.0, 484.90     60.5, 485.89     65.8, 487.42
GR           76.0, 495.97     84.4, 497.40    106.3, 499.57    113.8, 498.28
GR          138.5, 513.61
*
AS   APPR1     93  *  *  *  0.0199
GT          * * 106.3
N           0.080         0.060
SA                -3.2
*
HP 1 BRIDG   496.65 1 496.65
HP 2 BRIDG   496.65 * * 7547
HP 1 BRIDG   492.82 1 492.82
HP 2 RDWAY   499.29 * * 411
HP 1 APPR1   499.29 1 499.29
HP 2 APPR1   499.29 * * 7960
*
HP 1 BRIDG   496.04 1 496.04
HP 2 BRIDG   496.04 * * 8803
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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     U.S. Geological Survey WSPRO Input File linc046.wsp
     Hydraulic analysis for structure LINCTH00060046   Date: 06-FEB-97
     TH006, NEW HAVEN RIVER, LINCOLN, VERMONT    ECW
        *** RUN DATE & TIME: 07-24-97  15:40
 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1      690     50948     0    153                              0
 496.65          690     50948     0    153  1.00      0     69        0

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.65     0.0    68.9   689.8   50948.    7547.  10.94

X STA.        0.0       16.5       20.7       23.8       26.5       29.1
 A(I)            68.3       44.1       37.4       33.5       32.5
 V(I)            5.53       8.55      10.08      11.28      11.60

X STA.       29.1       31.5       34.0       36.3       38.6       40.9
 A(I)            30.8       30.5       29.6       29.4       29.5
 V(I)           12.25      12.38      12.76      12.85      12.80

X STA.       40.9       43.2       45.5       48.0       50.4       52.9
 A(I)            28.4       29.6       29.4       29.6       29.3
 V(I)           13.27      12.76      12.84      12.75      12.88

X STA.       52.9       55.3       57.9       60.5       63.7       68.9
 A(I)            30.0       30.4       32.0       35.1       50.5
 V(I)           12.59      12.39      11.80      10.74       7.48

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

  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1      490     48390    58     70                           8115
 492.82          490     48390    58     70  1.00     11     69     8115

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      12.

      WSEL     LEW     REW    AREA        K        Q    VEL
    499.29    33.0   122.1    70.2    1478.     411.   5.86

X STA.       33.0       60.1       68.2       73.9       78.5       82.3
 A(I)             7.6        5.2        4.4        4.1        3.7
 V(I)            2.72       3.94       4.63       5.07       5.52

X STA.       82.3       85.6       88.8       91.7       94.6       97.2
 A(I)             3.5        3.4        3.1        3.2        3.0
 V(I)            5.95       6.09       6.53       6.51       6.80

X STA.       97.2       99.8      102.3      104.7      107.0      109.2
 A(I)             3.0        2.8        2.8        2.7        2.7
 V(I)            6.88       7.21       7.30       7.53       7.54

X STA.      109.2      111.6      113.8      116.0      118.2      122.1
 A(I)             2.9        2.7        2.9        2.8        3.6
 V(I)            7.11       7.51       7.15       7.25       5.71

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      93.

  WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
          1       21       693     8      9                            202
          2     1049    114454   104    114                          18865
 499.29         1070    115147   112    123  1.02    -10    101    18564

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      93.

      WSEL     LEW     REW    AREA        K        Q    VEL
    499.29   -10.7   101.3  1070.3  115147.    7960.   7.44

X STA.      -10.7        3.5        8.3       12.4       16.1       19.6
 A(I)            79.3       51.4       48.8       45.2       50.6
 V(I)            5.02       7.74       8.15       8.81       7.86

X STA.       19.6       22.2       24.7       27.6       30.1       32.6
 A(I)            41.9       40.1       44.2       40.6       41.2
 V(I)            9.49       9.93       9.01       9.80       9.66

X STA.       32.6       35.3       38.1       41.0       44.0       47.2
 A(I)            41.9       43.7       43.7       46.2       48.2
 V(I)            9.50       9.10       9.10       8.61       8.26

