LEVEL II SCOUR ANALYSIS FOR BRIDGE 11 (BAKETH00030011) on TOWN HIGHWAY 3, crossing "THE BRANCH", BAKERSFIELD, VERMONT

U.S. Geological Survey
Open-File Report 98-014

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

U.S. Department of the Interior
U.S. Geological Survey

USGS
science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 11 (BAKETH00030011) on TOWN HIGHWAY 3, crossing "THE BRANCH", BAKERSFIELD, VERMONT

By ERICK M. BOEHMLER

U.S. Geological Survey
Open-File Report 98-014

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

Pembroke, New Hampshire

1998

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 11 (BAKETH00030011) ON TOWN HIGHWAY 3, CROSSING "THE BRANCH", BAKERSFIELD, VERMONT

By **Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BAKETH00030011 on Town Highway 3 crossing "The Branch", Bakersfield, 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 5.01-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 and brush except for the left overbank upstream, which is pasture.

In the study area, "The Branch" has a sinuous channel with a slope of approximately 0.003 ft/ft, an average channel top width of 47 feet and an average bank height of 4 feet. The predominant channel bed materials are sand and gravel with a median grain size (D_{50}) of 21.8 mm (0.0714 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 27, 1995, indicated that the reach was laterally unstable. There were multiple cut-banks evident upstream of the site with some bank undermining and erosion. The sinuosity of the channel was greater upstream than downstream of the site.

The Town Highway 3 crossing of "The Branch" is a 43-ft-long, two-lane bridge consisting of one 41-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March 7, 1995). The opening length of the structure parallel to the bridge face is 39 ft. The bridge is supported by vertical, concrete abutments with spill-through embankments in front of each abutment wall. The channel is skewed approximately 15 degrees to the opening. The historical data for this site indicates the opening-skew-to-roadway is 25 degrees while the computed value is 15 degrees from surveyed points at the site.

The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the entire length of each abutment wall. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 2.2 to 3.1 feet. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 2.9 to 7.4 feet. 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 Davis, 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 BAKETH00030011 ***Stream*** "The Branch"

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

Description of Bridge

Bridge length 43 ***ft*** ***Bridge width*** 23.6 ***ft*** ***Max span length*** 41 ***ft***

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

Abutment type Spillthrough ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 6/27/95

Description of stone fill Type-2 along each abutment wall.

Abutments are skeletal type concrete walls with spillthrough embankments in front of each abutment wall.

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

There is a mild channel bend in the upstream reach. The stone fill has slumped where the flow impacts the spill-through embankment on the 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	6/27/95	0	0
Level II	6/27/95	0	0

Moderate. There is some debris on the stone fill under the bridge.

Potential for debris Lots of shrubs and other vegetation on banks of a laterally unstable channel.

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

None evident on 6/27/95.

Description of the Geomorphic Setting

General topography The channel is located in a low relief valley setting with irregular overbank areas and moderately steep valley walls on both sides.

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

Date of inspection 6/27/95

DS left: Mildly sloping channel bank and a narrow overbank to the TH 3 roadway.

DS right: Moderately sloping channel bank to a narrow overbank.

US left: Moderately sloping channel bank and valley wall.

US right: Moderately sloping channel bank and narrow flood plain.

Description of the Channel

Average top width 47 *ft* ***Average depth*** 4 *ft*

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

Sinuous with alluvial channel boundaries and narrow point bars.

6/27/95

Vegetative co

DS left: Shrubs and brush.

DS right: Shrubs and brush.

US left: Shrubs and brush.

US right: Shrubs and brush.

Do banks appear stable? No

date of observation. On 6/27/95, multiple cut-banks were evident upstream of this site with some bank material undermining and other signs of bank erosion, particularly on the left bank upstream.

Describe any obstructions in channel and date of observation. The assessment of 6/27/95 indicated that a wire fence across the channel downstream, which may collect debris and obstruct flow.

Hydrology

Drainage area 5.01 ***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 1,050 ***ft³/s*** ***Q500*** 1,580 ***ft³/s***

The 100- and 500-year discharges are values selected from a discharge frequency curve available in the VTAOT database (written communication, VTAOT, May 1995) and extrapolated to the 500-year event. The VTAOT discharges selected were within a range defined by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Laraway, 1972; Johnson and Tasker, 1974; Potter, 1957; 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 the center point of a chiseled "X" on top of the downstream end of the right abutment (elev. 499.45 feet, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the upstream end of the left abutment (elev. 500.10 feet, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-29	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	66	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 0.035 to 0.040, and overbank "n" values ranged from 0.045 to 0.060.

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 0.00342 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1986).

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

For the 100-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profile, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.2 ***ft***
Average low steel elevation 497.2 ***ft***

100-year discharge 1,050 ***ft³/s***
Water-surface elevation in bridge opening 494.7 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 103 ***ft²***
Average velocity in bridge opening 10.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.3 ***ft/s***

Water-surface elevation at Approach section with bridge 496.8
Water-surface elevation at Approach section without bridge 495.0
Amount of backwater caused by bridge 1.8 ***ft***

500-year discharge 1,580 ***ft³/s***
Water-surface elevation in bridge opening 497.5 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 194 ***ft²***
Average velocity in bridge opening 8.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.5 ***ft/s***

Water-surface elevation at Approach section with bridge 499.1
Water-surface elevation at Approach section without bridge 495.8
Amount of backwater caused by bridge 3.3 ***ft***

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year discharge was computed by use of the clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 500-year discharge was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

Additional estimates of contraction scour also were computed for the 500-year event by use of Laursen's clear-water scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results from these equations are presented in appendix F. Furthermore, for the 500-year discharge, contraction scour was computed by substituting an alternative estimate for the depth of flow in the bridge at the downstream face in the contraction scour equations. Results with respect to this substitution also are provided in appendix F. For the 100-year discharge, the armoring depth computed indicates that streambed armoring potentially will limit contraction scour.

