LEVEL II SCOUR ANALYSIS FOR BRIDGE 47 (LYNDTH00360047) on TOWN HIGHWAY 36, crossing the EAST BRANCH PASSUMPSIC RIVER, LYNDON, VERMONT

Open-File Report 98-406

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 LORA K. STRIKER AND TIMOTHY A. SEVERANCE

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Pembroke, New Hampshire

1998

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 47 (LYNDTH00360047) ON TOWN HIGHWAY 36, CROSSING THE EAST BRANCH PASSUMPSIC RIVER, LYNDON, VERMONT

***By* Lora K. Striker and Timothy A. Severance**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure LYNDTH00360047 on Town Highway 36 crossing the East Branch Passumpsic River, Lyndon, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in north-eastern Vermont. The 79.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture along the left bank while the right bank upstream is shrub and brushland and the right bank downstream is row crops. The downstream left and upstream right banks have dense woody vegetation on the immediate banks.

In the study area, the East Branch Passumpsic River has an incised, straight channel with a slope of approximately 0.0003 ft/ft, an average channel top width of 86 ft and an average bank height of 10 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 56.2 mm (0.184 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 3, 1995, indicated that the reach was stable.

The Town Highway 36 crossing of the East Branch Passumpsic River is a 53-ft-long, two-lane bridge consisting of one 51-foot steel-beam span (Vermont Agency of Transportation, written communication, March 27, 1995). The opening length of the structure parallel to the bridge face is 49.4 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 35 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 1.0 to 1.5 ft deeper than the mean thalweg depth was observed in front of the right abutment during the Level I assessment. The same hole extends downstream of the bridge where it is 4.5 feet deeper than the mean thalweg depth. In addition, the left abutment and upstream left wingwall footing were exposed 1.5 ft. Scour protection measures at the site included type-1 (less than 12 inches diameter) and type-2 (less than 36 inches diameter) stone fill. Type-1 stone fill was observed along the right bank downstream and type-2 stone fill was observed along the right bank upstream, the upstream right wingwall, the right abutment, and the downstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was 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 1.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 10.7 to 15.2 ft. The worst-case abutment scour occurred at the incipient roadway-overtopping discharge for the left abutment and at the 500-year 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 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.

Burke Mountain, VT. Quadrangle, 1:24,000, 1988

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 LYNDTH00360047 ***Stream*** East Branch Passumpsic River

County Caledonia ***Road*** TH 36 ***District*** 7

Description of Bridge

Bridge length 53 ***ft*** ***Bridge width*** 26.0 ***ft*** ***Max span length*** 51 ***ft***

Alignment of bridge to road (on curve or straight) Straight, right; Curve, left.

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

Stone fill on abutment? Yes ***Date of inspection*** 8/3/95

Description of stone fill Type-2, along the base of the right abutment, upstream right wingwall, and downstream right wingwall.

Abutments and wingwalls are concrete. The left abutment and upstream left wingwall footing were exposed 1.5 ft and vertically undermined up to 0.75 ft.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 35

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	8/3/95	0	0
Level II	8/3/95	0	0

Potential for debris Low.

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

None as of 8/3/95.

Description of the Geomorphic Setting

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

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

Date of inspection 8/3/95

DS left: Steep channel bank to a narrow flood plain

DS right: Steep channel bank to a narrow flood plain

US left: Steep channel bank to a narrow flood plain

US right: Moderately sloped channel bank and overbank

Description of the Channel

Average top width 86 ***ft*** ***Average depth*** 10 ***ft***

Predominant bed material Gravel/Cobbles ***Bank material*** Gravel/Cobbles

The stream is perennial, straight, and incised, with semi-alluvial channel boundaries.

8/3/95

Vegetative co Trees and brush on the immediate banks with short grass on the overbank

DS left: Brush on the immediate banks to TH 36 and row crops

DS right: Brush on the immediate banks with pasture overbank

US left: Shrubs and brush with a few trees and grass on the overbank

US right:

Yes

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

None as of 8/3/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 79.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	*Percent of drainage area*
New England/New England Upland	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 East Branch Passumpic River near East Haven,VT

USGS gage number 01133000

Gage drainage area 53.8 ***mi²***

Is there a lake/ No

-

-

Calculated Discharges

Q100 5,700 ***ft³/s*** ***Q500*** 7,800 ***ft³/s***

The 100- and 500-year discharges are from the Flood Insurance Study for the Town of Lyndon for the East Branch Passumpsic River at the confluence with the Passumpsic River (FEMA, 1988). The FEMA discharges 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).

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 left wingwall at the junction with the left abutment (elev. 499.93 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream right corner of the concrete bridge deck (elev. 499.97 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-56	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	74	2	Modelled Approach section (Templated from APTEM)
APTEM	116	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. Although flow approaches this site at an angle greater than the opening-skew-to-roadway, flow was assumed to align with the abutments in the bridge. 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 0.030 to 0.060.

Normal depth at the exit section (EXIT1) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user’s manual for WSPRO (Shearman, 1990). The slope used was 0.0003 ft/ft, which was estimated from the 100-year water surface profile presented in the Flood Insurance Study downstream of this site (FEMA, 1988).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0002 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 provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.2 ***ft***
Average low steel elevation 496.9 ***ft***

100-year discharge 5,700 ***ft^3/s***
Water-surface elevation in bridge opening 495.9 ***ft***
Road overtopping? No ***Discharge over road*** 0 ***ft^3/s***
Area of flow in bridge opening 601 ***ft^2***
Average velocity in bridge opening 9.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.5 ***ft/s***

Water-surface elevation at Approach section with bridge 496.8
Water-surface elevation at Approach section without bridge 496.4
Amount of backwater caused by bridge 0.4 ***ft***

500-year discharge 7,800 ***ft^3/s***
Water-surface elevation in bridge opening 497.0 ***ft***
Road overtopping? Yes ***Discharge over road*** 786 ***ft^3/s***
Area of flow in bridge opening 653 ***ft^2***
Average velocity in bridge opening 10.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.4 ***ft/s***

Water-surface elevation at Approach section with bridge 499.1
Water-surface elevation at Approach section without bridge 497.2
Amount of backwater caused by bridge 1.9 ***ft***

Incipient overtopping discharge 6,080 ***ft^3/s***
Water-surface elevation in bridge opening 496.0 ***ft***
Area of flow in bridge opening 607 ***ft^2***
Average velocity in bridge opening 10.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.2 ***ft/s***

Water-surface elevation at Approach section with bridge 497.0
Water-surface elevation at Approach section without bridge 496.6
Amount of backwater caused by bridge 0.4 ***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-year and incipient roadway-overtopping discharges were computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 500-year discharge resulted in submerged 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 the 500-year discharge was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison, contraction scour for the 500-year discharge also was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). The results are provided in appendix F.

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

Because the influence of scour processes on the stone fill embankment material at the right abutment is uncertain, the scour depth at the vertical concrete abutment wall is unknown. Therefore, the scour depth was applied for the entire stone fill embankment on the right abutment below the elevation at the toe of the embankment, as shown in figure 8.

Scour Results

Contraction scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	1.7	0.0
Depth to armoring	2.2	4.7	3.7
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	13.3	13.6	13.9
Right abutment	10.7	15.2	11.3
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.8	2.1	2.0
Right abutment	1.8	2.1	2.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--
	--	--	--

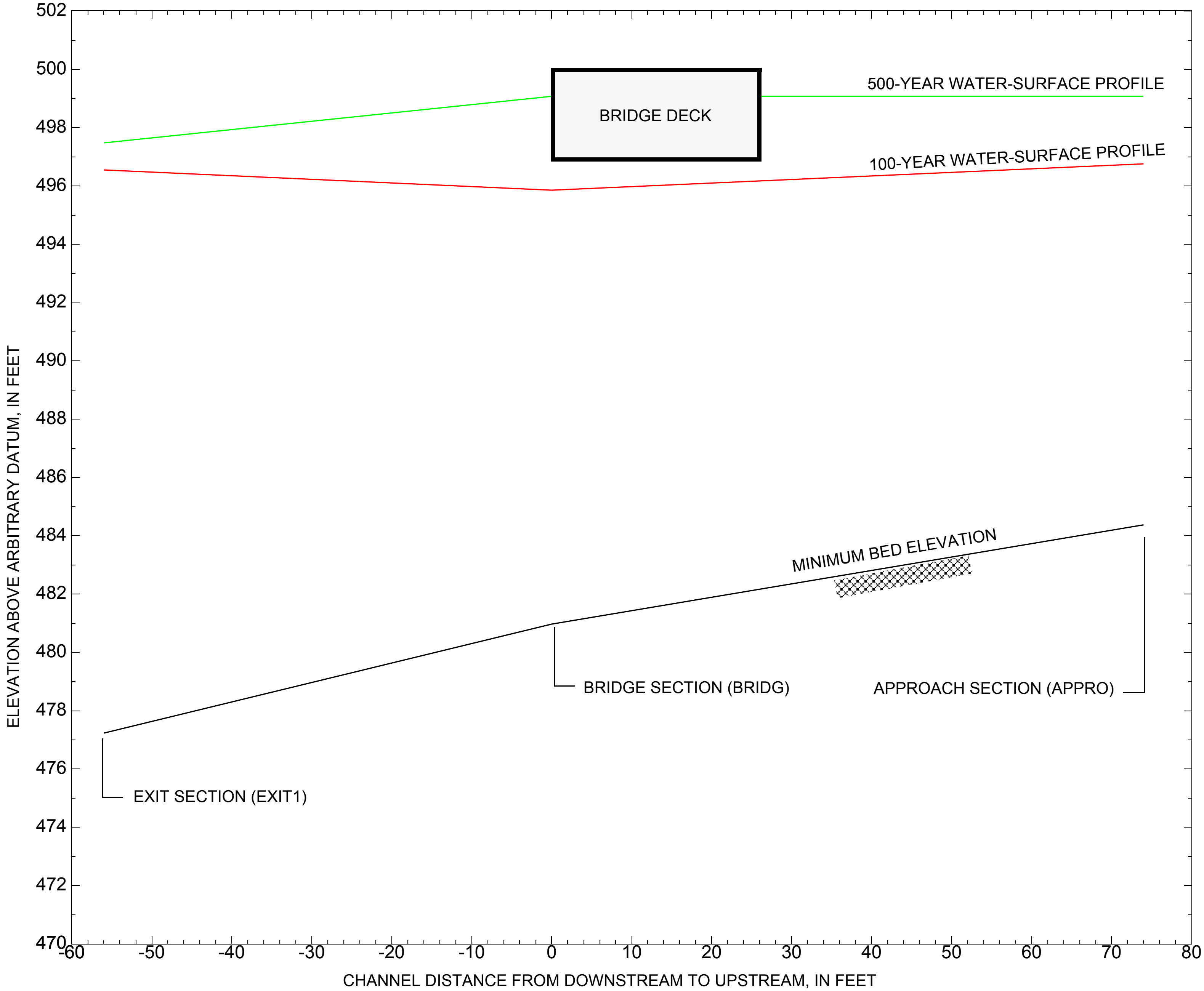

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure LYNDTH00360047 on Town Highway 36, crossing the East Branch Passumpsic River, Lyndon, Vermont.

