LEVEL II SCOUR ANALYSIS FOR BRIDGE 5 (IRASTH00010005) on TOWN HIGHWAY 1, crossing LORDS CREEK, IRASBURG, VERMONT

U.S. Geological Survey
Open-File Report 96-571

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 5 (IRASTH00010005) on TOWN HIGHWAY 1, crossing LORDS CREEK, IRASBURG, VERMONT

By Erick M. Boehmler and Donald L. Song

U.S. Geological Survey
Open-File Report 96-571

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

Pembroke, New Hampshire

1996

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

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information write to:

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

Copies of this report may be purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Federal Center
Denver, CO 80225

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 5 (IRASTH00010005) ON TOWN HIGHWAY 1, CROSSING LORDS CREEK, IRASBURG, VERMONT

***By* Erick M. Boehmler and Donald L. Song**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure IRASTH00010005 on town highway 1 crossing Lords Creek, Irasburg, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from VTAOT files, was compiled prior to conducting Level I and Level II analyses and can be found in Appendix D.

The site is in the New England Upland section of the New England physiographic province of north-central Vermont in the town of Irasburg. The 15.1-mi^2 drainage area is in a predominantly rural and forested basin with some pasture land mainly along the valley bottom. In the vicinity of the study site, the bank vegetation coverage is pasture grasses.

In the study area, Lords Creek has a meandering channel with a slope of approximately 0.0026 ft/ft, an average channel top width of 32 ft and an average channel depth of 3 ft. The channel bed material ranged from gravel (D_{50} is 46.6 mm or 0.153 ft) to silt/clay material (D_{50} of 1.006 mm or 0.0033 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 5 and 6, 1994, indicated that the reach was laterally unstable.

The town highway 1 crossing of Lords Creek is a 65-ft-long, two-lane bridge consisting of one 61-foot, steel-beam span (Vermont Agency of Transportation, written communication, August 2, 1994). The bridge is supported by vertical, concrete abutments on wooden piles driven to bedrock with no wingwalls. Each abutment wall has a spill-through slope protected with type-2 stone fill (less than 36 inches diameter). The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway is 15 degrees. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995).

Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 2.4 to 4.6 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 7.2 to 9.8 ft. The worst-case abutment scour also 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 others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Irasburg, VT. Quadrangle, 1:24,000, 1986
Aerial photography, 1981

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 IRASTH00010005 ***Stream*** Lords Creek

County Orleans ***Road*** TH 1 ***District*** 09

Description of Bridge

Bridge length 65 ***ft*** ***Bridge width*** 25.8 ***ft*** ***Max span length*** 61 ***ft***

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

Abutment type Spill-through ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 10/5/94

Description of stone fill Type-2, stone riprap placed on the spill-through embankments of the left and right abutments.

Abutments are concrete with stone fill and riprap embankments.

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

There is a mild channel bend in the upstream reach.

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	10/5/94	0	0
Level II	10/6/94	0	0

Potential for debris Low. While the channel is laterally unstable, there are very few trees along the immediate banks.

Describe any features near or at the bridge that may affect flow (include observation date) The left bank side at the channel bend immediately downstream is a location where ice frequently is lodged according to local residents. 10/6/94.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley setting with narrow, irregular flood plains and moderately sloping valley walls on both sides.

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

Date of inspection 10/5/94

DS left: Steep channel bank to a moderately sloped hillside.

DS right: Steep channel bank to a narrow, irregular flood plain and hillside.

US left: Steep bank to a narrow flood plain and hillside.

US right: Steep bank to a narrow, irregular flood plain and hillside.

Description of the Channel

Average top width 32 *ft* ***Average depth*** 3 *ft*

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

Perennial, meandering, and wider at bends with narrow point bars and alluvial channel boundaries

10/5/94

Vegetative co Pasture grass

DS left: Pasture grass and brush

DS right: Pasture grass

US left: Pasture grass and brush

US right: N

Do banks appear stable? ***If not, describe location and type of instability and date of observation.*** On 10/5/94 there was a cut-bank evident on the upstream left bank, a point bar on the downstream right bank side, and a channel scour hole along the downstream left bank, which are indicative of a laterally unstable reach.

None evident on 10/5/94.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 15.1 ***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:*** None.

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

USGS gage description -

USGS gage number -

Gage drainage area - ***mi²***

Is there a lake/p - No

-

Calculated Discharges

Q100 1,600 ***ft³/s*** ***Q500*** 2,280 ***ft³/s***

The 100-year discharge is based on a drainage area relationship [(15.1/15.8)exp 0.67] with bridge number 123 in Irasburg and several empirical relationships (Potter, 1957b; Johnson and Tasker, 1974; Benson, 1962; Talbot, 1887; and FHWA, 1983). Bridge number 123 crosses Lords Creek downstream of this site with a drainage area of 15.8 square miles and has flood frequency estimates available from the VTAOT database (Written communication, May 4, 1995). The 500-year discharge was derived from extrapolations of the empirical flood frequency curves.

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 Subtract 7 feet from the USGS survey to obtain VTAOT plans' datum to the nearest foot.

Description of reference marks used to determine USGS datum. RM1 is the center point of a chiseled "X" in a square on top of the concrete curb at the upstream left corner of the bridge deck (elev. 508.58 ft, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the concrete curb at the DS right corner of the bridge deck (elev. 507.58 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-92	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	89	1	Approach section

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

Data and Assumptions Used in WSPRO Model

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

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

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0026 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1986).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 508.0 *ft*
Average low steel elevation 503.9 *ft*

100-year discharge 1,600 *ft³/s*
Water-surface elevation in bridge opening 501.7 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 241 *ft²*
Average velocity in bridge opening 6.6 *ft/s*
Maximum WSPRO tube velocity at bridge 8.8 *ft/s*

Water-surface elevation at Approach section with bridge 502.6 *ft*
Water-surface elevation at Approach section without bridge 502.2 *ft*
Amount of backwater caused by bridge 0.4 *ft*

500-year discharge 2,280 *ft³/s*
Water-surface elevation in bridge opening 502.4 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 277 *ft²*
Average velocity in bridge opening 8.2 *ft/s*
Maximum WSPRO tube velocity at bridge 11.0 *ft/s*

Water-surface elevation at Approach section with bridge 503.9 *ft*
Water-surface elevation at Approach section without bridge 503.3 *ft*
Amount of backwater caused by bridge 0.6 *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 - *ft*
Water-surface elevation at Approach section without bridge - *ft*
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 others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

For this site, the channel composite sieve analyses resulted in a bed-material median diameter of 0.0033 ft., while the pebble count analysis result was 0.153 ft. Field inspection notes indicate the coarser bed material was detected about one foot beneath the silt/clay layer in the bridge section. The difference in median diameter gives conflicting indications of live-bed and clear-water contraction scour conditions as the governing process during the 100- and 500-year discharges.