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

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

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the elevation of scour was computed based on the elevation at the toe of each spill-through embankment and applied for the entire area 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	2.2	3.1	--
Depth to armoring	2.1	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	6.6	7.4	--
Right abutment	2.9	5.7	--
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	1.9	2.1	--
Right abutment	1.9	2.1	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

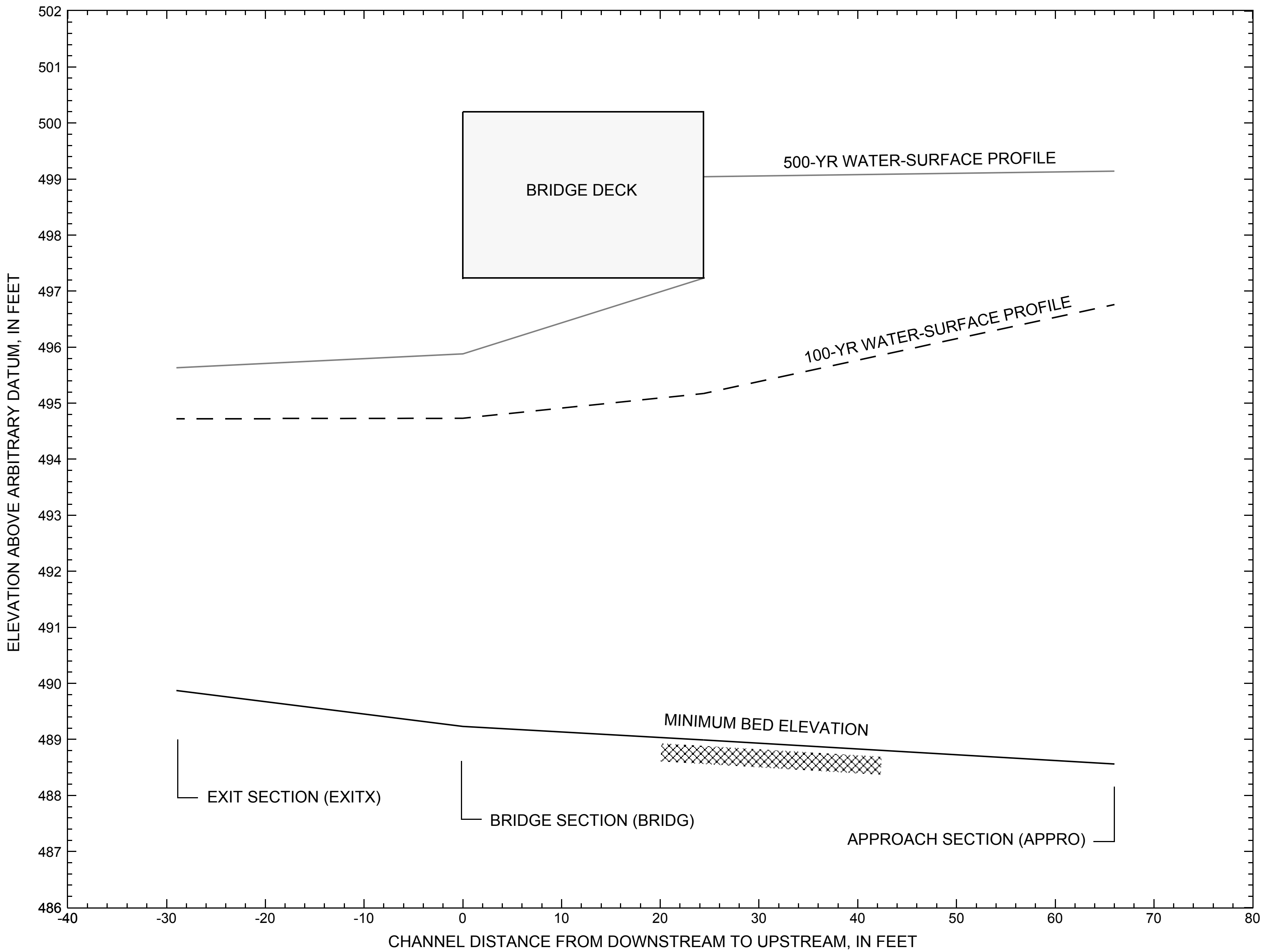


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BAKETH00030011 on Town Highway 3, crossing "The Branch", Bakersfield, Vermont.

