LEVEL II SCOUR ANALYSIS FOR BRIDGE 30 (NEWHTH00050030) on TOWN HIGHWAY 5, crossing the NEW HAVEN RIVER, NEW HAVEN, VERMONT

Open-File Report 98-058

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 RONDA L. BURNS and 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.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 30 (NEWHTH00050030) ON TOWN HIGHWAY 5, CROSSING THE NEW HAVEN RIVER, NEW HAVEN, 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 NEWHTH00050030 on Town Highway 5 crossing the New Haven River, New Haven, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (Federal Highway Administration, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Champlain section of the St. Lawrence Valley physiographic province in west-central Vermont. The 115-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the right bank upstream and downstream of the bridge while the immediate banks have dense woody vegetation. The upstream left bank is also pasture. The downstream left bank is forested.

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 127 ft and an average bank height of 5 ft. The channel bed material ranges from silt to cobble with a median grain size (D_{50}) of 20.4 mm (0.067 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 19, 1996, indicated that the reach was laterally unstable. The stream bends through the bridge and impacts the left bank where there is a cut bank and scour hole.

The Town Highway 5 crossing of the New Haven River is a 181-ft-long, two-lane bridge consisting of four 45-ft concrete tee-beam spans (Vermont Agency of Transportation, written communication, December 15, 1995). The opening length of the structure parallel to the bridge face is 175.9 ft. The bridge is supported by vertical, concrete abutments with stone fill spill-through embankments and three concrete piers. The channel is skewed approximately 15 degrees to the opening while the computed opening-skew-to-roadway is 10 degrees.

A scour hole 4.5 ft deeper than the mean thalweg depth was observed along the downstream left bank during the Level I assessment. Also observed was a scour hole 1.5 ft deeper than the mean thalweg depth at the upstream end of the middle pier. The only scour protection measure at the site was type-3 stone fill (less than 48 inches diameter) in front of the left and right abutments creating spill through slopes. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.7 to 2.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 6.8 to 8.4 ft. The worst-case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 11.2 to 14.0 ft. The worst-case right abutment scour occurred at the 500-year discharge. Pier scour ranged from 12.9 to 19.3 ft. The worst-case pier scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number NEWHTH00050030 ***Stream*** New Haven River

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

Description of Bridge

Bridge length 181 ***ft*** ***Bridge width*** 23.2 ***ft*** ***Max span length*** 45 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 6/19/96

Description of stone fill Type-3, in front of the left and right abutments creating spill through slopes.

The abutments and piers are concrete. There is a 1.5 ft deep scour hole in front of the middle pier and a 4.5 ft deep scour hole along the downstream left bank.

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

There is a moderate channel bend through the bridge. The upstream left cut-bank and downstream scour hole have developed in the location where the flow impacts the left bank.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	6/19/96	0	0
Level II	6/19/96	0	0

Potential for debris Moderate. There is some debris caught on the upstream banks and at the bridge.

Describe any features near or at the bridge that may affect flow (include observation date) It was observed on 6/19/96 that this bridge has spill through embankments and three piers.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with narrow flood plains.

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

Date of inspection 6/19/96

DS left: Steep valley wall.

DS right: Moderately sloped overbank.

US left: Steep channel bank to a narrow flood plain.

US right: Moderately sloped overbank.

Description of the Channel

Average top width 127 ***ft*** ***Average depth*** 5 ***ft***

Predominant bed material Silt/Gravel ***Bank material*** Silt/Gravel

Sinuous with semi-alluvial channel boundaries.

6/19/96

Vegetative co Trees

DS left: Trees and brush with grass on the overbank

DS right: Short grass with a few shrubs and trees

US left: Trees and brush with grass on the overbank

US right:

Do banks appear stable? No ***If not, describe location and type of instability and date of observation.***

There is moderate fluvial erosion and cut-banks on the upstream and downstream left bank, 6/19/96.

None as of 6/19/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 115 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: There are houses on all the overbanks except for the downstream left overbank area.

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

USGS gage description New Haven River at Brooksville near Middlebury, VT

USGS gage number 04282525

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

Is there a lake/p No

Calculated Discharges

Q100 13,400 ***ft***^{3}***/s*** ***Q500*** 19,800 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a log-pearson-type 3 flood frequency analysis of gaged peak discharge records from 1990 through 1996 (Interagency Advisory Committee on Water Data, 1982). Despite the short record, the values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). The gage values were also comparable to the flood frequency estimates from FEMA and the VTAOT database.

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 end of the bridge curb (elev. 503.05 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream right end of the bridge curb (elev. 501.95 ft, arbitrary survey datum). RM3 is the top of the gage orifice elbow (elev. 483.01ft, arbitrary survey datum). RM4 is the top of a nut screwed onto a bolt in the left pier on the downstream side at a staff height of 7.86 ft (elev. 487.21 ft, arbitrary survey datum). BM 2 is a chiseled square on top of the downstream end of the right abutment (elev. 501.11 ft, arbitrary survey datum).

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT2	-399	1	Exit section at bedrock control
EXIT1	-150	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APPRO	200	1	Approach section

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.050, and overbank "n" values ranged from 0.035 to 0.085.

The starting water surface at the exit section (EXIT2) for each flow modeled was estimated by use of the rating curve for the gage, extrapolated to the 100-year and 500-year discharges.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 502.3 *ft*
Average low steel elevation 498.2 *ft*

100-year discharge 13,400 *ft³/s*
Water-surface elevation in bridge opening 493.1 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 1,390 *ft²*
Average velocity in bridge opening 8.8 *ft/s*
Maximum WSPRO tube velocity at bridge 11.9 *ft/s*

Water-surface elevation at Approach section with bridge 493.8
Water-surface elevation at Approach section without bridge 493.6
Amount of backwater caused by bridge 0.2 *ft*

500-year discharge 19,800 *ft³/s*
Water-surface elevation in bridge opening 494.7 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 1,630 *ft²*
Average velocity in bridge opening 11.1 *ft/s*
Maximum WSPRO tube velocity at bridge 14.8 *ft/s*

Water-surface elevation at Approach section with bridge 496.2
Water-surface elevation at Approach section without bridge 495.8
Amount of backwater caused by bridge 0.4 *ft*

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100- and 500-year discharges was computed by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p. 30, equation 17). The area of flow in the bridge was reduced by the area of the piers.

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

Scour at the left abutment was computed by use of the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depth computed at the toe of the embankment was applied for the entire spill-through embankment as shown in figure 8.