Contraction scour depths were computed by use of the live-bed and clear-water scour equations applying the fine bed-material median diameter (Richardson and others, 1995, p. 30, equation 17 and p. 32, equation 20). Since large bed-material also is present, the smaller of the computed contraction scour results for each discharge were selected as recommended (Richardson and others, 1995, p. 31) Hence, results from the live-bed contraction scour equation are shown.

For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. Abutment scour for the 100- and 500-year discharges were computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping. The embankment lengths and scour elevations were measured from the toe of the riprap slope on each abutment (Written communication, D. Mueller, 12/8/94).

The length to depth ratio of the embankment blocking flow exceeded 25 for the 100-year discharge at both abutments. Although the HIRE equation (Richardson and others, 1995, p. 49, equation 29) generally is applicable when this ratio exceeds 25, the results from the HIRE equation were not used. Hydraulic Engineering Circular 18 recommends that the field conditions are similar to those from which the HIRE equation was derived (Richardson and others, 1995). Since the equation was developed from Army Corp. of Engineers' data obtained for spurs dikes in the Mississippi River, the HIRE equation was not adopted for the narrow upland valley at this site.

Data collected from VTAOT indicate that the bridge abutments are founded on piles that penetrate the local bedrock (Appendix D, E); this may limit the actual amount of total scour that can occur at this site.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	2.4	4.6	--
Clear-water scour	--	--	--
Depth to armoring	N/A	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
Abutment scour			
Left abutment	7.2	8.7	--
Right abutment	7.5	9.8	--
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	0.8	1.5	--
Right abutment	0.8	1.5	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

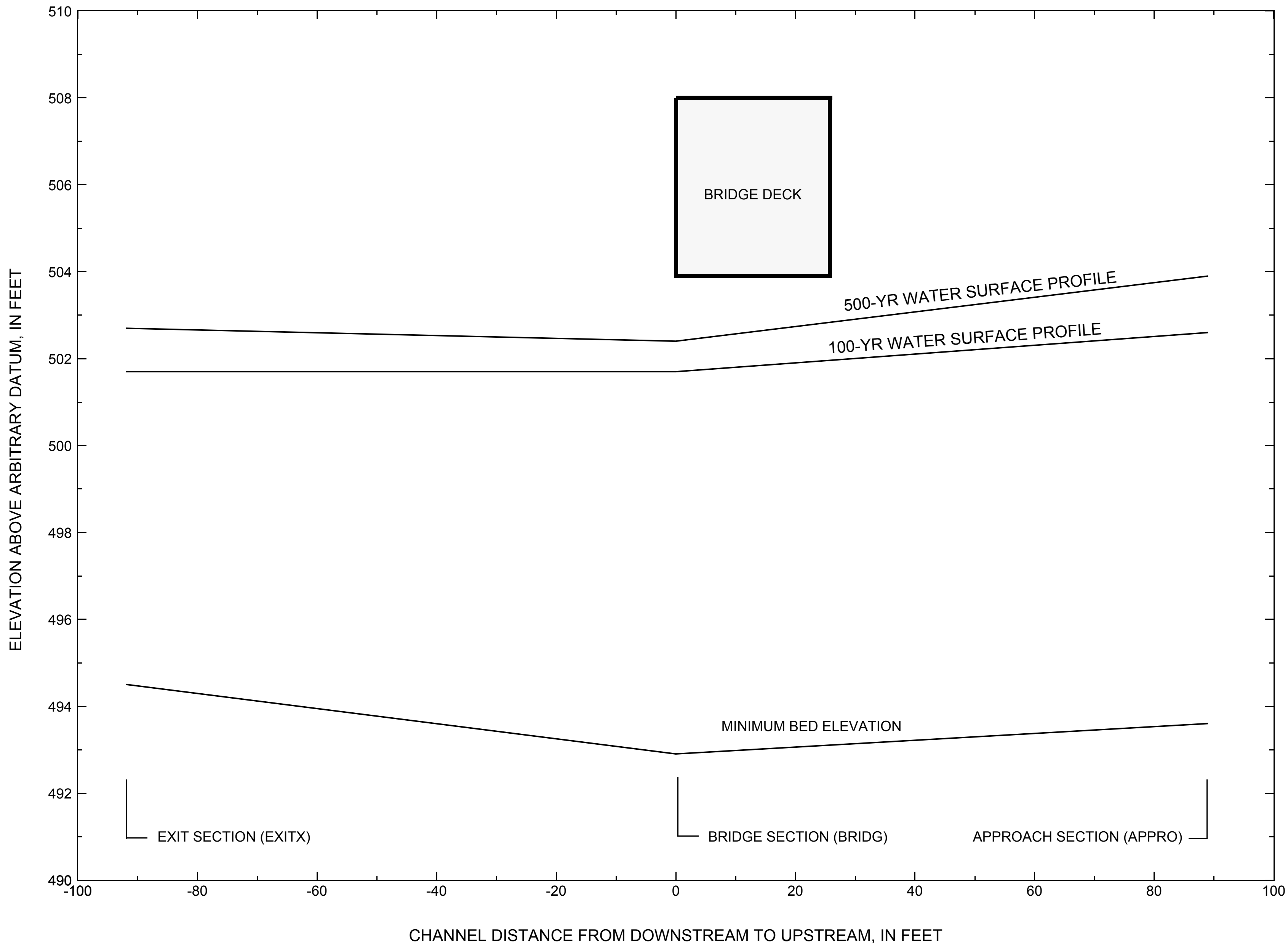


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure IRASTH00010005 on town highway 1, crossing Lords Creek, Irasburg, Vermont.