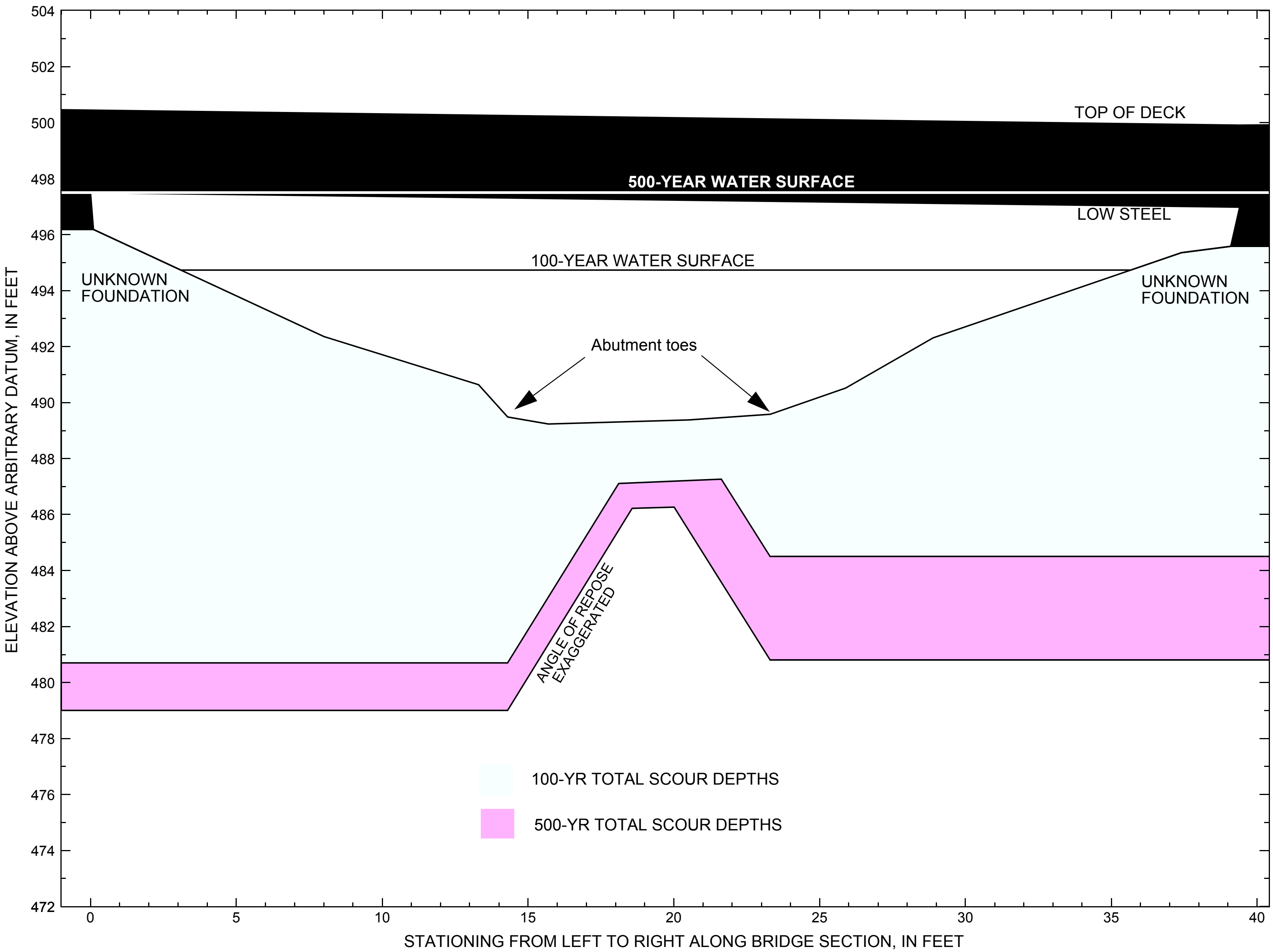


Figure 8. Scour elevations for the 100- and 500-yr discharges at structure BAKETH00030011 on Town Highway 3, crossing "The Branch", Bakersfield, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure BAKETH00030011 on Town Highway 3, crossing "The Branch", Bakersfield, 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 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 1,050 cubic-feet per second											
Left abutment	0.0	--	497.5	--	496.2	--	--	--	--	--	--
Left abutment toe	14.3	--	--	--	489.5	2.2	6.6	--	8.8	480.7	--
Right abutment toe	23.3	--	--	--	489.6	2.2	2.9	--	5.1	484.5	--
Right abutment	39.4	--	497.0	--	495.6	--	--	--	--	--	--

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-yr discharge at structure BAKETH00030011 on Town Highway 3, crossing "The Branch", Bakersfield, 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 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 1,580 cubic-feet per second											
Left abutment	0.0	--	497.5	--	496.2	--	--	--	--	--	--
Left abutment toe	14.3	--	--	--	489.5	3.1	7.4	--	10.5	479.0	--
Right abutment toe	23.3	--	--	--	489.6	3.1	5.7	--	8.8	480.8	--
Right abutment	39.4	--	497.0	--	495.6	--	--	--	--	--	--

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.

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.

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. Geological Survey, 1986, Bakersfield, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Aerial photographs, 1981; Contour interval, 6 meters; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File bake011.wsp
T2        Hydraulic analysis for structure BAKETH00030011   Date: 19-MAY-97
T3        Town Highway 3 crossing “The Branch”, Bakersfield, VT             EMB
*
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1050.0   1580.0
SK          0.00342  0.00342
*
XS   EXITX    -29
GR         -217.8, 511.12   -202.2, 505.53   -142.6, 503.42    -41.2, 500.58
GR          -14.0, 492.63      0.0, 492.46      6.8, 490.41     10.4, 490.27
GR           11.8, 489.98     24.0, 489.87     29.7, 490.23     33.1, 491.60
GR           68.1, 494.52    121.7, 497.80    139.9, 500.91    147.6, 503.26
*
N           0.055        0.040        0.045
SA                  0.0          33.1
*
XS   FULLV      0  * * *   0.0000
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    497.23      15.0
GR            0.0, 497.49      0.0, 496.18      8.0, 492.36     13.3, 490.64
GR           14.3, 489.48     15.7, 489.23     20.5, 489.38     23.3, 489.58
GR           25.9, 490.52     28.9, 492.32     37.4, 495.35     39.4, 495.58
GR           39.4, 496.98      0.0, 497.49
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD            3      28.2      1.4    500.2
N           0.035
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     14       23.6     1
GR         -234.6, 514.64   -202.3, 509.76   -141.7, 503.75    -71.0, 501.61
GR            0.0, 500.45      0.0, 501.86     41.0, 501.11     41.0, 499.91
GR          106.5, 500.01    178.5, 501.93    247.6, 505.68
*
AS   APPRO     66
GR         -113.0, 507.01    -73.1, 506.21    -41.1, 503.72    -12.2, 499.05
GR            0.0, 494.44      6.8, 491.15     17.6, 490.39     21.9, 488.88
GR           24.9, 488.56     28.4, 489.39     31.3, 490.42     38.1, 494.67
GR           47.9, 496.05     65.2, 495.71    104.9, 495.39    136.3, 496.24
GR          178.5, 497.37    247.6, 501.12
*
N           0.040        0.060
SA                  47.9
*
HP 1 BRIDG 494.73 1 494.73
HP 2 BRIDG 494.73 * * 1050
HP 1 APPRO 496.76 1 496.76
HP 2 APPRO 496.76 * * 1050
*
HP 1 BRIDG 497.49 1 497.49
HP 2 BRIDG 497.49 * * 1580
HP 2 BRIDG 495.88 * * 1580
HP 1 APPRO 499.14 1 499.14
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File bake011.wsp
      Hydraulic analysis for structure BAKETH00030011   Date: 19-MAY-97
      Town Highway 3 crossing “The Branch”, Bakersfield, VT             EMB
         *** RUN DATE & TIME: 05-28-97  07:29

