LEVEL II SCOUR ANALYSIS FOR BRIDGE 24 (BERLTH00600024) on TOWN HIGHWAY 60, crossing COX BROOK, BERLIN, VERMONT

Open-File Report 98-057

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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By JAMES R. DEGNAN

U.S. Geological Survey
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Pembroke, New Hampshire

1998

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 24 (BERLTH00600024) ON TOWN HIGHWAY 60, CROSSING COX BROOK, BERLIN, VERMONT

By **James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BERLTH00600024 on Town Highway 60 crossing Cox Brook, Berlin, 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 (Federal Highway Administration, 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 central Vermont. The 9.26-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream of the bridge. Downstream of the bridge the surface cover is pasture on the left bank and brush on the right bank.

In the study area, Cox Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 53 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 54.0 mm (0.177 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 18, 1996, indicated that the reach was stable.

The Town Highway 60 crossing of Cox Brook is a 59-ft-long, one-lane bridge consisting of one 50-foot steel-beam span (Vermont Agency of Transportation, written communication, October 13, 1995). The opening length of the structure parallel to the bridge face is 53 ft. The bridge is supported by vertical, concrete abutments and wingwalls with stone fill spill-through slopes at the face of each abutment. The channel is skewed approximately 5 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

During the Level I assessment, a scour hole 1.5 ft deeper than the mean thalweg depth was observed in the center of the bridge opening. Scour countermeasures at the site included type-2 stone fill (less than 36 inches diameter) along the abutments, wingwalls, and upstream banks and type-1 stone fill (less than 12 inches diameter) along the downstream banks. 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). In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 1.3 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge. Abutment scour ranged from 3.0 to 6.1 ft. The worst-case left abutment scour occurred at the 500-year discharge and the worst case right abutment scour occurred at the 500-year and incipient roadway-overtopping discharges. 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 BERLTH00600024 ***Stream*** Cox Brook

County Washington ***Road*** TH60 ***District*** 6

Description of Bridge

Bridge length 59 ***ft*** ***Bridge width*** 18.5 ***ft*** ***Max span length*** 50 ***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*** 7/18/96

Description of stone fill Type-2, along the entire length of both abutments and wingwalls.

Abutments and wingwalls are concrete with stone fill spill-through slopes in front of each abutment.

Brief description of piers/abutments

Yes

Is bridge skewed to flood flow according to - survey? ***Angle*** 5 No

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

7/18/96

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	0	0	7/18/
Level II	96	0	0

Potential for debris Moderate. There is some debris caught on boulders and trees leaning over the channel upstream.

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

Trees were observed on 7/18/96 leaning into the channel above the upstream cut banks.

Description of the Geomorphic Setting

General topography The channel is located within a 800 foot-wide, flat to slightly irregular flood plain with steep valley walls on both sides.

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

Date of inspection 7/18/96

DS left: Steep channel bank to a wide flood plain and a steep valley wall

DS right: Steep channel bank to a narrow flood plain and a steep valley wall

US left: Steep channel bank to a wide flood plain and a steep valley wall

US right: Steep channel bank and valley wall

Description of the Channel

Average top width 53 ***ft*** ***Average depth*** 4 ***ft***

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

Sinuous but stable with semi-alluvial to non-alluvial channel boundaries.

7/18/96

Vegetative co

Pasture

DS left: Trees and brush

DS right: Trees

US left: Trees

US right:

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

None as of 7/18/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 9.26 ***mi***^{2}

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 -- ***mi***^{2}

Is there a lake/p No

--

-

Calculated Discharges

Q100 1,910 ***ft***^{3}***/s*** ***Q500*** 2,750 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(9.26/6.46)exp 0.67] with bridge number 36 in Moretown. Bridge number 36 crosses Cox Brook upstream of this site and has flood frequency estimates available from the VTAOT database (Vermont Agency of Transportation, written communication, May 1995). The drainage area above bridge number 36 is 6.46 square miles. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

Description of the Water-Surface Profile Model (WSPRO) Analysis

Datum for WSPRO analysis (USGS survey, sea level, VTAOT plans) USGS survey

Datum tie between USGS survey and VTAOT plans Add 227.4 ft to the USGS arbitrary survey datum to obtain the VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled "X" on top of the upstream right wingwall where it joins the abutment (elev. 499.47 ft, arbitrary survey datum). RM2 is a chiseled "X" on the downstream end of the left abutment (elev. 498.69 ft, arbitrary survey datum). RM3 is a nail in a telephone pole on the upstream right bank, two feet up (elev. 501.47 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	-33	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	73	2	Modelled Approach section (Templated from APTEM)
APTEM	80	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.037 to 0.052, and overbank "n" values ranged from 0.035 to 0.065.

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 0.010 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1980).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.040 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.6 *ft*
Average low steel elevation 496.6 *ft*

100-year discharge 1,910 *ft³/s*
Water-surface elevation in bridge opening 493.0 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 169 *ft²*
Average velocity in bridge opening 11.3 *ft/s*
Maximum WSPRO tube velocity at bridge 15.0 *ft/s*

Water-surface elevation at Approach section with bridge 495.4
Water-surface elevation at Approach section without bridge 494.8
Amount of backwater caused by bridge 0.6 *ft*

500-year discharge 2,750 *ft³/s*
Water-surface elevation in bridge opening 497.0 *ft*
Road overtopping? Y *Discharge over road* 163 *ft³/s*
Area of flow in bridge opening 345 *ft²*
Average velocity in bridge opening 7.5 *ft/s*
Maximum WSPRO tube velocity at bridge 9.8 *ft/s*

Water-surface elevation at Approach section with bridge 497.9
Water-surface elevation at Approach section without bridge 496.2
Amount of backwater caused by bridge 1.7 *ft*

Incipient overtopping discharge 2,390 *ft³/s*
Water-surface elevation in bridge opening 493.7 *ft*
Area of flow in bridge opening 199 *ft²*
Average velocity in bridge opening 12.0 *ft/s*
Maximum WSPRO tube velocity at bridge 15.9 *ft/s*

Water-surface elevation at Approach section with bridge 496.8
Water-surface elevation at Approach section without bridge 495.6
Amount of backwater caused by bridge 1.2 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis for the 100-year and 500-year discharges are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the 100-year and incipient roadway-overtopping discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 500-year discharge resulted in 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 this discharge was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For the 500-year discharge, estimates of contraction scour were also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144) and are presented in appendix F. Furthermore, for the 500-year discharge, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution are provided in appendix F.