X STA.       47.2       50.7       54.5       58.9       64.5      101.3
 A(I)            50.8       54.8       60.6       72.7      124.4
 V(I)            7.84       7.26       6.57       5.47       3.20
```

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       U.S. Geological Survey WSPRO Input File linc046.wsp
       Hydraulic analysis for structure LINCTH00060046   Date: 06-FEB-97
       TH006, NEW HAVEN RIVER, LINCOLN, VERMONT    ECW
          *** RUN DATE & TIME: 07-24-97  15:40

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      680     59421     32    117                        17702
  496.04           680     59421     32    117  1.00      2     69    17702

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     496.04     1.7    68.9   680.0   59421.    8803.  12.95

X STA.        1.7       15.9       19.4       22.2       24.4       26.5
  A(I)            56.2       34.6       30.2       27.3       25.6
  V(I)            7.84      12.73      14.59      16.10      17.19

X STA.       26.5       28.5       30.5       32.4       34.4       37.0
  A(I)            24.6       25.1       24.4       25.4       32.9
  V(I)           17.91      17.56      18.02      17.31      13.40

X STA.       37.0       39.6       42.2       44.8       47.7       50.5
  A(I)            32.6       32.7       33.5       34.3       34.3
  V(I)           13.49      13.47      13.14      12.83      12.85

X STA.       50.5       53.5       56.4       59.5       62.9       68.9
  A(I)            35.6       35.7       37.0       39.5       58.5
  V(I)           12.35      12.33      11.89      11.13       7.52

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      589     61843     62     77                        10261
  494.46           589     61843     62     77  1.00      6     69    10261

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      12.

       WSEL     LEW     REW    AREA        K        Q    VEL
     501.21   -11.2   125.4   303.6   12964.    2199.   7.24

X STA.      -11.2       13.1       24.9       34.8       43.1       50.6
  A(I)            24.9       19.3       18.4       16.9       16.6
  V(I)            4.41       5.70       5.98       6.52       6.60

X STA.       50.6       57.2       63.1       68.8       74.0       78.9
  A(I)            15.6       14.7       14.7       14.1       13.7
  V(I)            7.06       7.50       7.49       7.81       8.01

X STA.       78.9       83.4       87.8       92.1       96.3      100.4
  A(I)            13.3       13.1       12.7       12.8       12.7
  V(I)            8.27       8.37       8.65       8.58       8.69

X STA.      100.4      104.4      108.4      112.6      117.1      125.4
  A(I)            12.4       12.2       13.3       14.2       18.0
  V(I)            8.89       8.99       8.28       7.72       6.10

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      93.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       38      1509     10     12                          422
            2     1258    149314    110    120                        24198
  501.21          1296    150823    119    133  1.03    -12    106    23863

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      93.

       WSEL     LEW     REW    AREA        K        Q    VEL
     501.21   -13.1   106.3  1296.1  150823.   11000.   8.49

X STA.      -13.1        2.9        7.7       11.9       15.6       19.4
  A(I)           101.8       60.0       57.0       52.9       60.9
  V(I)            5.40       9.17       9.65      10.39       9.03

X STA.       19.4       22.2       25.1       28.0       30.7       33.5
  A(I)            50.7       49.9       52.3       48.9       49.6
  V(I)           10.86      11.02      10.53      11.24      11.09

X STA.       33.5       36.4       39.4       42.5       45.8       49.3
  A(I)            51.4       52.0       53.4       56.2       58.0
  V(I)           10.70      10.57      10.30       9.78       9.48

X STA.       49.3       53.0       57.3       62.2       69.0      106.3
  A(I)            61.2       67.6       76.1       89.8      146.4
  V(I)            8.99       8.14       7.23       6.12       3.76
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      U.S. Geological Survey WSPRO Input File linc046.wsp
      Hydraulic analysis for structure LINCTH00060046   Date: 06-FEB-97
      TH006, NEW HAVEN RIVER, LINCOLN, VERMONT    ECW
         *** RUN DATE & TIME: 07-24-97  15:40

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

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      455     43506     57     69                          7312
 492.21           455     43506     57     69  1.00     12     69     7312


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

      WSEL     LEW     REW    AREA        K        Q    VEL
    492.21    11.6    68.7   455.4   43506.    7310.  16.05

X STA.       11.6       18.5       22.2       25.0       27.5       29.9
  A(I)           38.2       25.8       23.3       21.5       21.1
  V(I)           9.56      14.14      15.71      16.98      17.36

X STA.       29.9       32.3       34.5       36.7       38.9       41.0
  A(I)           20.4       19.9       19.4       19.7       19.2
  V(I)          17.89      18.40      18.84      18.59      18.99

X STA.       41.0       43.2       45.5       47.8       50.1       52.6
  A(I)           19.3       20.0       19.7       19.9       20.8
  V(I)          18.97      18.31      18.51      18.34      17.57

X STA.       52.6       55.0       57.4       60.0       63.1       68.7
  A(I)           20.6       21.1       22.3       25.1       38.1
  V(I)          17.73      17.36      16.38      14.57       9.59


  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      93.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1        6       139      5      5                            44
           2      823     87816     83     92                         14698
 496.85           829     87955     88     98  1.01     -7     80    14402


  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      93.

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.85    -7.7    79.9   829.5   87955.    7310.   8.81

X STA.       -7.7        5.4       10.6       14.9       18.9       21.7
  A(I)           63.8       45.6       41.5       45.1       36.8
  V(I)           5.73       8.02       8.81       8.10       9.94

X STA.       21.7       24.2       27.0       29.5       31.9       34.4
  A(I)           34.4       36.4       34.6       33.2       33.5
  V(I)          10.61      10.05      10.56      11.02      10.90

X STA.       34.4       37.0       39.7       42.4       45.2       48.1
  A(I)           34.5       34.8       34.5       35.8       36.3
  V(I)          10.61      10.52      10.59      10.21      10.07

X STA.       48.1       51.3       54.7       58.6       63.2       79.9
  A(I)           38.5       40.1       43.5       49.8       76.7
  V(I)           9.48       9.11       8.39       7.33       4.76
```