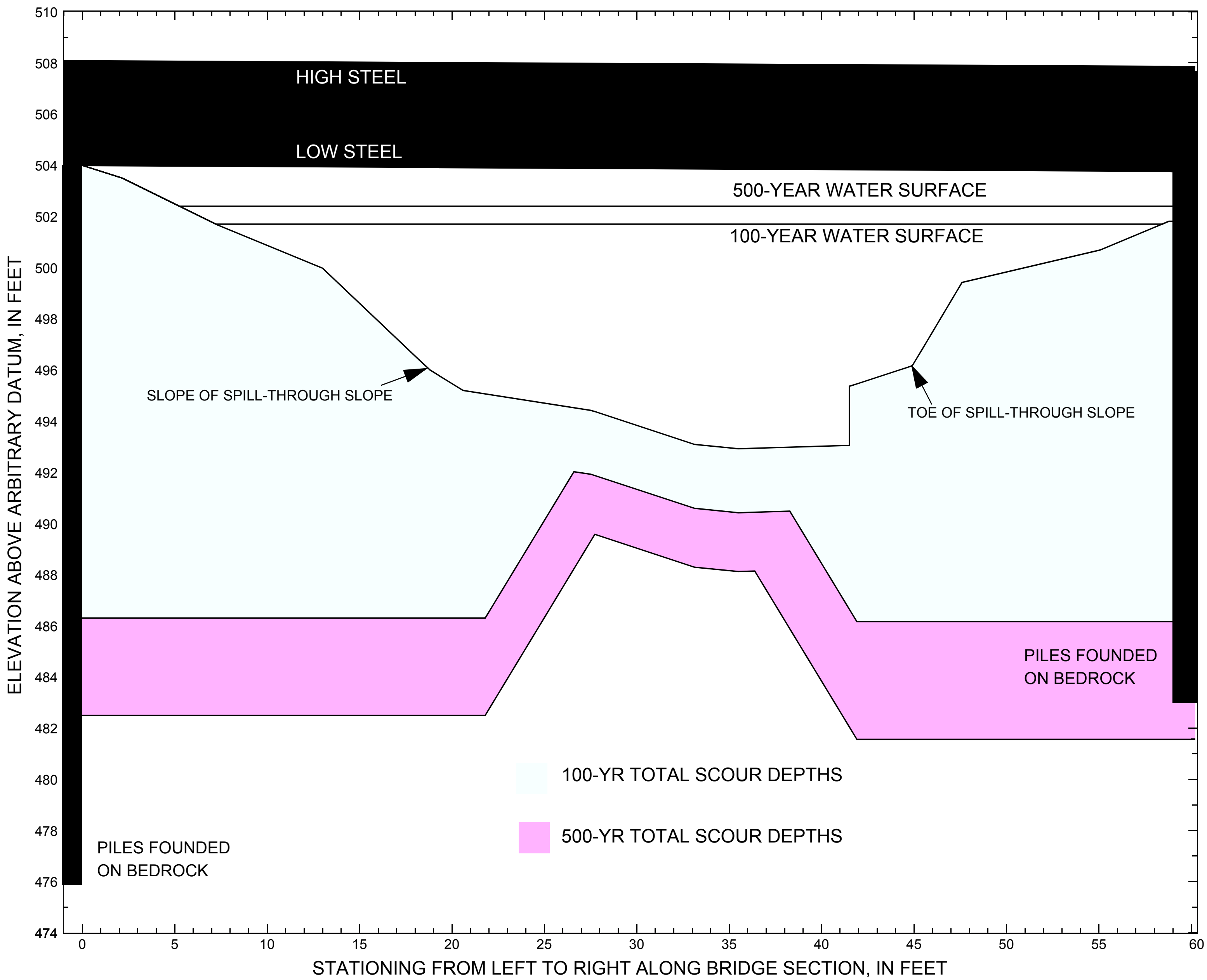


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure IRASTH00010005 on town highway 1, crossing Lords Creek, Irasburg, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure IRASTH00010005 on Town Highway 1, crossing Lords Creek, Irasburg, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT plans' bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,600 cubic-feet per second											
Left abutment	0.0	497.6	504.3	476	501.7	--	--	--	--	--	--
Left abutment toe	18.8	--	--	--	496.0	2.4	7.2	--	9.6	486.4	10
Right abutment toe	44.9	--	--	--	496.2	2.4	7.5	--	9.9	486.3	3
Right abutment	59.3	496.7	503.5	483	501.8	--	--	--	--	--	--

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 IRASTH00010005 on Town Highway 1, crossing Lords Creek, Irasburg, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT plans' bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,280 cubic-feet per second											
Left abutment	0.0	497.6	504.3	476	501.7	--	--	--	--	--	--
Left abutment toe	18.8	--	--	--	496.0	4.6	8.7	--	13.3	482.7	7
Right abutment toe	44.9				496.2	4.6	9.8	--	14.4	481.8	-1
Right abutment	59.3	496.7	503.5	483	501.8	--	--	--	--	--	--

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

SELECTED REFERENCES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

U.S. Geological Survey, 1986, Irasburg, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; aerial photographs, 1981; contour interval, 6 meters; scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File iras005.wsp
T2        Hydraulic analysis for structure IRASTH00010005   Date: 07-MAR-96
T3        Town Highway 1 Bridge Crossing Lords Creek, Irasburg, VT           EMB
Q           1600.0   2280.0
SK          0.0026   0.0026
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -92           0.
GR          -95.0, 521.00    -84.9, 518.88    -44.9, 509.86    -21.9, 503.07
GR          -13.1, 500.91     -3.1, 497.49      0.0, 496.08      0.8, 495.30
GR            4.9, 494.48     14.7, 495.24     27.0, 495.53     27.7, 496.18
GR           29.7, 497.96     32.2, 498.80     39.5, 498.82     44.4, 500.23
GR           50.6, 501.17     74.9, 500.21     86.9, 506.29    104.6, 506.90
GR          145.4, 507.32    258.2, 509.49
*
N           0.035        0.040
SA                44.4
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    503.86      15.0
GR            0.0, 504.26      7.3, 501.67     13.0, 499.97     18.8, 496.00
GR           20.6, 495.20     27.5, 494.42     33.1, 493.09     35.5, 492.92
GR           41.5, 493.05     41.5, 495.36     44.9, 496.16     47.6, 499.42
GR           55.1, 500.69     58.8, 501.81     59.3, 503.47      0.0, 504.26
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD           3      29.7      1.8    506.4
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     15      25.8     1
GR         -180.2, 512.39   -141.7, 511.97    -66.7, 509.96      0.0, 508.17
GR           30.9, 507.77     60.4, 507.24     96.7, 506.99    175.1, 507.37
GR          175.8, 507.32    288.6, 509.49
*
AS   APPRO     89           0.
GR         -167.8, 512.39   -130.8, 511.97    -75.0, 510.38    -48.1, 503.41
GR          -32.8, 501.38      0.0, 500.52      5.3, 500.05      7.5, 497.59
GR           10.0, 496.12     11.6, 494.11     12.9, 493.60     18.9, 494.48
GR           25.1, 495.20     30.1, 495.53     31.7, 496.01     37.1, 498.98
GR           45.4, 499.72     73.8, 499.87    104.6, 500.47    183.2, 511.83
GR          232.9, 515.72
BP          9.65
*
N           0.040        0.035        0.040
SA                   5.3          45.4
*
HP 1 BRIDG   501.74 1 501.74
HP 2 BRIDG   501.74 * * 1600
HP 1 APPRO   502.57 1 502.57
HP 2 APPRO   502.57 * * 1600
*
HP 1 BRIDG   502.45 1 502.45
HP 2 BRIDG   502.45 * * 2280
HP 1 APPRO   503.92 1 503.92
HP 2 APPRO   503.92 * * 2280
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      *** RUN DATE & TIME: 03-11-96  15:55

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      241     23796     50     56                          3012
   501.74           241     23796     50     56  1.00      7     59      3012