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

Scour at the left 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 material of spill-through embankments is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depth computed at the toe of the embankment was applied for the entire spill-through 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	1.0	0.0	1.3
Depth to armoring	N/A	21.7	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	3.8	4.4	3.0
Right abutment	4.9	6.1	6.1
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.5	1.7	1.7
Right abutment	1.5	1.7	1.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

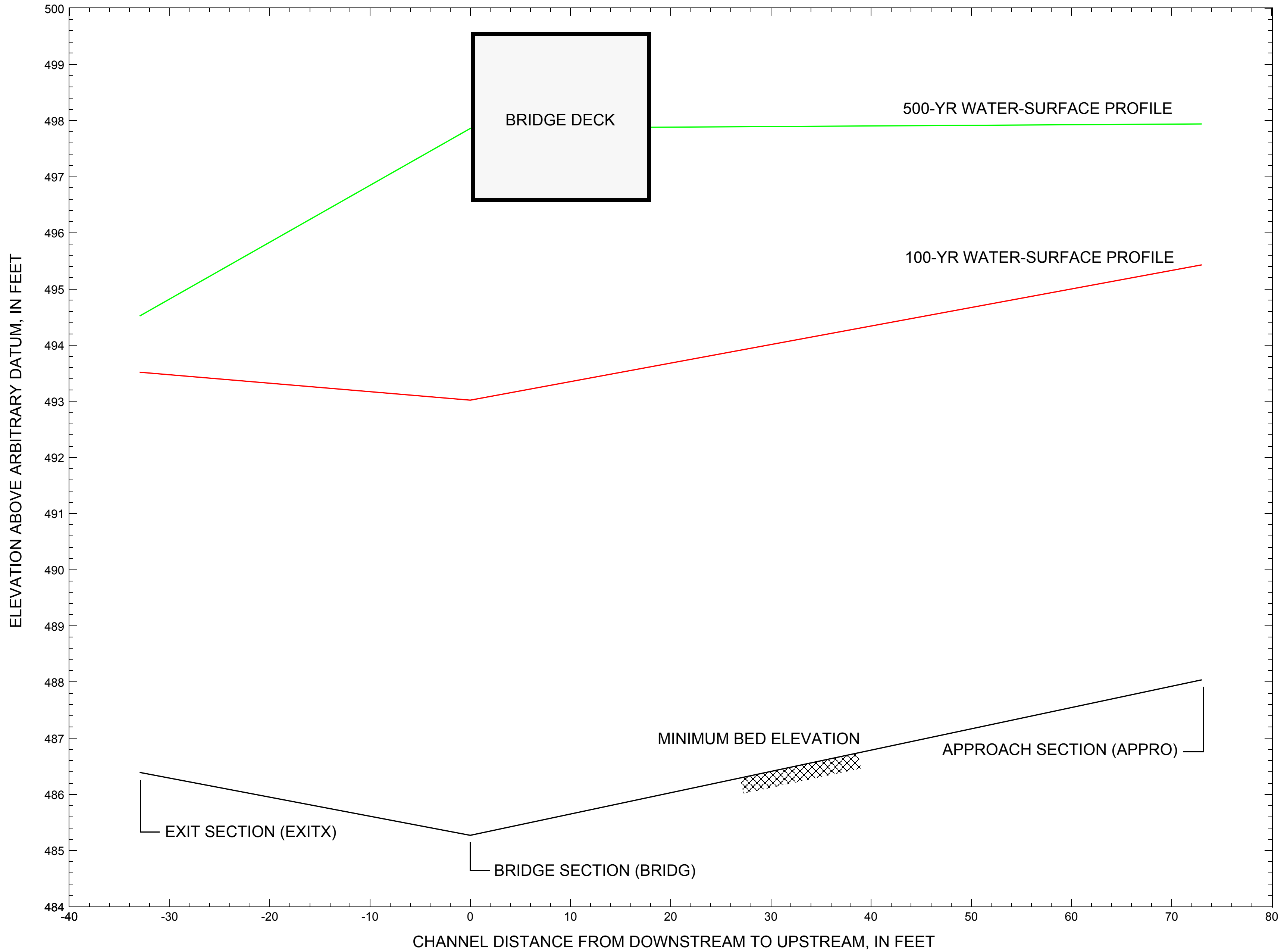

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BERLTH00600024 on Town Highway 60, crossing Cox Brook, Berlin, Vermont.