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        U.S. Geological Survey WSPRO Input File linc046.wsp
        Hydraulic analysis for structure LINCTH00060046   Date: 06-FEB-97
        TH006, NEW HAVEN RIVER, LINCOLN, VERMONT    ECW
           *** RUN DATE & TIME: 07-24-97  15:40

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

EXIT1:XS   ******     -2      780  1.63 *****  493.57  489.96    7960  491.94
       -74 ******    101    72357  1.01 ***** *******    0.66   10.20

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.80     492.81     491.82

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.44     515.04    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.44     515.04     491.82

FULLV:FV       75     -1      680  2.14  1.13  494.96  491.82    7960  492.82
         0     75    100    58323  1.00  0.25    0.01    0.80   11.71
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       93     -3      627  2.51  1.72  496.87 *******    7960  494.36
        93     93     74    58683  1.00  0.19    0.00    0.79   12.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   492.70     496.69     497.50     496.04

 ===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       75      0      690  1.86 *****  498.51  492.38    7547  496.65
         0 ******     69    50948  1.00 ***** *******    0.61   10.94

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.467  0.000  496.04 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.    72.  0.34  0.88  499.83    0.00    411.  499.29

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    45.    -4.    41.   1.3   0.8   5.3   5.6   1.3   3.1
   RT:    411.    81.    41.   122.   1.3   0.9   5.5   5.9   1.4   3.1

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

APPR1:AS       56    -10     1070  0.88  0.59  500.17  493.07    7960  499.29
        93     58    101   115129  1.02  1.04    0.00    0.43    7.44

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -75.    -3.   101.   7960.   72357.     780.   10.20  491.94
   FULLV:FV       0.    -2.   100.   7960.   58323.     680.   11.71  492.82
   BRIDG:BR       0.     0.    69.   7547.   50948.     690.   10.94  496.65
   RDWAY:RG      12.*******     0.    411.      0.        0.    1.00  499.29
   APPR1:AS      93.   -11.   101.   7960.  115129.    1070.    7.44  499.29

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS   ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXIT1:XS    489.96    0.66  480.86  513.18************  1.63  493.57  491.94
   FULLV:FV    491.82    0.80  482.72  515.04  1.13  0.25  2.14  494.96  492.82
   BRIDG:BR    492.38    0.61  483.08  496.65************  1.86  498.51  496.65
   RDWAY:RG   ****************  497.99  524.63  0.34******  0.88  499.83  499.29
   APPR1:AS    493.07    0.43  482.81  513.83  0.59  1.04  0.88  500.17  499.29
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        U.S. Geological Survey WSPRO Input File linc046.wsp
        Hydraulic analysis for structure LINCTH00060046   Date: 06-FEB-97
        TH006, NEW HAVEN RIVER, LINCOLN, VERMONT    ECW
           *** RUN DATE & TIME: 07-24-97  15:40

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

EXIT1:XS   ******     -4      962  2.06 *****  495.71  491.42   11000  493.65
       -74 ******    103    99987  1.01 ***** *******    0.68   11.43

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81     494.46     493.28
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.15     515.04    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.15     515.04     493.28

FULLV:FV       75     -3      850  2.63  1.10  497.09  493.28   11000  494.46
         0     75    102    82615  1.01  0.28    0.00    0.81   12.94
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPR1":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.87     495.85     494.84
 ===110 WSEL NOT FOUND AT SECID "APPR1":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.96     513.83    0.50
 ===115 WSEL NOT FOUND AT SECID "APPR1":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.96     513.83     494.84
APPR1:AS       93     -5      745  3.41  1.78  499.26  494.84   11000  495.84
        93     93     76    76409  1.01  0.39   -0.01    0.87   14.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   500.30       0.00     494.99     497.99

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   506.75         0.     11000.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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       75      2      680  2.61 *****  498.65  493.39    8803  496.04
         0 ******     69    59421  1.00 ***** *******    0.73   12.95

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.492  0.000  496.04 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.    72.  0.38  1.16  501.98    0.00   2199.  501.21

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   533.    52.   -11.    41.   2.1   1.4   6.9   7.1   2.2   3.1
   RT:  1666.    84.    41.   125.   3.2   2.7   8.5   7.3   3.5   3.0

