LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (BERKTH00030007) on TOWN HIGHWAY 3, crossing the PIKE RIVER, BERKSHIRE, VERMONT

U.S. Geological Survey
Open-File Report 96-645

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (BERKTH00030007) on TOWN HIGHWAY 3, crossing the PIKE RIVER, BERKSHIRE, VERMONT

By Erick M. Boehmler and Donald L. Song

U.S. Geological Survey
Open-File Report 96-645

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
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 7 (BERKTH00030007) ON TOWN HIGHWAY 3, CROSSING THE PIKE RIVER, BERKSHIRE, 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 BERKTH00030007 on Town Highway 3 crossing the Pike River, Berkshire, 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 north-central Vermont. The 11.5-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is row crops upstream and pasture downstream of the bridge.

In the study area, the Pike River has a sinuous channel with a slope of approximately 0.001 ft/ft, an average channel top width of 48 ft and an average channel depth of 5 ft. The predominant channel bed material is sand with a median grain size (D_{50}) of 1.40 mm (0.00916 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 29, 1995, indicated that the reach was laterally unstable. Steep cut-banks with slip failure of bank material leaving an overhanging soil layer and vegetation root exposure were evident on the upstream left and downstream right banks near this bridge. Further, a hummocky, dune-like streambed appearance was noted, which indicates a laterally shifting streambed.

The Town Highway 3 crossing of the Pike River is a 69-ft-long, two-lane bridge consisting of one 67-foot steel-beam span (Vermont Agency of Transportation, written communication, March 9, 1995). The bridge is supported by vertical, concrete abutments with stone-fill spill-through abutment slopes and no wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 0.5 ft deeper than the mean thalweg depth was observed along the right bank side of the channel immediately downstream of the bridge during the Level I assessment. The only scour protection measure at the site was type-3 stone-fill (less than 48 inches diameter), which form the spill-through embankments on each abutment. 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 4.2 to 5.6 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 3.5 to 4.9 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.

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 BERKTH00030007 ***Stream*** Pike River

County Franklin ***Road*** TH 3 ***District*** 8

Description of Bridge

Bridge length 69 ***ft*** ***Bridge width*** 27.5 ***ft*** ***Max span length*** 67 ***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*** 6/29/95

Description of stone fill Type-3 stone fill forms the spill-through embankments in front of each vertical concrete abutment wall.

Brief description of piers/abutments Abutments are vertical concrete walls on each side. There are stone fill embankments in front of each abutment.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 10

There is a mild channel bend in the reach through the bridge. The scour hole has developed in the location where the bend impacts the DS right bank.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	6/29/95	0	0
Level II	6/29/95	0	0

Potential for debris Moderate. There are some trees and other vegetation along the channel banks upstream on this laterally unstable reach.

Describe any features near or at the bridge that may affect flow (include observation date) None noted 6/29/95.

Description of the Geomorphic Setting

General topography The channel is located in a low relief valley setting with wide, slightly irregular flood plains and moderately sloping valley walls on both sides.

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

Date of inspection 6/29/95

DS left: Moderately sloping channel bank to flood plain.

DS right: Steep channel bank to flood plain.

US left: Steep channel bank to flood plain.

US right: Moderately sloping channel bank to flood plain.

Description of the Channel

Average top width 48 ***ft*** ***Average depth*** 5 ***ft***

Predominant bed material Sand ***Bank material*** Silt & Clay

Perennial, sinuous, and laterally unstable with alluvial channel boundaries and irregular point bars.

6/29/95

Vegetative co Grass and a few trees.

DS left: Grass and a few trees.

DS right: Grass, row crops, and a few trees

US left: Grass, row crops, and a few trees.

US right: N

Do banks appear stable? The upstream left and downstream right banks have been cut with overlying soil undermined and vegetation roots exposed.These banks also are oversteepened. Continued bank erosion will further contribute to channel widening and lateral instability.

If not, describe location and type of instability and date of observation.

The assessment of 6/29/95 indicated a partially vegetated point bar has developed on the right bank side under the bridge.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 11.5 ***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 1,480 ***ft³/s*** ***Q500*** 1,900 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency curves computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957; Talbot, 1887). The 100- and 500-year discharges from the Johnson and Tasker (1974) relationship given above were selected for this site due to the central tendency of the relationship with the others.

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 397.6 feet from the USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is the center point of a chiseled "X" on top of the concrete right abutment, upstream end (elev. 500.18 ft, arbitrary survey datum). RM2 is a nail hole at the center point of a chiseled "X" on top of the concrete left abutment, downstream end (elev. 498.81 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	-51	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	94	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). Although backwater may occur from a bridge downstream, no backwater was assumed and the slope used was 0.0012 ft/ft. This slope was estimated from the topographic map (U.S. Geological Survey, 1986).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 499.9 *ft*
Average low steel elevation 496.3 *ft*

100-year discharge 1,530 *ft³/s*
Water-surface elevation in bridge opening 493.5 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 190 *ft²*
Average velocity in bridge opening 8.0 *ft/s*
Maximum WSPRO tube velocity at bridge 10.1 *ft/s*

Water-surface elevation at Approach section with bridge 495.1
Water-surface elevation at Approach section without bridge 493.9
Amount of backwater caused by bridge 1.2 *ft*

500-year discharge 1,900 *ft³/s*
Water-surface elevation in bridge opening 493.6 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 196 *ft²*
Average velocity in bridge opening 9.7 *ft/s*
Maximum WSPRO tube velocity at bridge 12.3 *ft/s*

Water-surface elevation at Approach section with bridge 496.1
Water-surface elevation at Approach section without bridge 494.1
Amount of backwater caused by bridge 2.0

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and 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 was computed by use of the clear-water contraction scour equations (Richardson and others, 1995, p. 32, equation 20). 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 was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

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

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	4.2	5.6	--
Depth to armoring	--	--	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	3.6	4.9	--
Right abutment	3.6	3.5	--
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	1.2	1.3	--
Right abutment	1.2	1.3	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

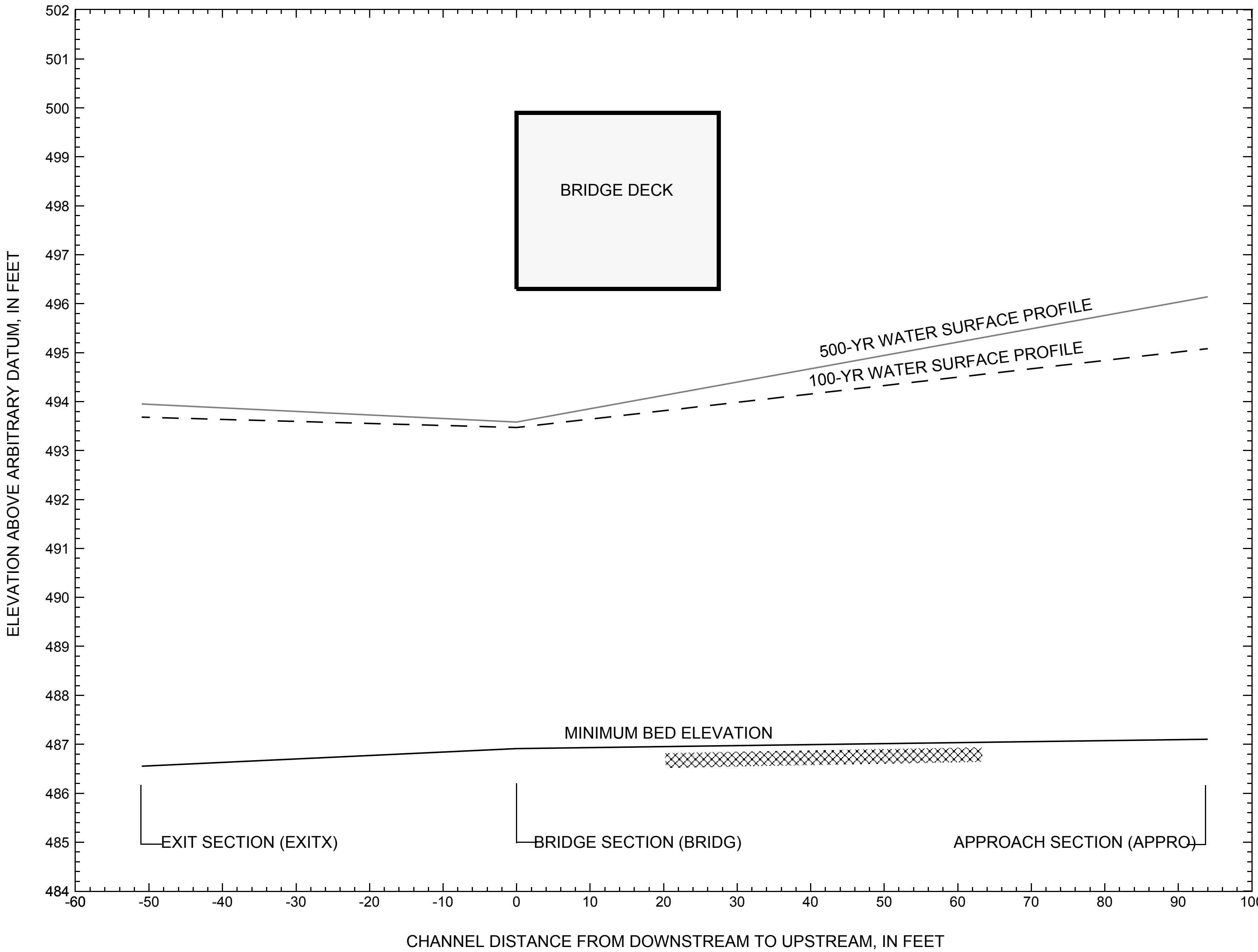


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BERKTH00030007 on Town Highway 3, crossing Pike River, Berkshire, Vermont.

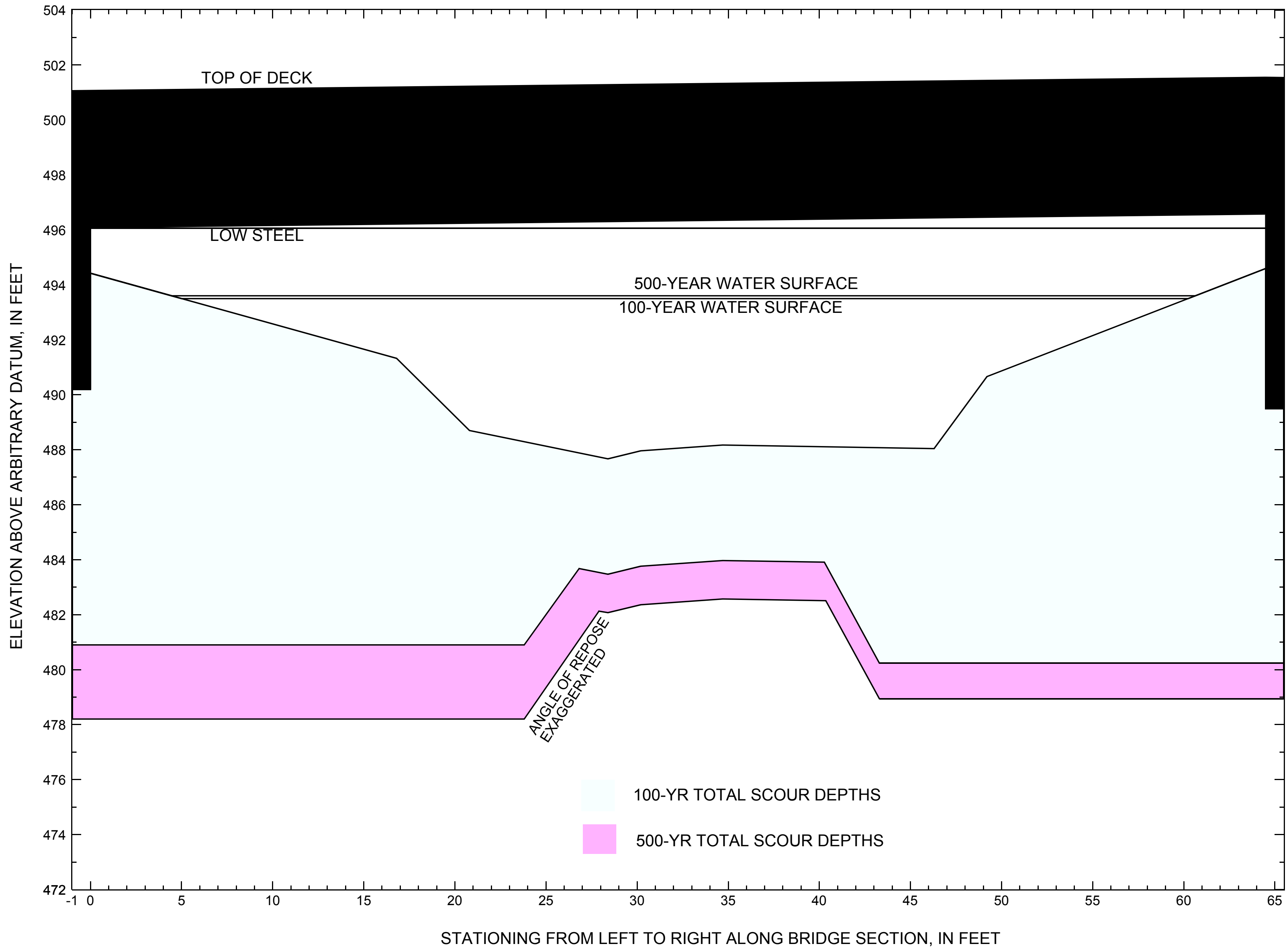


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BERKTH00030007 on Town Highway 3, crossing Pike River, Berkshire, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BERKTH00030007 on Town Highway 3, crossing Pike River, Berkshire, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT 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 1,530 cubic-feet per second											
Left abutment	0.0	98.6	496.1	490.2	494.4	--	--	--	--	--	--
Toe of Left Abutment slope	20.8	--	--	--	488.7	4.2	3.6	--	7.8	480.9	--
Toe of Right Abutment slope	46.3	--	--	--	488.0	4.2	3.6	--	7.8	480.2	--
Right abutment	64.5	98.9	496.6	489.5	494.6	--	--	--	--	--	--

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 BERKTH00030007 on Town Highway 3, crossing Pike River, Berkshire, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT 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 1,900 cubic-feet per second											
Left abutment	0.0	98.6	496.1	490.2	494.4	--	--	--	--	--	--
Toe of left Abutment slope	20.8	--	--	--	488.7	5.6	4.9	--	10.5	478.2	--
Toe of right Abutment slope	46.3	--	--	--	488.0	5.6	3.5	--	9.1	478.9	--
Right abutment	64.5	98.9	496.6	489.5	494.6	--	--	--	--	--	--

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., 1957, 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, Enosburg Falls, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Aerial photography 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 test.wsp
T2        Hydraulic analysis for structure BERKTH00030007   Date: 18-SEP-96
T3        Town Highway 3 bridge crossing the Pike River, Berkshire, VT       EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1530.0   1900.0
SK          0.0012   0.0012
*
XS   EXITX    -51
GR         -711.2, 505.47   -677.2, 498.41   -465.8, 498.55   -359.5, 493.73
GR         -234.6, 492.45     12.0, 492.45     20.0, 487.49     28.0, 486.96
GR           38.4, 486.55     43.4, 487.30     52.1, 492.90    153.4, 492.90
GR          317.5, 499.04    539.7, 515.60
*
N           0.040        0.035         0.040
SA                  12.0        52.1
*           In order to flatten overbanks and address froude number problems
*           an average of elevations at stations -234.6 and 12.0 were computed
*           for the left overbank and applied to these stations. The elevations
*           were 492.21 and 492.69. The same was done for the right overbank
*           at stations 52.1 and 153.4. The elevations were 492.94 and 492.85.
*
XS   FULLV      0  * * *   0.0070
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.30       0.0
GR            0.0, 496.06      0.0, 494.42     16.8, 491.33     20.8, 488.70
GR           26.5, 487.92     28.4, 487.67     30.2, 487.96     34.7, 488.17
GR           46.3, 488.04     49.2, 490.66     64.5, 494.59     64.5, 496.55
GR            0.0, 496.06
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD           3      29.8      2.4    499.9
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     15      27.5     1
GR         -713.8, 505.47   -680.0, 498.41   -470.2, 498.55   -270.3, 498.91
GR           -3.5, 499.69     -3.5, 501.07     65.2, 501.55     65.2, 500.14
GR          282.4, 501.87    404.1, 507.20    593.3, 521.60
BP          0.0
*
AS   APPRO     94
GR         -727.4, 511.72   -678.9, 499.56   -536.7, 498.86   -257.2, 492.92
GR            5.7, 493.93     15.0, 488.75     25.3, 488.02     31.4, 487.73
GR           42.7, 487.10     47.2, 488.38     61.1, 494.06    321.8, 500.05
GR          467.3, 513.55    501.7, 515.88    511.9, 518.42
BP          0.0
*
N           0.040        0.035        0.040
SA                  5.7         61.1
*
HP 1 BRIDG  493.47 1  493.47
HP 2 BRIDG  493.47 * *  1530
HP 1 APPRO  495.08 1  495.08
HP 2 APPRO  495.08 * *  1530
*
HP 1 BRIDG  493.58 1  493.58
HP 2 BRIDG  493.58 * *  1900
HP 1 APPRO  496.14 1  496.14
HP 2 APPRO  496.14 * *  1900
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
U.S. Geological Survey WSPRO Input File test.wsp
Hydraulic analysis for structure BERKTH00030007   Date: 18-SEP-96
Town Highway 3 bridge crossing the Pike River, Berkshire, VT       EMB
   *** RUN DATE & TIME: 09-25-96  14:08

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      191     15788     55     57                         2013
493.47           191     15788     55     57  1.00      5     60     2013

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

      WSEL     LEW     REW    AREA       K        Q    VEL
    493.47     5.2    60.1   190.5   15788.    1530.   8.03

X STA.         5.2       19.1       21.8       23.7       25.4       26.9
  A(I)            19.1       11.8        9.8        8.8        8.4
  V(I)            4.01       6.48       7.80       8.64       9.07

X STA.        26.9       28.3       29.7       31.1       32.5       33.9
  A(I)             8.1        7.7        7.6        7.7        7.6
  V(I)            9.44       9.93      10.00       9.91      10.03

X STA.        33.9       35.3       36.8       38.2       39.7       41.1
  A(I)             7.6        7.6        7.7        7.8        7.9
  V(I)           10.09      10.08       9.93       9.78       9.71

X STA.        41.1       42.7       44.3       46.0       48.5       60.1
  A(I)             8.3        8.5        9.2       11.5       17.7
  V(I)            9.22       8.99       8.34       6.67       4.32

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      94.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      545     26531    365    365                         3780
          2      321     42710     55     58                         4384
          3       23       538     44     44                           92
495.08           888     69780    464    467  1.90   -358    105     5055

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      94.

      WSEL     LEW     REW    AREA       K        Q    VEL
    495.08  -358.8   105.5   888.5   69780.    1530.   1.72

X STA.      -358.8     -264.6     -233.4     -202.6     -169.4     -131.4
  A(I)            94.3       65.8       61.9       62.6       66.4
  V(I)            0.81       1.16       1.24       1.22       1.15

X STA.      -131.4      -88.6      -35.5       12.7       17.3       21.0
  A(I)            68.4       74.9       72.0       28.1       24.7
  V(I)            1.12       1.02       1.06       2.72       3.09

X STA.        21.0       24.5       27.7       30.9       33.9       36.8
  A(I)            23.7       22.9       22.8       22.3       22.4
  V(I)            3.23       3.33       3.35       3.44       3.41

X STA.        36.8       39.8       42.6       45.9       50.4      105.5
  A(I)            22.6       22.6       24.9       28.1       56.9
  V(I)            3.38       3.38       3.07       2.72       1.34
```

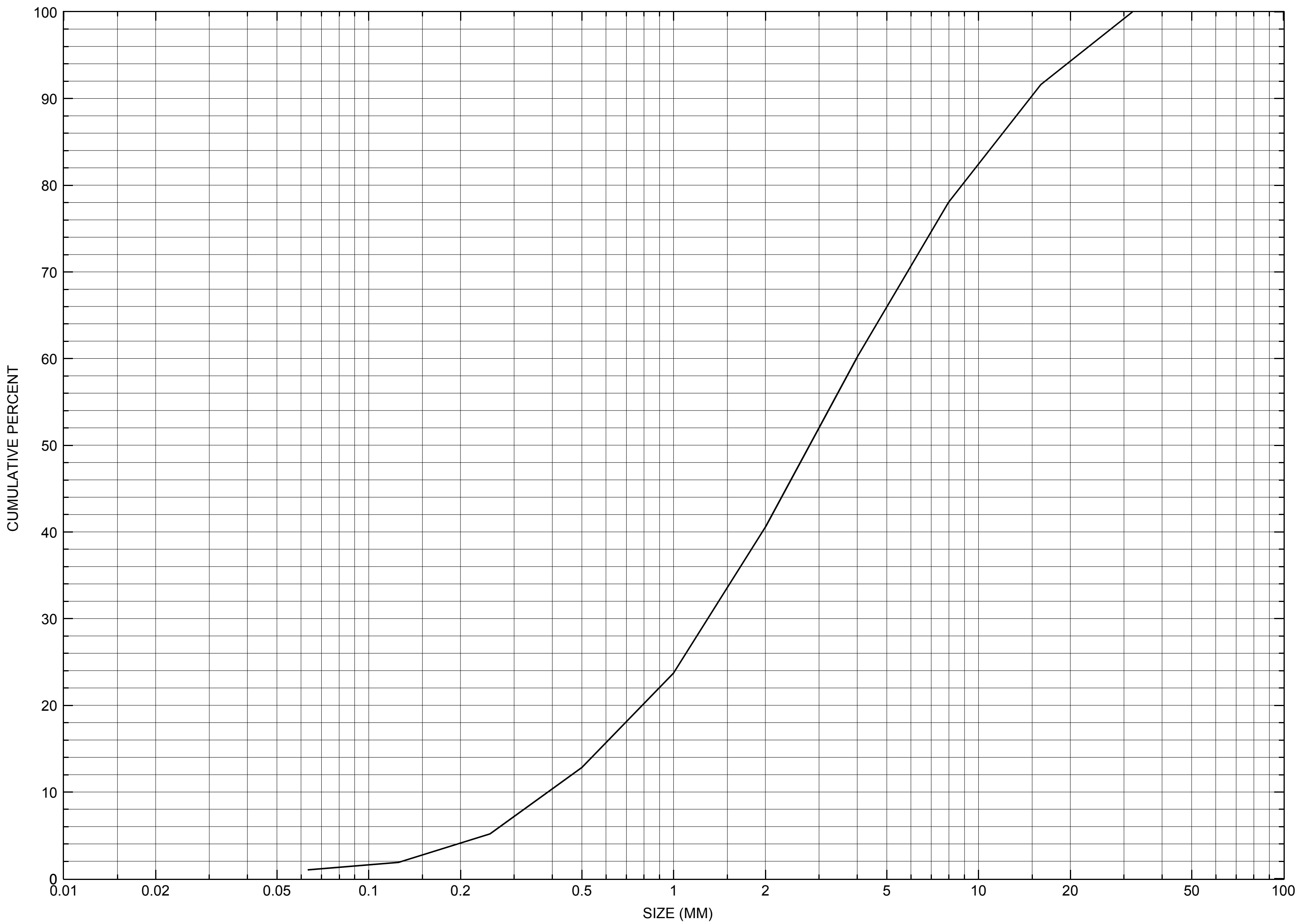
```
       U.S. Geological Survey WSPRO Input File test.wsp
       Hydraulic analysis for structure BERKTH00030007   Date: 18-SEP-96
       Town Highway 3 bridge crossing the Pike River, Berkshire, VT       EMB
          *** RUN DATE & TIME: 09-25-96  14:08

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      197     16440     56     58                         2091
  493.58           197     16440     56     58  1.00      5     61     2091

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      493.58     4.6    60.6   196.6   16440.    1900.   9.66

X STA.        4.6       18.8       21.6       23.5       25.3       26.8
  A(I)           19.5       12.5        9.8        9.4        8.7
  V(I)           4.87       7.57       9.66      10.15      10.94

X STA.       26.8       28.3       29.6       31.1       32.5       33.9
  A(I)            8.3        8.0        8.1        7.7        7.9
  V(I)          11.40      11.95      11.76      12.26      12.02

X STA.       33.9       35.3       36.8       38.2       39.7       41.2
  A(I)            7.8        7.8        7.9        8.2        8.1
  V(I)          12.19      12.18      12.01      11.58      11.67

X STA.       41.2       42.7       44.4       46.1       48.7       60.6
  A(I)            8.3        9.0        9.5       11.8       18.2
  V(I)          11.39      10.54      10.03       8.05       5.22

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      94.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      958     62355    414    414                         8262
            2      380     56513     55     58                         5641
            3       94      3599     91     91                          545
  496.14          1432    122468    560    563  1.70   -408    152     9966

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      94.

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.14  -408.7   151.6  1431.6  122468.    1900.   1.33

X STA.     -408.7     -291.2     -257.3     -229.9     -202.3     -174.2
  A(I)          146.8       96.8       86.8       84.5       83.2
  V(I)           0.65       0.98       1.09       1.12       1.14

X STA.     -174.2     -144.6     -112.9      -79.1      -43.0       -2.1
  A(I)           84.1       86.5       87.8       89.0       94.9
  V(I)           1.13       1.10       1.08       1.07       1.00

X STA.       -2.1       15.5       20.6       25.2       29.7       33.9
  A(I)           65.5       39.2       36.5       36.8       35.6
  V(I)           1.45       2.42       2.60       2.58       2.67

X STA.       33.9       38.1       42.1       46.5       53.7      151.6
  A(I)           36.1       35.3       38.3       47.3      120.6
  V(I)           2.63       2.69       2.48       2.01       0.79
```

```
        U.S. Geological Survey WSPRO Input File test.wsp
        Hydraulic analysis for structure BERKTH00030007   Date: 18-SEP-96
        Town Highway 3 bridge crossing the Pike River, Berkshire, VT       EMB
           *** RUN DATE & TIME: 09-25-96  14:08

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

EXITX:XS   ******   -353      681  0.19 *****  493.87  491.65    1530  493.68
       -50 ******    174    44137  2.43 ***** *******    0.54    2.25

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.84     493.67     492.01

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   493.18     515.96    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   493.18     515.96     492.01

FULLV:FV       51   -316      490  0.37  0.08  494.03  492.01    1530  493.66
         0     51    164    32527  2.46  0.09   -0.01    0.86    3.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.87     493.84     491.80

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   493.16     518.42    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   493.16     518.42     491.80

APPRO:AS       94   -300      384  0.43  0.21  494.27  491.80    1530  493.85
        94     94     61    31841  1.74  0.03    0.00    0.87    3.98
         <<<<<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       51      5      190  1.16  0.17  494.63  492.72    1530  493.47
         0     51     60    15769  1.15  0.58    0.00    0.82    8.04

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.931 ******  496.30 ****** ****** ******

    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       64   -358      890  0.09  0.16  495.17  491.80    1530  495.08
        94     74    106    69892  1.90  0.39    0.01    0.30    1.72

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.843  0.377   43349.     3.    58.   495.05

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -51.  -354.   174.   1530.   44137.     681.    2.25  493.68
   FULLV:FV       0.  -317.   164.   1530.   32527.     490.    3.12  493.66
   BRIDG:BR       0.     5.    60.   1530.   15769.     190.    8.04  493.47
   RDWAY:RG      15.**************      0.******************    1.00********
   APPRO:AS      94.  -359.   106.   1530.   69892.     890.    1.72  495.08

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    58.   43349.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    491.65    0.54  486.55  515.60************  0.19  493.87  493.68
   FULLV:FV    492.01    0.86  486.91  515.96  0.08  0.09  0.37  494.03  493.66
   BRIDG:BR    492.72    0.82  487.67  496.55  0.17  0.58  1.16  494.63  493.47
   RDWAY:RG  ****************  498.41  521.60**********************************
   APPRO:AS    491.80    0.30  487.10  518.42  0.16  0.39  0.09  495.17  495.08
```

```
        U.S. Geological Survey WSPRO Input File test.wsp
        Hydraulic analysis for structure BERKTH00030007   Date: 18-SEP-96
        Town Highway 3 bridge crossing the Pike River, Berkshire, VT       EMB
           *** RUN DATE & TIME: 09-25-96  14:08

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

EXITX:XS   ******   -363      828  0.18 *****  494.13  493.33    1900  493.95
       -50 ******    181    54848  2.25 ***** *******    0.49    2.29

FULLV:FV       51   -345      636  0.34  0.08  494.29 *******    1900  493.95
         0     51    172    41262  2.46  0.08    0.00    0.74    2.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.87     494.09     492.36

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.45     518.42    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.45     518.42     492.36

APPRO:AS       94   -311      474  0.48  0.22  494.57  492.36    1900  494.09
        94     94     63    37125  1.92  0.07   -0.01    0.87    4.01
         <<<<<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       51      5      196  1.95  0.20  495.53  493.30    1900  493.58
         0     51     61    16417  1.34  1.19    0.00    1.06    9.67

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.863 ******  496.30 ****** ****** ******

    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       64   -408     1432  0.05  0.14  496.19  492.36    1900  496.14
        94     78    152   122562  1.70  0.52    0.01    0.19    1.33

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.841  0.533   56945.     0.    56.   496.13

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -51.  -364.   181.   1900.   54848.     828.    2.29  493.95
   FULLV:FV       0.  -346.   172.   1900.   41262.     636.    2.99  493.95
   BRIDG:BR       0.     5.    61.   1900.   16417.     196.    9.67  493.58
   RDWAY:RG      15.**************      0.******************    1.00********
   APPRO:AS      94.  -409.   152.   1900.  122562.    1432.    1.33  496.14

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       0.    56.   56945.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.33    0.49  486.55  515.60************  0.18  494.13  493.95
   FULLV:FV  ********    0.74  486.91  515.96  0.08  0.08  0.34  494.29  493.95
   BRIDG:BR    493.30    1.06  487.67  496.55  0.20  1.19  1.95  495.53  493.58
   RDWAY:RG  ****************  498.41  521.60**********************************
   APPRO:AS    492.36    0.19  487.10  518.42  0.14  0.52  0.05  496.19  496.14
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one channel composite sample transect at the approach section for structure BERKTH00030007, in Berkshire, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BERKTH00030007

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 03 / 09 / 95

Highway District Number *(I - 2; nn)* 08

County *(FIPS county code; I - 3; nnn)* 011

Town *(FIPS place code; I - 4; nnnnn)* 05425

Mile marker *(I - 11; nnn.nnn)* 001010

Waterway *(I - 6)* PIKE RIVER

Road Name *(I - 7):* -

Route Number TH003

Vicinity *(I - 9)* 1.7 MI S JCT. VT.120

Topographic Map Enosburg.Falls

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44590

Longitude *(i - 17; nnnnn.n)* 72476

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20030200070602

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

Maximum span length *(I - 48; nnnn)* 0067

Year built *(I - 27; YYYY)* 1947

Structure length *(I - 49; nnnnnn)* 000069

Average daily traffic, ADT *(I - 29; nnnnnn)* 001396

Deck Width *(I - 52; nn.n)* 275

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)* 7

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*) 65.0

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

Vertical clearance from streambed (*nnn.n ft*) 7.5

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

Waterway of full opening (*nnn.n ft*^{2}) 380.0

Comments:

The structural inspection report of 5/12/94 indicates the structure is a single span steel stringer type bridge. The upstream end on the right abutment has some areas of cracking and scaling reported. The left abutment wall concrete is in good condition, with only minor scaling noted. The channel makes a slight turn into the structure. Bank erosion is noted both upstream and downstream. Both abutments are protected with heavy stone riprap. There is a small sand and gravel point bar noted just downstream of the bridge along the right bank.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 11.45 mi^2 Lake and pond area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 532 ft Headwater elevation 2336 ft

Main channel length 6.38 mi

10% channel length elevation 558 ft 85% channel length elevation 984 ft

Main channel slope *(S)* 89.03 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? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY):* **07** / **1947**

Project Number **SA 13-1946** Minimum channel bed elevation: **88.5**

Low superstructure elevation: USLAB **98.59** DSLAB **97.59** USRAB **98.88** DSRAB **97.88**

Benchmark location description:

BM #1 - Spike in trunk or root of a 20 inch elm tree at the bottom of the riprap flow through abutment on the upstream left abutment side, elevation 100.0.

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

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

If 1: Footing Thickness **4.5** Footing bottom elevation: **91.88***

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? **Y** *If no, type ctrl-n bi* Number of borings taken: **3**

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

Briefly describe material at foundation bottom elevation or around piles:

The borings taken show the channel material is mainly sand and gravel to a depth of about 10 feet. But the borings were taken below the elevation of the concrete abutment footings. Therefore, the sand and gravel material shown may not be the foundation material for the concrete abutment walls.

Comments:

The plans show flow through type abutments were constructed at this site. The bridge deck was replaced on the original abutments later in 1993. The footings thickness shown above is actually the proposed depth of the bottom of the right abutment footing below the top of the riprap slope above.

***The bottom of the footing on the left abutment is at elevation 92.59, 3.5 feet below the top of the riprap slope.**

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **3/13/96**
Computerized by: **RB** Date: **3/15/96**
Reviewd by: **EB** Date: **9/18/96**

Structure Number **BERKTH00030007**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **D**. **SONG** Date *(MM/DD/YY)* **6** / **29** / 19**95**

2. Highway District Number **08** Mile marker **001010**

County **Franklin (011)** Town **Berkshire (05425)**

Waterway *(I - 6)* **PIKE RIVER** Road Name **-**

Route Number **TH003** Hydrologic Unit Code: **02010007**

3. Descriptive comments:
Located 1.7 miles south from the junction TH 3 with VT 120.

B. Bridge Deck Observations

4. Surface cover... LBUS **3** RBUS **3** 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 **2** 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 **69** *(feet)* Span length **67** *(feet)* Bridge width **27.5** *(feet)*

Road approach to bridge:

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

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

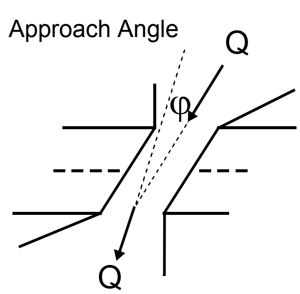
10. Embankment slope (*run / rise in feet / foot*):
US left **2.8:1** US right **2.0:1**

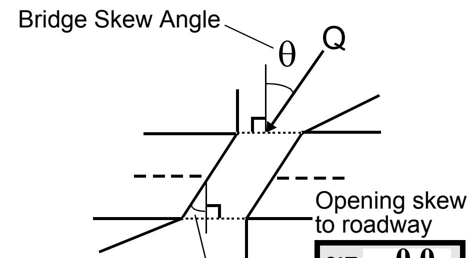
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: **5** 16. Bridge skew: **10**





α= **0.0**

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

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

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

18. Bridge Type: **3**

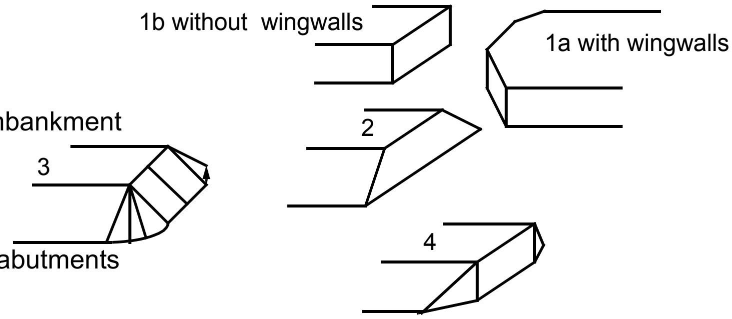
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

7. Values are from the VTAOT files.

18. The concrete abutments are set back from the channel and there is stone rip rap that forms a spill through abutment.

11. No embankment protection is evident.

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
64.0	**5.0**			**5.5**	**2**	**2**	**321**	**321**	**2**	**1**

23. Bank width **30.0**   24. Channel width **20.0**   25. Thalweg depth **55.5**   29. Bed Material **3**

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.):

The banks are obscured by vegetation, but the left bank is steep with overhanging roots and trees.

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

Small bars and/or a hummocky, dune-like streambed is evident throughout the upstream reach.

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: **20** 42. Cut bank extent: **40** feet **US** (*US, UB*) to **0** feet **US** (*US, UB, DS*)

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

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

The banks are steep and there are undermined trees and exposed roots.

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 **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
32.0		1.0		2	7	7	0

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **90.0** 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.):

3

Stone rip-rap forms a spill-through embankment on each abutment with the vertical concrete abutment walls set back from the main channel.

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

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

70. Debris and Ice Comments:

1

There is little constriction of the channel. The debris accumulation consists of a pile of twigs US on the right bank at 40 feet.

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	20	2	0	-	-	90.0
RABUT	2	-	20			2	0	64.5

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.):

-

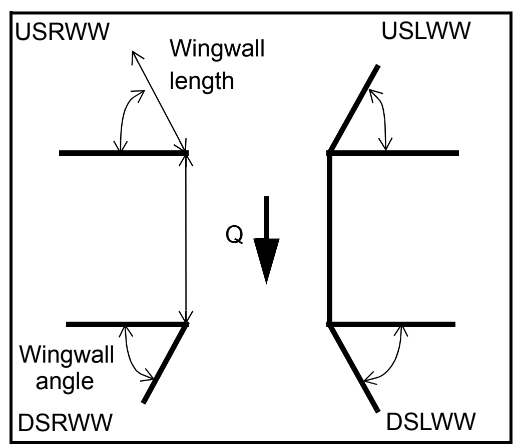
-

2

Stone rip-rap also is considered part of each abutment with the concrete abutments behind. Although the vertical concrete walls are set back from the main channel, the toe of each spill-through embankment protrudes the channel.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						64.5	
USRWW:	N		-		-	0.5	
DSLWW:	-		-		N	29.5	
DSRWW:	-		-		-	30.0	



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	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	3	3	-

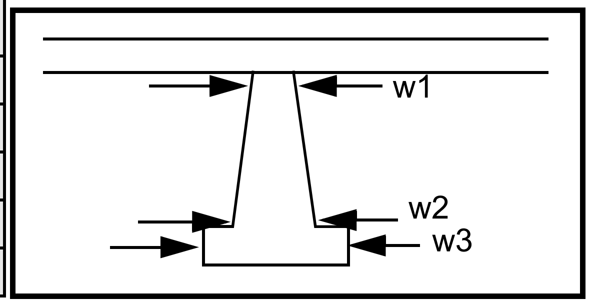
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

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

-
-
-
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

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

Bank width (BF) - ______ Channel width (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.):

1
1
321
321
1
2
3
0
0
-
-
Vegetative cover is thick brush.

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

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

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

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

Point bar extent: _______ feet ____ *(US, UB, DS)* to **N** feet **-** *(US, UB, DS)* positioned **NO** %LB to **DR** %RB

Material: **OP**

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

STRUCTURE

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

Cut bank extent: **2** feet **8** *(US, UB, DS)* to **10** feet **UB** *(US, UB, DS)*

Bank damage: **10** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
50
80
32

Is channel scour present? **Thi** *(Y or if N type ctrl-n cs)* Mid-scour distance: **s is a**

Scour dimensions: Length **grav** Width **el** Depth: **and** Positioned **san** %LB to **d** %RB

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

bar that is less than 25% vegetated with grass.

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

Confluence 1: Distance **30** Enters on **0** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

The bank is steep and there is undercutting of the vegetation.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

Y
15
10
8
0.5
60
100
A small pool is located beyond the point bar next to the cut bank.

N

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:	BERKTH00030007	Town:	Berkshire
Road Number:	TH 3	County:	Franklin
Stream:	Pike River		

Initials EMB   Date: 9/27/96 Checked: SAO   9/30/96

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	1530	1900	0
Main Channel Area, ft2	321	380	0
Left overbank area, ft2	545	958	0
Right overbank area, ft2	23	94	0
Top width main channel, ft	55	55	0
Top width L overbank, ft	365	414	0
Top width R overbank, ft	44	91	0
D50 of channel, ft	0.00916	0.00916	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	5.8	6.9	ERR
y1, average depth, LOB, ft	1.5	2.3	ERR
y1, average depth, ROB, ft	0.5	1.0	ERR
Total conveyance, approach	69780	122468	0
Conveyance, main channel	42710	56513	0
Conveyance, LOB	26531	62355	0
Conveyance, ROB	538	3599	0
Percent discrepancy, conveyance	0.0014	0.0008	ERR
Qm, discharge, MC, cfs	936.5	876.8	ERR
Ql, discharge, LOB, cfs	581.7	967.4	ERR
Qr, discharge, ROB, cfs	11.8	55.8	ERR
Vm, mean velocity MC, ft/s	2.9	2.3	ERR
Vl, mean velocity, LOB, ft/s	1.1	1.0	ERR
Vr, mean velocity, ROB, ft/s	0.5	0.6	ERR
Vc-m, crit. velocity, MC, ft/s	3.1	3.2	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	0	0	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)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	321	380	0
Main channel width, ft	55	55	0
y1, main channel depth, ft	5.84	6.91	ERR
Bridge Section			
(Q) total discharge, cfs	1530	1900	0
(Q) discharge thru bridge, cfs	1530	1900	
Main channel conveyance	15788	16440	
Total conveyance	15788	16440	
Q2, bridge MC discharge,cfs	1530	1900	ERR
Main channel area, ft2	191	197	0
Main channel width (skewed), ft	55.0	56.0	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	55	56	0
y_bridge (avg. depth at br.), ft	3.47	3.52	ERR
Dm, median (1.25*D50), ft	0.01145	0.01145	0
y2, depth in contraction,ft	7.68	9.10	ERR
ys, scour depth (y2-ybridge), ft	4.20	5.58	N/A
ARMORING			
D90	0.0483	0.0483	0
D95	0.0694	0.0694	0
Critical grain size,Dc, ft	0.1410	0.2036	ERR
Decimal-percent coarser than Dc			
Depth to armoring,ft	ERR	ERR	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	1530	1900	0	1530	1900	0
a', abut.length blocking flow, ft	379.6	429.5	0	59.2	105.3	0
Ae, area of blocked flow ft2	617.8	1047	0	82.5	169.6	0
Qe, discharge blocked abut.,cfs	760.9	1144	0	146.2	194.3	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.23	1.09	ERR	1.77	1.15	ERR
ya, depth of f/p flow, ft	1.63	2.44	ERR	1.39	1.61	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.170	0.123	ERR	0.265	0.159	ERR
ys, scour depth, ft	8.82	10.28	N/A	5.27	5.56	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)	379.6	429.5	0	59.2	105.3	0
y1 (depth f/p flow, ft)	1.63	2.44	ERR	1.39	1.61	ERR
a'/y1	233.24	176.19	ERR	42.48	65.38	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	0.00	1.00	1.00	0.00
Froude no. f/p flow	0.17	0.12	N/A	0.26	0.16	N/A
Ys w/ corr. factor K1/0.55:						
vertical	6.60	8.89	ERR	6.54	6.39	ERR
vertical w/ ww's	5.41	7.29	ERR	5.36	5.24	ERR
spill-through	3.63	4.89	ERR	3.59	3.51	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	Qother			
Fr, Froude Number	0.82	1	0	0.82	1	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	3.47	3.52	0.00	3.47	3.52	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (spillthrough abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (spillthrough abut.)	1.21	1.30	ERR	1.21	1.30	ERR