Pier scour was computed by use of an equation developed at Colorado State University (Richardson and Davis, 1995, p. 36, equation 21) for all discharges modelled. Variables for the pier scour equation include pier length, pier width, average depth and maximum velocity (for the Froude number) immediately upstream of the bridge, and correction factors for pier shape, flow attack angle, streambed-form, and streambed armoring.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	0.7	2.1	--
Clear-water scour	--	--	--
Depth to armoring	N/A	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	6.8	8.4	--
Right abutment	11.2	13.9	--
Pier scour			
Pier 1	15.3	17.0	--
Pier 2	17.3	19.3	--
Pier 3	12.9	14.4	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	1.6	2.9	--
Left abutment	1.6	2.9	--
Right abutment	1.3	2.1	--
Piers:	2.6	4.1	--
Pier 1	1.1	1.7	--
Pier 2			

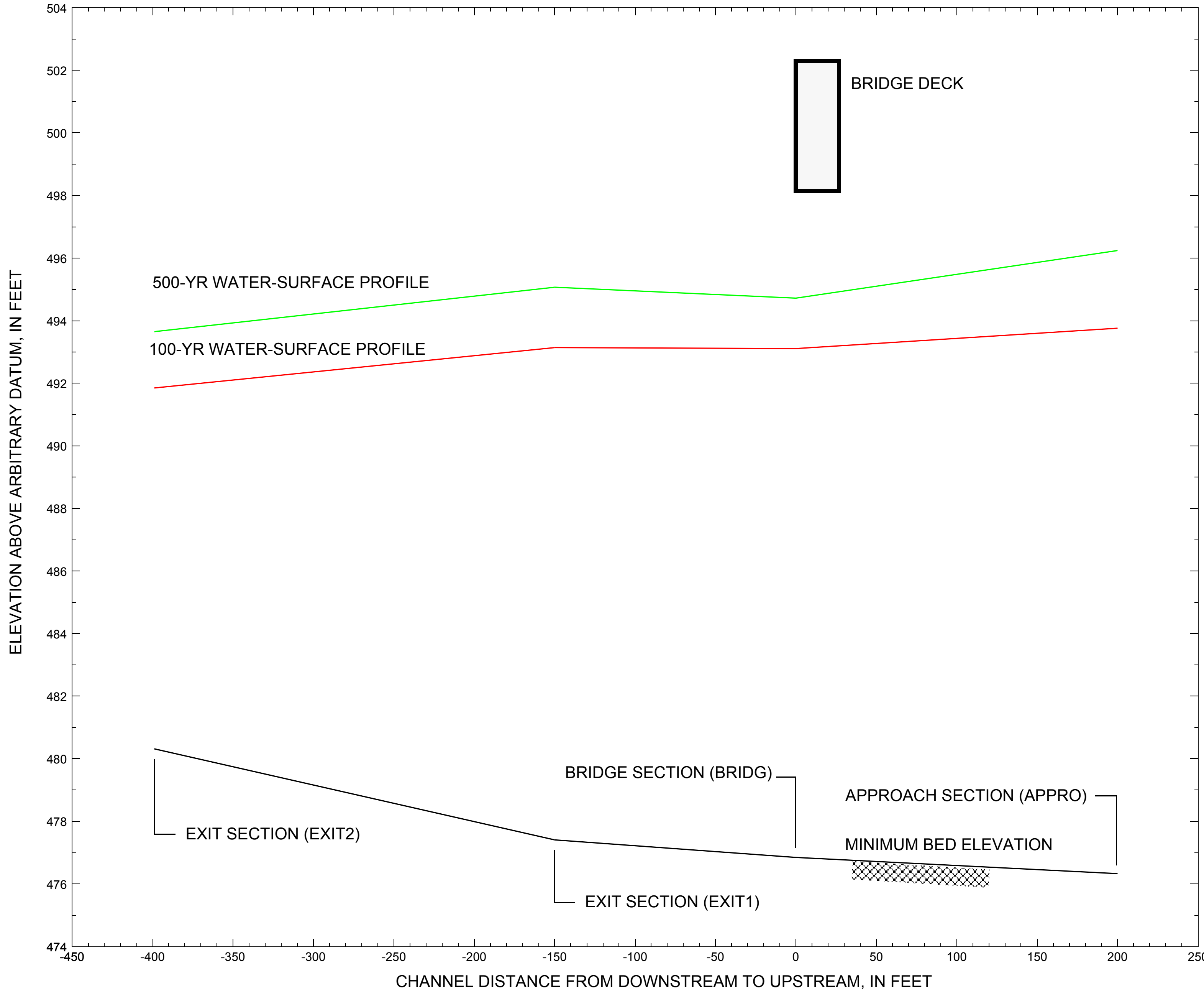

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure NEWHTH00050030 on Town Highway 5, crossing the New Haven River, New Haven, Vermont.

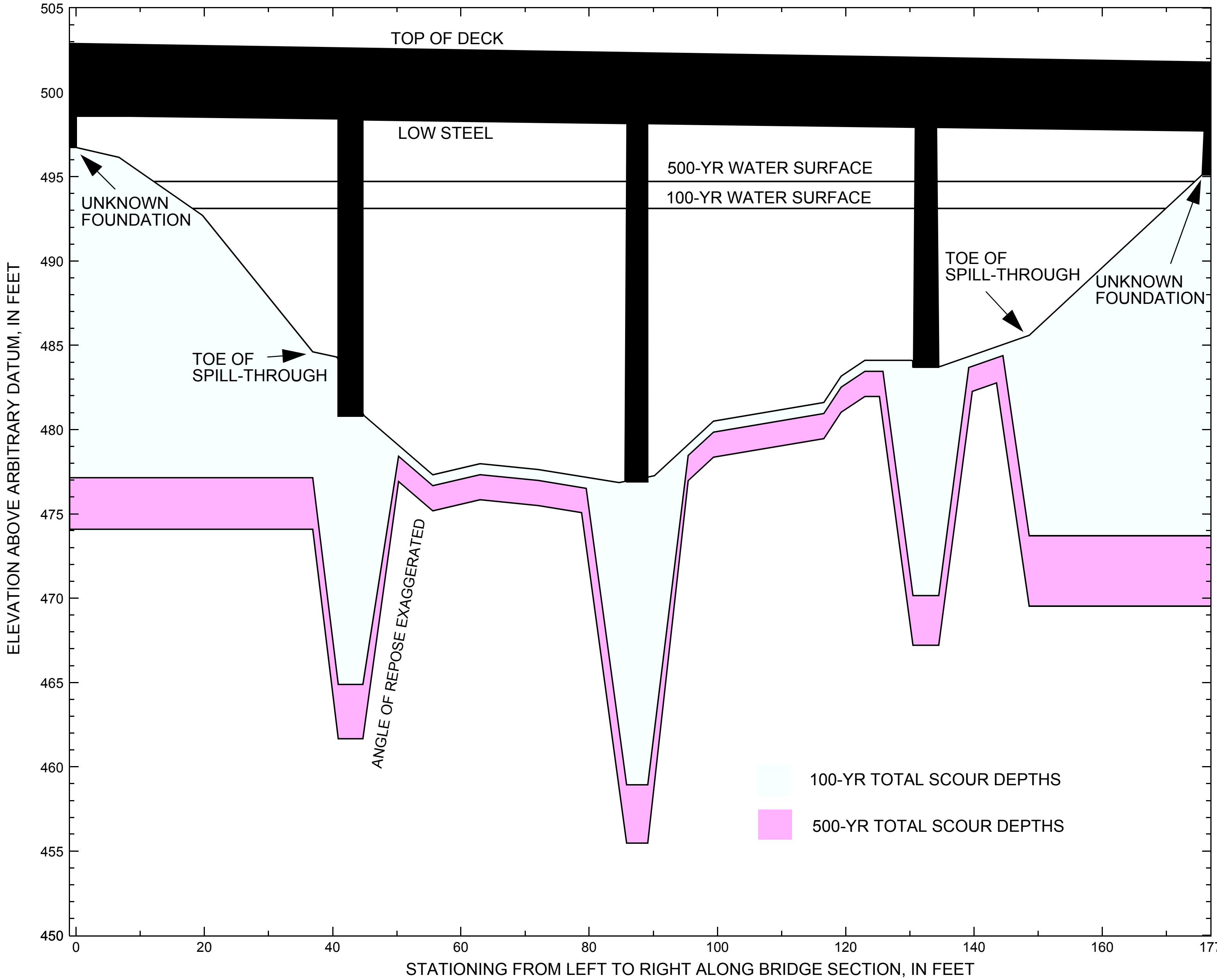

Figure 8. Scour elevations for the 100- and 500-yr discharges at structure NEWHTH00050030 on Town Highway 5, crossing the New Haven River, New Haven, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure NEWHTH00050030 on Town Highway 5, crossing the New Haven River, New Haven, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/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 13,400 cubic-feet per second											
Left abutment	0.0	--	498.6	--	496.7	--	--	--	--	--	--
Spill-through toe	36.9	--	--	--	484.6	0.7	6.8	--	7.5	477.1	--
Left Pier	42.8	--	--	--	480.8	0.7	--	15.3	16.0	464.8	--
Middle Pier	87.5	--	--	--	476.9	0.7	--	17.3	18.0	458.9	--
Right Pier	132.5	--	--	--	483.7	0.7	--	12.9	13.6	470.1	--
Spill-through toe	148.6	--	--	--	485.6	0.7	11.2	--	11.9	473.7	--
Right abutment	175.9	--	497.7	--	495.1	--	--	--	--	--	--

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-yr discharge at structure NEWHTH00050030 on Town Highway 5, crossing the New Haven River, New Haven, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/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 19,800 cubic-feet per second											
Left abutment	0.0	--	498.6	--	496.7	--	--	--	--	--	--
Spill-through toe	36.9	--	--	--	484.6	2.1	8.4	--	10.5	474.1	--
Left Pier	42.8	--	--	--	480.8	2.1	--	17.0	19.1	461.7	--
Middle Pier	87.5	--	--	--	476.9	2.1	--	19.3	21.4	455.5	--
Right Pier	132.5	--	--	--	483.7	2.1	--	14.4	16.5	467.2	--
Spill-through toe	148.6	--	--	--	485.6	2.1	13.9	--	16.0	469.6	--
Right abutment	175.9	--	497.7	--	495.1	--	--	--	--	--	--

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

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U.S. Geological Survey, 1963, Middlebury, 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 newh030.wsp
T2        Hydraulic analysis for structure NEWHTH00050030   Date: 08-DEC-97
T3        TH 5 CROSSING THE NEW HAVEN RIVER IN NEW HAVEN, VT            RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          13400.0  19800.0
WS          491.85   493.65
*
XS    EXIT2    -399           0.
GR            0.0, 512.44     34.7, 493.46     53.6, 490.80     70.5, 489.48
GR           91.8, 487.27    107.7, 485.63    126.6, 485.09    155.7, 484.44
GR          172.6, 485.13    175.2, 483.48    195.3, 483.63    210.0, 482.75
GR          211.0, 482.01    214.0, 481.52    217.3, 481.27    224.4, 480.81
GR          228.4, 480.32    231.5, 481.43    241.1, 481.46    248.0, 482.14
GR          260.3, 486.16    283.7, 501.18
*
N           0.050
*
XS    EXIT1    -150           0.
GR            0.0, 508.92     37.8, 482.12     48.9, 477.41     69.1, 477.95
GR           84.1, 478.92    109.1, 479.61    137.0, 481.48    137.1, 482.10
GR          142.8, 486.17    149.2, 487.28    197.1, 487.47    218.4, 491.93
GR          235.2, 494.32    244.4, 498.05    295.3, 499.43    319.0, 504.62
*
N           0.040        0.050
SA                149.2
*
XS    FULLV      0  * * *  0.0
*
*              SRD      LSEL     SKEW
BR    BRIDG      0    498.15       10
GR            0.0, 498.58      0.0, 496.73      6.7, 496.15     19.7, 492.71
GR           36.9, 484.61     40.7, 484.30     44.9, 480.83
GR           55.6, 477.32     63.0, 477.98     72.1, 477.63     84.7, 476.85
GR           90.2, 477.26     99.4, 480.50    116.6, 481.60
GR          119.3, 483.16    123.0, 484.10    130.2, 484.10    134.8, 483.74
GR          148.6, 485.58    175.6, 495.11    175.9, 497.71      0.0, 498.58
*
*           BRTYPE  BRWDTH  EMBSS  EMBELV
CD               3   28.13    2.0  501.61
N           0.040
PW          477.3, 3.3  480.9, 3.3  480.9, 7.1  483.9, 7.1  483.9, 11.1
PW          492.8, 10.5  498.2, 10.5  498.2, 0
*
*              SRD     EMBWID   IPAVE
XR    RDWAY     14       23.2       1
GR         -159.4, 537.11   -119.4, 516.16    -86.9, 504.29    -31.5, 502.86
GR            0.0, 502.89    178.3, 501.80    284.7, 506.52
*
AS    APPRO     200           0.
GR         -416.2, 536.99   -325.8, 519.66   -210.1, 500.36   -156.2, 497.74
GR         -133.4, 495.08    -65.4, 494.17    -39.8, 493.14     25.0, 491.30
GR           28.7, 488.36     34.7, 484.58     37.0, 482.70     46.8, 479.49
GR           59.1, 476.51     66.9, 476.33     85.7, 478.99     96.7, 480.40
GR          114.2, 480.92    116.4, 482.71    119.5, 484.33    126.4, 484.85
GR          129.0, 486.11    150.6, 486.08    175.8, 487.33    187.7, 492.16
GR          210.8, 505.33
*
N           0.035        0.040        0.085
SA                 25.0        129.0
*
HP 1 BRIDG  493.11 1 493.11
HP 2 BRIDG  493.11 * * 13400
HP 2 BRIDG  493.23 * * 13400
HP 1 APPRO  493.76 1 493.76
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File newh030.wsp
        Hydraulic analysis for structure NEWHTH00050030   Date: 08-DEC-97
        TH 5 CROSSING THE NEW HAVEN RIVER IN NEW HAVEN, VT            RLB
           *** RUN DATE & TIME: 02-06-98  10:27

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1529.  261035.   149.   156.                       27753.
   493.11         1529.  261035.   149.   156.  1.00    18.   170.  27753.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.11    18.2   169.9  1529.0  261035.   13400.   8.76

X STA.        18.2       46.7       51.4       55.6       59.5       63.6
  A(I)           174.2       63.6       61.3       60.2       61.8
  V(I)            3.85      10.54      10.94      11.13      10.84

X STA.        63.6       67.6       71.7       75.6       79.6       83.4
  A(I)            60.3       61.7       60.4       62.5       59.6
  V(I)           11.10      10.87      11.10      10.72      11.24

X STA.        83.4       86.9       90.7       94.9       99.8      105.2
  A(I)            56.3       59.0       62.2       63.9       66.8
  V(I)           11.90      11.35      10.77      10.49      10.04

X STA.       105.2      110.8      116.8      125.5      134.8      169.9
  A(I)            66.1       69.1       83.2       82.7      194.2
  V(I)           10.13       9.69       8.05       8.10       3.45

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.23    17.7   170.3  1547.0  265244.   13400.   8.66

X STA.        17.7       46.7       51.5       55.6       59.5       63.6
  A(I)           178.0       64.2       61.9       60.7       62.3
  V(I)            3.76      10.43      10.83      11.04      10.75

X STA.        63.6       67.7       71.7       75.8       79.7       83.5
  A(I)            60.9       62.2       62.3       61.4       60.4
  V(I)           11.00      10.77      10.75      10.92      11.10

X STA.        83.5       87.1       90.8       95.1      100.1      105.5
  A(I)            58.1       59.0       63.0       65.8       66.8
  V(I)           11.54      11.36      10.64      10.18      10.03

X STA.       105.5      111.1      117.2      125.7      135.0      170.3
  A(I)            67.2       70.2       82.2       84.2      196.2
  V(I)            9.96       9.54       8.15       7.96       3.42

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =     200.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     105.    5311.    80.    80.                         678.
             2    1364.  273467.   104.   109.                       28038.
             3     393.   23406.    62.    63.                        5645.
   493.76         1862.  302183.   246.   252.  1.39   -55.   191.  24647.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =     200.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.76   -55.2   190.5  1862.2  302183.   13400.   7.20

X STA.       -55.2       40.8       46.6       51.3       55.4       59.2
  A(I)           230.7       77.1       68.9       64.6       64.0
  V(I)            2.90       8.69       9.72      10.38      10.47

X STA.        59.2       62.9       66.4       70.1       74.0       78.0
  A(I)            63.7       61.8       64.1       63.9       65.7
  V(I)           10.52      10.84      10.45      10.49      10.19

X STA.        78.0       82.3       86.9       91.7       97.0      102.3
  A(I)            66.6       68.1       68.6       72.9       70.5
  V(I)           10.06       9.85       9.77       9.19       9.50

X STA.       102.3      107.9      113.6      122.9      144.8      190.5
  A(I)            73.5       73.8       97.2      174.3      272.2
  V(I)            9.12       9.08       6.89       3.84       2.46
```

```
U.S. Geological Survey WSPRO Input File newh030.wsp
Hydraulic analysis for structure NEWHTH00050030   Date: 08-DEC-97
TH 5 CROSSING THE NEW HAVEN RIVER IN NEW HAVEN, VT           RLB
   *** RUN DATE & TIME: 02-06-98  10:27

 CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1    1778.  320785.   160.   167.                       33643.
494.72         1778.  320785.   160.   167.  1.00    12.   174.  33643.

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

      WSEL     LEW     REW    AREA        K        Q    VEL
    494.72    12.1   174.5  1778.1  320785.   19800.  11.14

X STA.        12.1       46.4       51.3       55.6       59.7       63.9
  A(I)           219.2       73.6       70.5       69.2       71.1
  V(I)            4.52      13.45      14.04      14.31      13.92

X STA.        63.9       68.1       72.4       76.5       80.6       84.6
  A(I)            69.6       71.1       69.6       70.9       69.7
  V(I)           14.23      13.93      14.23      13.97      14.20

X STA.        84.6       88.4       92.5       97.3      102.6      108.1
  A(I)            67.0       69.4       74.0       75.4       75.2
  V(I)           14.77      14.26      13.38      13.13      13.16

X STA.       108.1      113.8      120.6      129.3      137.6      174.5
  A(I)            75.9       83.2       92.1       88.0      223.3
  V(I)           13.05      11.90      10.74      11.25       4.43

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

      WSEL     LEW     REW    AREA        K        Q    VEL
    494.87    11.5   174.9  1802.1  326719.   19800.  10.99

X STA.        11.5       46.4       51.3       55.6       59.7       63.9
  A(I)           224.9       74.6       71.4       69.9       70.3
  V(I)            4.40      13.27      13.87      14.17      14.09

X STA.        63.9       68.1       72.4       76.5       80.7       84.7
  A(I)            70.7       72.2       70.7       72.0       70.8
  V(I)           14.01      13.72      14.01      13.75      13.99

X STA.        84.7       88.6       92.7       97.4      102.8      108.3
  A(I)            68.6       70.9       73.1       76.3       76.2
  V(I)           14.43      13.95      13.54      12.97      12.99

X STA.       108.3      114.1      120.8      129.6      137.9      174.9
  A(I)            76.9       84.0       93.6       89.5      225.7
  V(I)           12.88      11.78      10.58      11.06       4.39

 CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =     200.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     442.   35829.   168.   168.                        4068.
          2    1622.  364956.   104.   109.                       36354.
          3     551.   39035.    66.    68.                        9051.
496.24         2616.  439821.   338.   346.  1.52  -143.   195.  33479.

 VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =     200.

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.24  -143.3   194.9  2615.7  439821.   19800.   7.57

X STA.      -143.3       -1.0       37.2       44.1       49.6       54.6
  A(I)           323.3      233.6      100.7       92.0       89.7
  V(I)            3.06       4.24       9.83      10.76      11.04

X STA.        54.6       58.9       63.1       67.3       71.6       76.1
  A(I)            83.9       82.3       82.9       85.2       85.0
  V(I)           11.80      12.03      11.95      11.63      11.64

X STA.        76.1       80.9       86.0       91.4       97.1      103.1
  A(I)            87.4       89.4       90.3       92.6       94.5
  V(I)           11.33      11.07      10.96      10.69      10.48

X STA.       103.1      109.1      115.8      125.9      149.4      194.9
  A(I)            94.3      101.5      122.5      240.3      344.3
  V(I)           10.49       9.76       8.08       4.12       2.88
```

WSPRO OUTPUT FILE (continued)

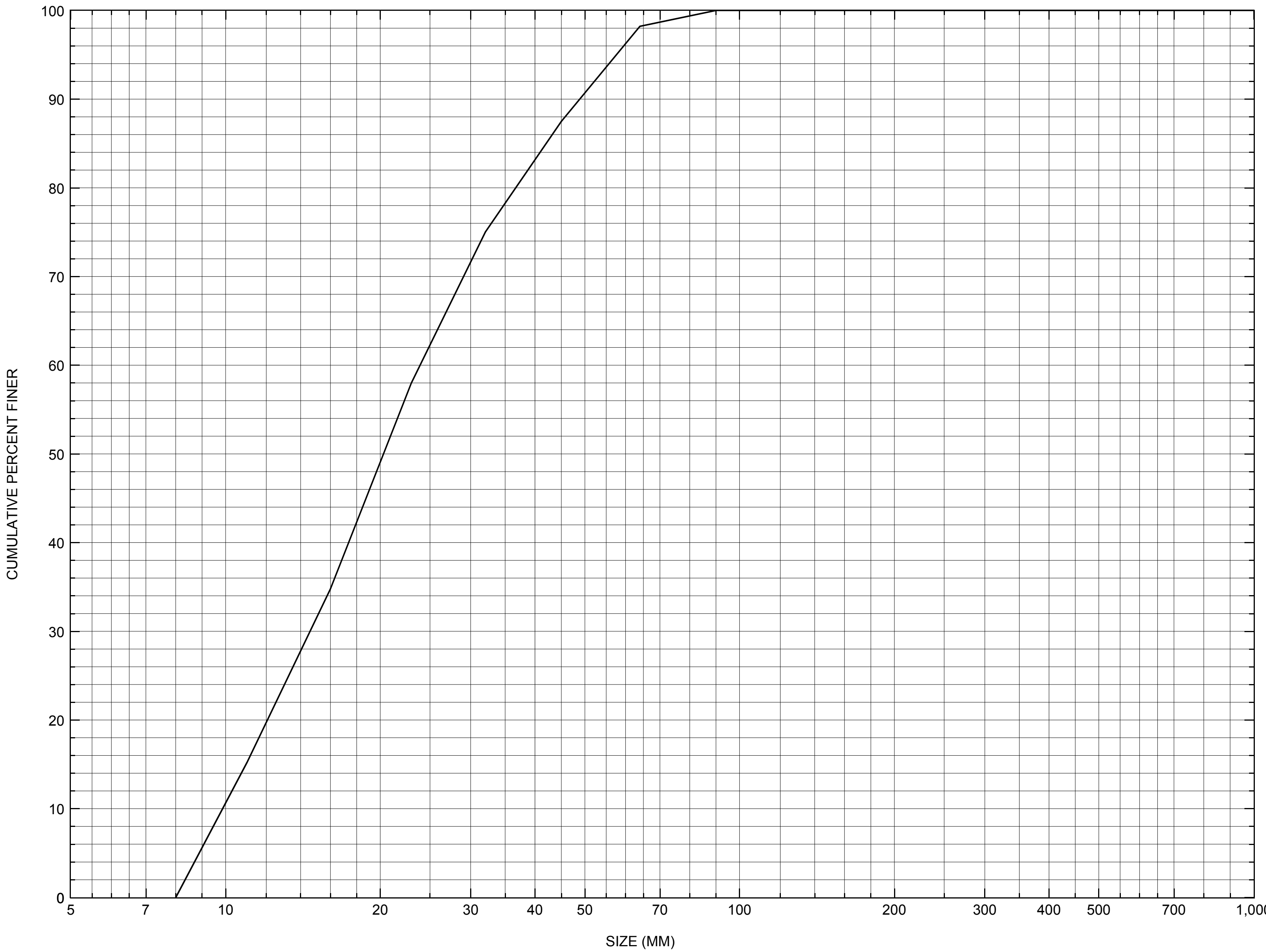
```
        U.S. Geological Survey WSPRO Input File newh030.wsp
        Hydraulic analysis for structure NEWHTH00050030   Date: 08-DEC-97
        TH 5 CROSSING THE NEW HAVEN RIVER IN NEW HAVEN, VT            RLB
           *** RUN DATE & TIME: 02-06-98  10:27

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

EXIT2:XS   ******    46.    1474.  1.29 *****  493.14  489.80  13400.  491.85
     -399. ******   269.  152972.  1.00 ***** *******    0.62    9.09

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "EXIT1"     KRATIO =  2.14

EXIT1:XS     249.    22.    1913.  0.89  0.89  494.03 *******  13400.  493.14
     -150.   249.   227.  327785.  1.16  0.00    0.00    0.44    7.00

FULLV:FV     150.    22.    1975.  0.83  0.24  494.27 *******  13400.  493.44
        0.   150.   229.  341950.  1.16  0.00    0.01    0.42    6.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     200.   -52.    1831.  1.16  0.35  494.79 *******  13400.  493.63
      200.   200.   190.  296256.  1.39  0.16    0.00    0.55    7.32
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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     150.    18.    1529.  1.27  0.31  494.38  489.00  13400.  493.11
        0.   150.   170.  261023.  1.06  0.03   -0.01    0.50    8.76

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.971  0.087  498.15 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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     172.   -55.    1862.  1.12  0.40  494.88  488.76  13400.  493.76
      200.   173.   191.  302071.  1.39  0.12    0.02    0.54    7.20

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.365  0.028  292636.    13.   164.   493.41

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXIT2:XS    -399.    46.    269.  13400.  152972.    1474.    9.09  491.85
   EXIT1:XS    -150.    22.    227.  13400.  327785.    1913.    7.00  493.14
   FULLV:FV       0.    22.    229.  13400.  341950.    1975.    6.79  493.44
   BRIDG:BR       0.    18.    170.  13400.  261023.    1529.    8.76  493.11
   RDWAY:RG      14.**************       0.******************    1.00********
   APPRO:AS     200.   -55.    191.  13400.  302071.    1862.    7.20  493.76

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      13.   164.  292636.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT2:XS    489.80    0.62  480.32  512.44************  1.29  493.14  491.85
   EXIT1:XS  ********    0.44  477.41  508.92  0.89  0.00  0.89  494.03  493.14
   FULLV:FV  ********    0.42  477.41  508.92  0.24  0.00  0.83  494.27  493.44
   BRIDG:BR    489.00    0.50  476.85  498.58  0.31  0.03  1.27  494.38  493.11
   RDWAY:RG  ****************  501.80  537.11**********************************
   APPRO:AS    488.76    0.54  476.33  536.99  0.40  0.12  1.12  494.88  493.76
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File newh030.wsp
        Hydraulic analysis for structure NEWHTH00050030   Date: 08-DEC-97
        TH 5 CROSSING THE NEW HAVEN RIVER IN NEW HAVEN, VT            RLB
           *** RUN DATE & TIME: 02-06-98  10:27

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

EXIT2:XS   ******    34.    1889.  1.71 *****  495.36  491.48  19800.  493.65
     -399. ******   272.  221537.  1.00 ***** *******    0.66   10.48

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           “EXIT1”     KRATIO =  1.92

EXIT1:XS     249.    20.    2322.  1.32  1.04  496.39 *******  19800.  495.07
     -150.   249.   237.  425676.  1.17  0.00    0.00    0.50    8.53

FULLV:FV     150.    19.    2412.  1.23  0.31  496.70 *******  19800.  495.48
        0.   150.   238.  448459.  1.17  0.00    0.00    0.47    8.21
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     200.  -139.    2450.  1.54  0.43  497.29 *******  19800.  495.75
      200.   200.   194.  407489.  1.52  0.16    0.00    0.65    8.08
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

            <<<<<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     150.    12.    1778.  2.25  0.43  496.97  491.39  19800.  494.72
        0.   150.   174.  320714.  1.17  0.14   -0.01    0.64   11.14

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.926  0.084  498.15 ****** ****** ******

   XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
  RDWAY:RG      14.        <<<<<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     172.  -143.    2614.  1.36  0.49  497.59  491.05  19800.  496.24
      200.   175.   195.  439498.  1.52  0.15    0.02    0.59    7.57

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      0.500  0.074  405671.     4.   166.   495.87

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

  FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
  EXIT2:XS    -399.    34.   272.  19800.  221537.    1889.   10.48  493.65
  EXIT1:XS    -150.    20.   237.  19800.  425676.    2322.    8.53  495.07
  FULLV:FV       0.    19.   238.  19800.  448459.    2412.    8.21  495.48
  BRIDG:BR       0.    12.   174.  19800.  320714.    1778.   11.14  494.72
  RDWAY:RG      14.**************       0.******************    1.00********
  APPRO:AS     200.  -143.   195.  19800.  439498.    2614.    7.57  496.24

   XSID:CODE   XLKQ   XRKQ       KQ
  APPRO:AS       4.   166.  405671.

 SECOND USER DEFINED TABLE.

   XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
  EXIT2:XS    491.48    0.66  480.32  512.44************  1.71  495.36  493.65
  EXIT1:XS   ********   0.50  477.41  508.92  1.04  0.00  1.32  496.39  495.07
  FULLV:FV   ********   0.47  477.41  508.92  0.31  0.00  1.23  496.70  495.48
  BRIDG:BR    491.39    0.64  476.85  498.58  0.43  0.14  2.25  496.97  494.72
  RDWAY:RG   ***************  501.80  537.11*********************************
  APPRO:AS    491.05    0.59  476.33  536.99  0.49  0.15  1.36  497.59  496.24
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure NEWHTH00050030, in New Haven, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number NEWHTH00050030

General Location Descriptive

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

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

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

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

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

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

Waterway *(I - 6)* NEW HAVEN RIVER

Road Name *(I - 7):* -

Route Number C2005

Vicinity *(I - 9)* 0.25 MI TO JCT W US7

Topographic Map Middlebury

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 44037

Longitude *(i - 17; nnnnn.n)* 73102

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011300300113

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

Maximum span length *(I - 48; nnnn)* 0045

Year built *(I - 27; YYYY)* 1927

Structure length *(I - 49; nnnnnn)* 000181

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

Deck Width *(I - 52; nn.n)* 232

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)* Y36

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 174

Number of spans *(I - 45; nnn)* 004

Vertical clearance from streambed (*nnn.n ft*) 13.86

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

Waterway of full opening (*nnn.n ft*^{2}) 2412

Comments:

According to the structural inspection report dated 12/8/94, this is a 4-span structure with a concrete T-beam deck. The concrete skeleton abutments have a few cracks, leaks, and small spalls. The piers are solid concrete columns with concrete caps. They have cracks and leaks overall, with rust stains and areas of spalling and section loss on their ends. Pier 1 has deep spalling near the water line on the US half. Pier 3 has deep spalling on its US end, with section loss. All the channel flow presently is through spans 2 and 3. The embankments in front of each abutment are boulder stone fill covered, with vegetation. Several small trees or large limbs are present at the US end of pier 2. The channel has scour 2-4 ft deep around piers 1 and 2.

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: **Logs and debris, sand and boulders**

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -
Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **114.78** mi^2 Lake/pond/swamp area **0.29** mi^2

Watershed storage *(ST)* **0.25** %

Bridge site elevation **230** ft Headwater elevation **3780** ft

Main channel length **24.25** mi

10% channel length elevation **265** ft 85% channel length elevation **1620** ft

Main channel slope *(S)* **74.51** 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? **Y** *If no, type ctrl-n xs*

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

Comments: **This cross-section is of the downstream face. The low chord points are from the survey log done for this report on 6/19/96. The low chord to bed length data came from the sketch attached to a bridge inspection report dated 12/8/94. (Continued below)**

Station	0	38.7	45.9	70.4	84.6	92.7	111.2	129.9	135.7	174	-
Feature	RAB	-	-	-	RMP	LMP	-	-	-	LAB	-
Low chord elevation	497.7	497.7	497.9	498.1	498.1	498.2	498.3	498.3	498.4	498.6	-
Bed elevation	494.4	484.6	485.3	480.7	481.6	478.4	476.3	478	482.8	495.3	-
Low chord to bed	3.3	13.3	12.6	17.4	16.5	19.8	22	20.3	15.6	3.3	-

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

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

Comments: **(Continued from above) The sketch was done on 11/12/92. RMP is the right side of the middle pier, LMP is the left side of the middle pier, relative to the downstream face.**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **MS** Date: **6/24/97**
Computerized by: **MS** Date: **6/24/97**
Reviewd by: **RB** Date: **12/29/97**

Structure Number **NEWHTH00050030**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E**. **WILD** Date *(MM/DD/YY)* **6** / **19** / 19**96**

2. Highway District Number **05** Mile marker **000000**

County **ADDISON (001)** Town **NEW HAVEN (48700)**

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

Route Number **TH 5** Hydrologic Unit Code: **2010002**

3. Descriptive comments:

This bridge is located 0.25 miles from the junction with US 7.
A resident of the US left bank house said her lawn has been steadily eroding the past 17 years.

B. Bridge Deck Observations

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

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

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

7. Bridge length **181** *(feet)* Span length **45** *(feet)* Bridge width **23.2** *(feet)*

Road approach to bridge:

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

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

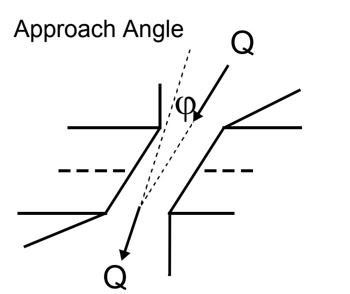
10. Embankment slope (*run / rise in feet / foot*):
US left **2.1:1** US right **2.8:1**

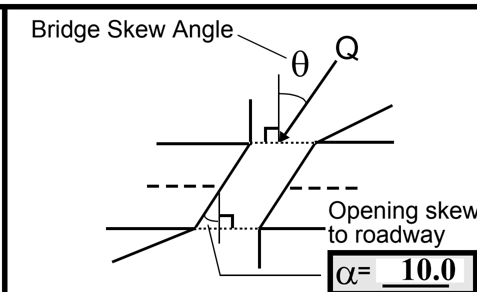
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	-	-
RBUS	0	-	-	-
RBDS	0	-	-	-
LBDS	0	-	-	-

*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: **15**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **350** 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? **0** feet **DS** *(US, UB, DS)* to **400** feet **DS**

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

18. Bridge Type: 3

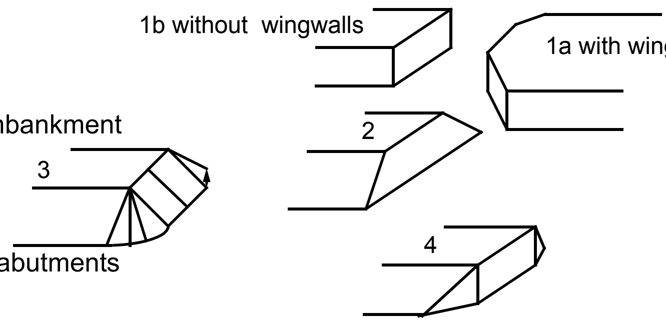
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

4. The right bank upstream and downstream has trees along the immediate bank and lawns on the overbanks.
7. Bridge dimension values are from the VTAOT database. The measured bridge length is 180 ft, the span length is 45 ft, and the bridge width is 23.6 ft.
18. There are no wingwalls.

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
177.5	6.5			3.5	1	2	10	10	2	1

23. Bank width 35.0   24. Channel width 15.0   25. Thalweg depth 104.0   29. Bed Material 123

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

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

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

29. The bed material changes from a cobble bed with a silt and gravel point bar on the US right bank to silt, cobbles, and boulders just upstream of the bridge. The material is fine-grained on the right bank and more coarse towards the left bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **12** 35. Mid-bar width: **26.5**
36. Point bar extent: **104** feet **US** (US, UB) to **225** feet **DS** (US, UB, DS) positioned **50** %LB to **100** %RB
37. Material: **13**
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
This point bar is under water. An additional point bar on the right bank is above the bar described. It acts like a bank at low flow and is heavily vegetated with grass and ferns and is composed of clay. It extends from 275 ft US to 0 ft DS. The mid bar width is 25 ft at 103 ft US. There is also a side bar located from 195 ft US to 370 ft US near the right bank. There is a channel bar located from 295 ft US to 410 ft US made up mostly of gravel.

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: **105** 42. Cut bank extent: **241** feet **US** (US, UB) to **0** feet **UB** (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.):
There is no protection on the US left bank. The erosion includes exposed roots and a slip failure that is located at 180 ft US. The total length of the slip failure is 35 ft.

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.):
There is local scour in front of a boulder located on the US right bank, US of the right bank point bar. The scour is 5 ft wide and 8 ft long. The water depth is 6.5 ft.

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)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
81.5		**6.5**		**2**	**-**	**-**	**-**

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.):
123
The vertical concrete abutments are high and set back from the channel. In front of them are dumped boulders creating spill-through slopes.

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

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

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

70. Debris and Ice Comments:

1

Debris has accumulated on both banks in front of the abutments and on the left pier.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**25**	**1**	**0**	**-**	**-**	**90.0**
RABUT	**1**	**0**	**19**			**1**	**0**	**176.0**

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

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

-

-

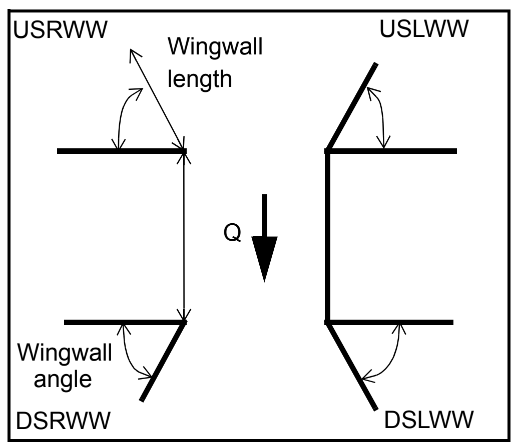
1

The abutments are spill-through abutments.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**176.0**	
USRWW:	**N**		**-**		**-**	**4.5**	
DSLWW:	**-**		**-**		**N**	**24.5**	
DSRWW:	**-**		**-**		**-**	**24.5**	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**-**	**N**	**-**	**-**	**-**	**-**	**-**
Condition	**N**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Extent	**-**	**-**	**-**	**-**	**-**	**0**	**0**	**-**

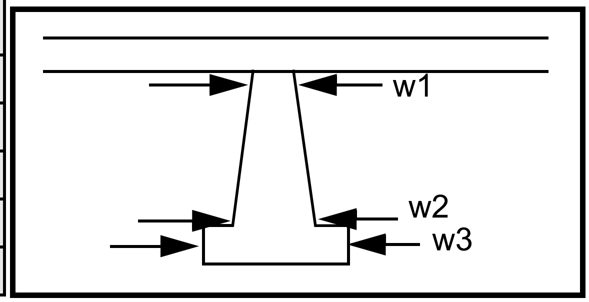
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	3.85	3.84	-	492.55	480.81
Pier 3	-	3.25	3.30	-	493.04	477.20
Pier 4	-	3.31	4.02	-	492.86	483.87



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	dumpe	ank-		LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	bank	d	ment	Y	1- Solid pier, 2- column, 3- bent
88. Material	s in	boul-	slope	LB	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	front	ders	s.	1	1- Round; 2- Square; 3- Pointed
90. Inclined?	of	that		2	Y- yes; N- no
91. Attack ∠ (BF)	the	cre-		3	
92. Pushed	abut	ate		N	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	ment	the		10	
95. Cross-members	s are	spill		LB	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	pro-	thro		1	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	tecte	ugh		0	
98. Exposure depth	d by	emb		1	

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

-
-
MCM
1
2
3
N
15
RB
1

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
-	-			-	0	2	1.5	0.2	RB	1

Bank width (BF) - Channel width 25 Thalweg depth 25.6 Bed Material 2

Bank protection type (Qmax): LB 3 RB N Bank protection condition: LB 5 RB RB

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

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

1
0
1
-
-
-
-
-
-
-
-
-
-
-
-

101. Is a drop structure present? - (Y or N, if N type ctrl-n ds) 102. Distance: 25.7 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):

All three piers have evidence of scour. The middle pier is the most severe. Surrounding pier 1 is dumped stone. Between pier 1 and pier 2 the bed is dumped stone consisting of cobbles and boulders and the water depth is 3 ft. Pier 3 was not submerged at time of site visit.

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

Point bar extent: ______ feet **3** (US, UB, DS) to **2** feet **13** (US, UB, DS) positioned **1** %LB to **2** %RB

Material: **1**

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

134
0
0
-

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

Cut bank extent: **right** feet **ba** *(US, UB, DS)* to **nk,** feet **300** *(US, UB, DS)*

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

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

DS, the bank material is bedrock. Also, 248 ft DS on the DS left bank, the material is bedrock.

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

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

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

N

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

Confluence 1: Distance **421** Enters on **ft** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

erfall, where the bedrock controls the channel bed and the channel width decreases extensively.

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
248
7.5
225
DS
256
DS
70
100
13
This is a side bar.

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: NEWHTH00050030 Town: NEW HAVEN
Road Number: TH5 (DOG TEAM TAVERN RD) County: ADDISON
Stream: NEW HAVEN RIVER

Initials RLB Date: 12/12/97 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	13400	19800	0
Main Channel Area, ft2	1364	1622	0
Left overbank area, ft2	105	442	0
Right overbank area, ft2	393	551	0
Top width main channel, ft	104	104	0
Top width L overbank, ft	80	168	0
Top width R overbank, ft	62	66	0
D50 of channel, ft	0.0666	0.0666	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	13.1	15.6	ERR
y1, average depth, LOB, ft	1.3	2.6	ERR
y1, average depth, ROB, ft	6.3	8.3	ERR
Total conveyance, approach	302183	439821	0
Conveyance, main channel	273467	364956	0
Conveyance, LOB	5311	35829	0
Conveyance, ROB	23406	39035	0
Percent discrepancy, conveyance	-0.0003	0.0002	ERR
Qm, discharge, MC, cfs	12126.6	16429.7	ERR
Ql, discharge, LOB, cfs	235.5	1613.0	ERR
Qr, discharge, ROB, cfs	1037.9	1757.3	ERR
Vm, mean velocity MC, ft/s	8.9	10.1	ERR
Vl, mean velocity, LOB, ft/s	2.2	3.6	ERR
Vr, mean velocity, ROB, ft/s	2.6	3.2	ERR
Vc-m, crit. velocity, MC, ft/s	7.0	7.2	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

	100 yr	500 yr	other Q
Main Channel	1	1	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour

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y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
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(Richardson and others, 1995, p. 30, eq. 17 and 18)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	13400	19800	0	13400	19800	0
Total conveyance	302183	439821	0	261035	320785	0
Main channel conveyance	273467	364956	0	261035	320785	0
Main channel discharge	12127	16430	ERR	13400	19800	ERR
Area - main channel, ft2	1364	1622	0	1393.8	1626	0
(W1) channel width, ft	104	104	0	129.7	135	0
(Wp) cumulative pier width, ft	10.8	10.8	0	10.8	10.8	0
W1, adjusted bottom width(ft)	93.2	93.2	0	118.9	124.2	0
D50, ft	0.0666	0.0666	0.0666			
w, fall velocity, ft/s (p. 32)	2.11	2.11	0			
y, ave. depth flow, ft	13.12	15.60	N/A	11.72	13.09	ERR
S1, slope EGL	0.0026	0.003	0			
P, wetted perimeter, MC, ft	109	109	0			
R, hydraulic Radius, ft	12.514	14.881	ERR			
V*, shear velocity, ft/s	1.024	1.199	N/A			
V*/w	0.485	0.568	ERR			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.59	0.64	0			
y2,depth in contraction, ft	12.38	15.23	ERR			
ys, scour depth, ft (y2-y_bridge)	0.65	2.14	N/A			

Armoring

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

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	13400	19800	N/A
Main channel area (DS), ft2	1393.8	1626	0
Main channel width (normal), ft	129.7	135	0.0
Cum. width of piers, ft	10.8	10.8	0.0
Adj. main channel width, ft	118.9	124.2	0.0
D90, ft	0.1603	0.1603	0.0000
D95, ft	0.1889	0.1889	0.0000
Dc, critical grain size, ft	0.2021	0.3139	ERR
Pc, Decimal percent coarser than Dc	0.029	0.000	0.000

Depth to armoring, ft	N/A	N/A	ERR

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	13400	19800	0	13400	19800	0
a', abut.length blocking flow, ft	83.8	168.9	0	32.2	34.3	0
Ae, area of blocked flow ft2	201.38	485.96	0	191.79	259.55	0
Qe, discharge blocked abut.,cfs	584.85	1679.37	0	472.08	746.31	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.90	3.46	ERR	2.46	2.88	ERR
ya, depth of f/p flow, ft	2.40	2.88	ERR	5.96	7.57	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	100	100	100	80	80	80
K2	1.01	1.01	1.01	0.98	0.98	0.98
Fr, froude number f/p flow	0.330	0.359	ERR	0.178	0.184	ERR
ys, scour depth, ft	9.53	14.11	N/A	11.23	13.92	N/A

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)	83.8	168.9	0	32.2	34.3	0
y1 (depth f/p flow, ft)	2.40	2.88	ERR	5.96	7.57	ERR
a'/y1	34.87	58.70	ERR	5.41	4.53	ERR
Skew correction (p. 49, fig. 16)	1.02	1.02	1.00	0.98	0.98	1.00
Froude no. f/p flow	0.33	0.36	N/A	0.18	0.18	N/A
Ys w/ corr. factor K1/0.55:						
vertical	12.39	15.25	ERR	ERR	ERR	ERR
vertical w/ ww's	10.16	12.51	ERR	ERR	ERR	ERR
spill-through	6.81	8.39	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.5	0.64	0	0.5	0.64	0
y, depth of flow in bridge, ft	11.72	13.09	0.00	11.72	13.09	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.81	3.31	0.00	1.81	3.31	0.00
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.58	2.89	0.00	1.58	2.89	0.00
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR

Pier Scour

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)
V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	42.8	42.8	0
Area of WSPRO flow tube, ft2	58.1	68.6	0
Skewed width of flow tube, ft	3.5	3.8	0
y1, pier approach depth, ft	16.60	18.05	ERR
y1 in meters	5.059	5.502	N/A
V1, pier approach velocity, ft/s	11.54	14.43	0
a, pier width, ft	3.8	3.8	0

L, pier length, ft	25	25	0
Fr1, Froude number at pier	0.499	0.599	ERR
Pier attack angle, degrees	10	10	0
K1, shape factor	0.9	0.9	0
K2, attack factor	1.63	1.63	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.0666	0.0666	0
D50, m	0.020299	0.020299	0
D90, ft	0.1603	0.1603	0
D90, m	0.048857	0.048857	0
Vc50,critical velocity(D50),m/s	2.212	2.244	N/A
Vc90,critical velocity(D90),m/s	2.965	3.007	N/A
Vi,incipient velocity,m/s	1.152	1.168	ERR
Vr, velocity ratio	1.305	1.757	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth (K4 not applied)ft	15.27	17.00	ERR
Pier 2	Q100	Q500	Qother
Pier stationing, ft	87.5	87.5	0
Area of WSPRO flow tube, ft2	58.1	68.6	0
Skewed width of flow tube, ft	3.5	3.8	0
y1, pier approach depth, ft	16.60	18.05	ERR
y1 in meters	5.059	5.502	N/A
V1, pier approach velocity, ft/s	11.54	14.43	0
a, pier width, ft	3.3	3.3	0
L, pier length, ft	25.6	25.6	0
Fr1, Froude number at pier	0.499	0.599	ERR
Pier attack angle, degrees	15	15	0
K1, shape factor	0.9	0.9	0
K2, attack factor	2.03	2.03	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.0666	0.0666	0
D50, m	0.020299	0.020299	0
D90, ft	0.1603	0.1603	0
D90, m	0.048857	0.048857	0
Vc50,critical velocity(D50),m/s	2.212	2.244	N/A
Vc90,critical velocity(D90),m/s	2.965	3.007	N/A
Vi,incipient velocity,m/s	1.160	1.177	ERR
Vr, velocity ratio	1.306	1.760	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth, (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth, (K4 not applied)ft	17.32	19.29	ERR
Pier 3	Q100	Q500	Qother
Pier stationing, ft	132.5	132.5	0
Area of WSPRO flow tube, ft2	58.1	68.6	0
Skewed width of flow tube, ft	3.5	3.8	0
y1, pier approach depth, ft	16.60	18.05	ERR
y1 in meters	5.059	5.502	N/A
V1, pier approach velocity, ft/s	11.54	14.43	0
a, pier width, ft	4	4	0
L, pier length, ft	25.7	25.7	0
Fr1, Froude number at pier	0.499	0.599	ERR
Pier attack angle, degrees	5	5	0
K1, shape factor	0.9	0.9	0
K2, attack factor	1.33	1.33	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.0666	0.0666	0

D50, m	0.020299	0.020299	0
D90, ft	0.1603	0.1603	0
D90, m	0.048857	0.048857	0
Vc50,critical velocity(D50),m/s	2.212	2.244	N/A
Vc90,critical velocity(D90),m/s	2.965	3.007	N/A
Vi,incipient velocity,m/s	1.149	1.165	ERR
Vr, velocity ratio	1.304	1.755	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth, (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth, (K4 not applied)ft	12.89	14.35	ERR

Pier rip-rap sizing

D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	0
V, velocity on pier, ft/s	9.5	12.01	0
D50, median stone diameter, ft	1.32	2.11	0.00
Pier 2			
K, pier shape coeff.	1.5	1.5	0
V, velocity on pier, ft/s	13.3	16.81	0
D50, median stone diameter, ft	2.59	4.14	0.00
Pier 3			
K, pier shape coeff.	1.5	1.5	0
V, velocity on pier, ft/s	8.55	10.81	0
D50, median stone diameter, ft	1.07	1.71	0.00