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

APPR1:AS       56    -12     1296  1.16  0.64  502.36  494.84   11000  501.21
        93     58    106   150784  1.03  0.00    0.00    0.46    8.49
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -75.    -5.   103.  11000.   99987.     962.   11.43  493.65
   FULLV:FV       0.    -4.   102.  11000.   82615.     850.   12.94  494.46
   BRIDG:BR       0.     2.    69.   8803.   59421.     680.   12.95  496.04
   RDWAY:RG      12.*******   533.   2199.******************    1.00  501.21
   APPR1:AS      93.   -13.   106.  11000.  150784.    1296.    8.49  501.21

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS    491.42    0.68  480.86  513.18************  2.06  495.71  493.65
   FULLV:FV    493.28    0.81  482.72  515.04  1.10  0.28  2.63  497.09  494.46
   BRIDG:BR    493.39    0.73  483.08  496.65************  2.61  498.65  496.04
   RDWAY:RG  ***************  497.99  524.63  0.38******  1.16  501.98  501.21
   APPR1:AS    494.84    0.46  482.81  513.83  0.64  0.00  1.16  502.36  501.21
```

```
        U.S. Geological Survey WSPRO Input File linc046.wsp
        Hydraulic analysis for structure LINCTH00060046   Date: 06-FEB-97
        TH006, NEW HAVEN RIVER, LINCOLN, VERMONT    ECW
           *** RUN DATE & TIME: 07-24-97  15:40

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

EXIT1:XS   ******     -2      738  1.53 *****  493.07  489.64    7310  491.54
       -74 ******    101    66392  1.00 ***** *******    0.65    9.90

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.80     492.42     491.50

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.04     515.04    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.04     515.04     491.50

FULLV:FV       75      0      639  2.04  1.14  494.46  491.50    7310  492.42
         0     75     99    52902  1.00  0.25    0.00    0.80   11.44
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       93     -2      599  2.31  1.71  496.32 *******    7310  494.01
        93     93     73    54778  1.00  0.14    0.01    0.77   12.20
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    7310.     492.21

            <<<<<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       75     12      455  4.01 *****  496.22  492.21    7310  492.21
         0     75     69    43515  1.00 ***** *******    1.00   16.05

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.04 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS       56     -7      829  1.22  0.81  498.07  492.64    7310  496.85
        93     58     80    87900  1.01  1.05    0.01    0.51    8.82

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.253  0.031   85090.     6.    63.   496.35

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -75.    -3.   101.   7310.   66392.     738.    9.90  491.54
   FULLV:FV       0.    -1.    99.   7310.   52902.     639.   11.44  492.42
   BRIDG:BR       0.    12.    69.   7310.   43515.     455.   16.05  492.21
   RDWAY:RG      12.**************       0.******************    1.00********
   APPR1:AS      93.    -8.    80.   7310.   87900.     829.    8.82  496.85

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       6.    63.   85090.

