LEVEL II SCOUR ANALYSIS FOR BRIDGE 44 (LINCTH00330044) on TOWN HIGHWAY 33, crossing the NEW HAVEN RIVER, LINCOLN, VERMONT

Open-File Report 97-659

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 44 (LINCTH00330044) on TOWN HIGHWAY 33, crossing the NEW HAVEN RIVER, LINCOLN, VERMONT

By RONDA L. BURNS & EMILY C. WILD

U.S. Geological Survey
Open-File Report 97-659

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

Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
Mark Schaefer, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

Copies of this report may be purchased from:

U.S. Geological Survey
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 44 (LINCTH00330044) ON TOWN HIGHWAY 33, CROSSING THE NEW HAVEN RIVER, LINCOLN, VERMONT

By Ronda L. Burns and Emily C. Wild

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure LINCTH00330044 on Town Highway 33 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 (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in west-central Vermont. The 6.3-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, the New Haven River has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 56 ft and an average bank height of 6 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 101.9 mm (0.334 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 stable.

The Town Highway 33 crossing of the New Haven River is a 33-ft-long, one-lane bridge consisting of one 31-foot timber-beam span (Vermont Agency of Transportation, written communication, December 14, 1995). The opening length of the structure parallel to the bridge face is 29.3 ft. The bridge is supported by vertical, wood-beam crib abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the right abutment during the Level I assessment. The scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) at the downstream end of the downstream left wingwall and along the downstream right bank, type-2 stone fill (less than 36 inches diameter) along the upstream right bank and type-3 stone fill (less than 48 inches diameter) at the upstream end of the upstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 1.3 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 9.4 to 12.6 ft. The worst-case abutment scour occurred at the 100-year discharge for the left abutment and at the incipient overtopping discharge for the right abutment. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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 LINCTH00330044 ***Stream*** New Haven River

County Addison ***Road*** TH 33 ***District*** 5

Description of Bridge

Bridge length 33 ***ft*** ***Bridge width*** 16.2 ***ft*** ***Max span length*** 31 ***ft***

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

Abutment type Vertical, timber ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 06/10/96

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

Abutments and wingwalls are wood crib. There is a one foot deep scour hole in front of the right abutment..

Yes 25

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

There is a mild channel bend in the upstream reach. The scour hole has developed in the location where the bend impacts the right abutment.

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	06/10/96	0	0
Level II	06/10/96	0	0

Potential for debris High. There are fallen trees and brush in the channel upstream and downstream of the bridge.

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

None. 06/10/96

Description of the Geomorphic Setting

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

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

Date of inspection 06/10/96

DS left: Moderately sloped overbank

DS right: Moderately sloped overbank

US left: Steep channel bank to a moderately sloped overbank

US right: Steep channel bank to a moderately sloped overbank

Description of the Channel

Average top width 56 ***ft*** ***Average depth*** 6 ***ft***

Predominant bed material Cobbles/Boulders ***Bank material*** Cobbles/Boulders

Sinuous but stable with semi-alluvial channel boundaries.

06/10/97

Vegetative co

Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: A few trees with short grass on the overbank

US right:

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

The assessment of 06/10/96 noted flow conditions up to bank-full level are influenced by a point bar along the left abutment. In addition, some debris is caught on boulders in the channel upstream.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 6.3 ***mi***^{2}

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***: -

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

USGS gage description New Haven River at Brooksville, VT

USGS gage number 04282525

Gage drainage area 115 ***mi***^{2}

Is there a lake/p No

-

-

Calculated Discharges

Q100 2,870 ***ft***^{3}***/s*** ***Q500*** 3,920 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(6.3/15)exp 0.67] with the drainage area at South Lincoln. This drainage area is 15 square miles and has flood frequency estimates available in the Flood Insurance Study for the town of Lincoln (Federal Emergency Management Agency, August 1986).

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. 499.06 ft, arbitrary survey datum). RM2 is a nail 6 ft above the ground in a tree 25 ft left of the left abutment and 25 ft downstream (elev. 500.06 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	-34	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	46	2	Modelled Approach section (Templated from APTEM)
APTEM	54	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 0.050 to 0.065, and overbank "n" values ranged from 0.045 to 0.075.

Normal depth at the exit section (EXITX) was assumed as the starting water surface for the 100-year and incipient overtopping discharges. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). Critical depth was assumed as the starting water surface elevation at the exit section for the 500-year event. Normal depth was computed as 0.11 foot below critical depth by use of the slope-conveyance method for this discharge. The slope used was 0.0239 ft/ft, which was estimated from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0306 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the incipient overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. By analyzing both the supercritical and subcritical profiles for this discharge, it was 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 499.5 *ft*
Average low steel elevation 497.5 *ft*

100-year discharge 2,870 *ft^3/s*
Water-surface elevation in bridge opening 497.8 *ft*
Road overtopping? Yes *Discharge over road* 91 *ft^3/s*
Area of flow in bridge opening 281 *ft^2*
Average velocity in bridge opening 9.9 *ft/s*
Maximum WSPRO tube velocity at bridge 11.4 *ft/s*

Water-surface elevation at Approach section with bridge 499.9
Water-surface elevation at Approach section without bridge 494.5
Amount of backwater caused by bridge 5.4 *ft*

500-year discharge 3,920 *ft^3/s*
Water-surface elevation in bridge opening 497.5 *ft*
Road overtopping? Yes *Discharge over road* 771 *ft^3/s*
Area of flow in bridge opening 279 *ft^2*
Average velocity in bridge opening 11.4 *ft/s*
Maximum WSPRO tube velocity at bridge 15.6 */s*

Water-surface elevation at Approach section with bridge 501.0
Water-surface elevation at Approach section without bridge 495.7
Amount of backwater caused by bridge 5.3 *ft*

Incipient overtopping discharge 2,760 *ft^3/s*
Water-surface elevation in bridge opening 494.4 *ft*
Area of flow in bridge opening 191 *ft^2*
Average velocity in bridge opening 14.5 *ft/s*
Maximum WSPRO tube velocity at bridge 18.1 *ft/s*

Water-surface elevation at Approach section with bridge 497.9
Water-surface elevation at Approach section without bridge 494.4
Amount of backwater caused by bridge 3.5 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). 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 others, 1995, p. 145-146). The streambed armoring depths computed 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 others, 1995, p. 144) and presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in Appendix F.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.6	1.3
Depth to armoring	36.2	64.4	44.9
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	12.0	11.9	11.6
Right abutment	11.2	9.4	12.6
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	2.8	3.0	2.7
Right abutment	2.8	3.0	2.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

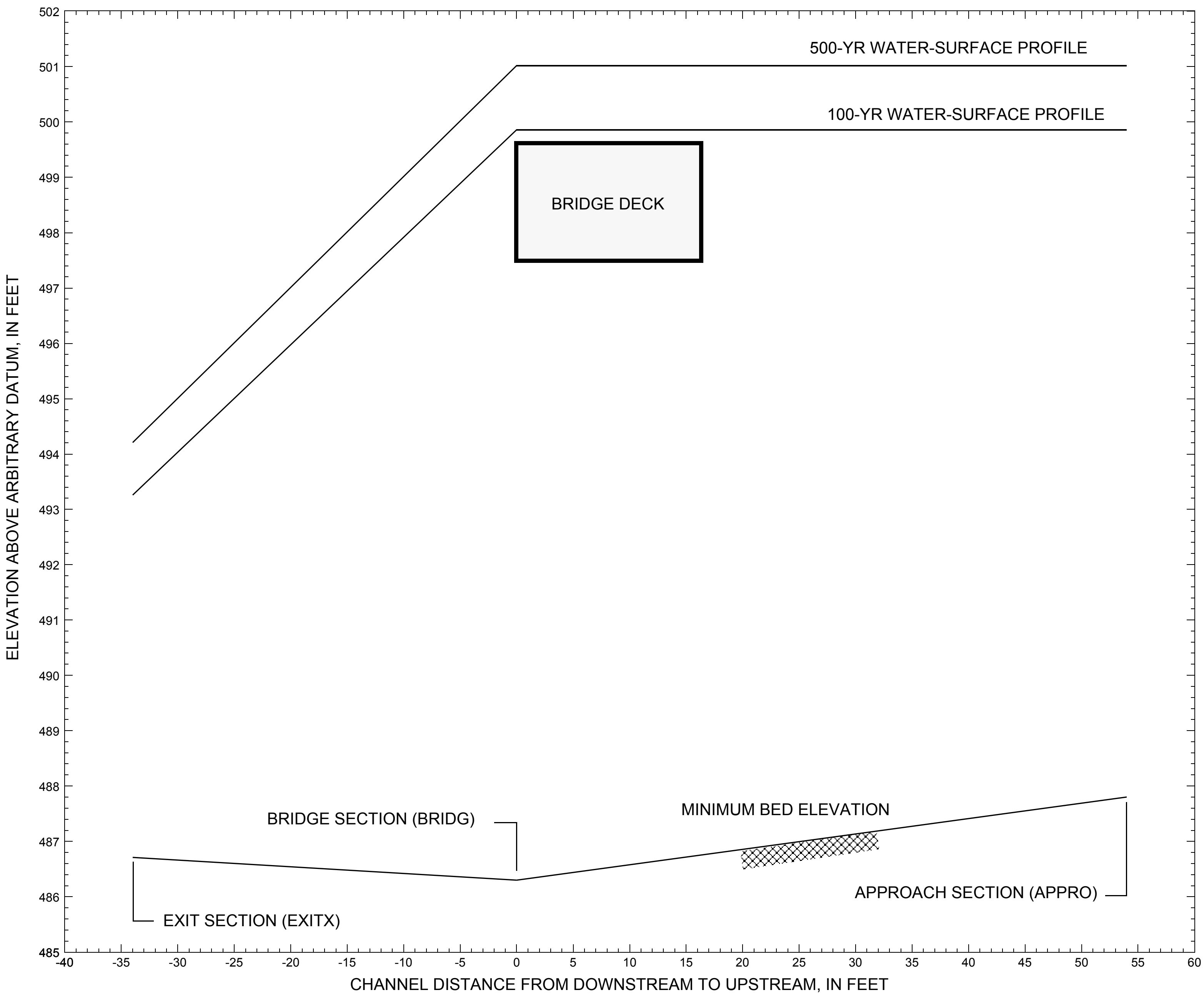


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure LINCTH00330044 on Town Highway 33, crossing the New Haven River, Lincoln, Vermont.