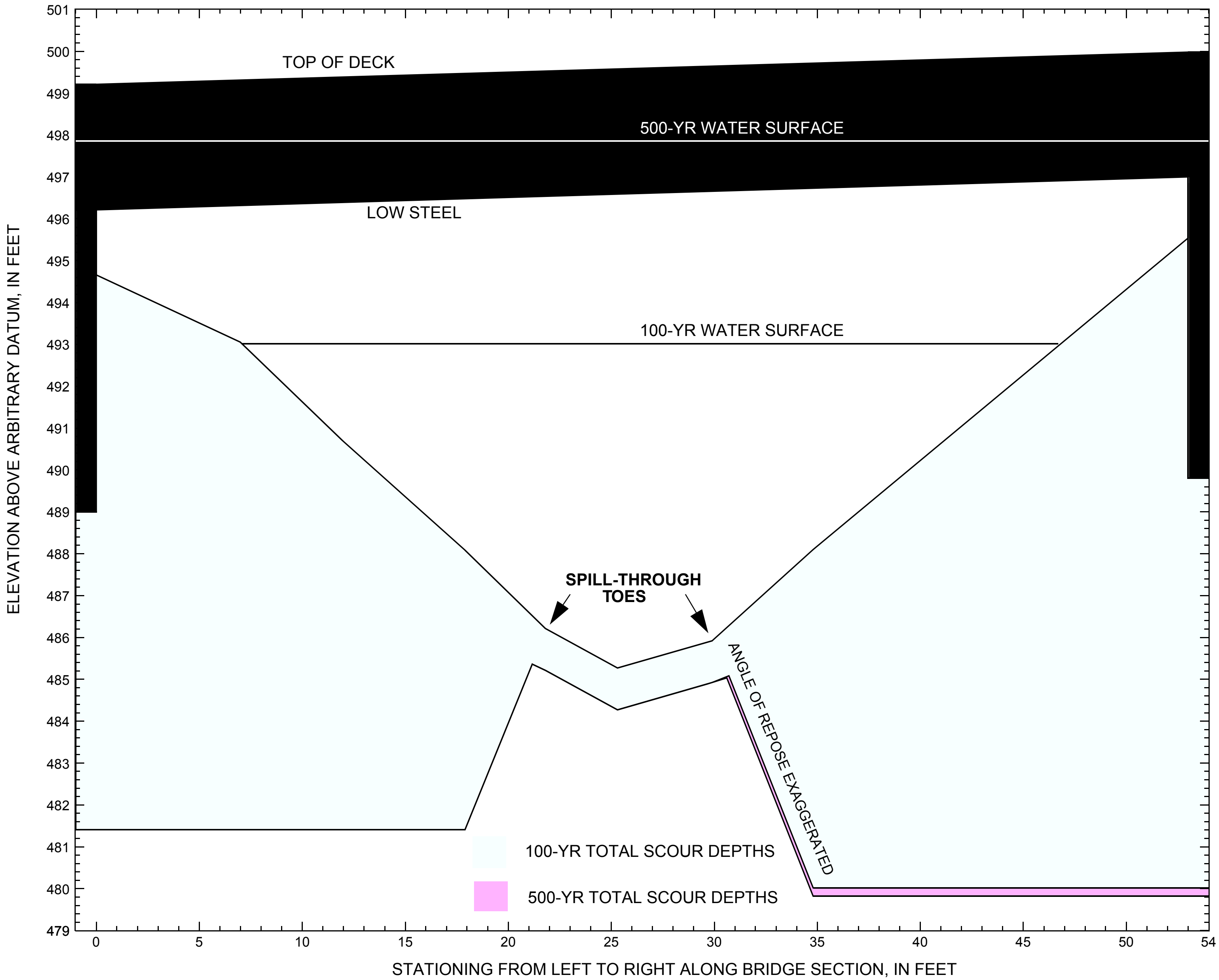

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BERLTH00600024 on Town Highway 60, crossing Cox Brook, Berlin, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure BERLTH00600024 on Town Highway 60, crossing Cox Brook, Berlin, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum 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 1,910 cubic-feet per second											
Left abutment	0.0	773.4	496.2	489.0	494.7	--	--	--	--	--	-7.6
LABUT toe	21.8	--	--	--	486.2	1.0	3.8	--	4.8	481.4	--
RABUT toe	29.9	--	--	--	485.9	1.0	4.9	--	5.9	480.0	--
Right abutment	53.0	774.2	497.0	489.8	495.5	--	--	--	--	--	-9.8

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

Table 2. Remaining footing/pile depth at abutments for the 500-yr discharge at structure BERLTH00600024 on Town Highway 60, crossing Cox Brook, Berlin, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,750 cubic-feet per second											
Left abutment	0.0	773.4	496.2	489.0	494.7	--	--	--	--	--	-7.2
LABUT toe	21.8	--	--	--	486.2	0.0	4.4	--	4.4	481.8	--
RABUT toe	29.9	--	--	--	485.9	0.0	6.1	--	6.1	479.8	--
Right abutment	53.0	774.2	497.0	489.8	495.5	--	--	--	--	--	-10.0

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

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U.S. Geological Survey, 1980, Northfield, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File berl024.wsp
T2        Hydraulic analysis for structure BERLTH00600024   Date: 12-JUN-97
T3        TH060 crossing Cox Brook, in Berlin Vermont                       JRD
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1910     2750    2390
SK          0.010    0.010   0.010
WS          493.53   494.54  494.16
*
XS   EXITX    -33           0.
GR         -600.6, 508.93   -577.5, 507.06   -564.0, 499.52   -538.3, 498.30
GR         -388.2, 495.23   -185.0, 495.03    -74.8, 495.17    -20.0, 494.05
GR            0.0, 493.45      5.8, 492.73     17.1, 488.07     19.2, 487.31
GR           20.9, 486.97     22.8, 486.39     27.3, 486.70     29.7, 486.58
GR           32.9, 487.39     37.3, 487.67     40.9, 488.09     48.7, 489.16
GR           53.7, 491.13     61.2, 494.11     95.3, 495.49    125.1, 495.79
GR          136.0, 496.07    146.6, 499.58    157.7, 500.33    169.2, 500.00
GR          182.9, 502.36    210.1, 504.44    244.8, 510.33
*
N           0.035        0.050        0.045
SA                   0.0         61.2
*
*
XS   FULLV      0  * * *   0.0178
*
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.60       0.0
GR            0.0, 496.21      0.0, 494.66      7.0, 493.05     12.0, 490.68
GR           17.9, 488.08     21.8, 486.21     25.3, 485.27     29.9, 485.92
GR           34.8, 488.10     53.0, 495.54     53.0, 496.85     53.0, 497.00
GR            0.0, 496.21
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD            3      19.8      3.8    499.6
N           0.037
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      18.5     1
GR         -595.1, 511.66   -557.4, 502.90   -502.2, 500.14   -407.2, 498.32
GR         -326.2, 497.25   -259.5, 497.57    -39.7, 498.29      0.0, 499.21
GR           53.4, 499.98     88.9, 499.96    142.5, 501.43    155.6, 500.93
GR          205.8, 503.34    255.1, 514.07
*
*
*
*           EXPECTED SRD =   73 AT ONE BR. LENGTH BUT COMPUTED SRD =   80
*
XT   APTEM     80           0.
GR         -596.0, 509.63   -568.7, 500.08   -477.6, 497.57   -401.4, 496.09
GR         -304.2, 496.45   -287.6, 496.79   -171.2, 496.67    -76.7, 494.82
GR          -49.4, 493.92    -22.2, 494.59     -3.9, 493.67      0.0, 490.40
GR            5.1, 490.83     13.7, 489.59     18.7, 489.20     22.5, 489.25
GR           25.1, 489.56     27.1, 489.73     28.3, 489.48     33.6, 488.67
GR           37.2, 488.54     39.6, 488.32     41.4, 488.40     43.9, 488.80
GR           44.0, 489.46     46.8, 493.18     54.2, 493.58     66.4, 494.89
GR           76.6, 497.55     94.1, 500.71    101.5, 503.68    111.9, 504.29
GR          122.0, 504.00    128.6, 503.22    134.2, 507.00    144.7, 509.54
*
AS   APPRO     73 * * * 0.040
GT
N           0.035        0.065        0.052        0.055
SA               -171.2         -3.9         46.8
*
HP 1 BRIDG   493.02 1 493.02
HP 2 BRIDG   493.02 * * 1910
HP 1 APPRO   495.43 1 495.43
HP 2 APPRO   495.43 * * 1910
*
HP 1 BRIDG   497.00 1 497.00
HP 2 BRIDG   497.00 * * 2588
HP 1 BRIDG   494.79 1 494.79
HP 2 RDWAY   497.86 * * 163
HP 1 APPRO   497.94 1 497.94
HP 2 APPRO   497.94 * * 2750
*
HP 1 BRIDG   493.74 1 493.74
HP 2 BRIDG   493.74 * * 2390
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File berl024.wsp
        Hydraulic analysis for structure BERLTH00600024   Date: 12-JUN-97
        TH060 crossing Cox Brook, in Berlin Vermont                      JRD
           *** RUN DATE & TIME: 07-03-97  10:27

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

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      169     16959    40     43                         1974
   493.02           169     16959    40     43  1.00      7     47     1974

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.02     7.1    46.8   168.9   16959.    1910.  11.31

X STA.         7.1        15.2        17.6        19.3        20.7        21.8
  A(I)             15.5        10.2         8.9         8.2         7.5
  V(I)             6.17        9.34       10.76       11.70       12.69

X STA.        21.8        22.8        23.8        24.7        25.5        26.3
  A(I)              7.1         6.7         6.7         6.4         6.4
  V(I)            13.44       14.28       14.21       14.96       15.00