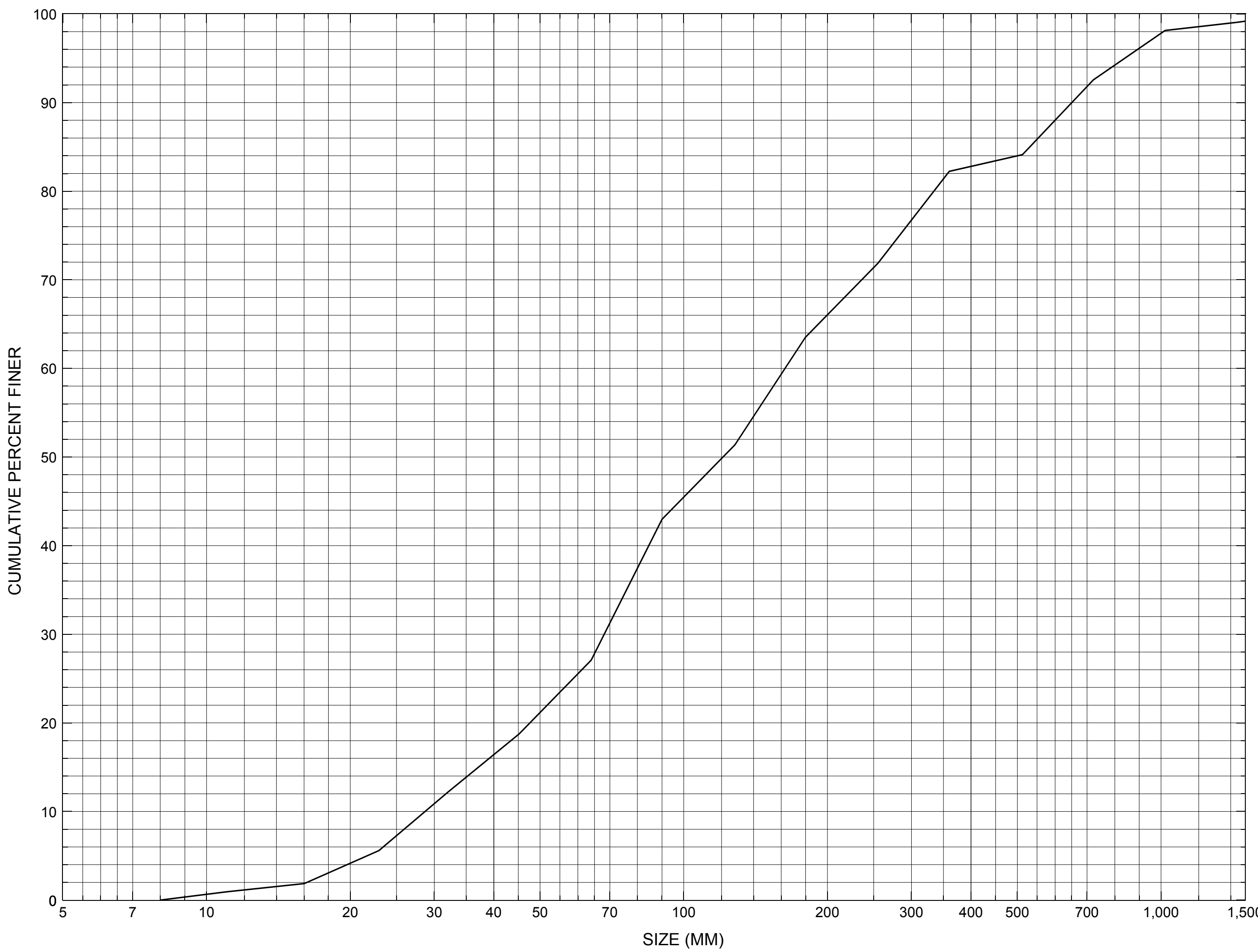
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    489.64    0.65  480.86  513.18************  1.53  493.07  491.54
   FULLV:FV    491.50    0.80  482.72  515.04  1.14  0.25  2.04  494.46  492.42
   BRIDG:BR    492.21    1.00  483.08  496.65************  4.01  496.22  492.21
   RDWAY:RG  ***************  497.99  524.63**********************************
   APPR1:AS    492.64    0.51  482.81  513.83  0.81  1.05  1.22  498.07  496.85
  ER

NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure LINCTH00060046, in Lincoln, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number LINCTH00060046

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)* NEW HAVEN RIVER

Road Name *(I - 7):* -

Route Number C3006

Vicinity *(I - 9)* @ JCT W CL2 TH1

Topographic Map South Mountain

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 44071

Longitude *(i - 17; nnnnn.n)* 73012

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011000460110

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

Maximum span length *(I - 48; nnnn)* 0080

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

Structure length *(I - 49; nnnnnn)* 000085

Average daily traffic, ADT *(I - 29; nnnnnn)* 000200

Deck Width *(I - 52; nn.n)* 212

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

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

Opening skew to Roadway *(I - 34; nn)* 05

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

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

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

Structure type *(I - 43; nnn)* 310

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 75.25

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

Vertical clearance from streambed (*nnn.n ft*) 12

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

Waterway of full opening (*nnn.n ft*^{2}) 690

Comments:

According to the structural inspection report dated 11/14/94, the structure is a medium to heavy membered steel pony truss. The abutments and backwalls are concrete. The abutments have been poured on the embankments behind the faces of the original concrete and the stone abutments which are still in place, acting as channel protection. A low, coarse gravel bar at the Left abutments blocks a third of the channel flow. Ledge outcrops are showing in the channel. The wingwalls on the old abutments are cracked and spalled. According to a sketch dated 12/7/90, the Right abutment has extensive spalling and at least 3 sections of undermining, from 6”-2’ under, 4-8” deep, and 1-3’ long sections.

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*): ____ *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)* **45.87** mi^2 Lake and pond area **0.03** mi^2
Watershed storage *(ST)* **0.07** %
Bridge site elevation **880** ft Headwater elevation **3780** ft
Main channel length **11.36** mi
10% channel length elevation **940** ft 85% channel length elevation **2150** ft
Main channel slope *(S)* **142.01** ft / mi

Watershed Precipitation Data

Average site precipitation ______ in Average headwater precipitation ______ in

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

Average seasonal snowfall *(Sn)* ______ ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCKMARK INFORMATION

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO DRILL BORING INFORMATION

Comments:

Cross-sectional Data

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

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

Comments: **NO CROSS SECTIONAL INFORMATION**

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

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

Comments: -
-

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: **2/6/97**
Computerized by: **EW** Date: **2/6/97**
Reviewd by: **EW** Date: **4/2/97**

Structure Number **LINCTH00060046**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. WILD** Date *(MM/DD/YY)* **06** / **13** / 19**96**

2. Highway District Number **05** Mile marker **0**

County **ADDISON (001)** Town **LINCOLN (40075)**

Waterway *(I - 6)* **NEW HAVEN RIVER** Road Name **YORK HILL ROAD**

Route Number **C3006** Hydrologic Unit Code: **02010002**

3. Descriptive comments:
Bridge is located at junction with CL2 TH1. The structure is a medium to heavy membered steel pony truss.