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.74     7.1    58.6   241.1   23796.    1600.   6.64

 X STA.         7.1       18.1       20.5       22.4       24.0       25.5
  A(I)             22.3       14.0       11.8       10.9       10.3
  V(I)             3.59       5.71       6.80       7.33       7.75

 X STA.        25.5       27.0       28.3       29.6       30.8       32.0
  A(I)              9.9        9.7        9.5        9.4        9.1
  V(I)             8.04       8.21       8.44       8.54       8.79

 X STA.        32.0       33.1       34.2       35.3       36.4       37.6
  A(I)              9.2        9.1        9.5        9.4       10.1
  V(I)             8.68       8.78       8.46       8.49       7.96

 X STA.        37.6       38.8       40.1       42.2       44.8       58.6
  A(I)             10.4       11.0       15.5       14.8       25.0
  V(I)             7.68       7.26       5.16       5.39       3.19
1
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       71      3439     47     47                           490
             2      246     33152     40     44                          3456
             3      168     10820     74     74                          1439
   502.57           485     47411    161    165  1.44    -41    119      3971
1
    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.57   -41.8   119.1   484.5   47411.    1600.   3.30

 X STA.       -41.8       -3.1        8.7       11.7       13.5       15.1
  A(I)             52.3       32.9       20.6       15.6       14.5
  V(I)             1.53       2.43       3.89       5.13       5.52

 X STA.        15.1       16.8       18.6       20.4       22.3       24.3
  A(I)             14.7       14.5       14.7       14.7       15.2
  V(I)             5.45       5.53       5.45       5.45       5.27

 X STA.        24.3       26.4       28.7       31.0       34.3       41.1
  A(I)             15.5       16.2       16.6       19.7       26.0
  V(I)             5.16       4.95       4.83       4.06       3.08

 X STA.        41.1       51.9       63.6       76.1       90.6      119.1
  A(I)             31.4       32.5       34.1       36.5       46.5
  V(I)             2.55       2.47       2.35       2.19       1.72
1
```

WSPRO OUTPUT FILE (continued)

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      277     29028     52     59                         3631
   502.45           277     29028     52     59  1.00      5     59     3631

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.45     5.1    59.0   277.3   29028.    2280.   8.22

 X STA.         5.1       17.3       20.0       22.0       23.7       25.3
   A(I)             26.0       16.6       14.0       12.7       12.0
   V(I)             4.39       6.89       8.14       9.00       9.52

 X STA.        25.3       26.9       28.3       29.7       30.9       32.2
   A(I)             11.5       11.3       10.9       10.8       10.5
   V(I)             9.89      10.11      10.41      10.56      10.87

 X STA.        32.2       33.3       34.5       35.6       36.8       38.1
   A(I)             10.6       10.4       10.8       10.9       11.5
   V(I)            10.80      10.97      10.58      10.43       9.93

 X STA.        38.1       39.4       40.8       43.2       46.2       59.0
   A(I)             11.9       12.6       18.2       17.3       26.9
   V(I)             9.59       9.07       6.27       6.58       4.23
1
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      141      9712     55     56                         1270
             2      300     46186     40     44                         4658
             3      274     22546     83     83                         2821
   503.92           714     78444    179    183  1.37    -49    128     6934

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      89.

         WSEL     LEW     REW    AREA        K        Q    VEL
       503.92   -50.1   128.5   714.4   78444.    2280.   3.19

 X STA.       -50.1      -17.4       -1.1        8.7       12.1       14.3
   A(I)             66.1       51.4       42.5       28.5       22.1
   V(I)             1.72       2.22       2.68       4.00       5.15

 X STA.        14.3       16.4       18.7       21.0       23.4       26.0
   A(I)             21.4       21.6       21.9       21.8       22.5
   V(I)             5.32       5.27       5.21       5.22       5.06

 X STA.        26.0       28.7       31.5       35.9       43.3       52.7
   A(I)             23.1       23.8       29.4       35.5       39.5
   V(I)             4.94       4.79       3.88       3.22       2.89

 X STA.        52.7       63.2       73.6       85.1       98.0      128.5
   A(I)             43.2       42.4       45.5       48.0       64.2
   V(I)             2.64       2.69       2.50       2.38       1.78
1
   *
   EX
```