X STA.        26.3        27.2        28.1        29.0        29.9        31.0
  A(I)              6.5         6.4         6.6         6.8         7.4
  V(I)            14.62       14.86       14.43       13.97       12.95

X STA.        31.0        32.2        33.6        35.5        38.0        46.8
  A(I)              7.6         8.2         9.4        10.6        15.9
  V(I)            12.64       11.65       10.21        9.05        6.02


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             2      125      2984   118    118                          732
             3      302     27044    51     55                         4179
             4       37      1350    23     23                          263
   495.43           464     31378   192    196  1.54   -121     70     3302


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.43  -122.2    69.5   463.7   31378.    1910.   4.12

X STA.      -122.2       -39.3        -2.5         2.3         6.2         9.8
  A(I)             73.6        55.4        22.7        19.5        18.9
  V(I)             1.30        1.72        4.21        4.91        5.06

X STA.         9.8        12.8        15.5        18.1        20.6        23.1
  A(I)             17.4        16.8        16.6        16.1        16.1
  V(I)             5.48        5.67        5.76        5.92        5.95

X STA.        23.1        25.7        28.5        30.9        33.2        35.4
  A(I)             16.2        16.9        15.8        15.6        15.6
  V(I)             5.88        5.66        6.06        6.12        6.11

X STA.        35.4        37.6        39.7        41.9        45.4        69.5
  A(I)             15.4        15.6        16.2        22.1        41.3
  V(I)             6.22        6.10        5.91        4.33        2.31
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File berl024.wsp
       Hydraulic analysis for structure BERLTH00600024   Date: 12-JUN-97
       TH060 crossing Cox Brook, in Berlin Vermont                          JRD
          *** RUN DATE & TIME: 07-03-97  10:27

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      345     29309      0    113                             0
  497.00           345     29309      0    113  1.00      0     53         0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.00     0.0    53.0   345.2   29309.    2588.   7.50

X STA.         0.0       10.5       14.2       16.8       18.8       20.5
  A(I)             31.4       21.8       18.5       16.9       15.9
  V(I)             4.12       5.92       7.00       7.65       8.13

X STA.        20.5       22.0       23.3       24.6       25.8       26.9
  A(I)             14.6       13.9       14.0       13.3       13.2
  V(I)             8.85       9.28       9.23       9.73       9.78

X STA.        26.9       28.2       29.4       30.7       32.1       33.7
  A(I)             13.4       13.2       14.1       14.3       14.9
  V(I)             9.63       9.77       9.20       9.07       8.66

X STA.        33.7       35.5       37.6       40.2       43.9       53.0
  A(I)             15.7       16.9       18.2       21.4       29.4
  V(I)             8.22       7.66       7.12       6.04       4.40

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      250     27601     51     55                          3131
  494.79           250     27601     51     55  1.00      0     51      3131

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.86  -372.4  -171.0    56.9    1044.     163.   2.86

X STA.      -372.4     -347.4     -340.1     -334.8     -330.6     -326.9
  A(I)              4.1        2.8        2.5        2.2        2.1
  V(I)             1.98       2.95       3.32       3.69       3.80

X STA.      -326.9     -323.5     -320.0     -316.4     -312.5     -308.5
  A(I)              2.0        2.1        2.1        2.1        2.2
  V(I)             4.00       3.93       3.97       3.84       3.74

X STA.      -308.5     -304.1     -299.4     -294.2     -288.3     -281.6
  A(I)              2.2        2.3        2.5        2.6        2.8
  V(I)             3.67       3.49       3.31       3.17       2.95

X STA.      -281.6     -273.8     -264.1     -251.1     -232.7     -171.0
  A(I)              3.0        3.3        3.7        4.3        6.2
  V(I)             2.75       2.50       2.20       1.91       1.30

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      503     28371    330    330                          3525
            2      522     25518    167    167                          5227
            3      429     48607     51     55                          7084
            4      106      6137     34     34                          1071
  497.94          1560    108633    582    586  1.51   -500     80     11799

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.94  -501.2    80.3  1560.0  108633.    2750.   1.76

X STA.      -501.2     -399.9     -357.9     -312.1     -249.2     -185.5
  A(I)            116.9       85.8       86.4       96.4       95.6
  V(I)             1.18       1.60       1.59       1.43       1.44

X STA.      -185.5     -115.4      -75.6      -49.9      -25.7       -2.3
  A(I)            139.1      120.5       99.5       96.9       96.0
  V(I)             0.99       1.14       1.38       1.42       1.43

X STA.        -2.3        5.1       11.3       16.6       21.5       26.6
  A(I)             54.8       48.3       45.8       44.3       44.7
  V(I)             2.51       2.85       3.00       3.10       3.08

X STA.        26.6       31.7       36.3       40.7       48.7       80.3
  A(I)             44.7       44.6       42.8       60.4       96.7
  V(I)             3.08       3.09       3.21       2.28       1.42
```

```
     U.S. Geological Survey WSPRO Input File berl024.wsp
     Hydraulic analysis for structure BERLTH00600024   Date: 12-JUN-97
     TH060 crossing Cox Brook, in Berlin Vermont                     JRD
        *** RUN DATE & TIME: 07-03-97  10:27

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      199     20739     45     48                          2389
  493.74           199     20739     45     48  1.00      4     49      2389

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      493.74     4.0    48.6   199.2   20739.    2390.  12.00

X STA.        4.0       14.5       17.1       18.9       20.4       21.7
  A(I)            19.3       12.5       10.5        9.6        9.0
  V(I)            6.19       9.59      11.35      12.40      13.20

X STA.       21.7       22.8       23.8       24.7       25.6       26.5
  A(I)             8.4        7.9        7.7        7.6        7.5
  V(I)           14.27      15.18      15.47      15.77      15.86

X STA.       26.5       27.4       28.4       29.3       30.4       31.5
  A(I)             7.5        7.6        7.7        8.0        8.3
  V(I)           15.89      15.65      15.43      14.99      14.39

X STA.       31.5       32.8       34.4       36.4       39.1       48.6
  A(I)             9.1        9.5       10.8       12.2       18.4
  V(I)           13.18      12.63      11.04       9.77       6.49

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      155      4438    282    282                           653
            2      333     12053    167    167                          2662
            3      372     38280     51     55                          5714
            4       72      3590     28     28                           649
  496.81           931     58362    528    532  1.89   -452     75      5100

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      73.