B. Bridge Deck Observations

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

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

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

7. Bridge length **85** *(feet)* Span length **80** *(feet)* Bridge width **21.2** *(feet)*

Road approach to bridge:

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

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

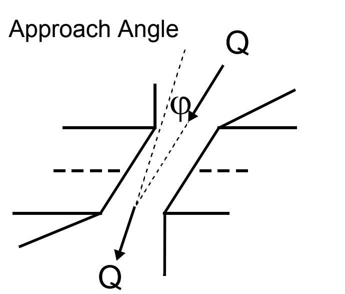
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

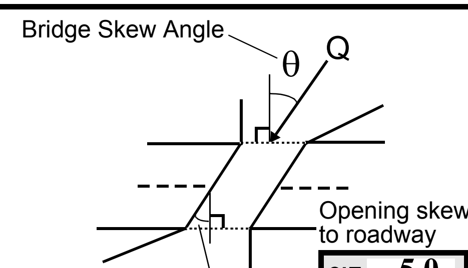
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	3	2	2	2
RBUS	3	1	2	1
RBDS	*3	2	2	2
LBDS	3	2	2	2

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

Channel approach to bridge (BF):

15. Angle of approach: **15** 16. Bridge skew: **25**





α= **5.0**

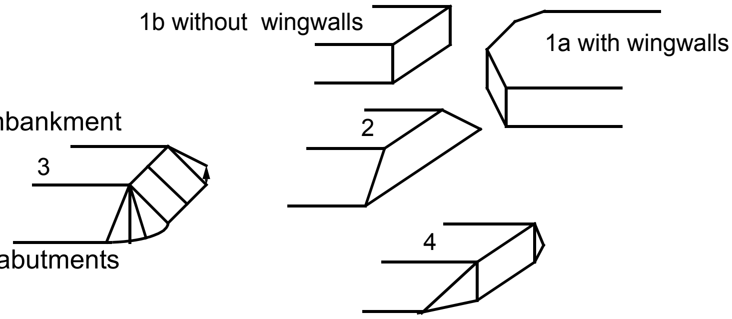
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **0**
Range? **300** feet **US** *(US, UB, DS)* to **95** feet **DS**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **200** feet **US** *(US, UB, DS)* to **30** feet **DS**

*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 upstream and downstream left overbanks, there are homes with yards and many trees. The upstream right bank is all forest, with the exception of the immediate bank where Town Highway 1 is parallel with stream. The downstream right overbank surface cover is Town Highway 1 along immediate bank and suburban (buildings, grass and less than fifty percent pavement) beyond.

7: Values are from Vermont AOT database. Measurements during site visit: bridge length = 83.4 feet and bridge width = 21.0 feet.

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
93.0	**5.0**			**9.0**	**3**	**1**	**3245**	**543**	**1**	**1**

23. Bank width **50.0** 24. Channel width **40.0** 25. Thalweg depth **80.0** 29. Bed Material **654**

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

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

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

29: Bed material is mostly bedrock from approximately 300 feet upstream to 49 feet upstream. The bedrock comprises about 65% of the channel from the right bank.

30: Protection is predominately small material (6-8 inches) with sparse boulders.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **49 US** 35. Mid-bar width: **17**

36. Point bar extent: **320** feet **US** (US, UB) to **2.5** feet **DS** (US, UB, DS) positioned **0** %LB to **35** %RB

37. Material: **543201**

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

37: Point bar material grades from large boulder, gravel, grass and ferns upstream (320 feet upstream to 30 feet upstream) to cobbles, gravel and sand downstream (30 feet upstream to 2.5 feet downstream).

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

41. Mid-bank distance: **87** 42. Cut bank extent: **150** feet **US** (US, UB) to **35** 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.):

The upstream is impacted, but due to the protection along bank and bedrock bed, the impact does not appear to be a problem. However, the left bank is evidently well eroded, many tree roots are exposed.

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

47. Scour dimensions: Length **-** Width **-** Depth : **-** Position **-** %LB to **-** %RB

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

NO CHANNEL SCOUR

Local scour exists behind boulders.

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

A 1.5 feet in diameter culvert enters the upstream right bank 95.5 feet from upstream bridge face.

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
66.0		3.5		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.):

532

Concrete has eroded from both abutment faces and all wingwalls.

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? **1**___ *(Y or N)* Ice Blockage Potential **N**____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

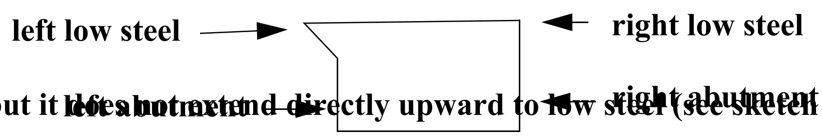
66: Debris has accumulated on point bar upstream, along the left bank, in front of the left wingwall and on downstream channel bar.

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		-	90	2	0	-	-	90.0
RABUT	1	30	90			2	3	68.5

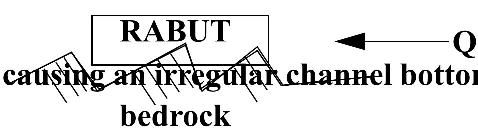
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1*- Concrete; *2*- Stone masonry or drywall; *3*- steel or metal; *4*- wood

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

1
3 **Looking downstream:**
1



72: The left abutment is vertical, but it does not extend directly upward to low steel (see sketch below).

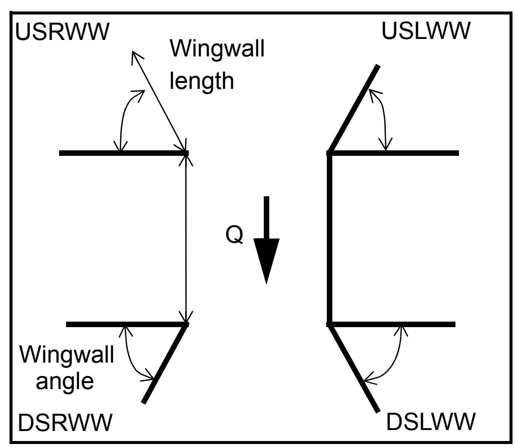


76: Due to dipping bedrock formation causing an irregular channel bottom, abutment is undermined 0.5 feet where exposed (see sketch below).

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						68.5	
USRWW:	Y		1		0	2.5	
DSLWW:	-		-		Y	24.5	
DSRWW:	1		0		-	25.0	

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	-	1	1	-	-
Condition	Y	-	1	-	1	1	-	-
Extent	1	-	0	1	3	0	0	-

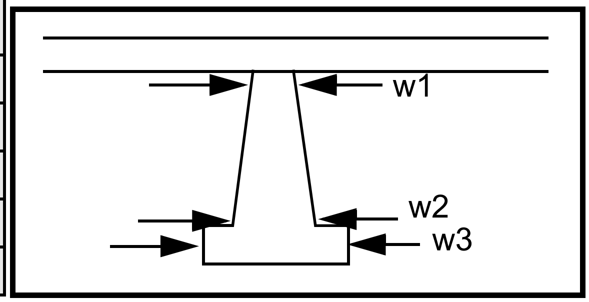
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? Up (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		9.0		40.0	65.0	20.5
Pier 2		3.5		35.0	40.0	11.0
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	strea	bed-	acts	adja-	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	m	rock.	like	cent	1- Solid pier, 2- column, 3- bent
88. Material	right		pro-	to	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	wing	Bed-	tec-	the	1- Round; 2- Square; 3- Pointed
90. Inclined?	wall	rock	tion.	point	Y- yes; N- no
91. Attack ∠ (BF)	pro-	alon	The	bar	
92. Pushed	tec-	g	wate	unde	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	tion	right	r	r	
95. Cross-members	is	side	flows	brid	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	boul-	of	the	ge.	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	der	chan	fast-		
98. Exposure depth	and	nel	est		

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

N
-
-
-
-

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -

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

NO PIERS

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 3 (US, UB, DS)

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

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

3245
3245
1
1

Is channel scour present? 453 (Y or if N type ctrl-n cs) Mid-scour distance: 0

Scour dimensions: Length 3 Width - Depth: 2 Positioned Rig %LB to ht %RB

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

bank protection has slumped into the stream. It extends from 0 feet downstream to 25 feet downstream.

A minor inflow enters the New Haven River at 80 feet downstream on the left bank. The width of the inflow is

Are there major confluences? 1 (Y or if N type ctrl-n mc) How many? foot.

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

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

Confluence comments (eg. confluence name):

enters, an 8 ft. wide silt and sand side bar exists. The side bar is 12 feet in length.

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N

-

NO DROP STRUCTURE

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: LINCTH00060046 Town: LINCOLN
Road Number: TH006 County: ADDISON
Stream: NEW HAVEN RIVER

Initials ECW Date: 7/24/97 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	7960	11000	7310
Main Channel Area, ft2	1049	1258	823
Left overbank area, ft2	21	38	6
Right overbank area, ft2	0	0	0
Top width main channel, ft	104	110	83
Top width L overbank, ft	8	10	5
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.396	0.396	0.396
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.1	11.4	9.9
y1, average depth, LOB, ft	2.6	3.8	1.2
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	115147	150823	87955
Conveyance, main channel	114454	149314	87816
Conveyance, LOB	693	1509	139
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	7912.1	10889.9	7298.4
Ql, discharge, LOB, cfs	47.9	110.1	11.6
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	7.5	8.7	8.9
Vl, mean velocity, LOB, ft/s	2.3	2.9	1.9
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	12.1	12.4	12.1
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?

	100 yr	500 yr	other Q
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	7960	11000	7310
(Q) discharge thru bridge, cfs	7547	8803	7310
Main channel conveyance	50948	59421	43506
Total conveyance	50948	59421	43506
Q2, bridge MC discharge,cfs	7547	8803	7310
Main channel area, ft2	690	680	455
Main channel width (normal), ft	68.6	66.9	56.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	68.6	66.9	56.9
y_bridge (avg. depth at br.), ft	10.06	10.16	8.00
Dm, median (1.25*D50), ft	0.495	0.495	0.495
y2, depth in contraction,ft	8.50	9.92	9.71
ys, scour depth (y2-ybridge), ft	-1.55	-0.25	1.72

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	7547	8803	7310
Main channel area (DS), ft2	490	589	455
Main channel width (normal), ft	68.6	66.9	56.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	68.6	66.9	56.9
D90, ft	2.1320	2.1320	2.1320
D95, ft	2.7550	2.7550	2.7550
Dc, critical grain size, ft	1.7361	1.4652	1.7793
Pc, Decimal percent coarser than Dc	0.151	0.166	0.145
Depth to armoring, ft	29.28	22.08	31.48

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	7960	11000	7310
Q, thru bridge MC, cfs	7547	8803	7310
Vc, critical velocity, ft/s	12.10	12.36	12.07
Va, velocity MC approach, ft/s	7.54	8.66	8.87
Main channel width (normal), ft	68.6	66.9	56.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	68.6	66.9	56.9
qbr, unit discharge, ft2/s	110.0	131.6	128.5
Area of full opening, ft2	690.0	680.0	455.0
Hb, depth of full opening, ft	10.06	10.16	8.00
Fr, Froude number, bridge MC	0.61	0.73	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	490	589	N/A
**Hb, depth at downstream face, ft	7.14	8.80	N/A
**Fr, Froude number at DS face	1.02	0.89	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	496	496	0
Elevation of Bed, ft	485.94	485.84	-8.00
Elevation of Approach, ft	499.3	501.21	0
Friction loss, approach, ft	0.59	0.64	0
Elevation of WS immediately US, ft	498.71	500.57	0.00
ya, depth immediately US, ft	12.77	14.73	8.00
Mean elevation of deck, ft	499.1	499.1	0
w, depth of overflow, ft (>=0)	0.00	1.47	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.93	1.00
**Cc, for downstream face (<=1.0)	0.79	0.891855	ERR
Ys, scour w/Chang equation, ft	-0.40	1.24	N/A
Ys, scour w/Umbrell equation, ft	0.52	2.13	N/A

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

**Ys, scour w/Chang equation, ft	4.37	3.14	N/A

**Ys, scour w/Umbrell equation, ft	3.44	3.49	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	8.50	9.92	9.71
WSEL at downstream face, ft	492.80	494.50	--
Depth at downstream face, ft	7.14	8.80	N/A
Ys, depth of scour (Laursen), ft	1.36	1.11	N/A

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	7960	11000	7310	7960	11000	7310
a', abut.length blocking flow, ft	10.8	15	19.4	32.8	37.6	11.3
Ae, area of blocked flow ft2	60.5	83.6	120	78.4	39.4	51.9
Qe, discharge blocked abut.,cfs	303.6	--	824.5	--	--	247.3
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	5.02	5.40	6.87	3.20	3.81	4.76
ya, depth of f/p flow, ft	5.60	5.75	6.19	2.39	1.05	4.59
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	65	65	65	115	115	115
K2	0.96	0.96	0.96	1.03	1.03	1.03
Fr, froude number f/p flow	0.374	0.377	0.487	0.365	0.336	0.392
ys, scour depth, ft	12.87	13.97	17.82	10.05	5.87	11.93

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)	10.8	15	19.4	32.8	37.6	11.3
y1 (depth f/p flow, ft)	5.60	5.75	6.19	2.39	1.05	4.59
a'/y1	1.93	2.69	3.14	13.72	35.88	2.46
Skew correction (p. 49, fig. 16)	0.92	0.92	0.92	1.06	1.06	1.06
Froude no. f/p flow	0.37	0.38	0.49	0.36	0.34	0.39
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	5.62	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	4.60	ERR
spill-through	ERR	ERR	ERR	ERR	3.09	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1.02	0.89	1	1.02	0.89	1
y, depth of flow in bridge, ft	7.14	8.80	8.00	7.14	8.80	8.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	3.00	3.56	3.35	3.00	3.56	3.35