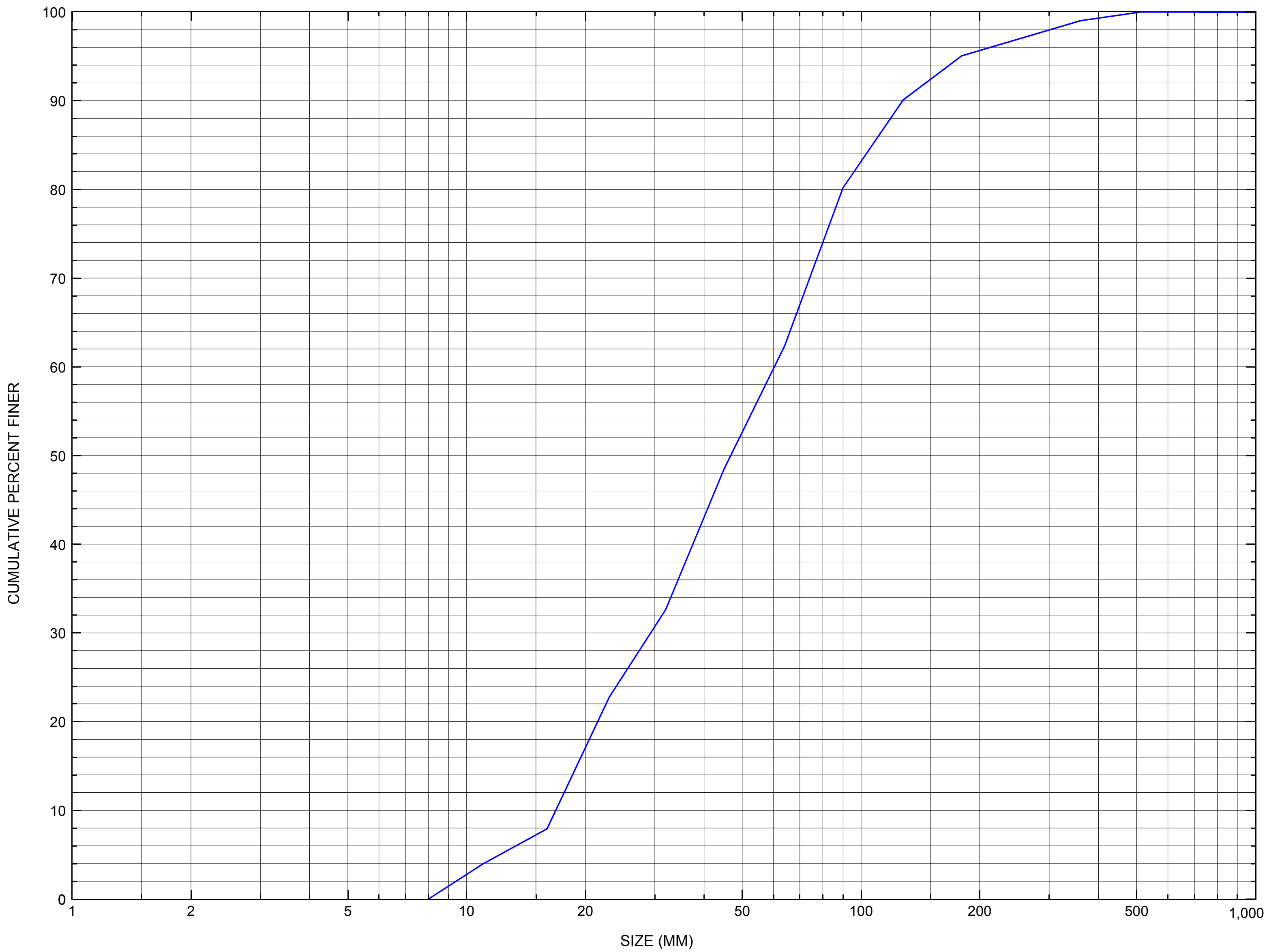
WSPRO OUTPUT FILE (continued)

```
+++ BEGINNING PROFILE CALCULATIONS --   2

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

EXITX:XS   ******    -15      302  0.49 *****  502.15  499.75    1600  501.66
       -91 ******     78    31367  1.12 ***** *******    0.55    5.31

FULLV:FV       92    -16      330  0.41  0.21  502.37 *******    1600  501.96
         0     92     78    35039  1.13  0.00    0.01    0.49    4.85
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       89    -38      428  0.32  0.16  502.53 *******    1600  502.21
        89     89    117    40695  1.46  0.00    0.00    0.48    3.74
         <<<<<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       92      7      241  0.76  0.32  502.50  499.18    1600  501.74
         0     92     59    23795  1.11  0.04    0.00    0.56    6.64

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.947 ******  503.86 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<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       59    -41      484  0.25  0.15  502.81  500.64    1600  502.57
        89     65    119    47383  1.44  0.17    0.01    0.40    3.30

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.664  0.259   35042.    -1.    50.   502.50

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -92.   -16.    78.   1600.   31367.     302.    5.31  501.66
   FULLV:FV       0.   -17.    78.   1600.   35039.     330.    4.85  501.96
   BRIDG:BR       0.     7.    59.   1600.   23795.     241.    6.64  501.74
   RDWAY:RG      15.**************      0.******************    1.00********
   APPRO:AS      89.   -42.   119.   1600.   47383.     484.    3.30  502.57

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    50.   35042.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    499.75    0.55  494.48  521.00************  0.49  502.15  501.66
   FULLV:FV  ********    0.49  494.48  521.00  0.21  0.00  0.41  502.37  501.96
   BRIDG:BR    499.18    0.56  492.92  504.26  0.32  0.04  0.76  502.50  501.74
   RDWAY:RG ****************  506.99  512.39**********************************
   APPRO:AS    500.64    0.40  493.60  515.72  0.15  0.17  0.25  502.81  502.57
```