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.81  -452.9    74.8   931.2   58362.    2390.   2.57

X STA.     -452.9     -331.9     -108.7      -66.7      -42.6      -17.7
  A(I)            86.3      133.3       87.1       70.7       68.0
  V(I)            1.38       0.90       1.37       1.69       1.76

X STA.      -17.7       -0.5        4.3        9.0       12.9       16.5
  A(I)            59.0       31.0       30.3       27.9       27.1
  V(I)            2.03       3.85       3.94       4.28       4.40

X STA.       16.5       19.8       23.1       26.6       30.2       33.3
  A(I)            26.1       26.2       26.5       26.9       25.7
  V(I)            4.57       4.56       4.52       4.44       4.64

X STA.       33.3       36.3       39.3       42.3       49.8       74.8
  A(I)            24.9       26.1       26.4       41.4       60.2
  V(I)            4.80       4.57       4.53       2.89       1.98
```

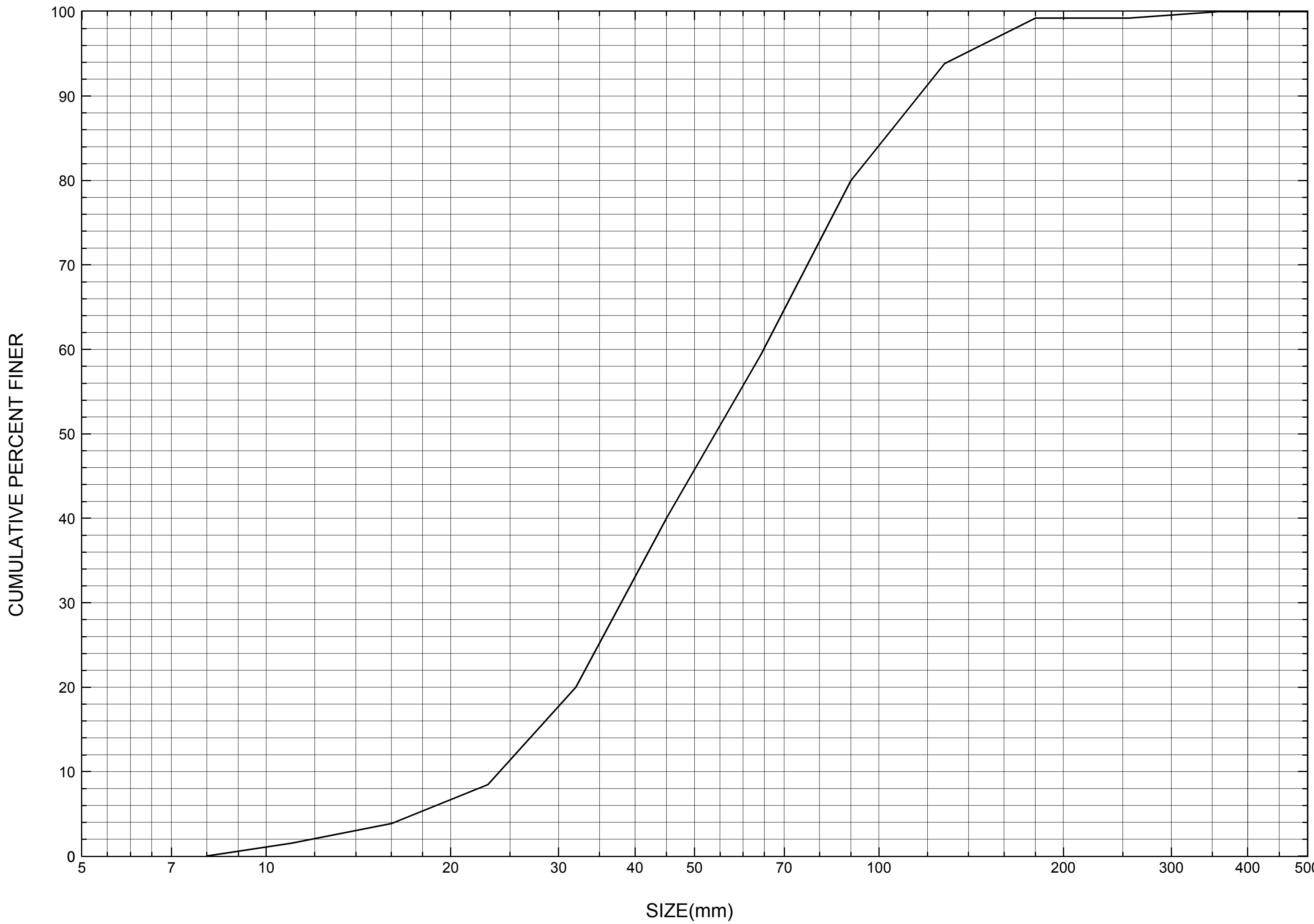
```
        U.S. Geological Survey WSPRO Input File berl024.wsp
        Hydraulic analysis for structure BERLTH00600024   Date: 12-JUN-97
        TH060 crossing Cox Brook, in Berlin Vermont                       JRD
           *** RUN DATE & TIME: 07-03-97  10:27

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

 EXITX:XS   ******     -1      252  0.89 *****  494.42  492.14    1910  493.52
        -32 ******     60    19100  1.00 ***** *******    0.66    7.58

 FULLV:FV       33      2      234  1.04  0.36  494.84 *******    1910  493.81
          0     33     59    17402  1.00  0.07   -0.01    0.71    8.17
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             “APPRO”     KRATIO =  1.42

 APPRO:AS       73    -91      360  0.61  0.62  495.45 *******    1910  494.84
         73     73     67    24653  1.39  0.00   -0.02    0.73    5.30
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

 BRIDG:BR       33      7      169  1.99  0.37  495.01  492.91    1910  493.02
          0     33     47    16959  1.00  0.21   -0.01    0.97   11.31

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  1.000 ******  496.60 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      10.        <<<<<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       53   -121      463  0.41  0.38  495.83  493.01    1910  495.43
         73     55     70    31341  1.53  0.45    0.01    0.58    4.12

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.717  0.215   24473.     5.    45.   495.22

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q         K      AREA     VEL    WSEL
    EXITX:XS     -33.    -2.    60.   1910.   19100.     252.    7.58  493.52
    FULLV:FV       0.     2.    59.   1910.   17402.     234.    8.17  493.81
    BRIDG:BR       0.     7.    47.   1910.   16959.     169.   11.31  493.02
    RDWAY:RG      10.**************       0.*****************    1.00********
    APPRO:AS      73.  -122.    70.   1910.   31341.     463.    4.12  495.43

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS       5.    45.   24473.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    492.14    0.66  486.39  510.33************  0.89  494.42  493.52
    FULLV:FV  ********    0.71  486.98  510.92  0.36  0.07  1.04  494.84  493.81
    BRIDG:BR    492.91    0.97  485.27  497.00  0.37  0.21  1.99  495.01  493.02
    RDWAY:RG  ****************  497.25  514.07**********************************
    APPRO:AS    493.01    0.58  488.04  509.35  0.38  0.45  0.41  495.83  495.43
```

```
       U.S. Geological Survey WSPRO Input File berl024.wsp
       Hydraulic analysis for structure BERLTH00600024   Date: 12-JUN-97
       TH060 crossing Cox Brook, in Berlin Vermont                     JRD
          *** RUN DATE & TIME: 07-03-97  10:27