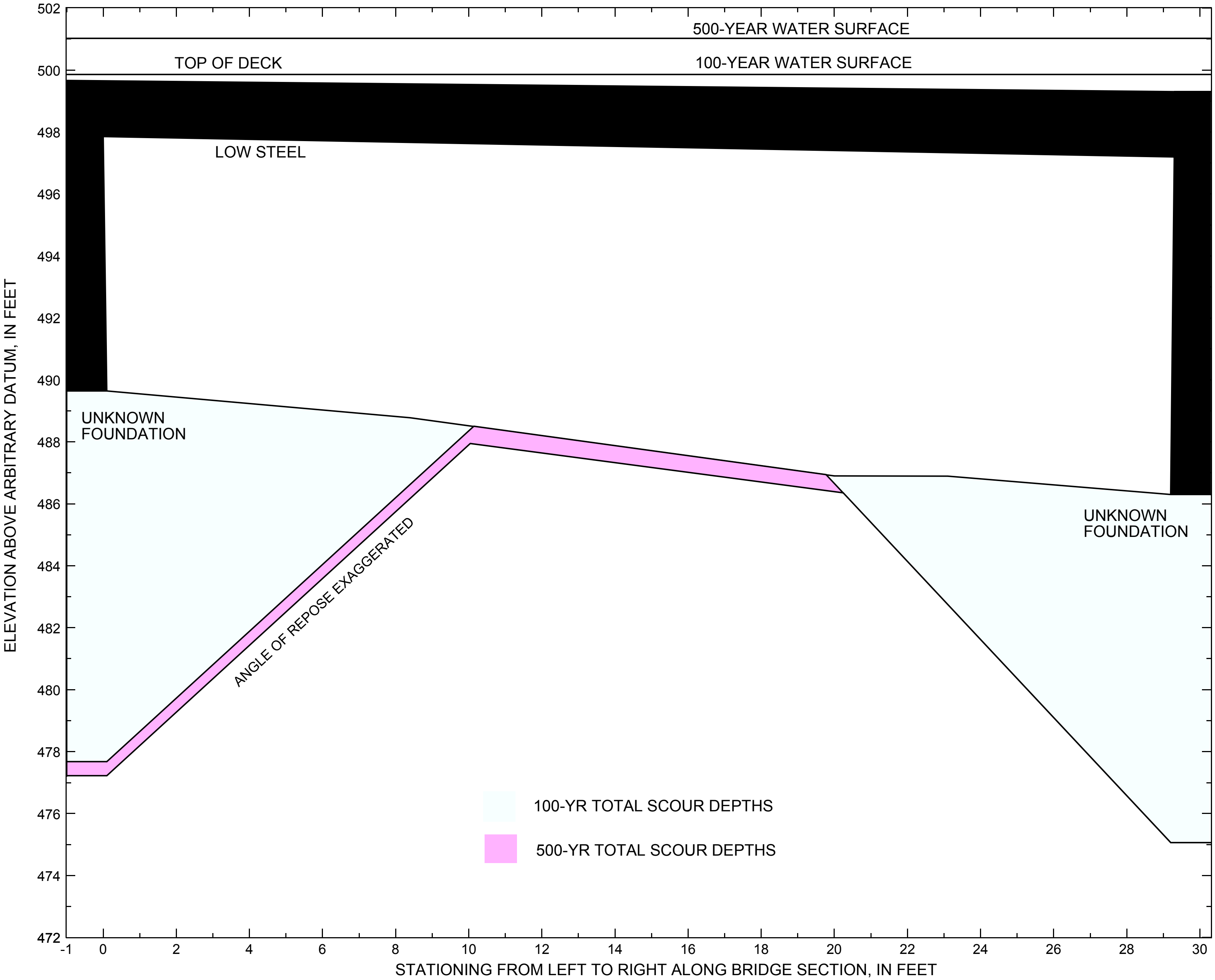


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure LINCTH00330044 on Town Highway 33, crossing the New Haven River, Lincoln, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure LINCTH00330044 on Town Highway 33, 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/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-yr. discharge is 2,870 cubic-feet per second											
Left abutment	0.0	--	497.9	--	489.6	0.0	12.0	--	12.0	477.6	--
Right abutment	29.3	--	497.2	--	486.3	0.0	11.2	--	11.2	475.1	--

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 LINCTH00330044 on Town Highway 33, 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/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-yr. discharge is 3,920 cubic-feet per second											
Left abutment	0.0	--	497.9	--	489.6	0.6	11.9	--	12.5	477.1	--
Right abutment	29.3	--	497.2	--	486.3	0.6	9.4	--	10.0	476.3	--

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158.

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

Federal Emergency Management Agency, 1986, Flood Insurance Study, Town of Lincoln, Addison County, Vermont: Washington, D.C., August 1986.

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

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 linc044.wsp
T2        Hydraulic analysis for structure LINCTH00330044   Date: 23-JUN-97
T3        TH 44 CROSSING THE NEW HAVEN RIVER IN LINCOLN, VT           RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2870.0   3920.0  2760.0
SK          0.0239   0.0239  0.0239
*
XS   EXITX    -34           0.
* GR          -56.4, 499.93     79.7, 498.95
GR          -89.8, 495.21    -39.8, 493.73     -2.3, 492.62      0.0, 488.20
GR            4.3, 487.78     18.4, 487.35     24.1, 486.71     28.9, 487.11
GR           36.0, 487.67     38.6, 488.39     42.9, 490.45     68.1, 491.88
GR          118.1, 494.72
*
N           0.075        0.065        0.075
SA                  -2.3         42.9
*
XS   FULLV      0  * * *   0.0035
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.52       0.0
GR            0.0, 497.85      0.1, 489.64      8.4, 488.77     12.1, 488.19
GR           20.0, 486.90     23.1, 486.89     29.2, 486.30     29.2, 488.73
GR           29.3, 497.19      0.0, 497.85
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      16.4      1.8    499.5     48.3
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      16.2     2
GR         -123.1, 501.98    -72.0, 500.77      0.0, 499.66     30.2, 499.30
GR           39.6, 499.54     46.6, 500.62     54.7, 500.76     72.5, 501.14
GR           87.4, 502.58
* GR           76.9, 499.18     80.7, 499.14    116.7, 499.25    135.6, 500.81
*
XT   APTEM     54           0.
GR         -130.4, 507.11   -116.4, 500.59    -96.4, 500.73    -63.0, 500.82
GR          -17.7, 498.39     -8.8, 495.93     -4.4, 490.65      0.0, 489.77
GR            5.7, 488.88     14.8, 488.60     22.3, 488.04     27.3, 488.83
GR           29.1, 489.95     35.7, 492.77     39.6, 499.54     46.6, 500.62
GR           54.7, 500.76     72.5, 501.14     87.4, 502.58
*
AS   APPRO     46  * * *  0.0306
GT
N           0.075        0.055        0.045
SA                  -17.7         46.6
*
HP 1 BRIDG  497.75 1 497.75
HP 2 BRIDG  497.75 * * 2777
HP 1 BRIDG  494.55 1 494.55
HP 2 RDWAY  499.86 * * 91
HP 1 APPRO  499.86 1 499.86
HP 2 APPRO  499.86 * * 2870
*
HP 1 BRIDG  497.52 1 497.52
HP 2 BRIDG  497.52 * * 3169
HP 1 BRIDG  495.04 1 495.04
HP 2 RDWAY  501.02 * * 771
HP 1 APPRO  501.02 1 501.02
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File linc044.wsp
      Hydraulic analysis for structure LINCTH00330044   Date: 23-JUN-97
      TH 44 CROSSING THE NEW HAVEN RIVER IN LINCOLN, VT           RLB
         *** RUN DATE & TIME: 10-15-97  11:57

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      281     20587      4     73                        12718
  497.75           281     20587      4     73  1.00      0     29    12718

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.75     0.0    29.3   281.5   20587.    2777.   9.87

X STA.        0.0        2.7        4.2        5.8        7.3        8.8
  A(I)            22.1       12.7       13.3       13.6       13.0
  V(I)            6.29      10.95      10.45      10.18      10.65

X STA.        8.8       10.2       11.6       13.0       14.3       15.5
  A(I)            13.0       12.7       12.6       12.4       12.3
  V(I)           10.65      10.91      11.03      11.16      11.30

X STA.       15.5       16.8       18.0       19.1       20.3       21.5
  A(I)            12.4       12.2       12.3       12.4       12.3
  V(I)           11.23      11.39      11.29      11.18      11.31

X STA.       21.5       22.8       24.0       25.4       26.8       29.3
  A(I)            13.0       13.2       14.2       15.5       26.1
  V(I)           10.66      10.51       9.76       8.93       5.32

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      195     16017     29     42                         2853
  494.55           195     16017     29     42  1.00      0     29     2853

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.86   -13.0    41.7    17.2     197.      91.   5.28

X STA.      -13.0        2.2        6.6       10.0       12.8       15.2
  A(I)             1.8        1.1        1.0        0.9        0.9
  V(I)            2.59       4.10       4.40       4.86       5.12

X STA.       15.2       17.4       19.3       21.1       22.7       24.3
  A(I)             0.9        0.8        0.8        0.8        0.7
  V(I)            5.35       5.60       5.80       6.03       6.16

X STA.       24.3       25.7       27.1       28.4       29.6       30.9
  A(I)             0.7        0.7        0.7        0.7        0.7
  V(I)            6.29       6.47       6.69       6.64       6.65

X STA.       30.9       32.2       33.7       35.3       37.5       41.7
  A(I)             0.7        0.7        0.8        0.8        1.1
  V(I)            6.68       6.17       5.99       5.37       4.23