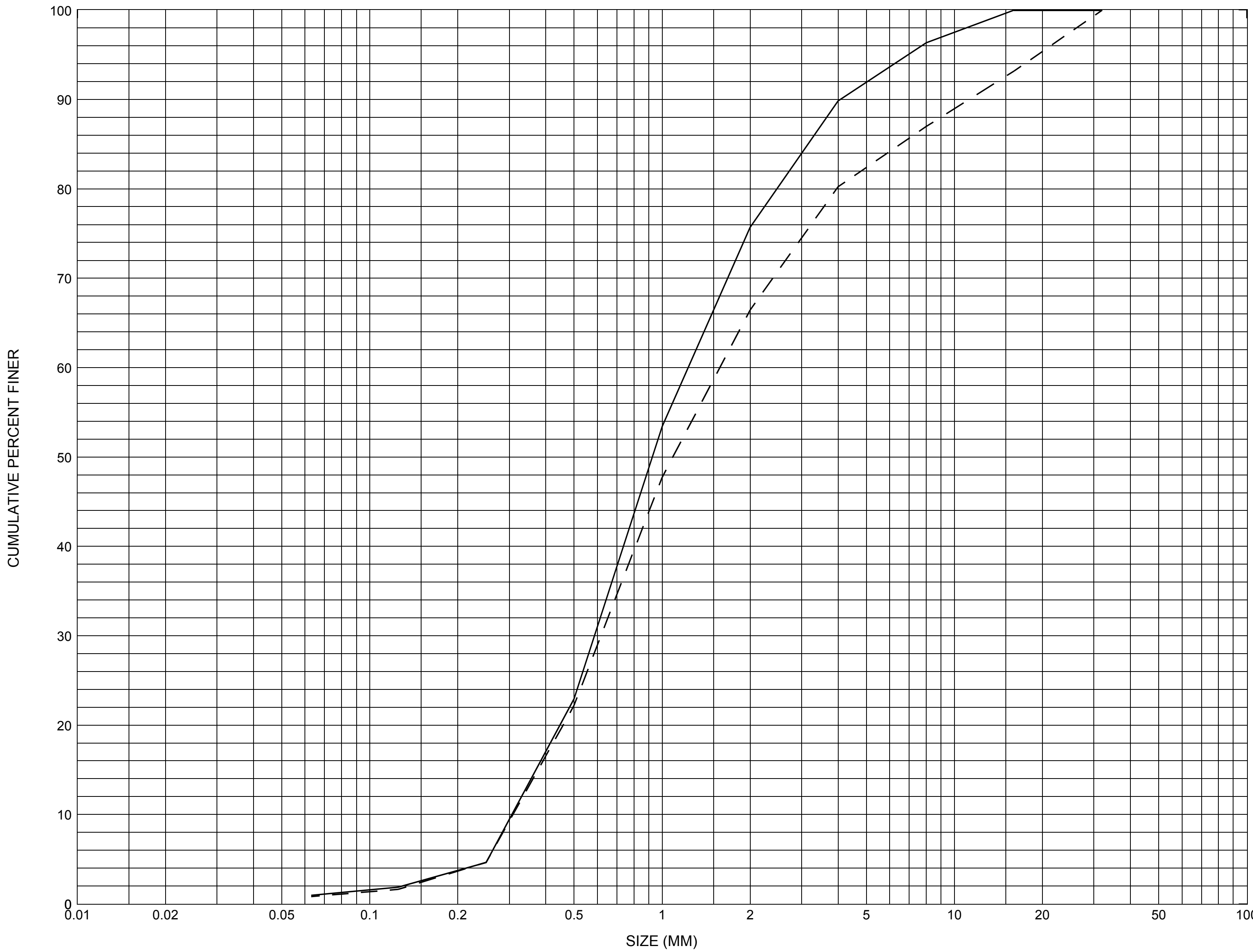
```
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******    -19      398  0.58 *****  503.24  500.71    2280  502.66
       -91 ******     80    44683  1.13 ***** *******    0.54    5.72

FULLV:FV       92    -20      429  0.49  0.22  503.46 *******    2280  502.96
         0     92     80    49275  1.13  0.00    0.01    0.48    5.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       89    -46      604  0.31  0.15  503.60 *******    2280  503.29
        89     89    124    62758  1.41  0.00   -0.01    0.42    3.78
         <<<<<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       92      5      277  1.34  0.37  503.79  500.64    2280  502.45
         0     92     59    29026  1.27  0.18   -0.01    0.71    8.22

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.887 ******  503.86 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<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       59    -49      715  0.22  0.15  504.14  501.47    2280  503.92
        89     65    128    78501  1.37  0.21    0.02    0.33    3.19

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.676  0.348   50888.    -2.    52.   503.87

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -92.   -20.    80.   2280.   44683.     398.    5.72  502.66
   FULLV:FV       0.   -21.    80.   2280.   49275.     429.    5.31  502.96
   BRIDG:BR       0.     5.    59.   2280.   29026.     277.    8.22  502.45
   RDWAY:RG      15.**************      0.******************    1.00********
   APPRO:AS      89.   -50.   128.   2280.   78501.     715.    3.19  503.92

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    52.   50888.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    500.71    0.54  494.48  521.00************  0.58  503.24  502.66
   FULLV:FV  ********    0.48  494.48  521.00  0.22  0.00  0.49  503.46  502.96
   BRIDG:BR    500.64    0.71  492.92  504.26  0.37  0.18  1.34  503.79  502.45
   RDWAY:RG  ****************  506.99  512.39**********************************
   APPRO:AS    501.47    0.33  493.60  515.72  0.15  0.21  0.22  504.14  503.92
  ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one pebble count transect at the approach cross-section for structure IRASTH00010005, in Irasburg, Vermont.



Appendix C. Bed material particle-size distribution for two composite channel sample transects at the approach cross-section for structure IRASTH00010005, in Irasburg, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number IRASTH00010005

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 02 / 94

Highway District Number *(I - 2; nn)* 09

County *(FIPS county code; I - 3; nnn)* 019

Town *(FIPS place code; I - 4; nnnnn)* 35575

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

Waterway *(I - 6)* Lords Creek

Road Name *(I - 7):* -

Route Number TH001

Vicinity *(I - 9)* 1.1 MI TO JCT W CL2 TH4

Topographic Map Irasburg

Hydrologic Unit Code: 01110000

Latitude *(I - 16; nnnn.n)* 44470

Longitude *(i - 17; nnnnn.n)* 72172

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10101100051011

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

Maximum span length *(I - 48; nnnn)* 0061

Year built *(I - 27; YYYY)* 1959

Structure length *(I - 49; nnnnnn)* 000065

Average daily traffic, ADT *(I - 29; nnnnnn)* 000370

Deck Width *(I - 52; nn.n)* 258

Year of ADT *(I - 30; YY)* 91

Channel & Protection *(I - 61; n)* 7

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

Waterway adequacy *(I - 71; n)* 8

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 009.6

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

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

Comments:

Structural inspection of 07/01/93 indicated that the left abutment may have rotated slightly, top towards the stream. There is a channel bend through the bridge. The road approach is straight and sags slightly at the bridge.

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: Mud and silt

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*) : Light Debris (*Heavy, Moderate, Light*): Light

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

07/01/93 ambient surface velocity noted as "slow."

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **15.13** mi^2 Lake and pond area **0.23** mi^2

Watershed storage *(ST)* **1.5** %

Bridge site elevation **869** ft Headwater elevation **1890** ft

Main channel length **8.88** mi

10% channel length elevation **876** ft 85% channel length elevation **1083** ft

Main channel slope *(S)* **31.08** 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? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **04** / **1958**

Project Number **SA 8 / 1957** Minimum channel bed elevation: **487.0**

Low superstructure elevation: USLAB **497.67** DSLAB **497.59** USRAB **496.74** DSRAB **496.66**

Benchmark location description:

BM#1 - spike in a 15 inch elm tree in a 15 inch elm tree almost 100 feet from the right abutment, off the right side of the road walking away from the bridge, elevation 500.0 feet.

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

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

If 1: Footing Thickness **-** Footing bottom elevation: **-**

If 2: Pile Type: **1** (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: **15.0***

If 3: Footing bottom elevation: **-**

Is boring information available? **Y** *If no, type ctrl-n bi* Number of borings taken: **2**

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

Briefly describe material at foundation bottom elevation or around piles:

Piles are driven to 1 to 2 feet depth into ledge. The boring nearest the left abutment hit ledge at elevation 471. The boring taken nearest the right abutment hit ledge at elevation 478.

Comments:

***Right abutment piles shown on plans driven about 15 feet while left abutment piles driven about 23 feet. The length of piles are: right 16 feet and left 24 feet. About 1 foot of the piles is within the footing base. The footing bottom elevations: left 492.5 and right 491.5. Piles may extend to elevations: 469.5 (left) and 476.5 (right); variability is possible at construction.**

Cross-sectional Data

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

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

Comments: **Upstream bridge face cross section.**

Station	0	1.0	6.0	20.0	31.04	2.0	52.5	60.0	61.0		
Feature	LCL	riprap	riprap	BLB		BRB	riprap	riprap	LCR		
Low cord elevation	497.5								496.5		
Bed elevation		495.6	495.6	487.0	487.0	487.0	495.6	495.6			
Low cord to bed length											

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

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

Comments: **Downstream bridge face cross section.**

Station	0	1.0	7.0	20.0	31.0	42.0	54.0	60.0	61.0		
Feature	LCL	riprap	riprap	BLB		BRB	riprap	riprap	LCR		
Low cord elevation	497.5								496.6		
Bed elevation		495.6	495.6	487.0	487.0	487.0	495.6	495.6			
Low cord to bed length											

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EMB** Date: **2/13/95**
Computerized by: **MAI** Date: **3/10/95**
Reviewd by: **EMB** Date: **4/16/96**

Structure Number **IRASTH00010005**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **D. SONG** Date *(MM/DD/YY)* **10** / **05** / 19**94**

2. Highway District Number **09** Mile marker **0**

County **ORLEANS (019)** Town **IRASBURG (35575)**

Waterway *(I - 6)* **LORDS CREEK** Road Name **-**

Route Number **TH001** Hydrologic Unit Code: **01110000**

3. Descriptive comments:

Structure is a steel stringer type bridge located about 1.1 miles south of TH 1 intersection with TH 4 and about 1.3 miles south from the intersection of TH 1 and VT 14.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **4** LBDS **4** 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 **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 **65** *(feet)* Span length **61** *(feet)* Bridge width **25.8** *(feet)*

Road approach to bridge:

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

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

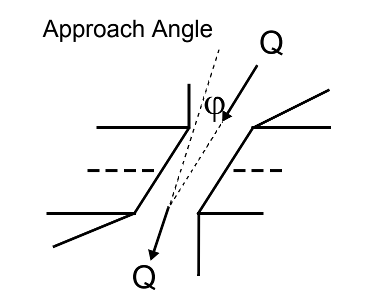
10. Embankment slope (*run / rise in feet / foot*):
US left **1.3:1** US right **2.3:1**

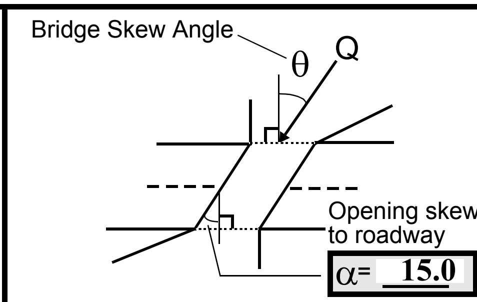
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **25**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **48** feet **US** *(US, UB, DS)* to **30** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **25** feet **DS** *(US, UB, DS)* to **50** feet **DS**