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

EXITX:XS   ******    -42      336  1.13 *****  495.66  493.30    2750  494.52
      -32 ******     71    27499  1.08 ***** *******    0.88    8.19

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     0.90     494.78     493.89

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.02     510.92    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.02     510.92     493.89

FULLV:FV       33    -27      303  1.34  0.37  496.13  493.89    2750  494.79
         0     33     64    24382  1.04  0.10    0.00    0.90    9.08
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.72

APPRO:AS       73   -418      637  0.50  0.54  496.66 *******    2750  496.16
        73     73     72    42035  1.74  0.00   -0.01    0.74    4.31
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.22       0.00     494.29     497.25

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.12     497.68     497.87     496.60

 ===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       33      0      345  0.87 *****  497.87  494.06    2588  497.00
         0 ******     53    29309  1.00 ***** *******    0.52    7.50

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   5.  0.439 ******  496.60 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    55.  0.03  0.07  497.98    0.00    163.  497.86

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    163.   202.  -372.  -171.   0.6   0.3   3.0   2.9   0.4   3.1
   RT:      0.   152.    27.   178.   2.4   1.5   7.3   8.0   2.5   3.1

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

APPRO:AS       53   -500     1563  0.07  0.14  498.02  494.54    2750  497.94
        73     63     80   108892  1.51  0.35    0.00    0.23    1.76

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW     REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -33.   -43.     71.   2750.   27499.     336.    8.19  494.52
   FULLV:FV       0.   -28.     64.   2750.   24382.     303.    9.08  494.79
   BRIDG:BR       0.     0.     53.   2588.   29309.     345.    7.50  497.00
   RDWAY:RG      10.*******    163.    163.*********      0.    1.00  497.86
   APPRO:AS      73.  -501.     80.   2750.  108892.    1563.    1.76  497.94

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.30    0.88  486.39  510.33************  1.13  495.66  494.52
   FULLV:FV    493.89    0.90  486.98  510.92  0.37  0.10  1.34  496.13  494.79
   BRIDG:BR    494.06    0.52  485.27  497.00************  0.87  497.87  497.00
   RDWAY:RG  ****************  497.25  514.07  0.03******  0.07  497.98  497.86
   APPRO:AS    494.54    0.23  488.04  509.35  0.14  0.35  0.07  498.02  497.94
```

```
        U.S. Geological Survey WSPRO Input File berl024.wsp
        Hydraulic analysis for structure BERLTH00600024   Date: 12-JUN-97
        TH060 crossing Cox Brook, in Berlin Vermont                        JRD
           *** RUN DATE & TIME: 07-03-97  10:27

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

 EXITX:XS   ******    -24      298  1.04 *****  495.19  492.80    2390  494.15
        -32 ******     62    23900  1.04 ***** *******    0.78    8.02

  ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     0.81     494.42     493.39

  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.65     510.92    0.50

  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.65     510.92     493.39

 FULLV:FV       33    -12      274  1.20  0.37  495.64  493.39    2390  494.44
          0     33     61    21499  1.01  0.08    0.00    0.80    8.71
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.59

 APPRO:AS       73   -132      505  0.55  0.57  496.19 *******    2390  495.64
         73     73     70    34114  1.58  0.00   -0.02    0.67    4.73
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    2390.      493.74

            <<<<<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       33      4      199  2.60 *****  496.34  493.74    2390  493.74
          0     33     49    20728  1.16 ***** *******    1.08   12.00

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        3. ****   1.  0.929 ******  496.60 ****** ****** ******

     XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG       10.         <<<<<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       53   -452      933  0.19  0.27  497.01  493.69    2390  496.81
         73     57     75    58482  1.89  0.40    0.02    0.47    2.56

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.757  0.361   36970.     0.    45.   496.72

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
    EXITX:XS     -33.   -25.    62.   2390.   23900.      298.    8.02  494.15
    FULLV:FV       0.   -13.    61.   2390.   21499.      274.    8.71  494.44
    BRIDG:BR       0.     4.    49.   2390.   20728.      199.   12.00  493.74
    RDWAY:RG      10.**************       0.******************    1.00********
    APPRO:AS      73.  -453.    75.   2390.   58482.      933.    2.56  496.81

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS       0.    45.   36970.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    EXITX:XS    492.80    0.78  486.39  510.33************  1.04  495.19  494.15
    FULLV:FV    493.39    0.80  486.98  510.92  0.37  0.08  1.20  495.64  494.44
    BRIDG:BR    493.74    1.08  485.27  497.00************  2.60  496.34  493.74
    RDWAY:RG  ****************  497.25  514.07**********************************
    APPRO:AS    493.69    0.47  488.04  509.35  0.27  0.40  0.19  497.01  496.81
   ER

1  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 BERLTH00600024, in Berlin, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BERLTH00600024

General Location Descriptive

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

Date *(MM/DD/YY)* 10 / 13 / 95

Highway District Number *(I - 2; nn)* 06

County *(FIPS county code; I - 3; nnn)* 023

Town *(FIPS place code; I - 4; nnnnn)* 05650

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

Waterway *(I - 6)* COX BROOK

Road Name *(I - 7):* -

Route Number C3060

Vicinity *(I - 9)* 0.02 MI TO JCT W CL2 TH3

Topographic Map Northfield

Hydrologic Unit Code: 2010003

Latitude *(I - 16; nnnn.n)* 44113

Longitude *(i - 17; nnnnn.n)* 72405

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10120300241203

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

Maximum span length *(I - 48; nnnn)* 0050

Year built *(I - 27; YYYY)* 1990

Structure length *(I - 49; nnnnnn)* 000059

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 185

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

Channel & Protection *(I - 61; n)* 8

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

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

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

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

Comments:

According to the structural inspection report dated 8/15/94, the bridge deck is untreated lumber. There is a gravel buildup around the bearing areas at each abutment. The abutments, wingwalls and backwalls are concrete with minor cracks and small leaks. Stone and boulder riprap has been placed on the embankments in front of the abutments and around their ends. Random boulders and some erosion are showing along the US and DS channel embankments, erosion from past flooding. A couple of trees are in the DS channel.

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*): U Frequency: -

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 9.26 mi^2

Lake/pond/swamp area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 780 ft

Headwater elevation 1983 ft

Main channel length 5 mi

10% channel length elevation 810 ft

85% channel length elevation 1360 ft

Main channel slope *(S)* 146.67 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)*: **-** / **-**

Project Number **R11776** Minimum channel bed elevation: **-**

Low superstructure elevation: USLAB **773.42** DSLAB **773.42** USRAB **774.24** DSRAB **774.24**

Benchmark location description:

-

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

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

If 1: Footing Thickness **1.5** Footing bottom elevation: **767**

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

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

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO DRILL BORING INFORMATION

Comments:

Bottom of footing at right abutment = 767.24; at left abutment = 766.42

The low superstructure elevations are the bridge seat elevations from the bridge plans.

Cross-sectional Data

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

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

Comments: NO CROSS SECTIONAL 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: -

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: **JD** Date: **5/30/97**

Computerized by: **JD** Date: **5/30/97**

Reviewd by: **JD** Date: **8/25/97**

Structure Number **BERLTH00600024**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. Medalie** Date *(MM/DD/YY)* **07** / **18** / 19**96**

2. Highway District Number **06** Mile marker **0**

County **Washington (023)** Town **Berlin (05650)**

Waterway *(I - 6)* **Cox Brook** Road Name **-**

Route Number **TH 6, C3060** Hydrologic Unit Code: **2010003**

3. Descriptive comments:

This structure is located two hundredths of a mile from the junction with Town Highway 3.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **4** RBDS **5** Overall **5**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **2** UB **2** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **59.0** *(feet)* Span length **50.0** *(feet)* Bridge width **18.5** *(feet)*

Road approach to bridge:

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

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

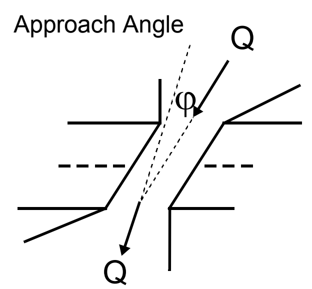
10. Embankment slope (*run / rise in feet / foot*):
US left **3.3:1** US right **4.3:1**

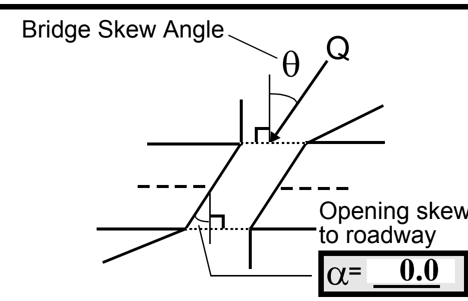
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: **5** 16. Bridge skew: **5**





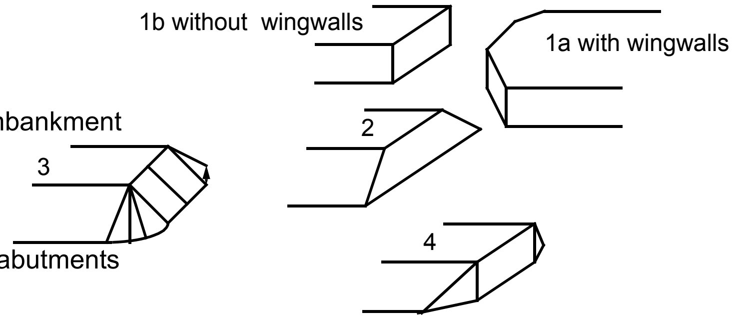
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **20** feet **US** *(US, UB, DS)* to **90** feet **US**

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

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

18. Bridge Type: 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. The measured bridge dimensions at this site differed from those on the historical form. The measured structure length was 57.2 ft. The measured span length was 53.5 ft.

9. The left road approach is paved for 38 ft beyond the bridge before it switches to gravel.

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
64.5	3.5			3.5	4	4	34	4	2	2

23. Bank width 40.0 24. Channel width 50.0 25. Thalweg depth 51.0 29. Bed Material 435

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

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

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

30. The left bank protection extends from 47 ft upstream to zero ft upstream. The right bank protection extends from 20 ft upstream to zero ft upstream.

29. Bedrock outcrops in the channel at 100 ft upstream and further upstream intermittently. It appears to have some control of the meanders.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 64 35. Mid-bar width: 32
36. Point bar extent: 12 feet US (US, UB) to 110 feet US (US, UB, DS) positioned 0 %LB to 65 %RB
37. Material: 34
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
This point bar has formed downstream of the bedrock in the channel.

39. Is a cut-bank present? Y (Y or if N type ctrl-n cb) 40. Where? RB (LB or RB)
41. Mid-bank distance: 65 42. Cut bank extent: 110 feet US (US, UB) to 33 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.):
-

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)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
44.0		1.0		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.):
435
-

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

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

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

70. Debris and Ice Comments:

2

Trees are leaning into the channel upstream of the bridge.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	60	0	0	-	-	90.0
RABUT	1	0	55			0	0	53.0

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

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

-

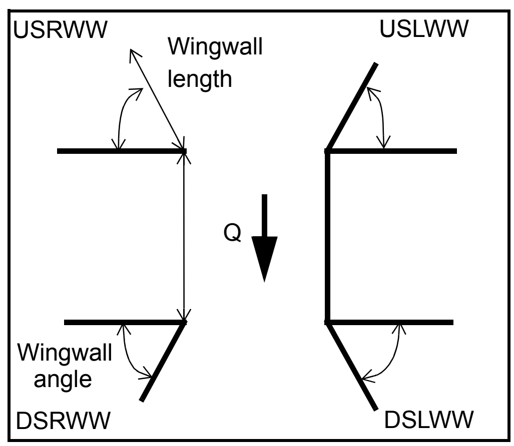
-

1

72. This measurement is of the stone fill slope in front of each abutment. The abutments have a 90 degree slope.
77. The abutments are concrete.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						53.0	
USRWW:	Y		1		0	3.0	
DSLWW:	-		-		Y	20.0	
DSRWW:	1		0		-	19.5	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	1	1	1	1
Condition	Y	-	1	-	1	1	1	1
Extent	1	-	0	2	2	2	2	-

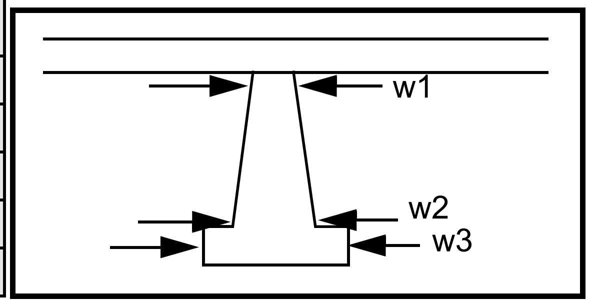
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**7.5**	**6.5**	**45.0**	**60.0**	**45.0**
Pier 2	**7.5**		-	**45.0**	**10.5**	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e stone**	.	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**fill**		-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**spill-**		-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**thro**		-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**ugh**		-	-	*Y- yes; N- no*
91. Attack ∠ (BF)	**slope**		-	-	
92. Pushed	**exte**		-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**nds**		-	-	
95. Cross-members	**alon**		-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**g the**		-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**wing**		-	-	
98. Exposure depth	**walls**	**N**	-	-	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

3
3

101. Is a drop structure present? **43** *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

103. Drop: - feet 104. Structure material: **23** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
0
1
435
1
1
1

106. Point/Side bar present? 1 *(Y or N. if N type ctrl-n pb)* Mid-bar distance: 100. Mid-bar width: The

Point bar extent: vege- feet tati *(US, UB, DS)* to on feet cov *(US, UB, DS)* positioned er %LB to is %RB

Material: less

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

than 50% upstream of 85 ft.
The bank protection extends to 26 ft on both banks.
The protection is mostly type 1, with some type 2 stone fill towards the bottom of the bank.
The bed material gets finer towards right bank.

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

Cut bank extent: bank feet ero *(US, UB, DS)* to sion feet inc *(US, UB, DS)*

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

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

ses beyond 80 ft downstream to light fluvial.

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

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

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

N
-
NO DROP STRUCTURE

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

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

Confluence 2: Distance 95 Enters on 11 *(LB or RB)* Type 85 *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

DS
105

F. Geomorphic Channel Assessment

107. Stage of reach evolution DS

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)*:

5

40

34

This side bar is covered with grass. There is an additional side bar beginning at 120 ft downstream, that consists of gravel and cobbles.

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: BERLTH00600024 Town: BERLIN
Road Number: TH060 County: ADDISON
Stream: COX BROOK

Initials JRD Date: 06/18/96 Checked: SAO

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

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

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1910	2750	2390
Main Channel Area, ft2	302	429	372
Left overbank area, ft2	125	1025	488
Right overbank area, ft2	37	106	72
Top width main channel, ft	51	51	51
Top width L overbank, ft	118	497	449
Top width R overbank, ft	23	34	28
D50 of channel, ft	0.177	0.177	0.177
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.9	8.4	7.3
y1, average depth, LOB, ft	1.1	2.1	1.1
y1, average depth, ROB, ft	1.6	3.1	2.6
Total conveyance, approach	31378	108633	58362
Conveyance, main channel	27044	48607	38280
Conveyance, LOB	2984	53889	16491
Conveyance, ROB	1350	6137	3590
Percent discrepancy, conveyance	0.0000	0.0000	0.0017
Qm, discharge, MC, cfs	1646.2	1230.5	1567.6
Ql, discharge, LOB, cfs	181.6	1364.2	675.3
Qr, discharge, ROB, cfs	82.2	155.4	147.0
Vm, mean velocity MC, ft/s	5.5	2.9	4.2
Vl, mean velocity, LOB, ft/s	1.5	1.3	1.4
Vr, mean velocity, ROB, ft/s	2.2	1.5	2.0
Vc-m, crit. velocity, MC, ft/s	8.5	9.0	8.8
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1910	2750	2390
(Q) discharge thru bridge, cfs	1910	2588	2390
Main channel conveyance	16959	29309	20739
Total conveyance	16959	29309	20739
Q2, bridge MC discharge,cfs	1910	2588	2390
Main channel area, ft2	169	345	199
Main channel width (normal), ft	39.7	53.0	44.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	39.7	53	44.6
y_bridge (avg. depth at br.), ft	4.26	6.51	4.46
Dm, median (1.25*D50), ft	0.22125	0.22125	0.22125
y2, depth in contraction,ft	5.27	5.34	5.78
ys, scour depth (y2-ybridge), ft	**1.01**	-1.17	**1.32**

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	1910	2750	2390
Q, thru bridge MC, cfs	1910	2588	2390
Vc, critical velocity, ft/s	8.47	8.98	8.77
Va, velocity MC approach, ft/s	5.45	2.87	4.21
Main channel width (normal), ft	39.7	53.0	44.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	39.7	53.0	44.6
qbr, unit discharge, ft2/s	48.1	48.8	53.6
Area of full opening, ft2	169.0	345.0	199.0
Hb, depth of full opening, ft	4.26	6.51	4.46
Fr, Froude number, bridge MC	0	0.52	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	250	N/A
**Hb, depth at downstream face, ft	N/A	4.72	N/A
**Fr, Froude number at DS face	ERR	0.84	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	496.6	0

Elevation of Bed, ft	-4.26	490.09	-4.46
Elevation of Approach, ft	0	497.94	0
Friction loss, approach, ft	0	0.14	0
Elevation of WS immediately US, ft	0.00	497.80	0.00
ya, depth immediately US, ft	4.26	7.71	4.46
Mean elevation of deck, ft	0	499.6	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.96	1.00
**Cc, for downstream face (<=1.0)	ERR	0.862004	ERR
Ys, scour w/Chang equation, ft	N/A	**-0.83**	N/A
Ys, scour w/Umbrell equation, ft	N/A	-2.24	N/A

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

**Ys, scour w/Chang equation, ft	N/A	1.59	N/A
**Ys, scour w/Umbrell equation, ft	ERR	-0.45	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	5.27	5.34	5.78
WSEL at downstream face, ft	--	494.79	--
Depth at downstream face, ft	N/A	4.72	N/A
Ys, depth of scour (Laursen), ft	N/A	0.62	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	1910	2588	2390
Main channel area (DS), ft2	169	250	199
Main channel width (normal), ft	39.7	53	44.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	39.7	53.0	44.6
D90, ft	0.3810	0.3810	0.3808
D95, ft	0.4520	0.4520	0.4518
Dc, critical grain size, ft	0.5332	0.4292	0.5906
Pc, Decimal percent coarser than Dc	N/A	0.056	N/A
Depth to armoring, ft	N/A	21.71	N/A

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1910	2750	2390	1910	2750	2390
a', abut.length blocking flow, ft	129.3	501.2	456.9	22.7	27.3	26.2

Ae, area of blocked flow ft2	175.9	993.2	533.5	38.9	83.54	66.8
Qe, discharge blocked abut.,cfs	405.9	--	829	90	118.79	138.6

(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)

Ve, (Qe/Ae), ft/s	2.31	1.35	1.55	2.31	1.42	2.07
ya, depth of f/p flow, ft	1.36	1.98	1.17	1.71	3.06	2.55

--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	0.349	0.164	0.253	0.311	0.143	0.229
ys, scour depth, ft	7.69	10.85	9.39	**4.90**	**6.05**	**6.08**

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

a'(abut length blocked, ft)	129.3	501.2	456.9	22.7	27.3	26.2
y1 (depth f/p flow, ft)	1.36	1.98	1.17	1.71	3.06	2.55
a'/y1	95.05	252.92	391.30	13.25	8.92	10.28
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.35	0.16	0.25	0.31	0.14	0.23
Ys w/ corr. factor K1/0.55:						
vertical	6.99	7.94	5.40	ERR	ERR	ERR
vertical w/ ww's	5.73	6.51	4.43	ERR	ERR	ERR
spill-through	**3.84**	**4.36**	**2.97**	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.99	0.85	1.08	0.99	0.85	1.08
y, depth of flow in bridge, ft	4.15	4.70	4.42	4.15	4.70	4.42
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (spillthrough abut.)	1.53	1.66	1.67	1.53	1.66	1.67