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       27       491     32     32                          144
            2      505     51600     61     69                         8242
  499.86           532     52091     93    101  1.08    -49     43     6952

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.86   -49.7    43.3   532.2   52091.    2870.   5.39

X STA.      -49.7       -6.4       -2.8       -0.2        2.1        4.2
  A(I)            66.8       32.5       26.3       23.6       23.3
  V(I)            2.15       4.42       5.46       6.08       6.16

X STA.        4.2        6.2        8.1        9.9       11.8       13.6
  A(I)            21.9       21.4       20.8       20.6       20.7
  V(I)            6.55       6.72       6.91       6.96       6.92

X STA.       13.6       15.3       17.1       18.9       20.6       22.4
  A(I)            20.5       20.7       20.5       21.0       21.2
  V(I)            6.99       6.92       7.01       6.82       6.78

X STA.       22.4       24.3       26.3       28.6       31.8       43.3
  A(I)            22.5       23.0       26.1       30.3       48.5
  V(I)            6.39       6.23       5.50       4.73       2.96
```

```
        U.S. Geological Survey WSPRO Input File linc044.wsp
        Hydraulic analysis for structure LINCTH00330044   Date: 23-JUN-97
        TH 44 CROSSING THE NEW HAVEN RIVER IN LINCOLN, VT           RLB
           *** RUN DATE & TIME: 10-15-97  11:57

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      279     22517    15     63                         6920
   497.52           279     22517    15     63  1.00      0     29     6920

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.52     0.0    29.3   279.3   22517.    3169.  11.35

X STA.        0.0        2.9        4.6        6.0        7.4        8.6
  A(I)            23.2       13.8       12.0       11.5       10.7
  V(I)            6.83      11.48      13.22      13.81      14.85

X STA.        8.6        9.8       10.9       12.0       13.1       14.2
  A(I)            10.5       10.3       10.2       10.2       10.4
  V(I)           15.13      15.37      15.59      15.48      15.20

X STA.       14.2       15.4       16.8       18.2       19.5       20.8
  A(I)            12.3       13.7       13.5       13.7       13.8
  V(I)           12.92      11.54      11.72      11.60      11.49

X STA.       20.8       22.1       23.6       25.0       26.6       29.3
  A(I)            14.0       14.9       15.1       17.6       28.0
  V(I)           11.35      10.63      10.50       9.00       5.66

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      209     17756    29     43                         3173
   495.04           209     17756    29     43  1.00      0     29     3173

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.02   -82.6    66.9   131.7    3018.     771.   5.86

X STA.      -82.6      -43.0      -29.9      -20.7      -13.3       -7.0
  A(I)            15.0       10.5        8.9        8.1        7.7
  V(I)            2.56       3.68       4.32       4.77       5.03

X STA.       -7.0       -1.7        2.3        6.1        9.6       13.0
  A(I)             6.8        5.5        5.3        5.2        5.0
  V(I)            5.63       7.07       7.32       7.46       7.73

X STA.       13.0       16.2       19.3       22.3       25.2       28.0
  A(I)             5.0        4.9        4.8        4.7        4.7
  V(I)            7.79       7.84       8.00       8.19       8.15

X STA.       28.0       30.7       33.5       36.5       39.9       66.9
  A(I)             4.6        4.7        4.9        5.1       10.4
  V(I)            8.35       8.21       7.94       7.56       3.72

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      104      2120   100    100                          603
             2      578     62728    64     72                         9846
             3       10       180    27     27                           36
   501.02           693     65028   192    200  1.29   -117     74     6585

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.02  -117.8    73.8   693.0   65028.    3920.   5.66

X STA.     -117.8      -12.3       -5.1       -2.1        0.4        2.7
  A(I)           123.5       44.9       31.9       28.7       26.4
  V(I)            1.59       4.36       6.15       6.82       7.44

X STA.        2.7        4.8        6.8        8.8       10.7       12.6
  A(I)            25.4       25.1       24.5       24.3       24.4
  V(I)            7.70       7.80       8.01       8.07       8.03

X STA.       12.6       14.5       16.4       18.3       20.2       22.2
  A(I)            23.9       24.1       24.6       24.7       25.5
  V(I)            8.19       8.14       7.95       7.93       7.69

X STA.       22.2       24.2       26.4       29.1       32.5       73.8
  A(I)            26.6       28.2       31.8       36.1       68.3
  V(I)            7.36       6.96       6.16       5.42       2.87
```

```
        U.S. Geological Survey WSPRO Input File linc044.wsp
        Hydraulic analysis for structure LINCTH00330044   Date: 23-JUN-97
        TH 44 CROSSING THE NEW HAVEN RIVER IN LINCOLN, VT           RLB
           *** RUN DATE & TIME: 10-15-97  11:57

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      191     15528     29     42                         2764
   494.41           191     15528     29     42  1.00      0     29     2764

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.41     0.0    29.3   190.7   15528.    2760.  14.48

X STA.        0.0        3.4        5.5        7.4        9.0       10.5
  A(I)           16.7       10.9       10.0        9.1        8.9
  V(I)           8.27      12.65      13.74      15.16      15.48

X STA.       10.5       11.9       13.3       14.5       15.7       16.8
  A(I)            8.5        8.4        7.9        8.0        7.8
  V(I)          16.24      16.43      17.41      17.16      17.77

X STA.       16.8       17.9       18.9       20.0       21.0       22.1
  A(I)            7.7        7.6        7.8        7.6        8.1
  V(I)          17.94      18.07      17.79      18.04      17.13

X STA.       22.1       23.2       24.3       25.5       26.9       29.3
  A(I)            8.2        8.4        9.4       10.8       18.7
  V(I)          16.76      16.39      14.65      12.80       7.36

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      393     36216     56     63                         5929
   497.92           393     36216     56     63  1.00    -16     39     5929

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      46.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.92   -16.9    38.8   393.2   36216.    2760.   7.02

X STA.      -16.9       -3.2       -0.2        2.3        4.5        6.4
  A(I)           39.7       24.4       21.2       19.4       17.9
  V(I)           3.48       5.66       6.52       7.10       7.72

X STA.        6.4        8.3       10.1       11.9       13.6       15.3
  A(I)           17.4       16.9       16.8       16.1       16.2
  V(I)           7.92       8.17       8.20       8.55       8.50

X STA.       15.3       16.9       18.5       20.1       21.7       23.3
  A(I)           15.8       16.0       15.8       15.9       16.1
  V(I)           8.75       8.65       8.74       8.68       8.55

X STA.       23.3       25.0       26.8       29.0       31.8       38.8
  A(I)           16.9       17.3       19.2       21.8       32.6
  V(I)           8.18       7.99       7.21       6.33       4.24
```

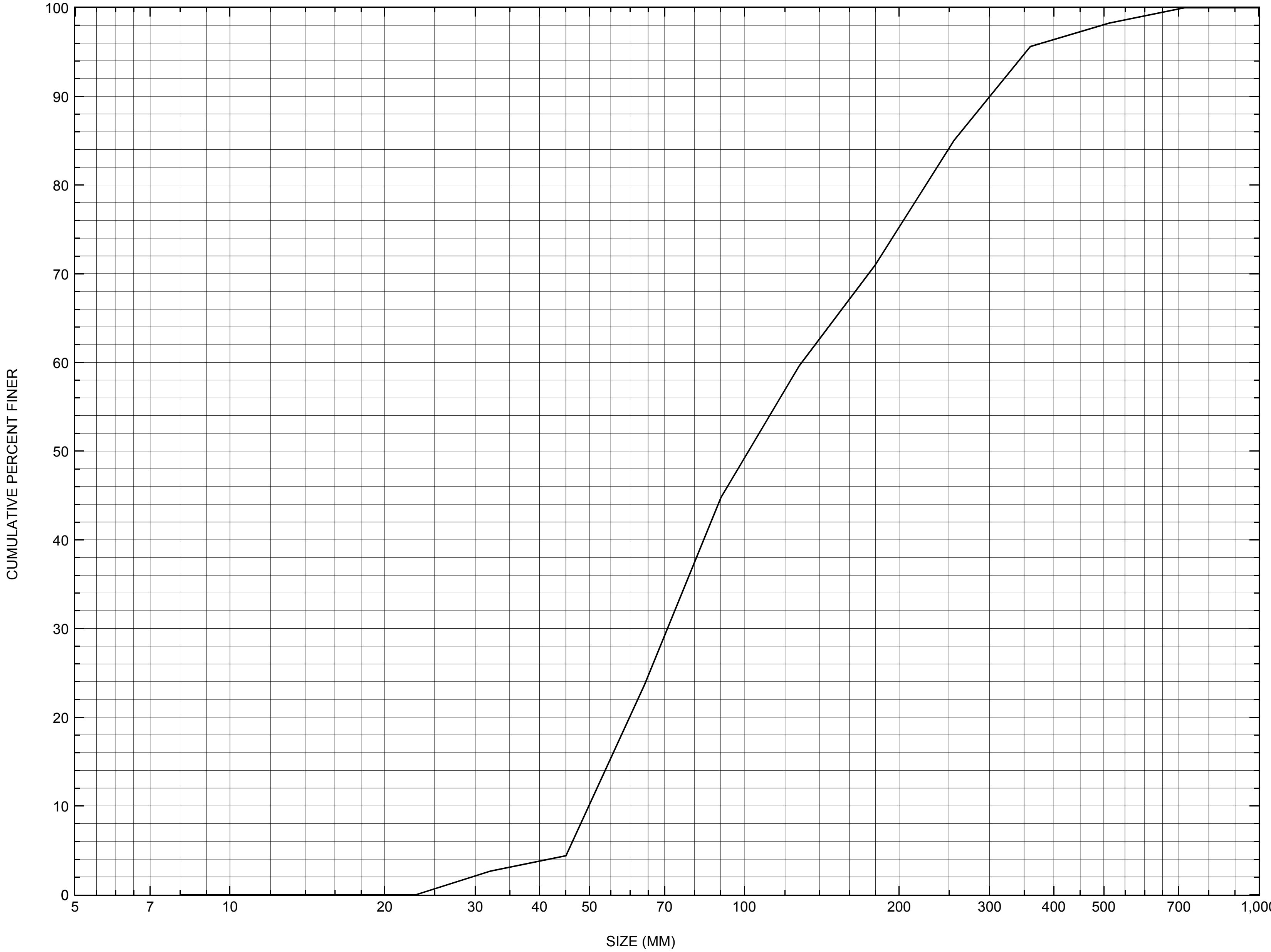
```
        U.S. Geological Survey WSPRO Input File linc044.wsp
        Hydraulic analysis for structure LINCTH00330044   Date: 23-JUN-97
        TH 44 CROSSING THE NEW HAVEN RIVER IN LINCOLN, VT           RLB
           *** RUN DATE & TIME: 10-15-97  11:57

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

EXITX:XS   ******    -23      323  1.57 *****  494.83  493.05    2870  493.26
       -33 ******     92    18558  1.28 ***** *******    1.06    8.87

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.54

FULLV:FV       34    -63      496  0.78  0.53  495.33 *******    2870  494.55
         0     34    113    28628  1.50  0.00   -0.02    0.75    5.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     1.01     494.45     494.51
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.05     506.87    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.05     506.87     494.51
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   494.51     506.87     494.51

APPRO:AS       46     -7      226  2.52 *****  497.02  494.51    2870  494.51
        46     46     37    16946  1.00 ***** *******    1.00   12.72
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.59     497.75     498.16     497.52
 ===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       34      0      281  1.51 *****  499.26  494.43    2777  497.75
         0 ******     29    20627  1.00 ***** *******    0.56    9.87

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.452  0.000  497.52 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    30.  0.09  0.49  500.26    0.00     91.  499.86

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     38.    29.   -13.    17.   0.4   0.2   3.2   6.2   0.6   2.7
   RT:     53.    25.    17.    42.   0.6   0.4   3.8   4.9   0.8   2.8

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

APPRO:AS       30    -49      532  0.49  0.23  500.35  494.51    2870  499.86
        46     30     43    52062  1.08  0.60    0.00    0.41    5.40

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********
                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -34.   -24.    92.   2870.   18558.     323.    8.87  493.26
   FULLV:FV       0.   -64.   113.   2870.   28628.     496.    5.79  494.55
   BRIDG:BR       0.     0.    29.   2777.   20627.     281.    9.87  497.75
   RDWAY:RG       8.*******    38.     91.******************    2.00  499.86
   APPRO:AS      46.   -50.    43.   2870.   52062.     532.    5.40  499.86

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

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.05    1.06  486.71  495.21************  1.57  494.83  493.26
   FULLV:FV  ********    0.75  486.83  495.33  0.53  0.00  0.78  495.33  494.55
   BRIDG:BR    494.43    0.56  486.30  497.85************  1.51  499.26  497.75
   RDWAY:RG  ****************  499.30  502.58  0.09******  0.49  500.26  499.86
   APPRO:AS    494.51    0.41  487.80  506.87  0.23  0.60  0.49  500.35  499.86
```

```
        U.S. Geological Survey WSPRO Input File linc044.wsp
        Hydraulic analysis for structure LINCTH00330044   Date: 23-JUN-97
        TH 44 CROSSING THE NEW HAVEN RIVER IN LINCOLN, VT           RLB
           *** RUN DATE & TIME: 10-15-97  11:57

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                           WSI,CRWS =   494.10     494.21

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

EXITX:XS   ******    -55      458  1.67 *****  495.88  494.21    3920  494.21
       -33 ******    109    26418  1.46 ***** *******    1.10    8.57

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.71     495.33    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.71     495.33     494.33
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "FULLV"
                  WSBEG,WSEND,CRWS =   494.33     495.33     494.33

FULLV:FV       34    -55      458  1.67 *****  496.00  494.33    3920  494.33
         0     34    109    26418  1.46 ***** *******    1.10    8.57
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.46     494.27     495.73
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.83     506.87    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.83     506.87     495.73
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   495.73     506.87     495.73

APPRO:AS       46     -8      281  3.02 *****  498.75  495.73    3920  495.73
        46     46     38    23500  1.00 ***** *******    1.00   13.93
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   500.37       0.00     496.13     499.30
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   503.68         0.      3920.
 ===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       34      0      279  2.00 *****  499.52  495.04    3169  497.52
         0 ******     29    22517  1.00 ***** *******    0.65   11.35

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.481  0.000  497.52 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    30.  0.11  0.64  501.56    0.01    771.  501.02

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    481.   100.   -83.    17.   1.6   0.8   5.3   5.7   1.4   3.0
   RT:    290.    50.    17.    67.   1.7   1.0   5.8   6.0   1.5   3.2

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

APPRO:AS       30   -117      694  0.64  0.26  501.67  495.73    3920  501.02
        46     30     74    65098  1.29  0.00    0.01    0.59    5.65

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -34.   -56.   109.   3920.   26418.     458.    8.57  494.21
   FULLV:FV       0.   -56.   109.   3920.   26418.     458.    8.57  494.33
   BRIDG:BR       0.     0.    29.   3169.   22517.     279.   11.35  497.52
   RDWAY:RG       8.*******   481.    771.******************    2.00  501.02
   APPRO:AS      46.  -118.    74.   3920.   65098.     694.    5.65  501.02

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

```
 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    494.21    1.10  486.71  495.21************  1.67  495.88  494.21
   FULLV:FV    494.33    1.10  486.83  495.33************  1.67  496.00  494.33
   BRIDG:BR    495.04    0.65  486.30  497.85************  2.00  499.52  497.52
   RDWAY:RG  ****************  499.30  502.58  0.11******  0.64  501.56  501.02
   APPRO:AS    495.73    0.59  487.80  506.87  0.26  0.00  0.64  501.67  501.02

        U.S. Geological Survey WSPRO Input File linc044.wsp
        Hydraulic analysis for structure LINCTH00330044   Date: 23-JUN-97
        TH 44 CROSSING THE NEW HAVEN RIVER IN LINCOLN, VT           RLB
           *** RUN DATE & TIME: 10-15-97  11:57

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

EXITX:XS   ******    -19      312  1.54 *****  494.69  492.90    2760  493.15
       -33 ******     91    17839  1.26 ***** *******    1.05    8.86

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.53

FULLV:FV       34    -58      473  0.78  0.53  495.20 *******    2760  494.42
         0     34    111    27321  1.48  0.00   -0.02    0.75    5.83
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.00     494.37     494.37
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.92     506.87    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.92     506.87     494.37
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.60

APPRO:AS       46     -7      219  2.46  0.79  496.83  494.37    2760  494.37
        46     46     37    16260  1.00  0.84    0.00    1.00   12.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    2760.     494.41
            <<<<<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       34      0      191  3.26 *****  497.67  494.41    2760  494.41
         0     34     29    15530  1.00 ***** *******    1.00   14.47

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  497.52 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS       30    -16      393  0.77  0.41  498.69  494.37    2760  497.92
        46     30     39    36221  1.00  0.61    0.01    0.47    7.02

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.343  0.090   32928.    -2.    27.   497.75
                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW     REW       Q        K     AREA     VEL    WSEL
   EXITX:XS      -34.   -20.     91.   2760.   17839.     312.    8.86  493.15
   FULLV:FV       0.    -59.    111.   2760.   27321.     473.    5.83  494.42
   BRIDG:BR       0.     0.      29.   2760.   15530.     191.   14.47  494.41
   RDWAY:RG       8.**************      0.******************     2.00********
   APPRO:AS      46.    -17.     39.   2760.   36221.     393.    7.02  497.92

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    27.   32928.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    492.90    1.05  486.71  495.21************  1.54  494.69  493.15
   FULLV:FV  ********    0.75  486.83  495.33  0.53  0.00  0.78  495.20  494.42
   BRIDG:BR    494.41    1.00  486.30  497.85************  3.26  497.67  494.41
   RDWAY:RG  ****************  499.30  502.58**********************************
   APPRO:AS    494.37    0.47  487.80  506.87  0.41  0.61  0.77  498.69  497.92
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure LINCTH00330044, in Lincoln, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number LINCTH00330044

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 C3033

Vicinity *(I - 9)* 0.1 MI TO JCT C3 TH 36

Topographic Map Lincoln

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 44027

Longitude *(i - 17; nnnnn.n)* 72575

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011000440110

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

Maximum span length *(I - 48; nnnn)* 0031

Year built *(I - 27; YYYY)* 1945

Structure length *(I - 49; nnnnnn)* 000033

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 162

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 702

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 26.58

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

Vertical clearance from streambed (*nnn.n ft*) 9.67

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

Waterway of full opening (*nnn.n ft*^{2}) 256.9

Comments:

According to the structural inspection report dated 11/14/94, the bridge deck consists of creosoted nail laminated 2x6's on edge. Abutments, wingwalls, and backwalls are wood beam crib. The faces of the abutments and wingwalls are bowed out at least 2-3 in. The LABUT face is the worst. The top horizontal beam at the RABUT is crushed on the left end, with stress cracks in the 3rd and 4th beam down from the top, near the centerline. The second beam down from the top of the LABUT also has a stress crack near its centerline. A low, coarse gravel bar in front of the LABUT blocks half of the channel flow, and pushes it against the RABUT, where there is about 1-2 ft of scour.

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*): U Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

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

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

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

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*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)* **9.47** mi^2

Lake/pond/swamp area **0.01** mi^2

Watershed storage *(ST)* **0.11** %

Bridge site elevation **1520** ft

Headwater elevation **3780** ft

Main channel length **4.3** mi

10% channel length elevation **1620** ft

85% channel length elevation **3000** ft

Main channel slope *(S)* **427.91** 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? 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:

-

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 downstream face. The low cord to bed length data is from the sketch attached to a bridge inspection report dated 11/14/94. The sketch was done on 9/24/92. There are no accurate low cord elevations available.**

Station	**0**	**6.5**	**13.2**	**26.6**	-	-	-	-	-	-	-
Feature	**RAB**	-	-	**LAB**	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	**11.5**	**10.8**	**9.4**	**8.1**	-	-	-	-	-	-	-

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: **11/12/96**

Computerized by: **RB** Date: **11/15/96**

Reviewd by: **RB** Date: **07/10/97**

Structure Number **LINCTH00330044**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. WILD** Date *(MM/DD/YY)* **06** / **10** / 19**96**

2. Highway District Number **05** Mile marker **0000**

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

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

Route Number **C3033** Hydrologic Unit Code: **2010002**

3. Descriptive comments:

Located 0.1 miles to the junction with TH36. This is a creosoted timber deck bridge with wood beam crib abutments.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **6** 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 **33** *(feet)* Span length **31** *(feet)* Bridge width **16.2** *(feet)*

Road approach to bridge:

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

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

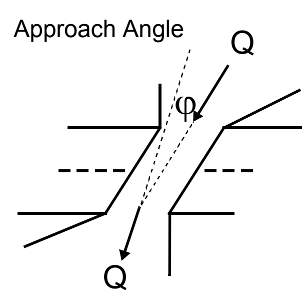
10. Embankment slope (*run / rise in feet / foot*):
US left **1.8:1** US right **--**

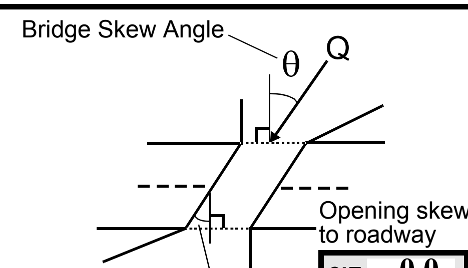
	Protection 11.Type	Protection 12.Cond.	13.Erosion	14.Severity
LBUS	0	-	-	-
RBUS	2	1	3	1
RBDS	1	3	2	1
LBDS	0	-	-	-

*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: **15** 16. Bridge skew: **25**





α= **0.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **86** feet **US** *(US, UB, DS)* to **0** feet **UB**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **15** feet **DS** *(US, UB, DS)* to **103** feet **DS**

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

18. Bridge Type: **4**

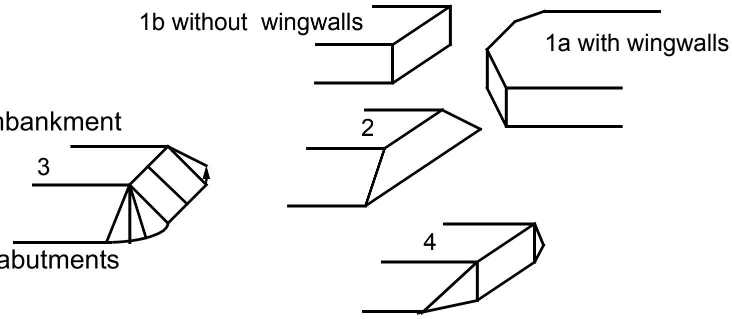
1a- Vertical abutments with wingwalls

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. On the left bank US there are dense trees and low brush and about 95 ft. to the left is a dirt road. On the right bank US there is a small house with a driveway parallel to the stream and surrounded by dense forest. The left bank DS is also covered with dense trees and Bluebank Brook enters DS. On the right bank there are dense trees and a dirt road.

7. Values are from the VT AOT files. Measured bridge length is 32.3 ft.

11. The right bank US road embankment protection consists of boulders with overlying stone fill.

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
37.5	7.5			10.5	3	1	543	435	2	2

23. Bank width **20.0** 24. Channel width **30.0** 25. Thalweg depth **67.0** 29. Bed Material **543**

30 .Bank protection type: LB **0** RB **2** 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.):

28. Both the right bank and the left bank have many trees leaning over the stream and the roots are exposed.

30. The right bank protection extends from 15 ft. US to the US bridge face. It consists of boulders with overlying stone fill.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **7UB** 35. Mid-bar width: **9.3**

36. Point bar extent: **26.3** feet **US** (US, UB) to **29.2** feet **DS** (US, UB, DS) positioned **0** %LB to **45** %RB

37. Material: **234**

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

There is an additional side bar 80 ft. US to 54 ft. US. The mid-bar distance is 63 ft. and the mid-bar width is 6.5 ft. It is positioned from 0% LB to 25% RB. It is also composed of sand, gravel and cobble.

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: **35** 42. Cut bank extent: **47** feet **US** (US, UB) to **15** feet **US** (US, UB, DS)

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

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

-

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **85**

47. Scour dimensions: Length **23** Width **6** Depth : **2.5** Position **30** %LB to **60** %RB

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

-

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
33.5		**2.0**		**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.):

432

61. The abutments, backwalls and wingwalls are wood beam crib.

62. Between the wood beams there are voided spaces 5-6 inches on the left and right abutments.

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

70. Debris and Ice Comments:

1

There are many trees, some whole, and brush in the channel US and DS of the bridge.

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	4	20	90			2	1	29.5

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

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

1

-

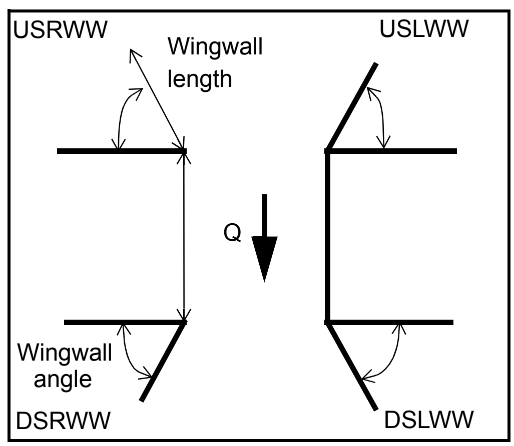
4

The total depth of the water in the scour hole is 2.5 ft. Where the scour hole is evident, the bed is well sorted with cobbles 6 in. to 8 in. in diameter.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						29.5	
USRWW:	Y		4		0	2.0	
DSLWW:	-		-		Y	16.5	
DSRWW:	4		0		-	16.5	

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



82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	-	1	-	-
Condition	Y	-	4	-	-	2	-	-
Extent	4	-	0	0	3	0	0	-

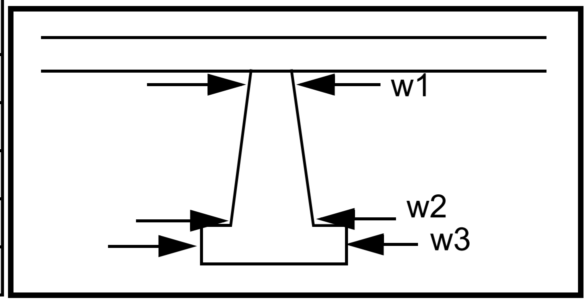
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
1
1
3
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**45.0**	**11.5**	**50.0**
Pier 2				**11.5**	**50.0**	**12.0**
Pier 3			-	**50.0**	**11.5**	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	NO	PIE	RS		

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

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

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

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

3
3
432
543
2
1
435
0
1
-
1
On the left bank there are many exposed roots. On the right bank the protection extends from the DS bridge face to 17 ft. DS.

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 **N** feet **-** *(US, UB, DS)* positioned **NO** %LB to **DR** %RB

Material: **OP**

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

STRUCTURE

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

Cut bank extent: **67** feet **24** *(US, UB, DS)* to **44** feet **DS** *(US, UB, DS)*

Bank damage: **94.** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

4
DS
30
100

Is channel scour present? **435** *(Y or if N type ctrl-n cs)* Mid-scour distance: **2**

Scour dimensions: Length **A** Width **scou** Depth: **r** Positioned **hol** %LB to **e is** %RB

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

present next to this point bar and is deepest at the mid-bar distance.

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

Confluence 1: Distance **57** Enters on **25** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **82** Enters on **DS** *(LB or RB)* Type **1** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

-

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
67
22
9.5
3.0
0
50
Average thalweg is 1.5 ft.

Y

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: LINCTH00330044 Town: LINCOLN
Road Number: TH 33 County: ADDISON
Stream: NEW HAVEN RIVER

Initials RLB Date: 7/1/97 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	2870	3920	2760
Main Channel Area, ft2	505	578	393
Left overbank area, ft2	27	104	0
Right overbank area, ft2	0	10	0
Top width main channel, ft	61	64	56
Top width L overbank, ft	32	100	0
Top width R overbank, ft	0	27	0
D50 of channel, ft	0.3344	0.3344	0.3344
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.3	9.0	7.0
y1, average depth, LOB, ft	0.8	1.0	ERR
y1, average depth, ROB, ft	ERR	0.4	ERR
Total conveyance, approach	52091	65028	36216
Conveyance, main channel	51600	62728	36216
Conveyance, LOB	491	2120	0
Conveyance, ROB	0	180	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	2842.9	3781.4	2760.0
Ql, discharge, LOB, cfs	27.1	127.8	0.0
Qr, discharge, ROB, cfs	0.0	10.9	0.0
Vm, mean velocity MC, ft/s	5.6	6.5	7.0
Vl, mean velocity, LOB, ft/s	1.0	1.2	ERR
Vr, mean velocity, ROB, ft/s	ERR	1.1	ERR
Vc-m, crit. velocity, MC, ft/s	11.1	11.2	10.8
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	2870	3920	2760
(Q) discharge thru bridge, cfs	2777	3169	2760
Main channel conveyance	20587	22517	15528
Total conveyance	20587	22517	15528
Q2, bridge MC discharge,cfs	2777	3169	2760
Main channel area, ft2	281	279	191
Main channel width (normal), ft	29.3	29.3	29.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.3	29.3	29.3
y_bridge (avg. depth at br.), ft	9.59	9.52	6.52
Dm, median (1.25*D50), ft	0.418	0.418	0.418
y2, depth in contraction,ft	7.86	8.80	7.81
ys, scour depth (y2-ybridge), ft	-1.74	-0.73	1.30

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	2777	3169	2760
Main channel area (DS), ft2	195	209	191
Main channel width (normal), ft	29.3	29.3	29.3
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	29.3	29.3	29.3
D90, ft	0.9847	0.9847	0.9847
D95, ft	1.1578	1.1578	1.1578
Dc, critical grain size, ft	1.0502	1.1540	1.0915
Pc, Decimal percent coarser than Dc	0.080	0.051	0.068
Depth to armoring, ft	36.23	64.42	44.88

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	2870	3920	2760
Q, thru bridge MC, cfs	2777	3169	2760
Vc, critical velocity, ft/s	11.07	11.23	10.77
Va, velocity MC approach, ft/s	5.63	6.54	7.02
Main channel width (normal), ft	29.3	29.3	29.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	29.3	29.3	29.3
qbr, unit discharge, ft2/s	94.8	108.2	94.2
Area of full opening, ft2	281.0	279.0	191.0
Hb, depth of full opening, ft	9.59	9.52	6.52
Fr, Froude number, bridge MC	0.56	0.65	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	195	209	N/A
**Hb, depth at downstream face, ft	6.66	7.13	N/A
**Fr, Froude number at DS face	0.97	1.00	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	497.52	497.52	0
Elevation of Bed, ft	487.93	488.00	-6.52
Elevation of Approach, ft	499.86	501.02	0
Friction loss, approach, ft	0.23	0.26	0
Elevation of WS immediately US, ft	499.63	500.76	0.00
ya, depth immediately US, ft	11.70	12.76	6.52
Mean elevation of deck, ft	499.48	499.48	0
w, depth of overflow, ft (>=0)	0.15	1.28	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.95	1.00
**Cc, for downstream face (<=1.0)	0.830241	0.868251	ERR
Ys, scour w/Chang equation, ft	-0.62	0.57	N/A
Ys, scour w/Umbrell equation, ft	-1.08	0.01	N/A

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

**Ys, scour w/Chang equation, ft	3.66	3.96	N/A

**Ys, scour w/Umbrell equation, ft	1.86	2.39	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	7.86	8.80	7.81
WSEL at downstream face, ft	494.55	495.04	--
Depth at downstream face, ft	6.66	7.13	N/A
Ys, depth of scour (Laursen), ft	1.20	1.66	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)

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	2870	3920	2760	2870	3920	2760
a', abut.length blocking flow, ft	49.7	117.8	16.9	14	44.5	9.5
Ae, area of blocked flow ft2	126.11	165.07	65.8	67.19	74.79	52.06
Qe, discharge blocked abut.,cfs	--	--	287.04	--	--	261.21
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.47	3.35	4.36	3.54	3.72	5.02
ya, depth of f/p flow, ft	2.54	1.40	3.89	4.80	1.68	5.48
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.382	0.428	0.390	0.275	0.432	0.378
ys, scour depth, ft	11.97	11.85	11.56	11.24	9.35	12.62

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)	49.7	117.8	16.9	14	44.5	9.5
y1 (depth f/p flow, ft)	2.54	1.40	3.89	4.80	1.68	5.48
a'/y1	19.59	84.07	4.34	2.92	26.48	1.73
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.38	0.43	0.39	0.28	0.43	0.38
Ys w/ corr. factor K1/0.55:						
vertical	ERR	7.70	ERR	ERR	9.27	ERR
vertical w/ ww's	ERR	6.32	ERR	ERR	7.60	ERR
spill-through	ERR	4.24	ERR	ERR	5.10	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.97	1	1	0.97	1	1
y, depth of flow in bridge, ft	6.66	7.13	6.52	6.66	7.13	6.52
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.)	2.76	2.98	2.73	2.76	2.98	2.73