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

18. Level II Bridge Type: **3**

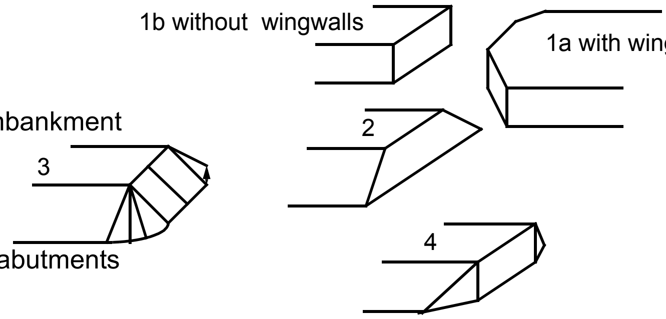
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. LBUS and RBUS surface cover is high grass and weeds. Banks downstream are cut pasture.
7. Measured bridge length: 63.5, span: 59.5, width: 26.0 feet.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
63.5	3.5			3.5	1	1	301	301	2	1

23. Bank width **40.0**   24. Channel width **25.0**   25. Thalweg depth **29.5**   29. Bed Material **243**

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.):

27. Silty clay, organics, some pebble/cobble.
28. Both banks slightly undermined under vegetation cover from fluvial erosion.
29. Gravel and cobble, surficial sand/silt (possibly from slumping bank); loosely packed (not armored). Drainage noted (very minor) 5 ft. US on right bank from culvert (1ft. diameter) road drainage. Culvert is about 100 ft. from stream on the US right floodplain

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

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

37. Material: **-**

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

NO POINT BARS

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: **40** 42. Cut bank extent: **30** feet **US** (US, UB) to **50** feet **US** (US, UB, DS)

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

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

Occurs at an upstream impact zone (not noted previously); steep banks.

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

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

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

NO CHANNEL SCOUR

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 **1** 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
18.5		**2.5**		**1**	**1**	**7**	**0**

58. Bank width (BF) **6.0** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **50.0** 63. Bed Material **0**

*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.):

4321

63. Silt and sandy surficial layer about 1 foot deep overlying gravel and cobble; bed returns to gravel/ cobble material about 150 ft. downstream.

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

70. Debris and Ice Comments:

2

67. No debris accumulation near the bridge, upstream is laterally stable, has few cut banks.
68. Moderate channel gradient, span length is between 50% and 80% of the upstream bank width.
69. Landowner on the downstream left bank has seen ice blocking; not limited to the bridge.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		-	90	2	0	-	-	90.0
RABUT	1	10	90			2	0	53.5

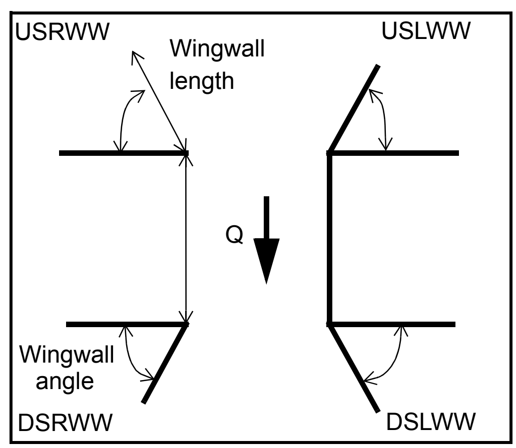
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1-* Concrete; *2-* Stone masonry or drywall; *3-* steel or metal; *4-* wood

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

-
-
1

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						49.0	
USRWW:	N		-		-	2.5	
DSLWW:	-		-		N	28.0	
DSRWW:	-		-		-	31.5	



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	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	2	2	0

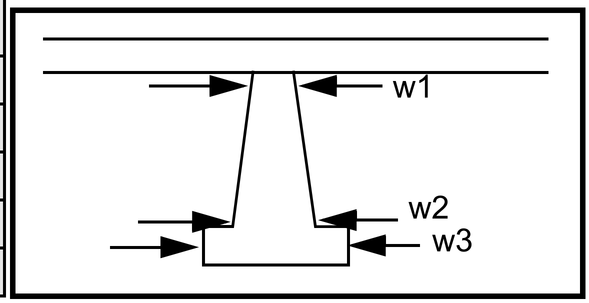
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

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



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
NO PIERS

1
1
1
1

101. Is a drop structure present? **1** *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

103. Drop: - feet 104. Structure material: **0** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
341
-
-
-
-
Bed material consist of a thicker surficial silt/clay layer about 2 feet than the upstream zone overlying cobble/

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

Point bar extent: rial. feet Ch (US, UB, DS) to anne feet l is (US, UB, DS) positioned wi %LB to der %RB

Material: wit

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

h less vegetation protection may have contributed to the bank material slumping.

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

Cut bank extent: _____ feet ____ (US, UB, DS) to _____ feet ____ (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.):

N

-

NO DROP STRUCTURE

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

Scour dimensions: Length ______ Width ______ Depth: _____ Positioned Y %LB to 115 %RB

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

7

100

DS

130

Are there major confluences? DS (Y or if N type ctrl-n mc) How many? 60

Confluence 1: Distance 90 Enters on 2 (LB or RB) Type Mat (**1**- perennial; **2**- ephemeral)

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

Confluence comments (eg. confluence name):

from silt to sand, more prominent at low flow(ambient) conditions.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N
-
-
-
-
-
-
-
NO CUT BANKS

109. G. Plan View Sketch

Y

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:	IRASTH00010005	Town:	Irasburg
Road Number:	TH 1	County:	Orleans
Stream:	Lords Creek		

Initials EMB   Date: 3/18/96   Checked: SAO   Date: 3/25/96

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	1600	2280	0
Main Channel Area, ft2	246	300	0
Left overbank area, ft2	71	141	0
Right overbank area, ft2	168	274	0
Top width main channel, ft	40.1	40.1	0
Top width L overbank, ft	47.1	55.4	0
Top width R overbank, ft	73.7	83.1	0
D50 of channel, ft	0.0033	0.0033	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	6.1	7.5	ERR
y1, average depth, LOB, ft	1.5	2.5	ERR
y1, average depth, ROB, ft	2.3	3.3	ERR
Total conveyance, approach	47411	78444	0
Conveyance, main channel	33152	46186	0
Conveyance, LOB	3439	9712	0
Conveyance, ROB	10820	22546	0
Percent discrepancy, conveyance	0	0	ERR
Qm, discharge, MC, cfs	1118.795	1342.411	ERR
Ql, discharge, LOB, cfs	116.0575	282.2824	ERR
Qr, discharge, ROB, cfs	365.1473	655.3067	ERR
Vm, mean velocity MC, ft/s	4.5	4.5	ERR
Vl, mean velocity, LOB, ft/s	1.6	2.0	ERR
Vr, mean velocity, ROB, ft/s	2.2	2.4	ERR
Vc-m, crit. velocity, MC, ft/s	2.3	2.3	N/A
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	N/A
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	N/A

Results

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

Main Channel	1	1	N/A

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(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	1600	2280	0	1600	2280	0
Total conveyance	47411	78444	0	23796	29028	0
Main channel conveyance	33152	46186	0	23796	29028	0
Main channel discharge	1119	1342	ERR	1600	2280	ERR
Area - main channel, ft2	246	300	0	241.1	277.3	0
(W1) channel width, ft	40.1	40.1	0	49.7	52.1	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	40.1	40.1	0	49.7	52.1	0
D50, ft	0.0033	0.0033	0.0033			
w, fall velocity, ft/s (p. 32)	0.444523	0.444523	0			
y1, ave. depth flow, ft	6.134663	7.481297	N/A	4.851107	5.322457	ERR
S1, slope EGL	0.0018	0.0016	0			
P, wetted perimeter, MC, ft	44	44	0			
R, hydraulic Radius, ft	5.590909	6.818182	ERR			
V*, shear velocity, ft/s	0.569253	0.592683	N/A			
V*/w	1.280592	1.3333	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	0.64	0.64	0			
y2,depth in contraction, ft	7.27	9.96	ERR			
ys, scour depth, ft (y2-y_bridge)	2.42	4.64	N/A			
ys, scour depth, ft (y2-y1)	1.13	2.48	N/A			

ARMORING			
D90	0.025	0.025	
D95	0.043	0.043	
Critical grain size,Dc, ft	0.0736	0.1104	ERR
Decimal-percent coarser than Dc	N/A	N/A	0
depth to armoring, ft	ERR	ERR	ERR

Clear Water Contraction Scour in MAIN CHANNEL

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

 Approach Section                      Q100     Q500    Qother

   Main channel Area, ft2            246      300      0
   Main channel width, ft            40.1     40.1     0
 y1, main channel depth, ft          6.134663 7.481297 ERR

 Bridge Section

   (Q) total discharge, cfs          1600     2280     0
   (Q) discharge thru bridge, cfs    1600     2280

   Main channel conveyance           23796    29028
   Total conveyance                  23796    29028
 Q2, bridge MC discharge,cfs         1600     2280     ERR
   Main channel area, ft2            241      277      0
   Main channel width (skewed), ft   49.7     52.1     0.0
   Cum. width of piers in MC, ft     0.0      0.0      0.0
 W, adjusted width, ft               49.7     52.1     0
 y_bridge (avg. depth at br.), ft    4.851107 5.322457 ERR
 Dm, median (1.25*D50), ft           0.004    0.004    0
 y2, depth in contraction,ft         11.75148 15.28898 ERR

 ys, scour depth (y2-ybridge), ft    6.90     9.97     N/A
 ys, scour depth (y2-y1), ft           5.62     7.81   N/A
```

Abutment Scour

Froehlich's Abutment Scour

$$Ys/Y1 = 2.27*K1*K2*(a'/Y1)^{0.43}*Fr1^{0.61}+1$$

(Richardson and others, 1995, p. 48, eq. 28)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1600	2280	0	1600	2280	0
a', abut.length blocking flow, ft	54.8	62	0	67.4	76.6	0
Ae, area of blocked flow ft2	117.1	186.8	0	150.2	246.7	0
Qe, discharge blocked abut.,cfs	297.8	449.3	0	321.5	579.7	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	2.543126	2.405246	ERR	2.140479	2.349818	ERR
ya, depth of f/p flow, ft	2.14	3.01	ERR	2.23	3.22	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0	0.55	0.55	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	75	75	0	105	105	0
K2	0.976577	0.976577	0	1.020242	1.020242	0
Fr, froude number f/p flow	0.31	0.24	ERR	0.25	0.23	ERR
ys, scour depth, ft	7.25	8.72	N/A	7.54	9.77	N/A

HIRE equation (a'/ya > 25)

$$ys = 4*Fr^{0.33}*y1*K/0.55$$

(Richardson and others, 1995, p. 49, eq. 29)

Characteristic	Left 100 yr Q	500 yr Q	Other Q	Right 100 yr Q	500 yr Q	Other Q
a'(abut length blocked, ft)	54.8	62	0	67.4	76.6	0
y1 (depth f/p flow, ft)	2.14	3.01	ERR	2.23	3.22	ERR
a'/y1	25.65	20.58	ERR	30.24	23.78	ERR
Skew correction (p. 49, fig. 16)	0.95	0.95	0.95	1.033	1.033	1.033
Froude no. f/p flow	0.31	0.24	N/A	0.25	0.23	N/A
Ys w/ corr. factor K1/0.55:						
vertical	9.99	ERR	ERR	10.63	ERR	ERR
vertical w/ ww's	8.20	ERR	ERR	8.72	ERR	ERR
spill-through	5.50	ERR	ERR	5.85	ERR	ERR

Abutment riprap Sizing

Isbash Relationship

$$D50=y*K*Fr^2/(Ss-1) \text{ and } D50=y*K*(Fr^2)^{0.14}/(Ss-1)$$

(Richardson and others, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.56	0.71		0.56	0.71	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	4.85	5.32		4.85	5.32	
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (spillthrough abut.)	0.82	1.45	0.00	0.82	1.45	0
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR