LEVEL II SCOUR ANALYSIS FOR BRIDGE 16 (RIPTTH00110016) on TOWN HIGHWAY 11, crossing the MIDDLE BRANCH MIDDLEBURY RIVER, RIPTON, VERMONT

Open-File Report 97-751

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

USGS

science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 16 (RIPTTH00110016) on TOWN HIGHWAY 11, crossing the MIDDLE BRANCH MIDDLEBURY RIVER, RIPTON, VERMONT

By RONDA L. BURNS

U.S. Geological Survey
Open-File Report 97-751

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

Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
Mark Schaefer, Acting Director

For additional information
write to:

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

Copies of this report may be
purchased from:

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

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 16 (RIPTTH00110016) ON TOWN HIGHWAY 11, CROSSING THE MIDDLE BRANCH MIDDLEBURY RIVER, RIPTON, VERMONT

By **Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure RIPTTH00110016 on Town Highway 11 crossing the Middle Branch Middlebury River, Ripton, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in west-central Vermont. The 6.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of shrubs, brush and trees except for the upstream left bank which is completely forested.

In the study area, the Middle Branch Middlebury River has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 68 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 97.6 mm (0.320 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 11, 1996, indicated that the reach was stable.

The Town Highway 11 crossing of the Middle Branch Middlebury River is a 44-ft-long, two-lane bridge consisting of one 42-foot steel-beam span (Vermont Agency of Transportation, written communication, December 15, 1995). The opening length of the structure parallel to the bridge face is 40.2 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening. The opening-skew-to-roadway value from the VTAOT database is 20 degrees while 30 degrees was computed from surveyed points.

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

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. 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 0.1 to 0.4 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 7.2 to 8.6 ft along the right abutment and from 11.7 to 13.7 ft along the left abutment. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number RIPTTH00110016 ***Stream*** Middle Branch Middlebury River

County Addison ***Road*** TH 11 ***District*** 5

Description of Bridge

Bridge length 44 ***ft*** ***Bridge width*** 19.8 ***ft*** ***Max span length*** 42 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 6/11/96

Description of stone fill Type-2, along the upstream end of the downstream left wingwall and along the upstream banks.

Abutments and wingwalls are concrete. There is a three foot deep scour hole in front of the upstream left wingwall and along the left abutment.

Yes

40 Yes

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

is a moderate channel bend in the upstream reach. The scour hole has developed in the location where the bend impacts the upstream left wingwall and left abutment.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	6/11/96	0	0
Level II	6/11/96	0	0

Potential for debris Moderate. There is some debris caught on the upstream right bank point bar. The channel is sinuous with many trees along the banks.

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

The point bar on the right bank extends under the bridge. It is well vegetated upstream and downstream of the bridge. The assessment of 6/11/96 noted that it causes the water to flow along the left side of the channel at lower flows.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley setting.

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

Date of inspection 6/11/96

DS left: Moderately sloped channel bank to Town Highway 14

DS right: Steep channel bank to a moderately sloped overbank

US left: Moderately sloped channel bank to a steep overbank

US right: Moderately sloped channel bank and overbank

Description of the Channel

Average top width 68 ***ft*** ***Average depth*** 5 ***ft***

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

Sinuous but stable with non-alluvial channel boundaries.

Vegetative co[ver] 6/11/96

Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: Trees and brush

US right:

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

Describe any obstructions in channel and date of observation. The assessment of 6/11/96 noted ambient flow conditions are influenced by a 1 ft high concrete drop structure at the downstream face of the bridge.

Hydrology

Drainage area 6.6 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/Green Mountain	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: -

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 1,400 ***ft³/s*** ***Q500*** 1,850 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(6.6/7.6)exp 0.6] with bridge number 12 in Ripton. Bridge number 12 crosses the North Branch Middlebury River and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 12 is 7.6 square miles. These values were selected due to the central tendency of the discharge frequency curve with others which were developed from empirical relationships and extended to the 500-year discharge (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 U.S. Department of Agriculture metal benchmark on top of the upstream end of the right abutment (elev. 499.82 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 500.50ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-31	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APPRO	62	2	Modelled Approach section (Templated from APTEM)
APTEM	80	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.056 to 0.065, and overbank "n" values were all 0.070.

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 0.0301 ft/ft, which was estimated from surveyed points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0182 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the 100-year and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.9 *ft*
Average low steel elevation 496.5 *ft*

100-year discharge 1,400 ft^3/s
Water-surface elevation in bridge opening 491.2 *ft*
Road overtopping? No *Discharge over road* - ft^3/s
Area of flow in bridge opening 128 ft^2
Average velocity in bridge opening 10.9 *ft/s*
Maximum WSPRO tube velocity at bridge 14.3 *t/s*

Water-surface elevation at Approach section with bridge 494.5
Water-surface elevation at Approach section without bridge 492.5
Amount of backwater caused by bridge 2.0

500-year discharge 1,850 ft^3/s
Water-surface elevation in bridge opening 491.9 *ft*
Road overtopping? No *Discharge over road* - $^3/s$
Area of flow in bridge opening 155 ft^2
Average velocity in bridge opening 12.0 *ft/s*
Maximum WSPRO tube velocity at bridge 15.4 *s*

Water-surface elevation at Approach section with bridge 495.6
Water-surface elevation at Approach section without bridge 493.2
Amount of backwater caused by bridge 2.4 *t*

Incipient overtopping discharge - ft^3/s
Water-surface elevation in bridge opening - *t*
Area of flow in bridge opening - ft^2
Average velocity in bridge opening - *ft/s*
Maximum WSPRO tube velocity at bridge - *ft/s*

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.1	0.4	--
Depth to armoring	15.5	20.1	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	11.7	13.7	--
Right abutment	7.2	8.6	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	1.5	1.9	--
Right abutment	1.5	1.9	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

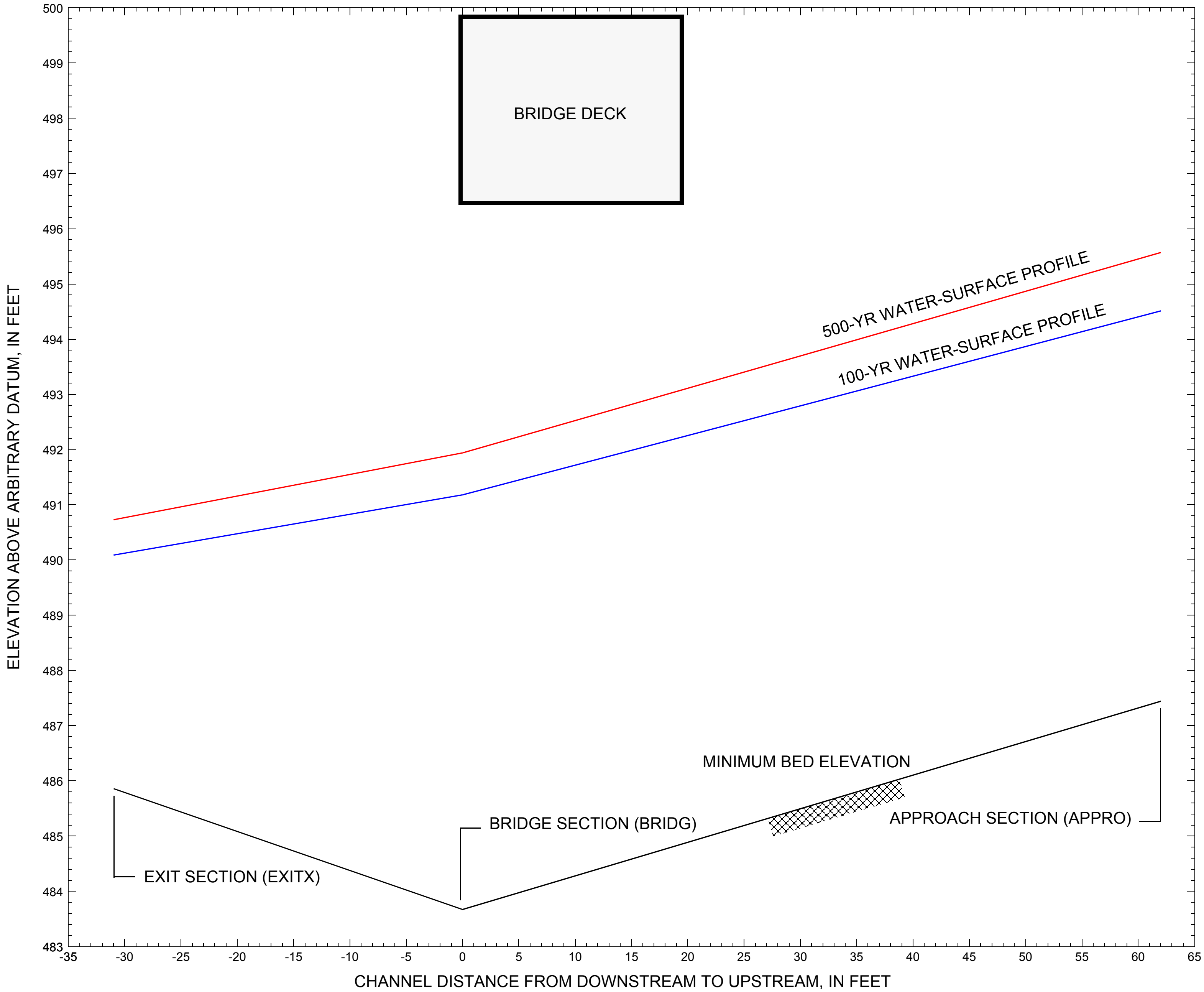


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RIPTTH00110016 on Town Highway 11, crossing the Middle Branch Middlebury River, Ripton, Vermont.

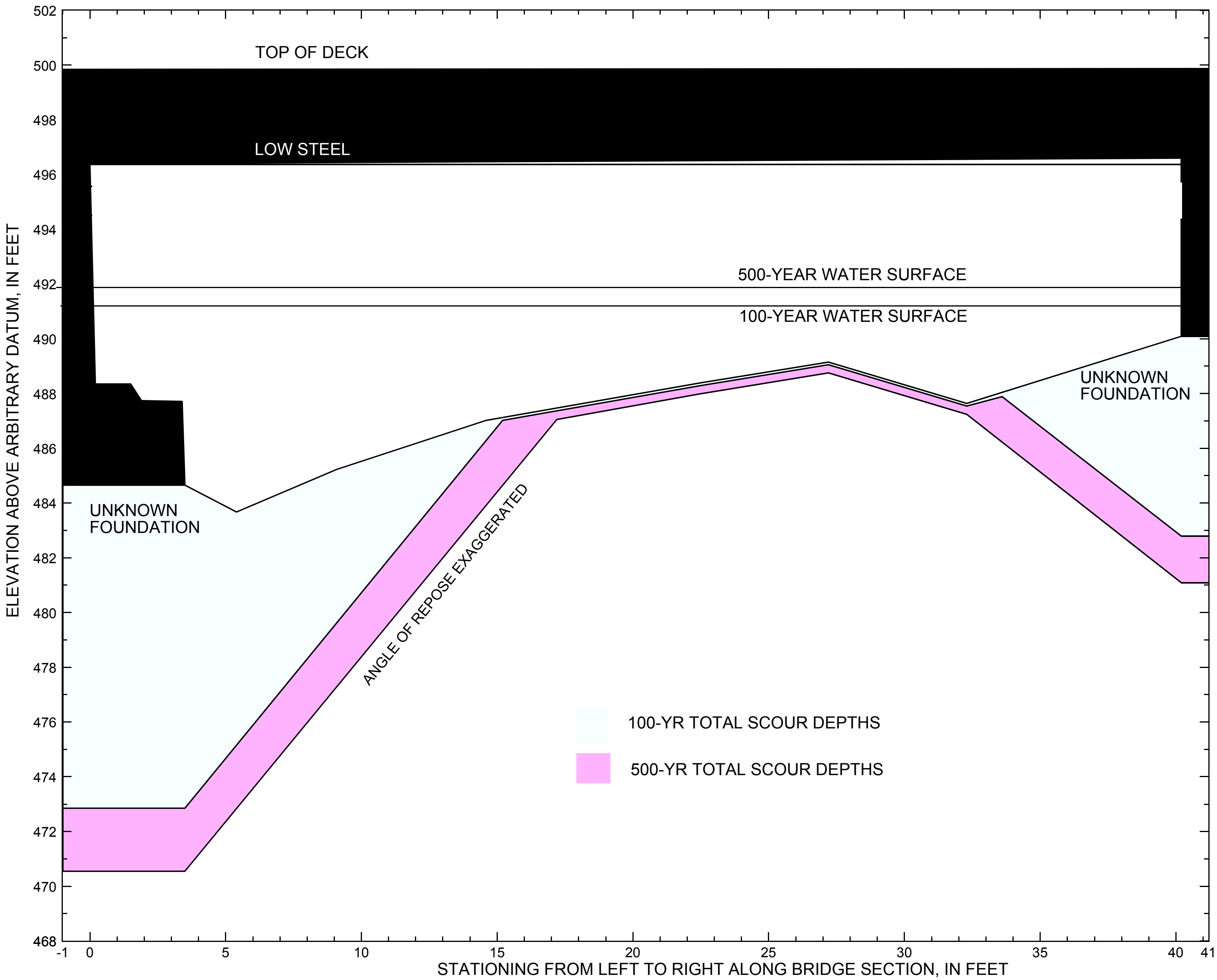


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RIPTTH00110016 on Town Highway 11, crossing the Middle Branch Middlebury River, Ripton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RIPTTH00110016 on Town Highway 11, crossing the Middle Branch Middlebury River, Ripton, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,400 cubic-feet per second											
Left abutment	0.0	--	496.4	--	484.7	0.1	11.7	--	11.8	472.9	--
Right abutment	40.2	--	496.6	--	490.1	0.1	7.2	--	7.3	482.8	--

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 RIPTTH00110016 on Town Highway 11, crossing the Middle Branch Middlebury River, Ripton, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 1,850 cubic-feet per second											
Left abutment	0.0	--	496.4	--	484.7	0.4	13.7	--	14.1	470.6	--
Right abutment	40.2	--	496.6	--	490.1	0.4	8.6	--	9.0	481.1	--

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

SELECTED REFERENCES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

U.S. Geological Survey, 1944, East Middlebury, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1972, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ript016.wsp
T2        Hydraulic analysis for structure RIPTTH00110016   Date: 30-JUN-97
T3        TH 11 CROSSING MIDDLE BRANCH MIDDLEBURY RIVER IN RIPTON, VT       RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1400.0   1850.0
SK          0.0301   0.0301
*
XS   EXITX    -31           0.
GR          -82.5, 500.08    -63.1, 495.15    -29.9, 494.68    -11.8, 492.94
GR            0.0, 487.49      3.1, 487.82      8.3, 486.65     14.8, 485.86
GR           22.2, 486.03     25.9, 486.18     31.8, 486.44     41.4, 486.38
GR           42.3, 487.36     50.1, 492.33    134.6, 495.65    160.1, 498.46
GR          174.9, 505.45
*
N           0.070        0.065        0.070
SA                 -11.8         50.1
*
XS   FULLV      0  * * *   0.0171
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    496.47      30.0
GR            0.0, 496.37      0.2, 488.35      1.5, 488.35      1.9, 487.74
GR            3.4, 487.71      3.5, 484.65      5.4, 483.67      9.1, 485.23
GR           14.6, 487.02     18.7, 487.70     22.5, 488.39     27.2, 489.15
GR           32.3, 487.64     34.6, 488.33     40.2, 490.09     40.2, 496.57
GR            0.0, 496.37
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL   WWWID
CD           1      33.9        *        *     58.8     5.2
N           0.056
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     14       19.8     1
GR         -209.1, 511.27   -185.1, 500.11   -151.2, 502.26   -101.3, 500.78
GR          -28.1, 499.59      0.0, 499.84      5.8, 499.73      6.0, 500.48
GR           49.2, 500.63     49.2, 499.79    106.7, 499.80
GR          209.9, 502.65    298.1, 508.52    444.1, 519.21
* GR           44.6, 499.87
*
XT   APTEM     80           0.
GR          -61.3, 505.36    -53.3, 500.64    -38.3, 494.21    -23.3, 493.48
GR          -18.4, 491.80      0.0, 489.44      0.7, 488.72      4.6, 488.36
GR           11.2, 487.98     16.0, 487.79     23.8, 487.77     24.8, 489.56
GR           46.1, 491.30     50.3, 493.72     70.6, 495.22    154.3, 499.13
GR          208.8, 502.92
*
AS   APPRO     62  * * *   0.0182
GT
N           0.070        0.065        0.070
SA                -23.3          50.3
*
HP 1 BRIDG  491.18 1 491.18
HP 2 BRIDG  491.18 * * 1400
HP 1 APPRO  494.51 1 494.51
HP 2 APPRO  494.51 * * 1400
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File ript016.wsp
       Hydraulic analysis for structure RIPTTH00110016   Date: 30-JUN-97
       TH 11 CROSSING MIDDLE BRANCH MIDDLEBURY RIVER IN RIPTON, VT       RLB
          *** RUN DATE & TIME: 07-17-97  13:32

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

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      128      7004    35     44                         1401
  491.18           128      7004    35     44  1.00      0     40     1401

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      491.18     0.1    40.2   128.4    7004.    1400.  10.90

X STA.         0.1        3.9        5.0        6.0        6.8        7.6
  A(I)            11.8        6.7        5.8        5.1        5.1
  V(I)            5.94      10.38      12.03      13.74      13.80

X STA.         7.6        8.6        9.5       10.5       11.6       12.8
  A(I)             5.0        4.9        4.9        5.0        5.1
  V(I)           14.04      14.30      14.23      13.93      13.64

X STA.        12.8       14.2       15.7       17.5       19.5       21.9
  A(I)             5.4        5.6        5.9        6.0        6.5
  V(I)           12.95      12.57      11.96      11.57      10.70

X STA.        21.9       25.2       29.3       31.9       34.4       40.2
  A(I)             7.5        8.1        6.7        7.2       10.0
  V(I)            9.35       8.59      10.48       9.77       6.99

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      62.

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1       15       310    16     17                           84
            2      359     23165    74     76                         4503
            3        8       122    15     15                           36
  494.51           383     23596   105    108  1.08    -39     65     3996

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      62.

        WSEL     LEW     REW    AREA        K        Q    VEL
      494.51   -39.8    65.4   383.0   23596.    1400.   3.66

X STA.       -39.8      -15.1       -9.4       -4.9       -1.1        2.0
  A(I)            36.8       22.0       20.2       18.9       17.7
  V(I)            1.90       3.19       3.46       3.70       3.95

X STA.         2.0        4.5        6.9        9.3       11.5       13.7
  A(I)            16.3       15.7       15.5       15.1       15.4
  V(I)            4.29       4.46       4.50       4.63       4.56

X STA.        13.7       15.8       18.0       20.1       22.3       25.1
  A(I)            15.0       15.1       15.3       15.1       18.7
  V(I)            4.68       4.65       4.59       4.62       3.74

X STA.        25.1       28.6       32.6       37.0       42.4       65.4
  A(I)            17.9       19.2       19.5       21.8       31.9
  V(I)            3.91       3.65       3.59       3.21       2.19
```

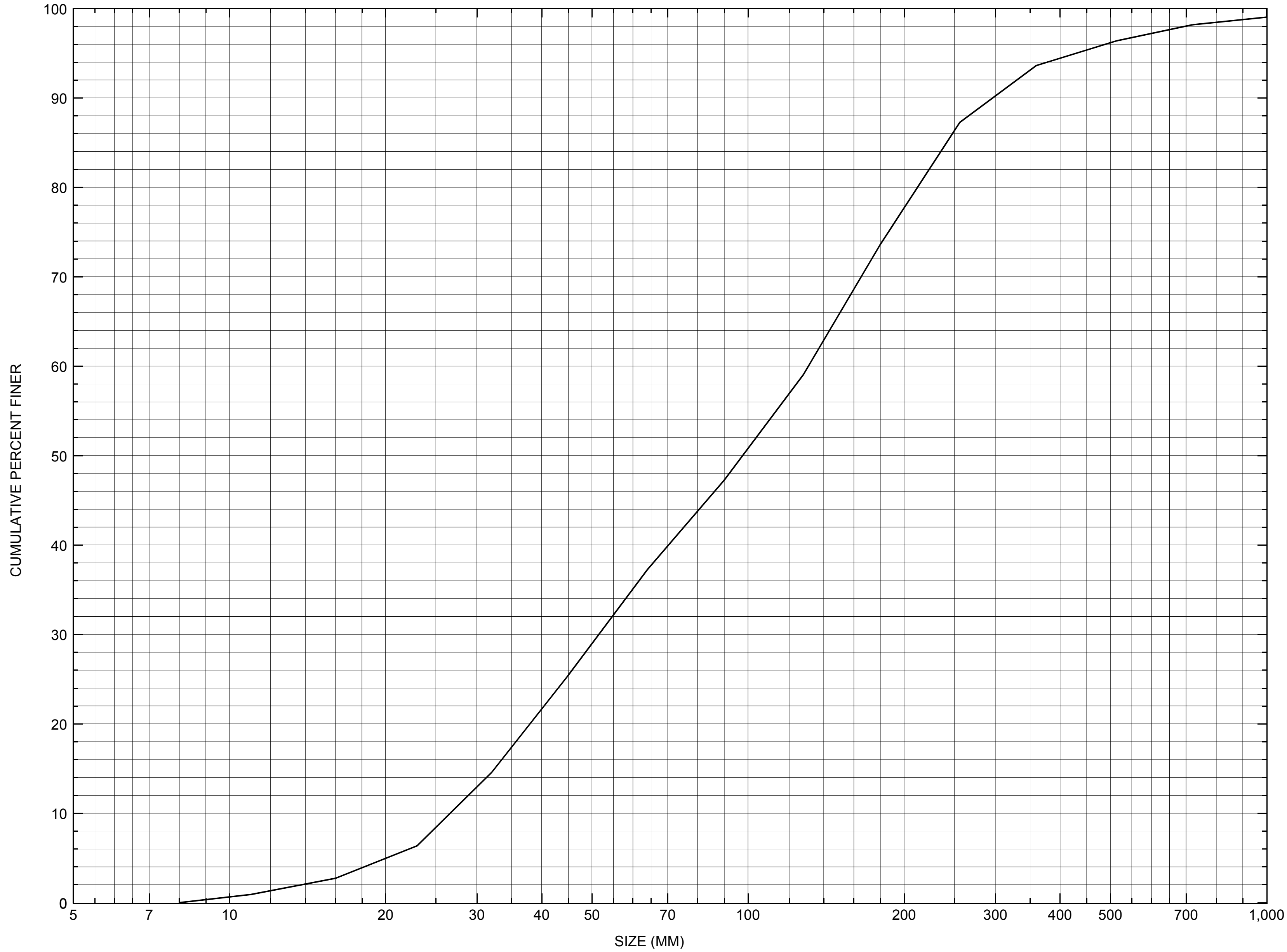
```
       U.S. Geological Survey WSPRO Input File ript016.wsp
       Hydraulic analysis for structure RIPTTH00110016   Date: 30-JUN-97
       TH 11 CROSSING MIDDLE BRANCH MIDDLEBURY RIVER IN RIPTON, VT       RLB
          *** RUN DATE & TIME: 07-17-97  13:32

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      155      9348     35     45                          1854
  491.94           155      9348     35     45  1.00      0     40      1854

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      491.94     0.1    40.2   154.8    9348.    1850.  11.95

X STA.        0.1        4.0        5.2        6.2        7.2        8.2
  A(I)           14.5        8.3        7.0        6.6        6.3
  V(I)           6.37      11.18      13.12      14.10      14.73

X STA.        8.2        9.2       10.3       11.4       12.6       14.0
  A(I)            6.0        6.1        6.1        6.1        6.4
  V(I)          15.36      15.16      15.10      15.06      14.35

X STA.       14.0       15.6       17.3       19.1       21.3       23.9
  A(I)            6.6        6.6        7.0        7.4        8.0
  V(I)          13.95      13.91      13.21      12.51      11.51

X STA.       23.9       27.2       30.2       32.4       35.0       40.2
  A(I)            8.7        8.5        7.7        8.5       12.1
  V(I)          10.62      10.88      11.94      10.86       7.67

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      62.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       34      1061     19     19                           260
            2      437     32143     74     76                          6047
            3       34       708     35     35                           190
  495.57           505     33912    127    130  1.15    -41     85      5335

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      62.

        WSEL     LEW     REW    AREA        K        Q    VEL
      495.57   -42.2    85.1   505.2   33912.    1850.   3.66

X STA.      -42.2      -18.9      -12.6       -7.5       -3.4        0.3
  A(I)           48.0       28.1       26.4       23.7       23.2
  V(I)           1.93       3.29       3.51       3.91       3.98

X STA.        0.3        3.3        6.0        8.6       11.1       13.5
  A(I)           21.7       19.8       20.1       19.8       19.5
  V(I)           4.26       4.66       4.61       4.67       4.74

X STA.       13.5       15.9       18.3       20.8       23.2       26.7
  A(I)           19.3       19.4       19.7       19.5       24.4
  V(I)           4.79       4.76       4.70       4.73       3.79

X STA.       26.7       30.6       34.8       39.5       44.8       85.1
  A(I)           23.2       24.1       24.8       26.5       53.9
  V(I)           3.98       3.83       3.72       3.49       1.71
```

```
       U.S. Geological Survey WSPRO Input File ript016.wsp
       Hydraulic analysis for structure RIPTTH00110016   Date: 30-JUN-97
       TH 11 CROSSING MIDDLE BRANCH MIDDLEBURY RIVER IN RIPTON, VT       RLB
          *** RUN DATE & TIME: 07-17-97  13:32

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

EXITX:XS   ******     -5      167  1.10 *****  491.19  489.70    1400  490.09
       -30 ******     47     8068  1.00 ***** *******    0.83    8.40

FULLV:FV       31     -6      192  0.83  0.75  491.93 *******    1400  491.10
         0     31     47     9989  1.00  0.00   -0.02    0.68    7.29
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       62    -20      211  0.68  1.23  493.16 *******    1400  492.48
        62     62     49     9906  1.00  0.00    0.01    0.67    6.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1400.     491.18

            <<<<<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       31      0      128  1.85 *****  493.03  491.18    1400  491.18
         0     31     40     7008  1.00 ***** *******    1.00   10.90

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.47 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS       28    -39      383  0.22  0.35  494.73  491.73    1400  494.51
        62     30     65    23581  1.08  1.35    0.00    0.35    3.66

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.428  0.270   17202.     2.    42.   494.36

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -31.    -6.    47.   1400.    8068.     167.    8.40  490.09
   FULLV:FV       0.    -7.    47.   1400.    9989.     192.    7.29  491.10
   BRIDG:BR       0.     0.    40.   1400.    7008.     128.   10.90  491.18
   RDWAY:RG      14.**************       0.*****************    1.00********
   APPRO:AS      62.   -40.    65.   1400.   23581.     383.    3.66  494.51

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    42.   17202.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    489.70    0.83  485.86  505.45************  1.10  491.19  490.09
   FULLV:FV  ********    0.68  486.39  505.98  0.75  0.00  0.83  491.93  491.10
   BRIDG:BR    491.18    1.00  483.67  496.57************  1.85  493.03  491.18
   RDWAY:RG  ****************  499.59  519.21**********************************
   APPRO:AS    491.73    0.35  487.44  505.03  0.35  1.35  0.22  494.73  494.51
```

```
         U.S. Geological Survey WSPRO Input File ript016.wsp
         Hydraulic analysis for structure RIPTTH00110016   Date: 30-JUN-97
         TH 11 CROSSING MIDDLE BRANCH MIDDLEBURY RIVER IN RIPTON, VT       RLB
            *** RUN DATE & TIME: 07-17-97  13:32

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

 EXITX:XS   ******     -6      201  1.32 *****  492.05  490.31    1850  490.73
       -30 ******     48    10663  1.00 ***** *******    0.85    9.21

 FULLV:FV       31     -7      230  1.00  0.76  492.80 *******    1850  491.79
         0      31     48    13054  1.00  0.00   -0.02    0.70    8.03
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS       62    -24      264  0.76  1.17  493.98 *******    1850  493.21
        62      62     50    13892  1.00  0.00    0.01    0.66    7.01
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                    SECID "BRIDG"     Q,CRWS =    1850.     491.94

              <<<<<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       31      0      155  2.22 *****  494.16  491.94    1850  491.94
         0      31     40     9359  1.00 ***** *******    1.00   11.94

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  1.000 ******  496.47 ****** ****** ******

     XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      14.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPRO:AS       28    -41      505  0.24  0.32  495.81  492.23    1850  495.57
        62      30     85    33878  1.15  1.32    0.00    0.35    3.66

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.462  0.321   22989.     0.    40.   495.44

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

   FIRST USER DEFINED TABLE.

     XSID:CODE     SRD    LEW    REW       Q         K      AREA     VEL    WSEL
    EXITX:XS      -31.    -7.    48.   1850.   10663.      201.    9.21  490.73
    FULLV:FV        0.    -8.    48.   1850.   13054.      230.    8.03  491.79
    BRIDG:BR        0.     0.    40.   1850.    9359.      155.   11.94  491.94
    RDWAY:RG       14.**************       0.*****************     1.00********
    APPRO:AS       62.   -42.    85.   1850.   33878.      505.    3.66  495.57

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS       0.    40.   22989.

  SECOND USER DEFINED TABLE.

     XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    490.31    0.85  485.86  505.45************  1.32  492.05  490.73
    FULLV:FV   ********    0.70  486.39  505.98  0.76  0.00  1.00  492.80  491.79
    BRIDG:BR    491.94    1.00  483.67  496.57************  2.22  494.16  491.94
    RDWAY:RG   ****************  499.59  519.21**********************************
    APPRO:AS    492.23    0.35  487.44  505.03  0.32  1.32  0.24  495.81  495.57
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure RIPTTH00110016, in Ripton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number RIPTTH00110016

General Location Descriptive

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

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

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

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

Town *(FIPS place code; I - 4; nnnnn)* 59650

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

Waterway *(I - 6)* MIDDLE BR. MIDDLEBURY R.

Road Name *(I - 7):* -

Route Number C3011

Vicinity *(I - 9)* 0.04 MI TO JCT W C3 TH14

Topographic Map East Middlebury

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 43584

Longitude *(i - 17; nnnnn.n)* 73019

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011600160116

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

Maximum span length *(I - 48; nnnn)* 0042

Year built *(I - 27; YYYY)* 1936

Structure length *(I - 49; nnnnnn)* 000044

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

Deck Width *(I - 52; nn.n)* 198

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

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

Opening skew to Roadway *(I - 34; nn)* 20

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

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

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*) 38.67

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

Vertical clearance from streambed (*nnn.n ft*) 8

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

Waterway of full opening (*nnn.n ft²*) 307.6

Comments:

According to the structural inspection report dated 12/8/94, the abutments, wingwalls, and backwalls are concrete. The LABUT and its wingwalls have a stepped concrete footing. Small voids are present along the bottom of the footing. The abutments and wingwalls have minor fine cracks and small leaks, mostly on their ends, with some spalling at the bottom of the US left wingwall and footing. Most of the channel flow is against the LABUT and US left wingwall. The channel is scoured down at least 4 ft. A partially vegetation covered gravel bar in front of the RABUT blocks half of the channel flow. A small homemade stone and concrete drop structure extends across the channel at the DS bridge face.

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: -

Terrain character: -

Stream character & type: -

Streambed material: Stones and boulders.

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

Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft²*): -

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 6.59 mi^2 Lake/pond/swamp area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 1090 ft Headwater elevation 3780 ft

Main channel length 5.45 mi

10% channel length elevation 1170 ft 85% channel length elevation 2380 ft

Main channel slope *(S)* 296.03 ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCKMARK INFORMATION

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO DRILL BORING INFORMATION

Comments:

-

Cross-sectional Data

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

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

Comments: **This cross-section is at the upstream face. The low chord elevation is from the survey log done for this report on 06/11/96. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 12/08/94. The sketch was done on 11/04/92.**

Station	0	5.8	17	25.8	38.7	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	496.4	-	-	-	496.6	-	-	-	-	-	-
Bed elevation	488.2	-	-	-	489.9	-	-	-	-	-	-
Low chord-bed	8.2	12.6	8.8	6.9	6.7	-	-	-	-	-	-

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

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

Comments:

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **MS** Date: **02/20/97**
Computerized by: **MS** Date: **06/18/97**
Reviewd by: **RB** Date: **08/01/97**

Structure Number **RIPTTH00110016**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **J** . **DEGNAN & E. WILD** Date *(MM/DD/YY)* **6** / **11** / 19**96**

2. Highway District Number **05**

Mile marker **000000**

County **001 ADDISON**

Town **59650 RIPTON**

Waterway *(I - 6)* **MIDDLE BR. MIDDLEBURY R.**

Road Name **-**

Route Number **C3011**

Hydrologic Unit Code: **02010002**

3. Descriptive comments:

This bridge is located 0.04 miles from the junction with Town Highway 14. The bridge consists of a concrete bridge deck and rails on top of steel I beams. Some residents described a 5 ft. diameter culvert US that washed out because debris had gotten in front of it causing it to fail. They also pointed out a high water mark from 6/10/96.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **5** LBDS **5** RBDS **5** Overall **5**
*(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 **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **44** *(feet)* Span length **42** *(feet)* Bridge width **19.8** *(feet)*

Road approach to bridge:

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

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

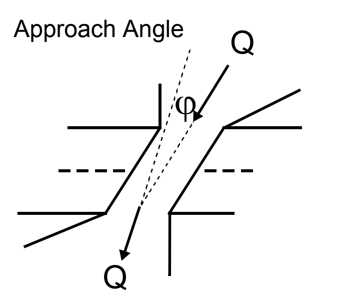
10. Embankment slope (*run / rise in feet / foot*):
US left **2.3:1** US right **2.2:1**

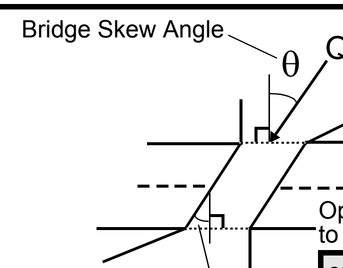
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	0	-	0	0
LBDS	0	-	2	1

*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: **40** 16. Bridge skew: **40**





Opening skew to roadway α= **30.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **30** feet **US** *(US, UB, DS)* to **0** feet **US**

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

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

18. Bridge Type: 1a

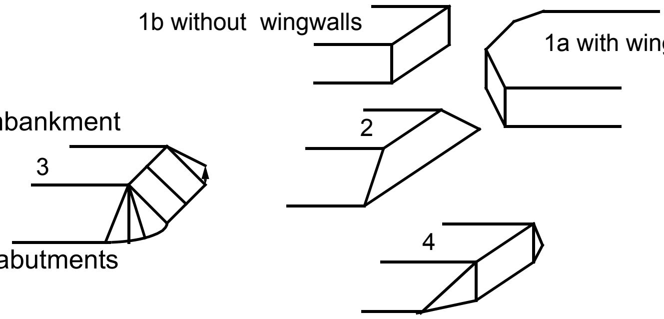
1a- Vertical abutments with wingwalls

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 banks are all lined with trees, shrubs and brush, but beyond them on the US right overbank and the DS left and right overbanks are houses with short grass, shrubs and brush.

7. The measured span length is 38.7 feet. The deck width includes the rails.

17. The channel impact zone is the most severe on the US end of the USLWW.

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
56.0	4.0			4.0	4	3	542	542	1	1

23. Bank width 10.0 24. Channel width 10.0 25. Thalweg depth 73.5 29. Bed Material 453

30 .Bank protection type: LB 2 RB 2 31. Bank protection condition: LB 1 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.):

30. The protection is dumped stone. The left bank protection extends from 27 ft US to the edge of the US left wingwall at 13 ft US. The right bank protection extends from 47 ft US to 16 ft US. The protection is more extensive on the left side. The right side protection consists of several boulders.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **0 US** 35. Mid-bar width: **15**

36. Point bar extent: **75** feet **US** (US, UB) to **15** feet **DS** (US, UB, DS) positioned **70** %LB to **100** %RB

37. Material: **304**

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

This point bar has abundant vegetation US and DS of the bridge. It contains boulders at the US end and small cobbles at the DS end. There is an additional point bar US on the left bank that extends from 220 ft US to 50 ft US. The mid-bar distance is 130 ft US and the width is 12 ft. The material is 345.

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

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

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

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

There is a cut-bank present on the RB at approximately 140 ft US to 250 ft US, at the confluence with an unnamed stream. The bank damage consists of erosion and/or creep.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **0**

47. Scour dimensions: Length **32** Width **8** Depth : **3** Position **0** %LB to **30** %RB

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

The scour hole is from 16 ft US to 0 ft DS. There is some localized scour around the boulders.

49. Are there major confluences? **Y** (Y or if N type ctrl-n mc) 50. How many? **1**

51. Confluence 1: Distance **80** 52. Enters on **LB** (LB or RB) 53. Type **1** (**1**- perennial; **2**- ephemeral)

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

54. Confluence comments (eg. confluence name):

250 ft US there is another stream that enters on the right bank.

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
24.5		1.5		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.):

345

-

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

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

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

70. Debris and Ice Comments:

2

65. There is debris accumulation on the US right bank point bar. There are logs caught in the small trees and grass.

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		10	90	2	2	3	4	90.0
RABUT	1	0	90			2	-	35.0

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.):

-

-

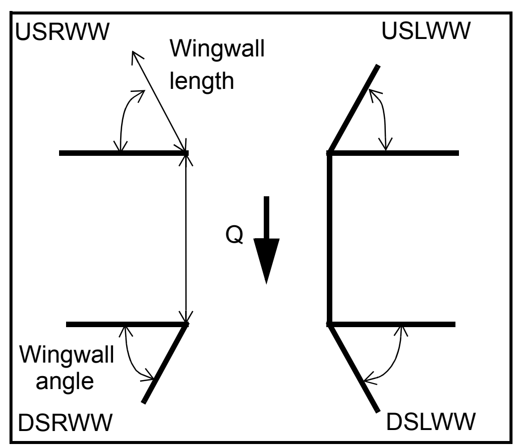
1

The US left wingwall attack angle is 30 degrees. The footing is exposed along the US left wingwall and left abutment. There is a three foot scour hole along the left abutment, assuming a 1.5 ft thalweg.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						35.0	
USRWW:	Y		1		2	4.0	
DSLWW:	3		2		Y	27.0	
DSRWW:	1		0		-	27.0	

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



82. Bank / Bridge Protection:

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

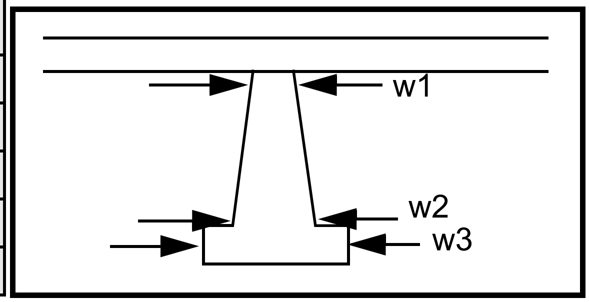
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **82.** *(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		**8.5**		**90.0**	**30.0**	**11.5**
Pier 2				**30.0**	**12.5**	**90.0**
Pier 3	**8.0**	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

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.):
-
-
-
-
-
-
-
-
-
-
-
-

NO PIERS

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):

3

106. Point/Side bar present? 2 (Y or N. if N type ctrl-n pb) Mid-bar distance: 354 Mid-bar width: 345

Point bar extent: 1 feet 2 (US, UB, DS) to 453 feet 0 (US, UB, DS) positioned 0 %LB to - %RB

Material: -

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

There is bank erosion occurring on the right bank caused, in part, by runoff from a lawn. The erosion occurs from 15 ft DS to 18 ft DS.

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.):

Y

Is channel scour present? 3 (Y or if N type ctrl-n cs) Mid-scour distance: The

Scour dimensions: Length drop Width struc Depth: ture Positioned is %LB to con %RB

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

crete with cobbles and boulders mixed in with it. The distance of the drop structure is 4 ft DS and it drops one foot. The channel is eroding the drop structure.

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

Confluence 1: Distance Y Enters on 18 (LB or RB) Type 8 (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance 0 Enters on UB (LB or RB) Type 40 (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

DS
50

F. Geomorphic Channel Assessment

107. Stage of reach evolution 80

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)*:

34

This bar is a mid-channel bar.

Y
RB
45
35
DS
50
DS
1

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: RIPTTH00110016   Town: RIPTON
Road Number: TH 11   County: ADDISON
Stream: MIDDLE B

Initials RLB   Date: 7/17/97   Checked: RF

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	1400	1850	0
Main Channel Area, ft2	359	437	0
Left overbank area, ft2	15	34	0
Right overbank area, ft2	8	34	0
Top width main channel, ft	74	74	0
Top width L overbank, ft	16	19	0
Top width R overbank, ft	15	35	0
D50 of channel, ft	0.3203	0.3203	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	4.9	5.9	ERR
y1, average depth, LOB, ft	0.9	1.8	ERR
y1, average depth, ROB, ft	0.5	1.0	ERR
Total conveyance, approach	23596	33912	0
Conveyance, main channel	23165	32143	0
Conveyance, LOB	310	1061	0
Conveyance, ROB	122	708	0
Percent discrepancy, conveyance	-0.0042	0.0000	ERR
Qm, discharge, MC, cfs	1374.4	1753.5	ERR
Ql, discharge, LOB, cfs	18.4	57.9	ERR
Qr, discharge, ROB, cfs	7.2	38.6	ERR
Vm, mean velocity MC, ft/s	3.8	4.0	ERR
Vl, mean velocity, LOB, ft/s	1.2	1.7	ERR
Vr, mean velocity, ROB, ft/s	0.9	1.1	ERR
Vc-m, crit. velocity, MC, ft/s	10.0	10.3	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1400	1850	0
(Q) discharge thru bridge, cfs	1400	1850	0
Main channel conveyance	7004	9348	0
Total conveyance	7004	9348	0
Q2, bridge MC discharge,cfs	1400	1850	ERR
Main channel area, ft2	128	155	0
Main channel width (normal), ft	34.7	34.7	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.7	34.7	0
y_bridge (avg. depth at br.), ft	3.69	4.47	ERR
Dm, median (1.25*D50), ft	0.400375	0.400375	0
y2, depth in contraction,ft	3.82	4.86	ERR
ys, scour depth (y2-ybridge), ft	0.14	0.39	N/A

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1400	1850	N/A
Main channel area (DS), ft2	128	155	0
Main channel width (normal), ft	34.7	34.7	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	34.7	34.7	0.0
D90, ft	0.9720	0.9720	0.0000
D95, ft	1.4085	1.4085	0.0000
Dc, critical grain size, ft	0.8196	0.8856	ERR
Pc, Decimal percent coarser than Dc	0.137	0.117	0.000
Depth to armoring, ft	15.49	20.05	ERR

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1400	1850	N/A	1400	1850	N/A
a', abut.length blocking flow, ft	42.6	45	0	27.9	47.6	0
Ae, area of blocked flow ft2	120.8	167.5	0	51.7	91	0
Qe, discharge blocked abut.,cfs	372.4	539.6	0	133.5	224.4	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.08	3.22	ERR	2.58	2.47	ERR
ya, depth of f/p flow, ft	2.84	3.72	ERR	1.85	1.91	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	120	120	0	60	60	0
K2	1.04	1.04	0.00	0.95	0.95	0.00
Fr, froude number f/p flow	0.323	0.294	ERR	0.334	0.314	ERR
ys, scour depth, ft	11.65	13.68	N/A	7.24	8.55	N/A

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

a'(abut length blocked, ft)	42.6	45	N/A	27.9	47.6	N/A
y1 (depth f/p flow, ft)	2.84	3.72	ERR	1.85	1.91	ERR
a'/y1	15.02	12.09	ERR	15.06	24.90	ERR
Skew correction (p. 49, fig. 16)	1.07	1.07	1.00	0.90	0.90	1.00
Froude no. f/p flow	0.32	0.29	N/A	0.33	0.31	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1	N/A	1	1	N/A
y, depth of flow in bridge, ft	3.69	4.47	0.00	3.69	4.47	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	N/A	ERR	ERR	N/A
Fr>0.8 (vertical abut.)	1.54	1.87	ERR	1.54	1.87	ERR