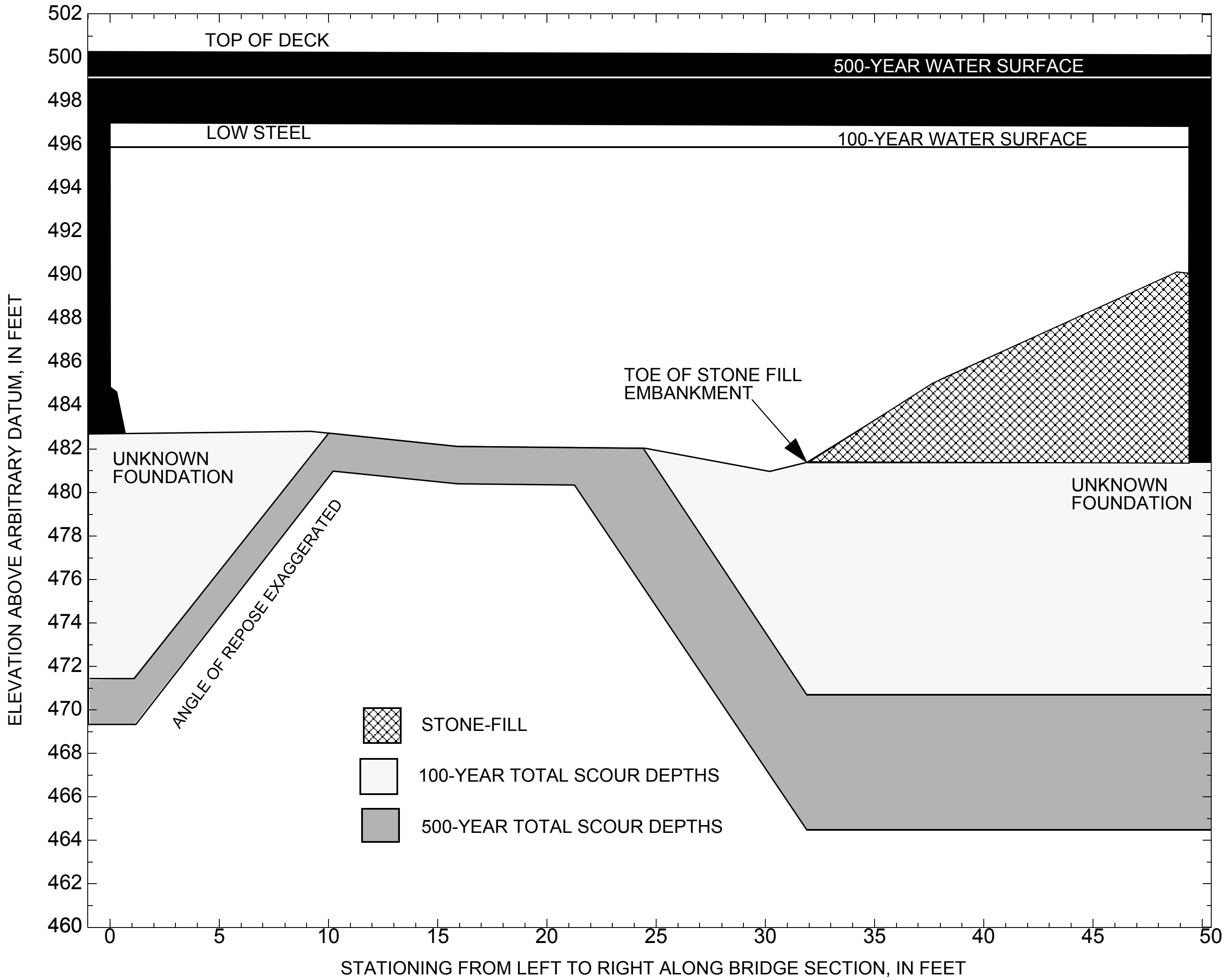

Figure 8. Scour elevations for the 100- and 500-year discharges at structure LYNDTH00360047 on Town Highway 36, crossing the East Branch Passumpsic River, Lyndon, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure LYNDTH00360047 on Town Highway 36, crossing the East Branch Passumpsic River, Lyndon, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 5,700 cubic-feet per second											
Left abutment	0.0	--	497.0	--	484.6	0.0	13.3	--	13.3	471.3	--
Right abutment	49.4	--	496.9	--	481.4	0.0	10.7	--	10.7	470.7	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure LYNDTH00360047 on Town Highway 36, crossing the East Branch Passumpsic River, Lyndon, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 7,800 cubic-feet per second											
Left abutment	0.0	--	497.0	--	484.6	1.7	13.6	--	15.3	469.3	--
Right abutment	49.4	--	496.9	--	481.4	1.7	15.2	--	16.9	464.5	--

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File lynd047.wsp
T2        Hydraulic analysis for structure LYNDTH00360047   Date: 08-SEP-97
T3        Bridge 47 crossing the East Branch Passumpsic River, LKS
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5700.0   7800.0   6080.0
SK          0.0003   0.0003   0.0003
*
XS   EXIT1    -56           0.
GR         -710.5, 508.70   -643.6, 493.83   -200.7, 494.42    -43.7, 494.53
GR            0.0, 494.49      6.6, 490.48     11.1, 485.95     13.9, 485.22
GR           23.7, 480.55     28.9, 479.48     46.5, 477.23     56.5, 478.55
GR           62.8, 481.88     72.9, 480.97     80.2, 485.18     92.3, 492.38
GR           98.6, 497.05    106.5, 497.81
* GR  135.3, 496.67
*
N           0.030        0.050        0.060
SA                   0.0         98.6
*
*
XS   FULLV      0
GR          -81.9, 498.05    -47.7, 497.46    -35.2, 497.04    -13.3, 493.34
GR            0.0, 484.80     10.0, 484.11     21.8, 483.74     34.1, 483.88
GR           41.2, 483.98     46.0, 484.70     53.5, 488.00     58.5, 493.45
GR           84.7, 495.07     93.1, 498.52    117.3, 499.07
*
N           0.030      0.050         0.060
SA               -13.3         58.5
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.85       0.0
GR            0.0, 497.01      0.1, 484.84      0.3, 484.63      0.7, 482.70
GR            9.2, 482.82     15.9, 482.12     24.5, 482.04     30.2, 480.97
GR           31.9, 481.39     38.0, 485.20     48.8, 490.09     49.4, 496.85
GR            0.0, 497.01
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      33.8 * *     46.8      8.8
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     13      26.0     2
GR         -826.1, 507.31   -640.7, 504.02   -198.9, 498.10    -50.3, 499.15
GR            0.0, 500.29     48.2, 500.14
* GR           82.8, 498.99    110.8, 496.92    410.8, 496.92
*
*
*
XT   APTEM    116           0.
GR         -816.1, 507.33
GR         -630.7, 504.04   -188.9, 498.12
GR          -81.9, 498.71    -47.7, 498.12    -35.2, 497.70    -13.3, 494.00
GR            0.0, 485.46     10.0, 484.77     21.8, 484.39     34.1, 484.54
GR           41.2, 484.64     46.0, 485.36     53.5, 488.66     58.5, 494.11
GR           84.7, 495.73     93.1, 499.18    117.3, 499.73
* GR          134.6, 497.14    241.0, 494.94    348.7, 493.83    410.5, 499.38
*
*
AS   APPRO    74  * * * 0.0002
GT
N           0.030        0.050        0.060
SA                 -13.3         58.5
*
HP 1 BRIDG   495.86 1 495.86
HP 2 BRIDG   495.86 * * 5700
HP 1 APPRO   496.76 1 496.76
HP 2 APPRO   496.76 * * 5700
*
HP 1 BRIDG   496.98 1 496.98
HP 2 BRIDG   496.98 * * 6942
```

APPENDIX B:

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File lynd047.wsp
       Hydraulic analysis for structure LYNDTH00360047   Date: 08-SEP-97
       Bridge 47 crossing the East Branch Passumpsic River,  LKS
          *** RUN DATE & TIME: 02-11-98  10:21
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     601.   94256.    49.    70.                      11901.
  495.86          601.   94256.    49.    70.  1.00     0.    49.  11901.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      495.86     0.0    49.3   600.8   94256.    5700.   9.49

X STA.        0.0        7.0        8.8       10.6       12.4       14.2
  A(I)            90.4       24.0       23.4       23.2       23.9
  V(I)            3.15      11.87      12.19      12.31      11.93

X STA.       14.2       15.8       17.5       19.3       21.0       22.7
  A(I)            22.8       23.6       23.8       23.6       23.6
  V(I)           12.51      12.06      11.95      12.08      12.06

X STA.       22.7       24.4       26.2       27.8       29.4       30.9
  A(I)            23.9       24.2       23.3       23.2       22.8
  V(I)           11.93      11.80      12.24      12.27      12.48

X STA.       30.9       32.5       34.5       36.6       39.2       49.3
  A(I)            23.3       26.0       26.6       27.8       77.4
  V(I)           12.21      10.96      10.73      10.27       3.68

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      74.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      23.    1386.    16.    17.                        151.
            2     748.  101143.    72.    77.                      13710.
            3      50.    1771.    29.    29.                        371.
  496.76          821.  104300.   117.   123.  1.10   -30.    87.  11759.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      74.

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.76   -29.7    87.2   820.8  104300.    5700.   6.94

X STA.      -29.7       -2.3        1.2        4.2        7.2       10.0
  A(I)            91.6       38.6       34.4       34.8       33.9
  V(I)            3.11       7.37       8.28       8.18       8.41

X STA.       10.0       12.8       15.6       18.3       21.0       23.8
  A(I)            33.6       33.2       33.7       33.5       33.7
  V(I)            8.49       8.60       8.47       8.51       8.47

X STA.       23.8       26.5       29.2       32.0       34.7       37.5
  A(I)            33.6       33.6       33.9       33.5       34.1
  V(I)            8.47       8.49       8.42       8.51       8.37

X STA.       37.5       40.2       43.1       46.0       49.7       87.2
  A(I)            32.8       34.5       34.4       38.6      110.9
  V(I)            8.69       8.26       8.29       7.38       2.57
```

```
     U.S. Geological Survey WSPRO Input File lynd047.wsp
     Hydraulic analysis for structure LYNDTH00360047   Date: 08-SEP-97
     Bridge 47 crossing the East Branch Passumpsic River,  LKS
        *** RUN DATE & TIME: 02-11-98  10:21
 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     653.   79002.     9.   112.                        31147.
496.98          653.   79002.     9.   112.  1.00     0.    49.  31147.

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.98     0.0    49.4   653.5   79002.    6942.  10.62

X STA.        0.0        4.6        6.2        7.8        9.5       11.5
 A(I)             63.4       23.1       22.5       23.8       29.6
 V(I)             5.47      15.00      15.42      14.57      11.74

X STA.       11.5       13.5       15.5       17.4       19.4       21.2
 A(I)             28.6       29.3       28.6       29.2       27.4
 V(I)            12.15      11.85      12.14      11.89      12.65

X STA.       21.2       23.0       24.9       26.8       28.5       30.2
 A(I)             26.9       27.8       28.1       27.3       27.3
 V(I)            12.91      12.50      12.35      12.70      12.73

X STA.       30.2       32.0       34.0       36.3       39.3       49.4
 A(I)             27.0       29.5       31.8       35.1       87.1
 V(I)            12.84      11.75      10.92       9.88       3.98

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

      WSEL     LEW     REW    AREA        K        Q    VEL
    499.08  -272.0   -60.2   103.8    3204.     786.   7.57

X STA.     -272.0     -230.6     -222.9     -216.9     -211.7     -206.9
 A(I)             11.5        4.7        4.2        4.0        4.0
 V(I)             3.42       8.43       9.25       9.75       9.88

X STA.     -206.9     -202.6     -198.5     -194.5     -190.1     -185.9
 A(I)              3.9        4.0        3.9        4.1        3.8
 V(I)            10.20       9.95      10.08       9.65      10.29

X STA.     -185.9     -181.8     -177.3     -172.5     -167.4     -161.9
 A(I)              3.5        3.9        3.9        3.9        4.1
 V(I)            11.16      10.20      10.06      10.04       9.63

X STA.     -161.9     -156.0     -149.5     -142.0     -133.1      -60.2
 A(I)              4.1        4.3        4.6        4.8       18.8
 V(I)             9.67       9.20       8.62       8.11       2.09


 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      74.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     216.    9758.   248.   248.                         1142.
          2     915.  141385.    72.    77.                        18533.
          3     123.    7043.    34.    35.                         1319.
499.08         1254.  158186.   354.   361.  1.36  -261.    93.  11488.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      74.

      WSEL     LEW     REW    AREA        K        Q    VEL
    499.08  -261.2    92.9  1253.6  158186.    7800.   6.22

X STA.     -261.2      -15.9       -3.6        0.6        4.0        7.3
 A(I)            203.1       92.2       53.8       46.9       45.6
 V(I)             1.92       4.23       7.25       8.32       8.56

X STA.        7.3       10.5       13.6       16.8       19.9       22.9
 A(I)             46.2       44.6       45.3       45.1       45.4
 V(I)             8.45       8.74       8.61       8.65       8.60

X STA.       22.9       26.1       29.2       32.2       35.3       38.5
 A(I)             45.7       45.5       44.4       45.0       45.7
 V(I)             8.54       8.56       8.79       8.68       8.53

X STA.       38.5       41.6       44.8       48.5       53.3       92.9
 A(I)             45.3       46.0       49.5       54.8      163.9
 V(I)             8.61       8.49       7.89       7.11       2.38
```

```
      U.S. Geological Survey WSPRO Input File lynd047.wsp
      Hydraulic analysis for structure LYNDTH00360047   Date: 08-SEP-97
      Bridge 47 crossing the East Branch Passumpsic River,  LKS
         *** RUN DATE & TIME: 02-11-98  10:21
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1      607.   95699.    49.    70.                       12090.
 495.99          607.   95699.    49.    70.  1.00     0.    49.  12090.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     495.99     0.0    49.3   607.2   95699.    6080.  10.01

X STA.        0.0        7.0        8.9       10.7       12.4       14.2
  A(I)           91.4       24.3       23.7       23.4       24.2
  V(I)           3.32      12.52      12.85      12.97      12.58

X STA.       14.2       15.8       17.6       19.3       21.0       22.7
  A(I)           23.0       23.9       23.6       24.1       24.2
  V(I)          13.19      12.72      12.90      12.59      12.58

X STA.       22.7       24.5       26.2       27.8       29.4       31.0
  A(I)           24.2       23.7       24.0       23.4       23.0
  V(I)          12.57      12.82      12.64      12.98      13.22

X STA.       31.0       32.6       34.5       36.7       39.3       49.3
  A(I)           24.2       25.5       26.8       28.0       78.5
  V(I)          12.58      11.90      11.35      10.84       3.87

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      74.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1       27.    1730.    18.    18.                         186.
          2      766.  105054.    72.    77.                       14186.
          3       57.    2171.    29.    30.                         448.
 497.00          849.  108956.   119.   125.  1.11   -31.    88.  12229.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      74.

       WSEL     LEW     REW    AREA        K        Q    VEL
     497.00   -31.1    87.8   849.1  108956.    6080.   7.16

X STA.      -31.1       -2.8        1.0        4.0        7.0        9.9
  A(I)           93.6       41.9       35.4       34.9       35.0
  V(I)           3.25       7.26       8.59       8.71       8.68

X STA.        9.9       12.7       15.5       18.3       21.0       23.8
  A(I)           34.7       34.8       34.6       34.4       34.6
  V(I)           8.77       8.74       8.79       8.83       8.79

X STA.       23.8       26.5       29.3       32.1       34.8       37.6
  A(I)           34.6       34.5       34.8       34.5       35.0
  V(I)           8.78       8.80       8.72       8.82       8.67

X STA.       37.6       40.4       43.3       46.2       50.0       87.8
  A(I)           33.8       35.5       35.3       40.7      116.4
  V(I)           9.01       8.57       8.61       7.48       2.61
```

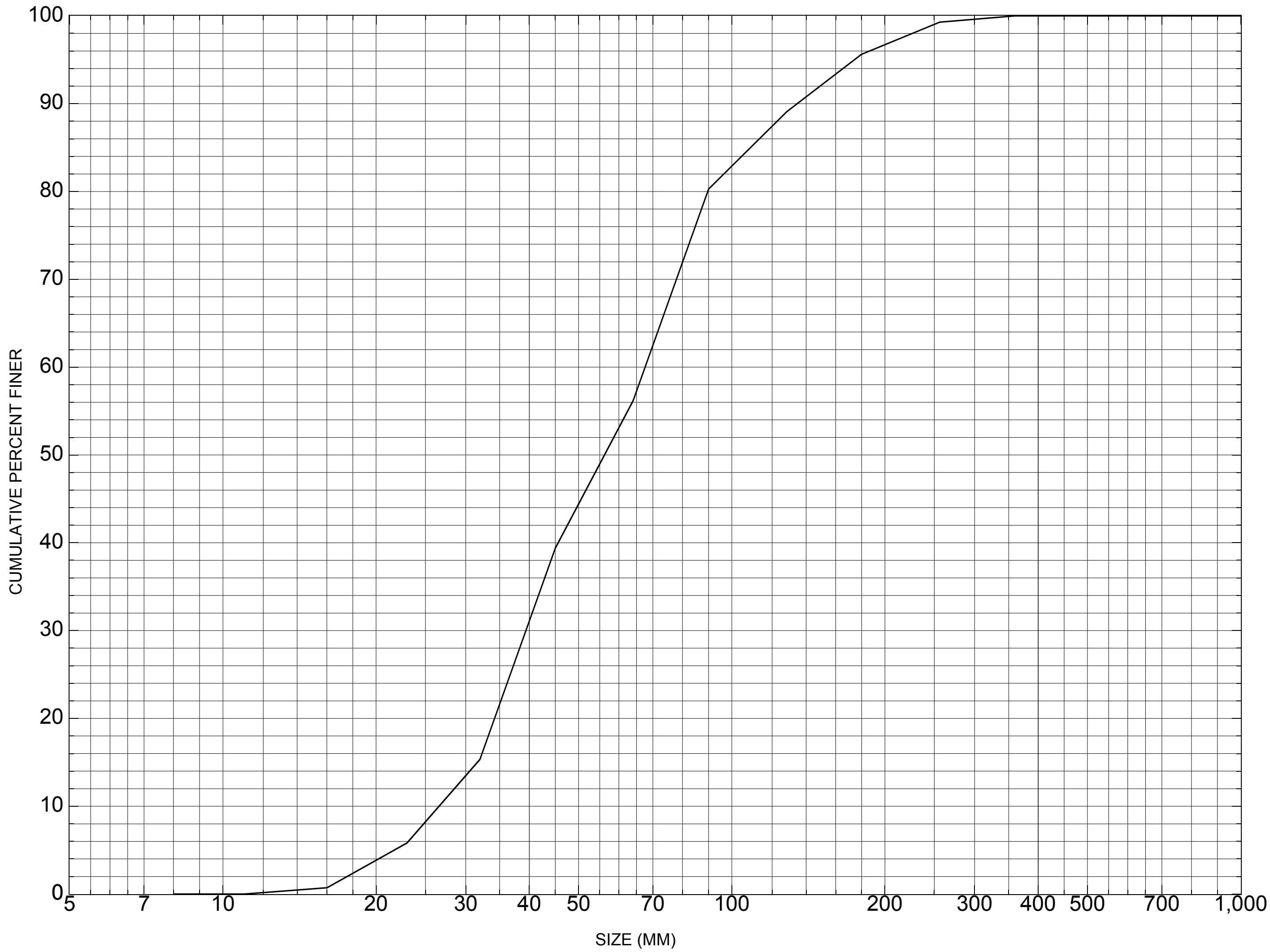
```
        U.S. Geological Survey WSPRO Input File lynd047.wsp
        Hydraulic analysis for structure LYNDTH00360047   Date: 08-SEP-97
        Bridge 47 crossing the East Branch Passumpsic River,  LKS
           *** RUN DATE & TIME: 02-11-98  10:21

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

EXIT1:XS   ******  -656.    2787.  0.08 *****  496.63  486.48   5700.  496.55
      -56. ******    98.  328975.  1.26 ***** *******    0.21    2.05

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  0.32

FULLV:FV      56.   -30.     836.  0.80  0.05  497.04 *******   5700.  496.24
        0.    56.    88.  106821.  1.11  0.36    0.00    0.47    6.82
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      74.   -28.     781.  0.90  0.23  497.32 *******   5700.  496.42
       74.    74.    86.   97877.  1.09  0.05    0.00    0.51    7.30
         <<<<<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      56.     0.     601.  1.45  0.06  497.32  491.10   5700.  495.86
        0.    56.    49.   94287.  1.04  0.63    0.01    0.49    9.49

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.981 ******  496.85 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      40.   -30.     821.  0.83  0.14  497.58  491.92   5700.  496.76
       74.    42.    87.  104256.  1.10  0.12    0.01    0.49    6.95

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.567  0.128   90745.     1.    50.  496.61

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXIT1:XS     -56.  -656.    98.   5700.  328975.    2787.    2.05  496.55
   FULLV:FV       0.   -30.    88.   5700.  106821.     836.    6.82  496.24
   BRIDG:BR       0.     0.    49.   5700.   94287.     601.    9.49  495.86
   RDWAY:RG      13.**************      0.******************    2.00********
   APPRO:AS      74.   -30.    87.   5700.  104256.     821.    6.95  496.76

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    50.   90745.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS     486.48    0.21  477.23  508.70************  0.08  496.63  496.55
   FULLV:FV   ********    0.47  483.74  499.07  0.05  0.36  0.80  497.04  496.24
   BRIDG:BR     491.10    0.49  480.97  497.01  0.06  0.63  1.45  497.32  495.86
   RDWAY:RG   ****************  498.10  507.31**********************************
   APPRO:AS     491.92    0.49  484.38  507.32  0.14  0.12  0.83  497.58  496.76
```

```
        U.S. Geological Survey WSPRO Input File lynd047.wsp
        Hydraulic analysis for structure LYNDTH00360047   Date: 08-SEP-97
        Bridge 47 crossing the East Branch Passumpsic River,  LKS
           *** RUN DATE & TIME: 02-11-98  10:21

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

EXIT1:XS   ****** -660.    3488.  0.09 *****  497.56  487.91   7800.  497.48
      -56. ******   103.  450155.  1.13 ***** *******    0.20    2.24

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  0.27

FULLV:FV      56.   -35.     925.  1.24  0.06  498.22 *******   7800.  496.98
        0.    56.    89.  121781.  1.12  0.58    0.01    0.58    8.43
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      74.   -32.     877.  1.37  0.33  498.60 *******   7800.  497.23
       74.    74.    88.  113618.  1.11  0.06    0.00    0.61    8.89
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =    496.98     496.85

            <<<<<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      56.     0.     653.  1.76 *****  498.73  492.16   6942.  496.98
        0. ******    49.   79587.  1.00 ***** *******    0.51   10.62

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800 ******  496.85 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      13.    48.  0.12  0.82  499.78   -0.01    786.  499.08

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    786.   211.  -272.   -61.   1.0   0.5   4.7   7.6   1.2   2.9
   RT:      0.    27.    21.    48.   1.5   1.4   6.5   6.5   2.1   3.0

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

APPRO:AS      40.  -261.    1253.  0.82  0.18  499.90  493.45   7800.  499.08
       74.    42.    93.  158088.  1.36  0.12   -0.01    0.68    6.23

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXIT1:XS     -56.  -660.   103.   7800.  450155.    3488.    2.24  497.48
   FULLV:FV       0.   -35.    89.   7800.  121781.     925.    8.43  496.98
   BRIDG:BR       0.     0.    49.   6942.   79587.     653.   10.62  496.98
   RDWAY:RG      13.*******   786.    786.       0.       0.    2.00  499.08
   APPRO:AS      74.  -261.    93.   7800.  158088.    1253.    6.23  499.08

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    487.91    0.20  477.23  508.70************  0.09  497.56  497.48
   FULLV:FV  ********    0.58  483.74  499.07  0.06  0.58  1.24  498.22  496.98
   BRIDG:BR    492.16    0.51  480.97  497.01************  1.76  498.73  496.98
   RDWAY:RG  ****************  498.10  507.31  0.12******  0.82  499.78  499.08
   APPRO:AS    493.45    0.68  484.38  507.32  0.18  0.12  0.82  499.90  499.08
```

```
        U.S. Geological Survey WSPRO Input File lynd047.wsp
        Hydraulic analysis for structure LYNDTH00360047   Date: 08-SEP-97
        Bridge 47 crossing the East Branch Passumpsic River,  LKS
           *** RUN DATE & TIME: 02-11-98  10:21

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

EXIT1:XS   ******  -657.    2926.  0.08 *****  496.82  486.75   6080.  496.73
      -56. ******    98.  351010.  1.23 ***** *******    0.21    2.08

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  0.31

FULLV:FV      56.   -31.     854.  0.88  0.05  497.26 *******   6080.  496.39
        0.    56.    88.  109725.  1.11  0.40    0.00    0.49    7.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      74.   -29.     800.  0.98  0.25  497.56 *******   6080.  496.58
       74.    74.    87.  100868.  1.10  0.05    0.00    0.53    7.60
         <<<<<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      56.     0.     607.  1.61  0.06  497.60  491.42   6080.  495.99
        0.    56.    49.   95701.  1.03  0.72    0.02    0.51   10.01

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.986 ******  496.85 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      40.   -31.     849.  0.88  0.15  497.88  492.22   6080.  497.00
       74.    42.    88.  108930.  1.11  0.14    0.02    0.50    7.16

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.572  0.136   93781.     1.    50.  496.85

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -56.  -657.    98.   6080.  351010.    2926.    2.08  496.73
   FULLV:FV       0.   -31.    88.   6080.  109725.     854.    7.12  496.39
   BRIDG:BR       0.     0.    49.   6080.   95701.     607.   10.01  495.99
   RDWAY:RG      13.**************      0.******************    2.00********
   APPRO:AS      74.   -31.    88.   6080.  108930.     849.    7.16  497.00

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    50.   93781.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    486.75    0.21  477.23  508.70************  0.08  496.82  496.73
   FULLV:FV  ********    0.49  483.74  499.07  0.05  0.40  0.88  497.26  496.39
   BRIDG:BR    491.42    0.51  480.97  497.01  0.06  0.72  1.61  497.60  495.99
   RDWAY:RG  ****************  498.10  507.31**********************************
   APPRO:AS    492.22    0.50  484.38  507.32  0.15  0.14  0.88  497.88  497.00
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure LYNDTH00360047, in Lyndon, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number LYNDTH00360047

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 27 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 41725

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

Waterway *(I - 6)* East Branch Passumpsic River

Road Name *(I - 7):* -

Route Number TH036

Vicinity *(I - 9)* @ JCT W VT114

Topographic Map Burke Mountain

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44329

Longitude *(i - 17; nnnnn.n)* 71591

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030700470307

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

Maximum span length *(I - 48; nnnn)* 0051

Year built *(I - 27; YYYY)* 1951

Structure length *(I - 49; nnnnnn)* 000053

Average daily traffic, ADT *(I - 29; nnnnnn)* 000800

Deck Width *(I - 52; nn.n)* 260

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)* 7

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

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

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

Year Reconstructed *(I - 106)* 1975

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 13.1

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

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

Comments:

The structural inspection report of 10/31/95 indicates the structure is a steel stringer type bridge with a concrete deck. The upstream end of the left abutment footing is exposed. The abutments and wingwalls have minor fine cracks, small leaks, and small spalls reported overall. Stone and boulder fill is noted in place along the right abutment and its wingwalls. Random boulders and some areas of erosion from previous flooding are reported on the banks. Debris accumulation and point bar development problems are minor.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area (*mi*²): 79.71

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data (*cfs*): $Q_{2.33}$ - Q_{10} - Q_{25} 4800

Q_{50} 5500 Q_{100} 7000 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*)	-	-	9.2	10.1	11.9
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): N 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)* 79.69 mi^2 Lake/pond/swamp area 0.43 mi^2

Watershed storage *(ST)* 0.6 %

Bridge site elevation 711 ft   Headwater elevation 3300 ft

Main channel length 20.82 mi

10% channel length elevation 750 ft   85% channel length elevation 1776 ft

Main channel slope *(S)* 65.69 ft / mi

Watershed Precipitation Data

Average site precipitation - in   Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:
There is no benchmark information available.

Reference Point (*MSL, Arbitrary, Other*): - Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness ______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:
There is no foundation material information available.

Comments:
There are no bridge plans available.

Cross-sectional Data

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

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

Comments: **The cross-section is at the downstream face.**

Station	**4979.1**	**4991**	**5000**	**5012**	**5030**	-	-	-	-	-	-
Feature	**LAB**	-	-	-	**RAB**	-	-	-	-	-	-
Low chord elevation	**714.8**	**714.8**	**714.9**	**714.9**	**715**	-	-	-	-	-	-
Bed elevation	**702.6**	**701.2**	**700.5**	**700.4**	**702.7**	-	-	-	-	-	-
Low chord to bed	**12.2**	**13.6**	**14.4**	**14.5**	**12.3**	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 03/04/96
Computerized by: EW Date: 03/04/96
Reviewd by: LKS Date: 02/13/98

Structure Number LYNDTH00360047

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. SEVERANCE Date *(MM/DD/YY)* 08 / 03 / 1995

2. Highway District Number 07 Mile marker -

County Caledonia (005) Town Lyndon (41725)

Waterway *(I - 6)* East Branch Passumpsic River Road Name Lily Pond Road

Route Number TH036 Hydrologic Unit Code: 01080102

3. Descriptive comments:

The bridge is located 25 ft from the junction with VT Route 114. The concrete deck of the bridge is supported at 6 ft intervals with corrugated steel rails. The guardrail extends 25 ft beyond the deck on the left road approach and wraps around to State Route 114.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 5 LBDS 4 RBDS 3 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 2 UB 1 DS 1 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 53 *(feet)* Span length 51 *(feet)* Bridge width 26 *(feet)*

Road approach to bridge:

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

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

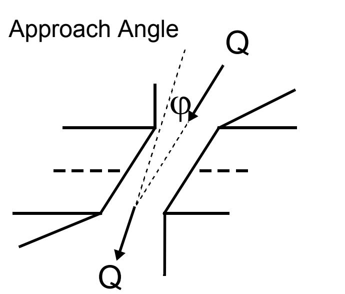
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

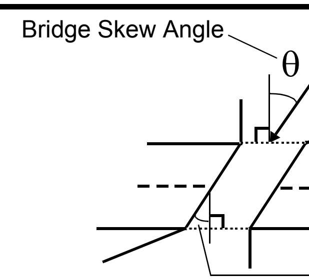
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	2	1	0	-
RBDS	2	1	0	-
LBDS	0	-	2	2

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

Channel approach to bridge (BF):

15. Angle of approach: 20 16. Bridge skew: 35





α= 0.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 0 feet US *(US, UB, DS)* to 26 feet UB

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 60 feet DS *(US, UB, DS)* to 80 feet DS

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

18. Bridge Type: **1a**

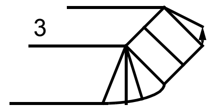
1a- Vertical abutments with wingwalls

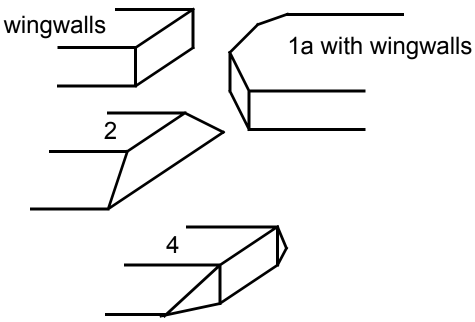
1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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 surface cover on the right bank upstream is brushland and State route 114. In addition, there is a runoff culvert (12 inches in diameter), a residence and two businesses (A garage and an ice-cream stand). The right bank downstream has a steep bank vegetated with brush. The overbank coverage includes State route 114 and row crops.

The left bank upstream is brush, then pasture and steep valley wall.

The left bank downstream is lined with trees. The left overbank is short grass for about 750 ft. Then the coverage changes to a forest. In addition, there is a pumping facility located 60 ft from the DSLWW.

#7: Bridge dimension values were taken from the VTAOT database. The bridge dimensions measured were a bridge length of 52.5 ft, a span length of 49.5 ft, and bridge width of 26 ft.

#17: There is a bend in the channel upstream and flow impacts the right abutment. Eddy currents also were observed where the flow impacts the right abutment.

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
90.0	**8.5**			**9.0**	**1**	**1**	**345**	**345**	**1**	**2**

23. Bank width **25.0** 24. Channel width **20.0** 25. Thalweg depth **74.0** 29. Bed Material **4**

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.):

The right bank protection covers only along the toe of the bank. It extends from 40 ft US to 10 ft DS. There is a laid-up stone wall extention of the concrete upstream left wingwall, which protects the embankment.
#26: The vegetation cover on the right bank increases to the range of 26 to 50 percent at 80 ft US of the bridge.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **142** 35. Mid-bar width: **10**

36. Point bar extent: **100** feet **US** (US, UB) to **185** feet **US** (US, UB, DS) positioned **5** %LB to **15** %RB

37. Material: **3**

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

The bar is a mid-channel bar covered with grass.

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: **300** 42. Cut bank extent: **100** feet **US** (US, UB) to **>500** feet **US** (US, UB, DS)

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

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

The bank material is fine sand and silt overlying gravel from 100 to >500 ft upstream. There is minor slump failure of the bank material along the cut-bank 500 ft upstream. The cut-bank is mostly vertical due to flood flow/ice flow erosion. Ice scars were observed on the trees

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **20**

47. Scour dimensions: Length **40** Width **30** Depth : **1-1.5** Position **30** %LB to **90** %RB

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

The scour hole begins about 40 ft US from the bridge and the thalweg depth upstream is 1.5 feet on average.

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

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

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

54. Confluence comments (eg. confluence name):

There are no major confluences upstream at this site.

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
46.5		1.0		2	7	7	-

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

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

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

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

34

The right abutment has sloping stone fill (type-2 and type-3). There is a small sand side bar along the left abutment near the junction with the wingwall.

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

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

#68: The bridge has a moderate capture efficiency due to stone fill.

#69: There is scarring evident on trees due to ice build-up.

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**	**3**	**1**	**1.5**	**90.0**
RABUT	**1**	**30**	**90**			**2**	**0**	**49.0**

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

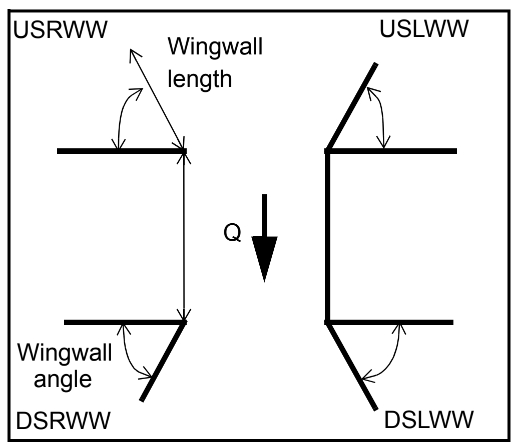
The footing thickness is 1 ft (measured on exposed USLAB, USLWW area). The water depth at edge of the abutment footing is 2.25 ft and the depth above the footing is 0.5 ft. The footing is undermined up to 0.75 ft vertically. The scour depth is greatest at the corner of the wingwall and abutment. The exposure of the footing is less severe towards the DS end of the left abutment and US end of the upstream left wingwall.

With a 1 foot graduated range pole, up to 3 ft of undermining was observed horizontally beneath the left abutment footing. The downstream left wingwall was undermined 0.5 ft vertically.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**49.0**	
USRWW:	**Y**		**1**		**3**	**4.0**	
DSLWW:	**1**		**1.5**		**Y**	**25.5**	
DSRWW:	**1**		**0**		**-**	**25.5**	

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**	**-**	**1**
Condition	**Y**	**-**	**1**	**-**	**-**	**1**	**-**	**1**
Extent	**1**	**-**	**0**	**0**	**2**	**0**	**2**	**-**

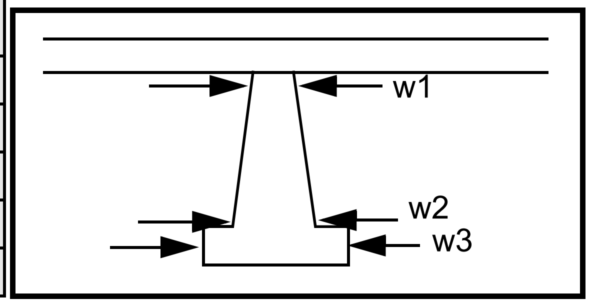
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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				30.0	15.5	65.0
Pier 2				10.0	70.0	12.0
Pier 3			-	45.0	11.0	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	ing,	fill	an old	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	upst	refer	mate	log-	1- Solid pier, 2- column, 3- bent
88. Material	ream	to	rial	crib	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	left	#79.	is	at	1- Round; 2- Square; 3- Pointed
90. Inclined?	wing	The	wash	the	Y- yes; N- no
91. Attack ∠ (BF)	wall	dow	ing	dow	
92. Pushed	has	nstre	out.	nstre	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	an	am	Ther	am	
95. Cross-members	unde	left	e is	left	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	rmin	wing	evi-	and	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	ed	wall	denc	right	
98. Exposure depth	foot-	back	e of	wing	

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