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

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      103      9109     32     34                           1050
 494.73           103      9109     32     34  1.00      3     36     1050

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     494.73     3.0    35.7   102.6    9109.    1050.  10.24

X STA.         3.0        9.4       11.4       12.9       14.2       15.1
  A(I)             9.1        6.2        5.5        5.4        4.4
  V(I)            5.77       8.42       9.57       9.69      11.83

X STA.        15.1       15.9       16.6       17.4       18.2       18.9
  A(I)             4.3        4.0        4.0        4.0        4.0
  V(I)           12.27      13.05      13.01      13.22      13.27

X STA.        18.9       19.7       20.5       21.2       22.1       22.9
  A(I)             4.0        4.0        4.0        4.2        4.2
  V(I)           13.05      13.11      13.05      12.50      12.38

X STA.        22.9       23.8       24.9       26.2       28.1       35.7
  A(I)             4.5        4.8        5.5        6.5        9.8
  V(I)           11.56      10.87       9.60       8.10       5.35

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      66.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      243     23775     54     57                           2925
           2       98      2283    108    108                            530
 496.76           341     26058    162    165  1.50     -5    156     2291

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      66.

       WSEL     LEW     REW    AREA        K        Q    VEL
     496.76    -6.1   155.7   341.0   26058.    1050.   3.08

X STA.        -6.1        4.6        7.6        9.8       11.9       13.9
  A(I)            23.1       15.3       13.0       12.4       11.9
  V(I)            2.27       3.44       4.05       4.25       4.41

X STA.        13.9       15.7       17.5       19.2       20.7       22.0
  A(I)            11.4       11.1       11.0       10.7       10.5
  V(I)            4.62       4.71       4.77       4.89       5.02

X STA.        22.0       23.3       24.6       25.9       27.3       28.9
  A(I)            10.2       10.4       10.5       10.9       12.0
  V(I)            5.14       5.05       4.99       4.81       4.38

X STA.        28.9       30.7       33.2       39.7       86.8      155.7
  A(I)            12.6       14.7       20.8       50.3       58.2
  V(I)            4.16       3.57       2.52       1.04       0.90
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File bake011.wsp
        Hydraulic analysis for structure BAKETH00030011   Date: 19-MAY-97
        Town Highway 3 crossing “The Branch”, Bakersfield, VT             EMB
           *** RUN DATE & TIME: 05-28-97  07:29

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      194     14664      0     82                            0
   497.49           194     14664      0     82  1.00      0     39        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.49     0.0    39.4   193.8   14664.    1580.   8.15

X STA.         0.0        6.1        8.6       10.5       12.1       13.5
  A(I)            16.2       11.2       10.1        9.4        9.1
  V(I)            4.88       7.07       7.85       8.44       8.66

X STA.        13.5       14.7       15.7       16.7       17.7       18.7
  A(I)             8.5        7.9        7.7        7.6        7.5
  V(I)            9.28       9.97      10.23      10.41      10.47

X STA.        18.7       19.7       20.7       21.8       22.8       24.0
  A(I)             7.7        7.7        8.0        7.9        8.5
  V(I)           10.25      10.30       9.93       9.94       9.34

X STA.        24.0       25.3       26.8       28.8       31.8       39.4
  A(I)             8.8        9.6       10.7       12.3       17.5
  V(I)            8.93       8.24       7.41       6.44       4.51

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.88     0.6    39.4   142.4   13971.    1580.  11.10

X STA.         0.6        8.0       10.3       11.9       13.4       14.5
  A(I)            12.7        8.3        7.4        6.9        6.7
  V(I)            6.22       9.53      10.71      11.51      11.74

X STA.        14.5       15.4       16.3       17.2       18.0       18.9
  A(I)             5.8        5.6        5.5        5.4        5.4
  V(I)           13.59      14.06      14.29      14.52      14.58

X STA.        18.9       19.8       20.6       21.5       22.5       23.4
  A(I)             5.4        5.6        5.5        5.9        5.8
  V(I)           14.59      14.20      14.37      13.48      13.54

X STA.        23.4       24.5       25.8       27.4       30.0       39.4
  A(I)             6.4        6.9        7.8        9.4       13.9
  V(I)           12.29      11.48      10.16       8.42       5.67

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      66.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      379     46171     61     64                         5379
             2      431     20420    163    163                         3971
   499.14           810     66592    224    227  1.62    -12    211     6862

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      66.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.14   -12.8   211.1   809.9   66592.    1580.   1.95

X STA.       -12.8        3.4        7.6       10.9       13.9       16.7
  A(I)            48.0       30.7       27.1       24.9       23.8
  V(I)            1.64       2.57       2.92       3.17       3.32

X STA.        16.7       19.3       21.6       23.6       25.7       27.8
  A(I)            23.3       22.7       21.0       21.5       21.5
  V(I)            3.39       3.47       3.76       3.67       3.68

X STA.        27.8       30.2       33.2       38.5       50.6       69.0
  A(I)            23.1       25.3       30.9       43.8       60.8
  V(I)            3.43       3.12       2.55       1.80       1.30

X STA.        69.0       86.3      102.7      120.9      145.2      211.1
  A(I)            61.4       60.1       64.7       72.6      102.6
  V(I)            1.29       1.31       1.22       1.09       0.77
```

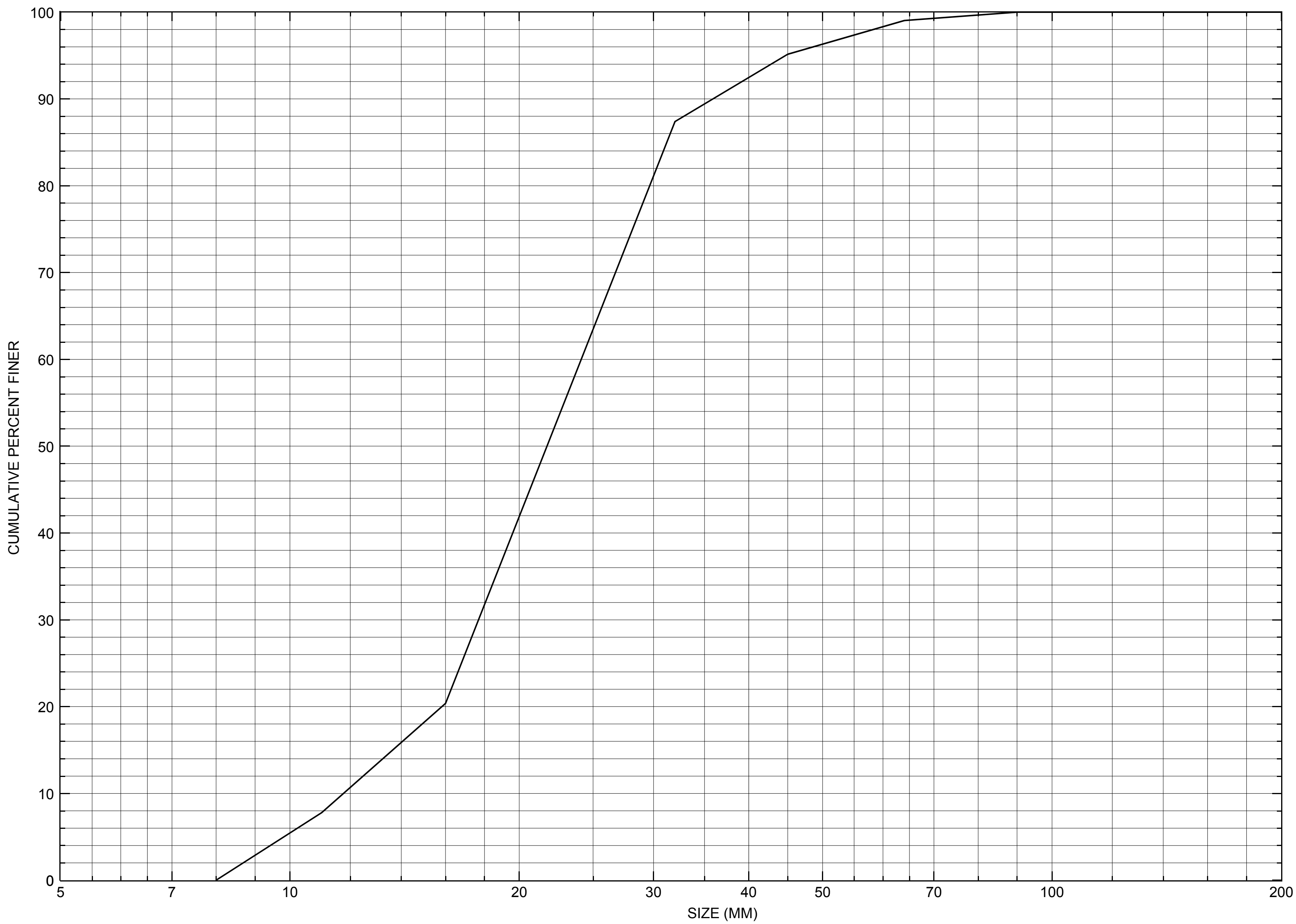
WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File bake011.wsp
       Hydraulic analysis for structure BAKETH00030011   Date: 19-MAY-97
       Town Highway 3 crossing "The Branch", Bakersfield, VT             EMB
          *** RUN DATE & TIME: 05-28-97  07:29

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

EXITX:XS   ******    -20      239  0.41 *****  495.13  493.61    1050  494.72
       -28 ******     71    17950  1.37 ***** *******    0.56    4.40

FULLV:FV       29    -21      252  0.37  0.09  495.23 *******    1050  494.86
         0     29     74    19186  1.38  0.00    0.01    0.53    4.17
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.69

APPRO:AS       66      0      154  0.72  0.29  495.68 *******    1050  494.96
        66     66     40    13243  1.00  0.17   -0.01    0.62    6.80
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1050.     494.73

            <<<<<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       29      3      103  1.63 *****  496.36  494.73    1050  494.73
         0     29     36     9101  1.00 ***** *******    1.00   10.24

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  1.000 ******  497.23 ****** ****** ******

    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       38     -5      341  0.22  0.18  496.98  493.69    1050  496.76
        66     39    156    26044  1.50  0.44    0.02    0.46    3.08

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.200  0.055   24398.     5.    38.   496.69

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -29.   -21.    71.   1050.   17950.     239.    4.40  494.72
   FULLV:FV       0.   -22.    74.   1050.   19186.     252.    4.17  494.86
   BRIDG:BR       0.     3.    36.   1050.    9101.     103.   10.24  494.73
   RDWAY:RG      14.**************      0.*****************    1.00********
   APPRO:AS      66.    -6.   156.   1050.   26044.     341.    3.08  496.76

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       5.    38.   24398.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    493.61    0.56  489.87  511.12************  0.41  495.13  494.72
   FULLV:FV  ********    0.53  489.87  511.12  0.09  0.00  0.37  495.23  494.86
   BRIDG:BR    494.73    1.00  489.23  497.49************  1.63  496.36  494.73
   RDWAY:RG  ****************  499.91  514.64**********************************
   APPRO:AS    493.69    0.46  488.56  507.01  0.18  0.44  0.22  496.98  496.76
```

```
       U.S. Geological Survey WSPRO Input File bake011.wsp
       Hydraulic analysis for structure BAKETH00030011   Date: 19-MAY-97
       Town Highway 3 crossing "The Branch", Bakersfield, VT             EMB
          *** RUN DATE & TIME: 05-28-97  07:29

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

EXITX:XS   ******    -23      331  0.50 *****  496.13  494.34    1580  495.63
       -28 ******     86    26994  1.42 ***** *******    0.58    4.77

FULLV:FV       29    -24      348  0.46  0.09  496.24 *******    1580  495.78
         0     29     89    28688  1.42  0.00    0.01    0.55    4.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.04     495.83     494.74

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   495.28     507.01    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   495.28     507.01     494.74

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.61

APPRO:AS       66     -3      210  1.00  0.33  496.84  494.74    1580  495.83
        66     66    121    17375  1.13  0.27    0.00    1.04    7.53
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.90     498.01     498.16     497.23

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<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       29      0      194  1.03 *****  498.52  495.88    1576  497.49
         0 ******     39    14664  1.00 ***** *******    0.65    8.13

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****    2.  0.485 ******  497.23 ****** ****** ******

    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       38    -12      810  0.10  0.10  499.24  494.74    1580  499.14
        66     39    211    66594  1.62  0.39    0.00    0.23    1.95

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.12

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -29.   -24.    86.   1580.   26994.     331.    4.77  495.63
   FULLV:FV       0.   -25.    89.   1580.   28688.     348.    4.54  495.78
   BRIDG:BR       0.     0.    39.   1576.   14664.     194.    8.13  497.49
   RDWAY:RG      14.**************      0.******************    1.00********
   APPRO:AS      66.   -13.   211.   1580.   66594.     810.    1.95  499.14

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     494.34    0.58  489.87  511.12************  0.50  496.13  495.63
   FULLV:FV   ********    0.55  489.87  511.12  0.09  0.00  0.46  496.24  495.78
   BRIDG:BR     495.88    0.65  489.23  497.49************  1.03  498.52  497.49
   RDWAY:RG   ***************  499.91  514.64************  0.02  502.14********
   APPRO:AS     494.74    0.23  488.56  507.01  0.10  0.39  0.10  499.24  499.14
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BAKETH00030011, in Bakersfield, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BAKETH00030011

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 07 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 02500

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

Waterway *(I - 6)* THE BRANCH

Road Name *(I - 7)*: -

Route Number TH003

Vicinity *(I - 9)* 0.4 MI TO JCT W VT108

Topographic Map Bakersfield

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44468

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

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10060100110601

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

Maximum span length *(I - 48; nnnn)* 0041

Year built *(I - 27; YYYY)* 1937

Structure length *(I - 49; nnnnnn)* 000043

Average daily traffic, ADT *(I - 29; nnnnnn)* 000300

Deck Width *(I - 52; nn.n)* 236

Year of ADT *(I - 30; YY)* 93

Channel & Protection *(I - 61; n)* 6

Opening skew to Roadway *(I - 34; nn)* 25

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 7.3

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

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

Comments:

The structural inspection report of 6/21/93 indicates the structure is a concrete T-beam type bridge. There are concrete skeleton abutments with boulder riprap protection in place on the embankments upstream and around each abutment. However, the riprap directly in front of the left abutment has slumped and needs to be replaced to help protect embankment. A voided pocket has formed behind the right end of left abutment. The void has been partially covered over with large flat boulders. The foundation type at this site is recorded as unknown. There are small areas of bank erosion reported. Debris and point bar problems are noted as minor.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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*): - Frequency: -

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **5.01** mi^2

Lake/pond/swamp area **0.03** mi^2

Watershed storage *(ST)* **0.6** %

Bridge site elevation **699** ft

Headwater elevation **1910** ft

Main channel length **4.07** mi

10% channel length elevation **709** ft

85% channel length elevation **1408** ft

Main channel slope *(S)* **228.99** 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 BENCHMARK 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 FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

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: 3/18/96
Computerized by: RB Date: 3/25/96
Reviewd by: EMB Date: 5/19/97

Structure Number BAKETH00030011

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. BOEHMLER Date *(MM/DD/YY)* 6 / 27 / 1995

2. Highway District Number 08 Mile marker 000

County FRANKLIN (011) Town BAKERSFIELD (02500)

Waterway *(I - 6)* THE BRANCH Road Name -

Route Number TH 3 Hydrologic Unit Code: 02010007

3. Descriptive comments:

Located about 0.4 mile east from the intersection of TH 3 with VT 108. J. Degnan assisted with the assessment.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 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 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 43 *(feet)* Span length 41 *(feet)* Bridge width 23.6 *(feet)*

Road approach to bridge:

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

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

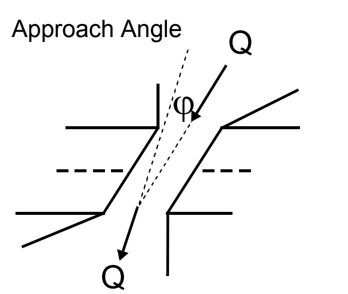
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

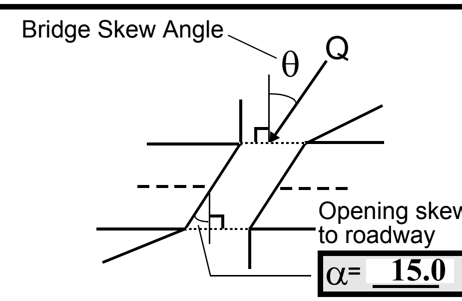
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	2	2

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

Channel approach to bridge (BF):

15. Angle of approach: 10 16. Bridge skew: 15





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 35 feet US *(US, UB, DS)* to 10 feet UB

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: **3**

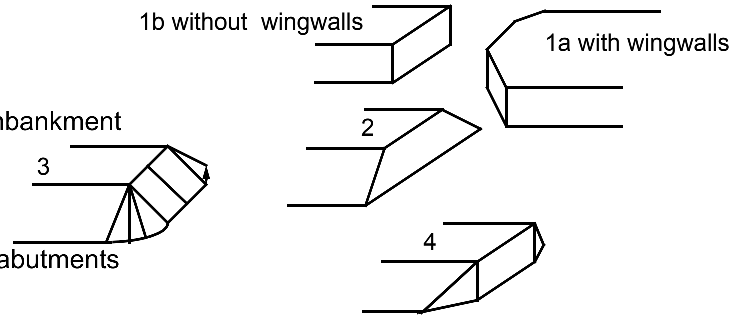
1a- Vertical abutments with wingwalls

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.)

Measured bridge dimensions matched the VTAOT values.
Surface cover is fairly consistent on each corner.
Embankment slope points were not surveyed. The right road embankment slope was measured using a compass and a range pole. There is no road embankment on the US left side. The average embankment angle is 35 degrees.

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
46.5	**8.0**			**5.5**	**1**	**1**	**123**	**120**	**2**	**1**

23. Bank width **25.0** 24. Channel width **20.0** 25. Thalweg depth **60.0** 29. Bed Material **231**

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.):

Bank material is mainly silt and clay with sand and a little fine gravel. There is more organic material in the left bank than the right.
The bed material is mainly fine to medium sand with some silt, clay and gravel. The gravel is under a thin layer of silt and fine sand.

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

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

37. Material: -

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

NO POINT BARS

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

41. Mid-bank distance: 20 42. Cut bank extent: 35 feet US (US, UB) to 0 feet US (US, UB, DS)

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

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

Another cut bank is on the right bank from 48 feet to 65 feet US near where flow enters from the confluence. Bank damage is eroded or creep.

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

Channel depths gradually vary between 0.5 feet to 2 feet.

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

51. Confluence 1: Distance 90 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):

The channel at the confluence area is somewhat anabranched with a couple channels where flow is divided mainly during higher water. The confluence and the main channel are about the same size.

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		2.0		2	7	7	-

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

231

Some debris, composed of mainly branches and leaves, is piled on the left side of the channel under the bridge. At the channel edges, type-2 stone fill is present. Up-slope from the stone fill on the left there is sand and gravel. Some of the sand and gravel has washed-out from the gap between the columns of the left abutment wall.

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

67. Debris Potential **2** ___ *(**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

There is significant vegetation (i.e. shrubs and brush) on the banks of this sinuous channel. The low gradient, stone-fill, and a slight bend in the channel at the bridge contribute to a moderate capture efficiency.

<u>Abutments</u>	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**	**15**	**2**	**2**	**0**	**2**	**90.0**
RABUT	**1**	**-**	**20**			**2**	**2**	**38.0**

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*

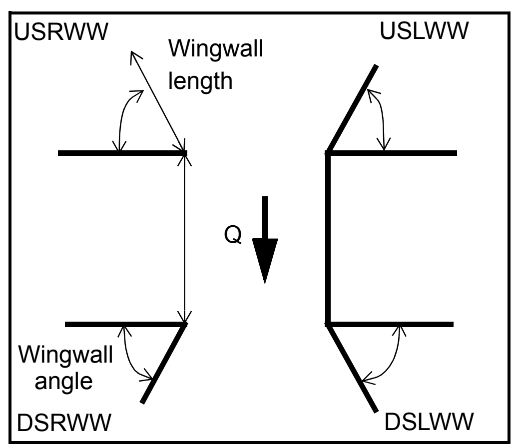
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
1
1

The abutment walls are the skeletal type with road-embankment fill exposed in the gap between the concrete columns. This fill is slumping or eroding. Type-2 stone fill is along the channel edges but is not up on the abutment walls. Although this is considered a spill-through abutment, the stone fill acting as the spill-through embankment has eroded and is no longer serving this purpose. Instead the stone fill is acting like bank protection for the road-embankment fill in front of the abutment walls.

80. <u>Wingwalls</u>:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**38.0**	
USRWW:	**N**		**-**		**-**	**1.5**	
DSLWW:	**-**		**-**		**N**	**28.5**	
DSRWW:	**-**		**-**		**-**	**28.0**	



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

82. <u>Bank / Bridge Protection</u>:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**-**	**N**	**-**	**-**	**-**	**2**	**2**
Condition	**N**	**-**	**-**	**-**	**-**	**-**	**1**	**1**
Extent	**-**	**-**	**-**	**-**	**-**	**2**	**2**	**-**

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

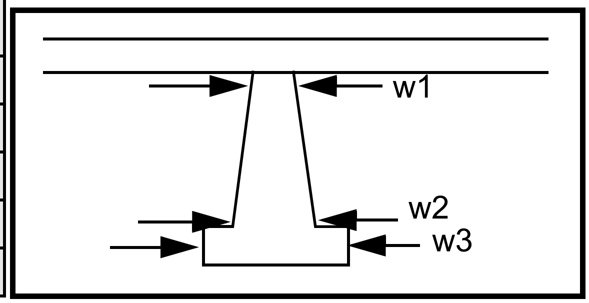
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
-
-
-
-
-
-

Piers:

84. Are there piers? **No** *(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)	**wing-**		-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**walls**	**N**	-	-	***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		-	-	-	
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

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

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
123
123
0
0
321
0
0
-

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

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

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

e banks are much lower and there is no bank erosion evident. There is more gravel on the surface of the bed material. Part of this may be due to the erosion of the road-embankment fill from spill-through embankments. The bank material is virtually the same as upstream.

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

Point bar extent: ______ feet ____ *(US, UB, DS)* to ______ feet ____ *(US, UB, DS)* positioned ____ %LB to _____ %RB

Material: **N**

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

-

NO DROP STRUCTURE

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

Cut bank extent: **Y** feet **39** *(US, UB, DS)* to **14** feet **28** *(US, UB, DS)*

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

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

50

DS

0

70

Is channel scour present? **32** *(Y or if N type ctrl-n cs)* Mid-scour distance: **The**

Scour dimensions: Length **mate** Width **rial** Depth: **of** Positioned **this** %LB to **bar** %RB

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

looks similar in composition to the road-embankment fill visible under the left abutment.

N

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

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

Confluence 2: Distance **-** Enters on **-** *(LB or RB)* Type **NO** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

CUT BANKS

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N
-
-
-
-
-
-
NO CHANNEL SCOUR

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:	BAKETH00030011	Town:	Bakersfield
Road Number:	TH 3	County:	Franklin
Stream:	The Branch		

Initials EMB   Date: 5/27/97 Checked: SAO   6/3/97

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	1050	1580	0
Main Channel Area, ft2	243	379	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	98	431	0
Top width main channel, ft	54	61	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	108	163	0
D50 of channel, ft	0.0714	0.0714	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	4.5	6.2	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	0.9	2.6	ERR
Total conveyance, approach	26058	66592	0
Conveyance, main channel	23775	46171	0
Conveyance, LOB	0	0	0
Conveyance, ROB	2283	20420	0
Percent discrepancy, conveyance	0.0000	0.0015	ERR
Qm, discharge, MC, cfs	958.0	1095.5	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	92.0	484.5	ERR
Vm, mean velocity MC, ft/s	3.9	2.9	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	0.9	1.1	ERR
Vc-m, crit. velocity, MC, ft/s	6.0	6.3	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

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	1050	1580	N/A
Main channel area (DS), ft2	102.6	142.4	0
Main channel width (normal), ft	19.8	22.6	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	19.8	22.6	0.0
D90, ft	0.1178	0.1178	0.1178
D95, ft	0.1467	0.1467	0.1467
Dc, critical grain size, ft	0.2675	0.2957	ERR
Pc, Decimal percent coarser than Dc	0.281	0.000	0.000
Depth to armoring, ft	2.05	N/A	ERR

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1050	1580	0
(Q) discharge thru bridge, cfs	1050	1580	0
Main channel conveyance	9109	14664	0
Total conveyance	9109	14664	0
Q2, bridge MC discharge,cfs	1050	1580	ERR
Main channel area, ft2	103	194	0
Main channel width (normal), ft	19.8	22.6	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.8	22.6	0
y_bridge (avg. depth at br.), ft	5.18	8.58	ERR
Dm, median (1.25*D50), ft	0.08925	0.08925	0
y2, depth in contraction,ft	7.42	9.41	ERR
ys, scour depth (y2-ybridge), ft	**2.24**	0.83	N/A

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	1050	1580	0
Q, thru bridge MC, cfs	1050	1580	N/A
Vc, critical velocity, ft/s	5.98	6.31	N/A
Va, velocity MC approach, ft/s	3.94	2.89	N/A
Main channel width (normal), ft	19.8	22.6	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.8	22.6	0.0
qbr, unit discharge, ft2/s	53.0	69.9	ERR
Area of full opening, ft2	102.6	193.8	0.0
Hb, depth of full opening, ft	5.18	8.58	ERR
Fr, Froude number, bridge MC	0	0.65	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	142.4	N/A
**Hb, depth at downstream face, ft	N/A	6.30	ERR
**Fr, Froude number at DS face	ERR	0.78	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	497.23	0
Elevation of Bed, ft	-5.18	488.65	N/A
Elevation of Approach, ft	0	499.14	0
Friction loss, approach, ft	0	0.1	0
Elevation of WS immediately US, ft	0.00	499.04	0.00
ya, depth immediately US, ft	5.18	10.39	N/A
Mean elevation of deck, ft	0	501.5	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.95	ERR
**Cc, for downstream face (<=1.0)	ERR	0.95	ERR
Ys, scour w/Chang equation, ft	N/A	**3.06**	N/A
Ys, scour w/Umbrell equation, ft	N/A	-1.42	N/A

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

**Ys, scour w/Chang equation, ft	N/A	5.37	N/A
**Ys, scour w/Umbrell equation, ft	ERR	0.85	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	7.42	9.41	0.00
WSEL at downstream face, ft	--	495.88	--
Depth at downstream face, ft	N/A	6.30	N/A
Ys, depth of scour (Laursen), ft	N/A	3.11	N/A

Abutment Scour

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

	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	1050	1580	0	1050	1580	0
a', abut.length blocking flow, ft	14.7	20.4	0	126	180.1	0
Ae, area of blocked flow ft2	44.3	78.7	0	151	515.4	0
Qe, discharge blocked abut.,cfs	128.9	158	0	239.2	689.9	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.91	2.01	ERR	1.58	1.34	ERR
ya, depth of f/p flow, ft	3.01	3.86	ERR	1.20	2.86	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	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.295	0.180	ERR	0.255	0.139	ERR
ys, scour depth, ft	**6.62**	**7.39**	N/A	5.90	9.09	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)	14.7	20.4	0	126	180.1	0
y1 (depth f/p flow, ft)	3.01	3.86	ERR	1.20	2.86	ERR
a'/y1	4.88	5.29	ERR	105.14	62.93	ERR
Skew correction (p. 49, fig. 16)	1.03	1.03	1.03	0.95	0.95	0.95
Froude no. f/p flow	0.30	0.18	N/A	0.26	0.14	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	5.27	10.32	ERR
vertical w/ ww's	ERR	ERR	ERR	4.33	8.46	ERR
spill-through	ERR	ERR	ERR	**2.90**	**5.68**	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)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	0.78	0	1	0.78	0
y, depth of flow in bridge, ft	5.18	6.30	0.00	5.18	6.30	0.00

Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (spillthrough abut.)	ERR	2.07	0.00	ERR	2.07	0.00
Fr>0.8 (spillthrough abut.)	1.92	ERR	ERR	1.92	ERR	ERR