walls.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: -

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

-
-
-
-

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

Cut bank extent: no feet pie (US, UB, DS) to rs. feet ____ (US, UB, DS)

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

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

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

Scour dimensions: Length ____ Width 3 Depth: 1 Positioned 324 %LB to 324 %RB

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

0
0
324
0

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

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

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

Confluence comments (eg. confluence name):

on the channel bed adjacent to the scour hole. There is a submerged sand bar on the left bank. The downstream right bank has minimal type-1 stone fill protection. The percent vegetation cover on the right bank

F. Geomorphic Channel Assessment

107. Stage of reach evolution inc

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)*:

reases to the range of 51 to 75 percent from 100 to 180 ft downstream.

109. G. Plan View Sketch

- N

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: LYNDTH00360047 Town: LYNDON
Road Number: TH 36 County: CALEDONIA
Stream: EAST BRANCH PASSUMPSIC RIVER

Initials LKS Date: 02/11/98 Checked: RLB

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

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

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	5700	7800	6080
Main Channel Area, ft2	748	915	766
Left overbank area, ft2	23	216	27
Right overbank area, ft2	50	123	57
Top width main channel, ft	72	72	72
Top width L overbank, ft	16	248	18
Top width R overbank, ft	29	34	29
D50 of channel, ft	0.1843	0.1843	0.1843
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.4	12.7	10.6
y1, average depth, LOB, ft	1.4	0.9	1.5
y1, average depth, ROB, ft	1.7	3.6	2.0
Total conveyance, approach	104300	158186	108956
Conveyance, main channel	101143	141385	105054
Conveyance, LOB	1386	9758	1730
Conveyance, ROB	1771	7043	2171
Percent discrepancy, conveyance	0.0000	0.0000	0.0009
Qm, discharge, MC, cfs	5527.5	6971.6	5862.3
Ql, discharge, LOB, cfs	75.7	481.2	96.5
Qr, discharge, ROB, cfs	96.8	347.3	121.1
Vm, mean velocity MC, ft/s	7.4	7.6	7.7
Vl, mean velocity, LOB, ft/s	3.3	2.2	3.6
Vr, mean velocity, ROB, ft/s	1.9	2.8	2.1
Vc-m, crit. velocity, MC, ft/s	9.4	9.7	9.5
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 Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	5700	7800	6080
(Q) discharge thru bridge, cfs	5700	6942	6080
Main channel conveyance	94256	79002	95699
Total conveyance	94256	79002	95699
Q2, bridge MC discharge,cfs	5700	6942	6080
Main channel area, ft2	601	654	607
Main channel width (normal), ft	49.3	49.4	49.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	49.3	49.4	49.3
y_bridge (avg. depth at br.), ft	12.19	13.23	12.32
Dm, median (1.25*D50), ft	0.230375	0.230375	0.230375
y2, depth in contraction,ft	11.04	13.05	11.67
ys, scour depth (y2-ybridge), ft	**-1.14**	-0.18	**-0.65**

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	5700	6942	6080
Main channel area (DS), ft2	600.8	653.5	607.2
Main channel width (normal), ft	49.3	49.4	49.3
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	49.3	49.4	49.3
D90, ft	0.4411	0.4411	0.4411
D95, ft	0.5718	0.5718	0.5718
Dc, critical grain size, ft	0.2680	0.3268	0.2975
Pc, Decimal percent coarser than Dc	0.266	0.172	0.195
Depth to armoring, ft	**2.22**	**4.74**	**3.69**

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and Davis, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	5700	7800	6080
Q, thru bridge MC, cfs	5700	6942	6080
Vc, critical velocity, ft/s	9.42	9.75	9.46
Va, velocity MC approach, ft/s	7.39	7.62	7.65
Main channel width (normal), ft	49.3	49.4	49.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	49.3	49.4	49.3
qbr, unit discharge, ft2/s	115.6	140.5	123.3
Area of full opening, ft2	600.8	653.5	607.2
Hb, depth of full opening, ft	12.19	13.23	12.32
Fr, Froude number, bridge MC	0	0.51	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	0	496.85	0
Elevation of Bed, ft	-12.19	483.62	-12.32
Elevation of Approach, ft	0	499.08	0
Friction loss, approach, ft	0	0.18	0
Elevation of WS immediately US, ft	0.00	498.90	0.00
ya, depth immediately US, ft	12.19	15.28	12.32
Mean elevation of deck, ft	0	500.22	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.96	1.00
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	N/A	**1.72**	N/A
Ys, scour w/Umbrell equation, ft	N/A	1.29	N/A

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

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

**Ys, scour w/Umbrell equation, ft	ERR	N/A	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	11.04	13.05	11.67
WSEL at downstream face, ft	--	--	--
Depth at downstream face, ft	N/A	N/A	N/A
Ys, depth of scour (Laursen), ft	N/A	N/A	N/A

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	5700	7800	6080	5700	7800	6080
a', abut.length blocking flow, ft	29.7	261.2	31.1	37.9	43.5	38.5
Ae, area of blocked flow ft2	116.97	237.61	124.47	115.07	208.42	123.9
Qe, discharge blocked abut.,cfs	472.29	--	528	315.81	706.87	360
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.04	3.26	4.24	2.74	3.39	2.91
ya, depth of f/p flow, ft	3.94	0.91	4.00	3.04	4.79	3.22
--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	0.359	0.503	0.374	0.278	0.273	0.285
ys, scour depth, ft	**13.29**	**13.61**	**13.87**	**10.69**	**15.22**	**11.32**

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

a'(abut length blocked, ft)	29.7	261.2	31.1	37.9	43.5	38.5
y1 (depth f/p flow, ft)	3.94	0.91	4.00	3.04	4.79	3.22
a'/y1	7.54	287.13	7.77	12.48	9.08	11.96
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.36	0.50	0.37	0.28	0.27	0.29
Ys w/ corr. factor K1/0.55:						
vertical	ERR	5.27	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	4.32	ERR	ERR	ERR	ERR
spill-through	ERR	2.90	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.49	0.51	0.51	0.49	0.51	0.51
y, depth of flow in bridge, ft	12.19	13.23	12.32	12.19	13.23	12.32
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.81**	**2.13**	**1.98**	**1.81**	**2.13**	**1.98**
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR