LEVEL II SCOUR ANALYSIS FOR BRIDGE 106 (NEWBUS00050106) on U.S. HIGHWAY 5, crossing WELLS RIVER, NEWBURY, VERMONT

U.S. Geological Survey
Open-File Report 97-5

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

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By MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1997

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

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 106 (NEWBUS00050106) ON U.S. HIGHWAY 5, CROSSING WELLS RIVER, NEWBURY, VERMONT

By **Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure NEWBUS00050106 on U.S. Highway 5 crossing the Wells River, in the village of Wells River, Newbury, 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 New England Upland section of the New England physiographic province in east-central Vermont. The 101-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of trees, cut grass, and brush in a suburban setting.

In the study area, the Wells River has an incised, straight channel with a slope of approximately 0.005 ft/ft, an average channel top width of 78 ft and an average channel depth of 11 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 68.3 mm (0.224 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 30, 1995, indicated that the reach was constructed. The reach has stone walls along the upstream channel banks and a concrete wall along the downstream right bank, but a natural streambed.

The U.S. Highway 5 crossing of the Wells River is a 70-ft-long, two-lane bridge consisting of one 64-foot steel-beam span (Vermont Agency of Transportation, written communication, March 27, 1995). The bridge is supported by vertical, concrete abutments with a wingwall on the downstream end of the left abutment. The channel is skewed approximately 10 degrees to the opening. The computed opening-skew-to-roadway is 15 degrees, but historical records indicate a skew of 9 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the center of the channel through the bridge during the Level I assessment. The scour protection measures at the site included type-3 stone fill (less than 48 inches diameter) at the left and right abutments. The upstream banks were protected by stone retaining walls extending from the bridge to 180 ft upstream. The downstream banks were protected by concrete retaining walls extending from the bridge to 230 feet downstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

There was no contraction scour computed for all modelled flows. Abutment scour ranged from 10.5 to 18.5 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Woodsville, VT. Quadrangle, 1:24,000, 1973
Photoinspected 1988

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 NEWBUS00050106 ***Stream*** Wells River

County Orange ***Road*** US 5 ***District*** 7

Description of Bridge

Bridge length 70 ***ft*** ***Bridge width*** 46.5 ***ft*** ***Max span length*** 64 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** Vertical walls

Stone fill on abutment? Yes ***Date of inspection*** 08/30/95

Description of stone fill Type-3, at the left and right abutment and along the downstream left wingwall and left bank. Type-2, sloping from the toe of a concrete wall along the downstream right bank to river. The upstream banks were protected by stacked stone walls.

Brief description of piers/abutments Abutments consist of mortared granite blocks on the upstream end and concrete downstream. The wingwalls are concrete on the downstream end of the bridge abutments.

Is bridge skewed to flood flow according to Level I survey? Yes ***Angle*** 10

Is bridge located on a bend in channel? No ***If so, describe (mild, moderate, severe)***

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	08/30/95	0	0
Level II	08/30/95	0	0

Potential for debris Moderate. There were some trees leaning into the upstream reach.

Describe any features near or at the bridge that may affect flow (include observation date) Side bars at the upstream left and downstream left bank near the bridge 08/30/95.

Description of the Geomorphic Setting

General topography The channel is in a moderate relief valley setting with a flat to slightly irregular flood plain and steep valley walls on both sides.

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

Date of inspection 08/30/95

DS left: Steep channel bank to a narrow flood plain

DS right: Flood plain

US left: Vertical stone wall to a narrow flood plain

US right: Vertical stone wall to a flood plain

Description of the Channel

Average top width 78 ***ft***

Average depth 11 ***ft***

Predominant bed material Cobbles

Bank material Cobbles

Constructed straight with non-alluvial channel boundaries and a narrow flood plain.

08/30/95

Vegetative co Some trees, cut grass, and brush

DS left: Some trees, cut grass, and brush

DS right: Some trees, cut grass, and brush

US left: Some trees, cut grass, and brush

US right: Some trees, cut grass, and brush

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

None, 08/30/95

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 101 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: There are houses on the upstream and downstream flood plains.

Is there a USGS gage on the stream of interest? Yes

USGS gage description Wells River at Wells River

USGS gage number 01139000

Gage drainage area 98.4 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 5,110 ***ft³/s*** ***Q500*** 6,860 ***ft³/s***

The 100- and 500-year discharges are based on a 1:1 drainage area relationship between the Wells River gage (01139000) and the bridge. The flood frequency estimates at the gage were determined from a Log-Pearson type-3 analysis (Interagency Advisory Committee on Water Data, 1982)

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 0.1 feet to the USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the left abutment (elev. 500.66 ft, arbitrary survey datum). RM2 is the center of chiseled mark on top of the upstream end of the left abutment (elev. 499.99 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	-66	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	29	1	Road Grade section
APPRO	100	1	Approach section as surveyed

[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 0.040 to 0.043, and overbank "n" values ranged from 0.045 to 0.050.

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 0.0054 ft/ft, which was determined from the slope of the 100-year flood profile downstream of the bridge depicted in the Flood Insurance Study for Newbury, VT (FEMA, May 17, 1990).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 499.7 ***ft***
Average low steel elevation 496.1 ***ft***

100-year discharge 5,110 ***ft^3/s***
Water-surface elevation in bridge opening 494.3 ***ft***
Road overtopping? Yes ***Discharge over road*** 571 ***ft^3/s***
Area of flow in bridge opening 519 ***ft^2***
Average velocity in bridge opening 8.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.7 ***ft/s***

Water-surface elevation at Approach section with bridge 495.2
Water-surface elevation at Approach section without bridge 495.1
Amount of backwater caused by bridge 0.1 ***ft***

500-year discharge 6,860 ***ft^3/s***
Water-surface elevation in bridge opening 496.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 2378 ***ft^3/s***
Area of flow in bridge opening 624 ***ft^2***
Average velocity in bridge opening 7.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.4 ***/s***

Water-surface elevation at Approach section with bridge 497.2
Water-surface elevation at Approach section without bridge 497.0
Amount of backwater caused by bridge 0.2

Incipient overtopping discharge 3,940 ***ft^3/s***
Water-surface elevation in bridge opening 492.8 ***ft***
Area of flow in bridge opening 432 ***ft^2***
Average velocity in bridge opening 9.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.1 ***ft/s***

Water-surface elevation at Approach section with bridge 493.7
Water-surface elevation at Approach section without bridge 493.6
Amount of backwater caused by bridge 0.1 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. In this case, the contraction scour at all discharges was 0.0 ft.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	1.8	0.6	2.7
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	12.1	12.4	10.5
Right abutment	13.3	18.5	11.6
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.5	1.3	1.6
Right abutment	1.5	1.3	1.6
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--
	--	--	--

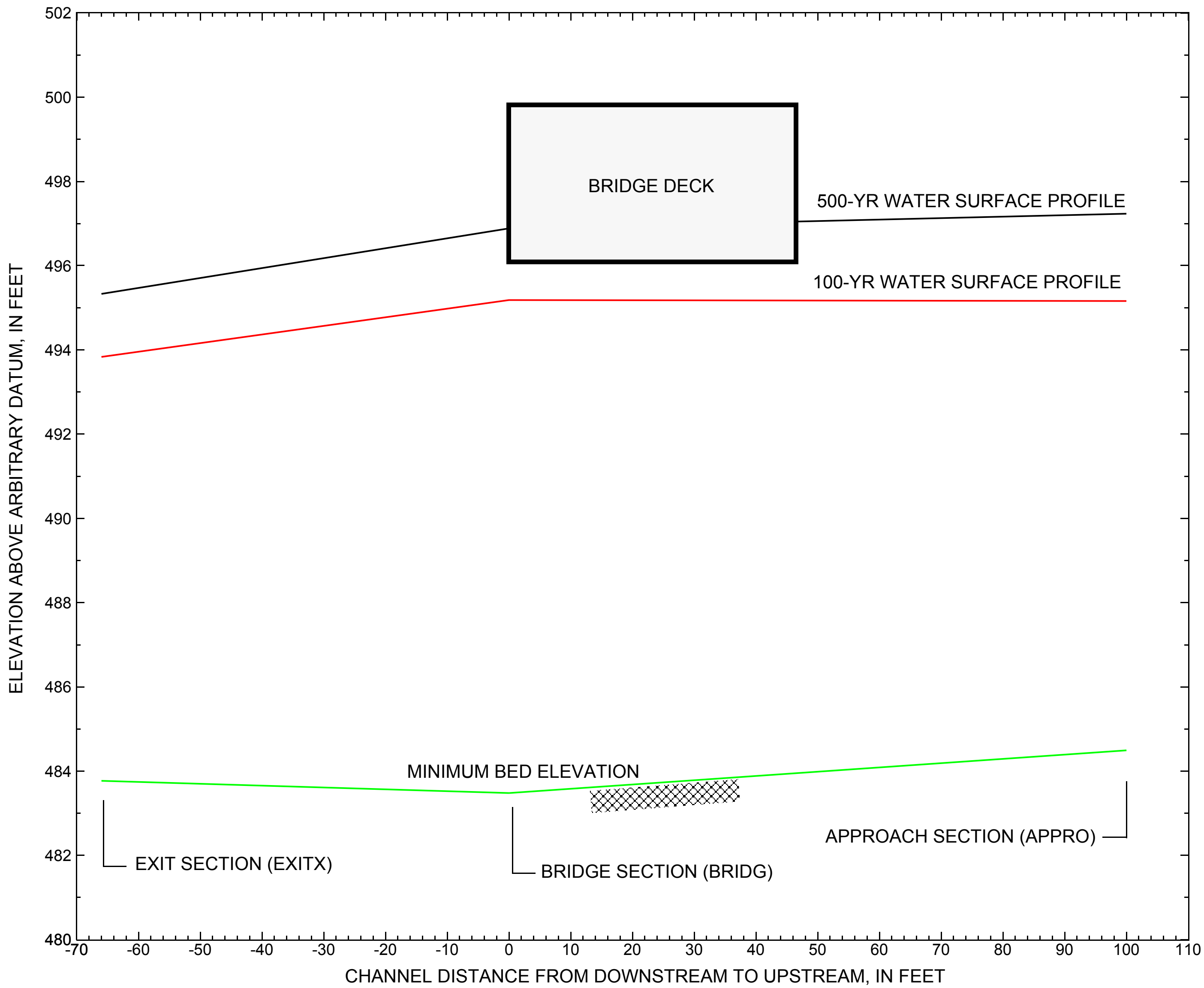

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure NEWBUS00050106 on U.S. Highway 5, crossing Wells River, Newbury, Vermont.

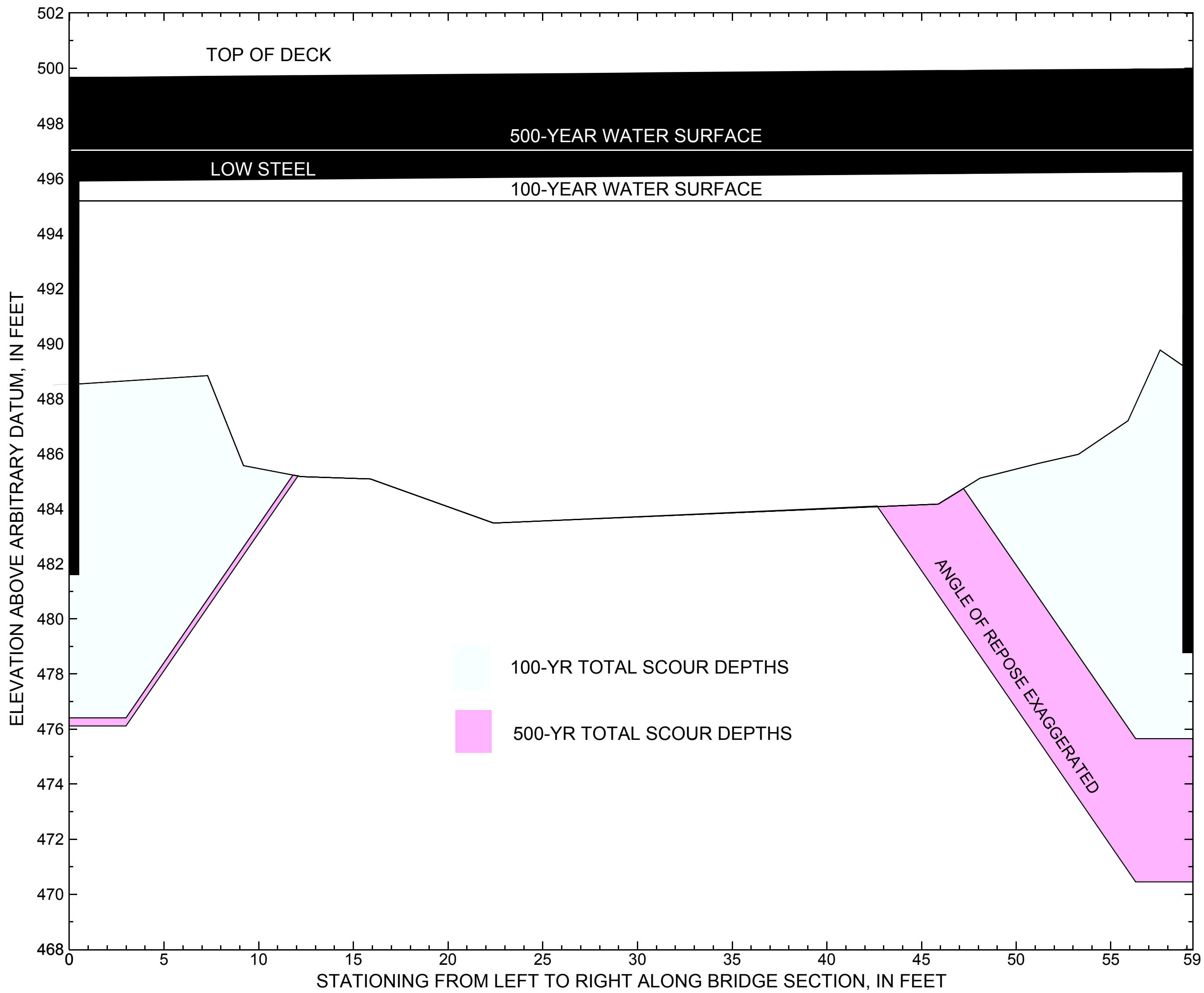

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure NEWBUS00050106 on U.S. Highway 5, crossing the Wells River, Newbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure NEWBUS00050106 on U.S. Highway 5, crossing the Wells River, Newbury, 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 5,110 cubic-feet per second											
Left abutment	0.0	496.3	496.2	481.6	488.5	0.0	12.1	--	12.1	476.4	-5.2
Right abutment	59.1	496.1	496.0	478.9	489.0	0.0	13.3	--	13.3	475.7	-3.2

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure NEWBUS00050106 on U.S. Highway 5, crossing the Wells River, Newbury, 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 6,860 cubic-feet per second											
Left abutment	0.0	496.3	496.2	481.6	488.5	0.0	12.4	--	12.4	476.1	-5.5
Right abutment	59.1	496.1	496.0	478.9	489.0	0.0	18.5	--	18.5	470.5	-8.4

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, 1973, Woodsville, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1988, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File newb106.wsp
T2        Hydraulic analysis for structure NEWBUS00050106   Date: 19-SEP-96
T3        Bridge #106 over the Wells River by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5110.0   6860.0   3940.0
SK          0.0054   0.0054   0.0054
*
XS   EXITX    -66
GR          -48.0, 499.83    -32.4, 499.87    -21.2, 499.71     -9.8, 493.64
GR            0.0, 488.65      7.3, 485.00     11.8, 485.06     19.9, 484.41
GR           28.9, 483.77     41.8, 484.39     48.6, 485.03     51.6, 485.58
GR           55.4, 487.50     60.9, 490.77     61.8, 493.86    135.7, 495.30
GR          170.8, 500.00
N           0.050        0.043        0.045
SA                 -21.2         61.8
*
XS   FULLV      0  * * *   0.0005
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.0      10.0
GR            0.0, 496.16      0.5, 488.51      7.3, 488.83      9.2, 485.56
GR           12.2, 485.17     15.9, 485.08     22.4, 483.48     31.1, 483.74
GR           40.7, 484.05     45.9, 484.17     48.1, 485.11     51.2, 485.65
GR           53.3, 485.98     55.9, 487.19     57.6, 489.76     58.8, 488.95
GR           59.1, 496.01      0.0, 496.16
*
*         BRTYPE  BRWDTH
CD           1      48.0
N          0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     29      46.5     1
GR         -193.8, 508.30   -176.7, 504.47   -171.4, 502.52    -48.7, 500.16
GR          -48.6, 499.49      0.0, 499.88      3.3, 500.85     63.2, 500.46
GR           70.0, 500.13     70.2, 499.61    133.4, 497.83    301.3, 493.37
GR          374.6, 497.00    374.6, 508.00
*
AS   APPRO     100
GR         -170.1, 511.15   -157.6, 508.54   -112.3, 504.42    -65.2, 502.83
GR          -64.8, 502.04    -46.5, 501.40    -38.3, 498.78    -35.0, 498.02
GR           -0.9, 495.11      0.0, 487.61      2.6, 486.27     12.0, 485.34
GR           17.7, 484.80     31.8, 484.59     42.5, 485.03     56.4, 485.53
GR           61.3, 487.84     71.2, 494.40    301.3, 493.63    374.6, 497.00
GR          374.6, 511.00
*
N           0.050        0.043       0.050
SA                  -0.9         71.2
*
HP 1 BRIDG   494.28 1 494.28
HP 2 BRIDG   494.28 * * 4539
HP 2 RDWAY   495.18 * * 571
HP 1 APPRO   495.16 1 495.16
HP 2 APPRO   495.16 * * 5110
*
HP 1 BRIDG   496.16 1 496.16
HP 2 BRIDG   496.16 * * 4482
HP 2 RDWAY   496.88 * * 2378
HP 1 APPRO   497.23 1 497.23
HP 2 APPRO   497.23 * * 6860
*
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File newb106.wsp
      Hydraulic analysis for structure NEWBUS00050106   Date: 19-SEP-96
      Bridge #106 over the Wells River by MAI
         *** RUN DATE & TIME: 10-21-96  12:03
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      519     71505     58     73                          8801
 494.28           519     71505     58     73  1.00      0     59     8801

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     494.28     0.1    59.0   518.7   71505.    4539.   8.75

X STA.        0.1        8.6       12.2       15.2       17.9       20.3
  A(I)           47.1       31.4       26.6       25.2       23.6
  V(I)           4.82       7.22       8.52       9.01       9.62

X STA.       20.3       22.5       24.5       26.6       28.7       30.7
  A(I)           22.8       21.7       21.8       21.4       21.3
  V(I)           9.97      10.45      10.42      10.61      10.67

X STA.       30.7       32.8       34.9       37.0       39.1       41.3
  A(I)           21.5       21.4       21.5       21.6       22.6
  V(I)          10.54      10.61      10.56      10.49      10.03

X STA.       41.3       43.6       46.0       48.8       52.2       59.0
  A(I)           22.7       23.8       26.5       28.9       45.2
  V(I)           9.98       9.52       8.58       7.85       5.02

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      29.

       WSEL     LEW     REW    AREA        K        Q    VEL
     495.18   233.2   337.8    94.7    2934.     571.   6.03

X STA.      233.2      259.7      267.7      273.3      277.7      281.5
  A(I)            9.4        6.5        5.5        5.0        4.7
  V(I)           3.04       4.40       5.19       5.75       6.11

X STA.      281.5      284.8      287.6      290.3      292.7      295.0
  A(I)            4.3        4.1        3.9        3.8        3.7
  V(I)           6.56       7.02       7.27       7.56       7.74

X STA.      295.0      297.2      299.2      301.2      303.3      305.5
  A(I)            3.6        3.5        3.6        3.7        3.7
  V(I)           7.83       8.06       8.03       7.81       7.77

X STA.      305.5      308.1      311.1      314.8      320.1      337.8
  A(I)            3.9        4.2        4.6        5.3        7.8
  V(I)           7.27       6.76       6.24       5.34       3.66
  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     100.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1        0         0      1      1                             0
           2      647     89191     72     82                         11008
           3      289      9157    263    263                          1717
 495.16           936     98348    336    346  1.57      0    335     7081

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     100.

       WSEL     LEW     REW    AREA        K        Q    VEL
     495.16    -1.5   334.6   936.3   98348.    5110.   5.46

X STA.       -1.5        6.2       10.2       13.8       17.1       20.1
  A(I)           57.3       38.1       35.0       33.4       31.7
  V(I)           4.46       6.71       7.31       7.65       8.06

X STA.       20.1       23.1       26.1       29.0       32.0       34.9
  A(I)           31.2       31.2       30.9       30.7       30.5
  V(I)           8.20       8.19       8.26       8.33       8.36

X STA.       34.9       37.8       40.9       44.0       47.3       50.6
  A(I)           31.0       31.6       31.1       33.1       32.9
  V(I)           8.25       8.09       8.22       7.73       7.77

X STA.       50.6       54.2       58.2       65.4      212.8      334.6
  A(I)           34.6       37.9       50.0      156.5      147.7
  V(I)           7.38       6.74       5.11       1.63       1.73
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File newb106.wsp
       Hydraulic analysis for structure NEWBUS00050106   Date: 19-SEP-96
       Bridge #106 over the Wells River by MAI
          *** RUN DATE & TIME: 10-21-96  12:03
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      624     64528      0    135                            0
  496.16           624     64528      0    135  1.00      0     59        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.16     0.0    59.1   623.6   64528.    4482.   7.19

X STA.        0.0        7.0       11.0       14.0       16.8       19.4
  A(I)           49.9       38.2       31.9       30.8       29.1
  V(I)           4.49       5.87       7.04       7.28       7.70

X STA.       19.4       21.7       23.9       26.1       28.3       30.4
  A(I)           28.0       27.0       27.2       26.7       26.5
  V(I)           8.01       8.29       8.25       8.39       8.44

X STA.       30.4       32.7       34.9       37.1       39.4       41.8
  A(I)           26.9       26.7       26.9       27.6       27.8
  V(I)           8.33       8.38       8.34       8.12       8.07

X STA.       41.8       44.1       46.7       49.5       52.8       59.1
  A(I)           27.7       29.6       30.7       34.0       50.3
  V(I)           8.09       7.58       7.30       6.59       4.45

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      29.

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.88   169.2   372.2   356.3   17157.    2378.   6.67

X STA.      169.2      220.7      236.2      246.9      255.5      262.9
  A(I)           35.3       24.4       20.7       18.7       17.6
  V(I)           3.37       4.87       5.75       6.37       6.77

X STA.      262.9      269.2      274.8      279.9      284.7      289.1
  A(I)           16.4       15.3       14.8       14.2       13.9
  V(I)           7.27       7.78       8.05       8.38       8.57

X STA.      289.1      293.3      297.3      301.2      305.2      309.5
  A(I)           13.7       13.3       13.4       13.7       13.8
  V(I)           8.67       8.93       8.90       8.65       8.61

X STA.      309.5      314.5      320.3      327.5      337.8      372.2
  A(I)           14.8       15.9       17.2       20.1       29.3
  V(I)           8.06       7.49       6.91       5.92       4.06
   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     100.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       26       814     25     25                          154
            2      797    126031     72     82                        15027
            3      880     53313    303    304                         8506
  497.23          1703    180157    400    410  1.66    -25    375    15461

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     100.

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.23   -25.7   374.6  1703.1  180157.    6860.   4.03

X STA.      -25.7        6.7       11.9       16.4       20.6       24.5
  A(I)          104.1       60.3       54.1       52.1       49.4
  V(I)           3.30       5.69       6.34       6.58       6.95

X STA.       24.5       28.5       32.4       36.4       40.5       44.6
  A(I)           50.4       49.2       50.2       49.9       50.8
  V(I)           6.81       6.96       6.83       6.87       6.75

X STA.       44.6       48.8       53.3       58.2       67.4      117.6
  A(I)           50.6       53.2       56.4       76.8      150.3
  V(I)           6.77       6.45       6.08       4.46       2.28

X STA.      117.6      164.4      207.8      249.4      289.5      374.6
  A(I)          143.4      139.3      139.6      140.4      182.5
  V(I)           2.39       2.46       2.46       2.44       1.88
```

```
        U.S. Geological Survey WSPRO Input File newb106.wsp
        Hydraulic analysis for structure NEWBUS00050106   Date: 19-SEP-96
        Bridge #106 over the Wells River by MAI
           *** RUN DATE & TIME: 10-21-96  12:03
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      432     54288     58     70                         6708
   492.79           432     54288     58     70  1.00      0     59     6708

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.79     0.2    59.0   432.4   54288.    3940.   9.11

X STA.         0.2        9.3       12.8       15.7       18.5       20.8
  A(I)            39.5       25.4       22.4       21.4       19.8
  V(I)            4.98       7.76       8.78       9.18       9.96

X STA.        20.8       22.9       24.9       26.9       28.9       30.9
  A(I)            18.8       18.2       18.3       17.9       17.8
  V(I)           10.46      10.80      10.78      10.98      11.05

X STA.        30.9       32.9       34.9       37.0       39.1       41.3
  A(I)            17.7       18.2       18.0       18.1       18.9
  V(I)           11.10      10.84      10.96      10.90      10.43

X STA.        41.3       43.5       45.8       48.6       51.9       59.0
  A(I)            19.0       19.9       22.0       24.3       36.7
  V(I)           10.39       9.92       8.96       8.12       5.36
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     100.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           2      545     68482     71     79                         8583
             3        2         8     35     35                            3
   493.74           547     68491    106    114  1.01      0    304     7028

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     100.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.74    -0.7   303.7   547.4   68491.    3940.   7.20

X STA.        -0.7        5.7        9.4       12.6       15.6       18.4
  A(I)            43.4       29.7       26.5       26.0       24.2
  V(I)            4.54       6.64       7.44       7.57       8.15

X STA.        18.4       21.1       23.8       26.4       28.9       31.5
  A(I)            24.4       24.2       23.5       23.3       23.4
  V(I)            8.08       8.14       8.38       8.45       8.41

X STA.        31.5       34.1       36.7       39.4       42.2       45.1
  A(I)            23.8       23.5       24.3       24.3       24.9
  V(I)            8.28       8.37       8.09       8.11       7.92

X STA.        45.1       48.1       51.1       54.5       58.3      303.7
  A(I)            25.5       26.0       27.7       31.0       47.8
  V(I)            7.72       7.59       7.12       6.35       4.12
```

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        U.S. Geological Survey WSPRO Input File newb106.wsp
        Hydraulic analysis for structure NEWBUS00050106   Date: 19-SEP-96
        Bridge #106 over the Wells River by MAI
           *** RUN DATE & TIME: 10-21-96  12:03

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

EXITX:XS   ******     -9      547  1.36 *****  495.19  491.39    5110  493.83
       -65 ******     62    69492  1.00 ***** *******    0.60    9.34

FULLV:FV       66    -10      586  1.20  0.33  495.53 *******    5110  494.33
         0     66     84    76195  1.01  0.00    0.02    0.63    8.73
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      100      0      925  0.74  0.35  495.87 *******    5110  495.13
       100    100    334    97353  1.56  0.00   -0.02    0.73    5.52
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   495.43       0.00     493.94     493.37

 ===260 ATTEMPTING FLOW CLASS 4 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       66      0      519  1.22  0.31  495.51  491.07    4539  494.28
         0     66     59    71557  1.03  0.01   -0.01    0.52    8.75

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.987 ******  496.00 ****** ****** ******

   XSID:CODE     SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
  RDWAY:RG      29.    54.  0.14  0.72  495.75    0.00    571.  495.18

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
  LT:      0.   106.   -82.    31.   1.3   0.6   6.8  14.9   2.1   3.1
  RT:    571.   104.   233.   338.   1.8   0.9   5.5   6.1   1.5   3.0

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

APPRO:AS       52     -1      937  0.73  0.20  495.89  491.35    5110  495.16
       100     60    335    98448  1.57  0.19    0.01    0.72    5.45

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.824  0.068   91315.     4.    63. ********

  FIRST USER DEFINED TABLE.

   XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
  EXITX:XS     -66.   -10.    62.   5110.   69492.     547.    9.34  493.83
  FULLV:FV       0.   -11.    84.   5110.   76195.     586.    8.73  494.33
  BRIDG:BR       0.     0.    59.   4539.   71557.     519.    8.75  494.28
  RDWAY:RG      29.*******     0.    571.       0.*********    1.00  495.18
  APPRO:AS     100.    -2.   335.   5110.   98448.     937.    5.45  495.16

   XSID:CODE   XLKQ   XRKQ       KQ
  APPRO:AS       4.    63.   91315.

 SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
  EXITX:XS    491.39    0.60  483.77  500.00************  1.36  495.19  493.83
  FULLV:FV  ********    0.63  483.80  500.03  0.33  0.00  1.20  495.53  494.33
  BRIDG:BR    491.07    0.52  483.48  496.16  0.31  0.01  1.22  495.51  494.28
  RDWAY:RG  ****************  493.37  508.30  0.14******  0.72  495.75  495.18
  APPRO:AS    491.35    0.72  484.59  511.15  0.20  0.19  0.73  495.89  495.16
```

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       U.S. Geological Survey WSPRO Input File newb106.wsp
       Hydraulic analysis for structure NEWBUS00050106   Date: 19-SEP-96
       Bridge #106 over the Wells River by MAI
          *** RUN DATE & TIME: 10-21-96  12:03

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

EXITX:XS   ******    -12      712  1.62 *****  496.95  492.70    6860  495.33
       -65 ******    136    93261  1.12 ***** *******    0.82    9.64

FULLV:FV       66    -13      795  1.35  0.32  497.26 *******    6860  495.91
         0     66    140   104302  1.17  0.00    0.00    0.72    8.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.64

APPRO:AS      100    -23     1631  0.46  0.26  497.51 *******    6860  497.05
       100    100    375   171160  1.68  0.00   -0.01    0.47    4.21
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   497.79       0.00     494.83     493.37

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   496.16     497.04     497.23     496.00

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

 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                       YU/Z,WSIU,WS = 1.09     496.99     497.18

 ===270 REJECTED 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       66      0      624  1.07  0.35  497.23  491.01    4482  496.16
         0     66     59    64528  1.34  0.09    0.00    0.45    7.19

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.865 ******  496.00 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      29.    54.  0.08  0.42  497.58    0.00   2378.  496.88

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:       0.   170.  -140.    31.   2.4   1.3   8.1  12.3   3.0   3.1
   RT:   2378.   203.   169.   372.   3.5   1.8   7.2   6.7   2.5   3.0

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

APPRO:AS       52    -25     1704  0.42  0.19  497.65  492.61    6860  497.23
       100     67    375   180247  1.66  0.23    0.00    0.44    4.03

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.852  0.400  108078.    13.    72. ********

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -66.   -13.   136.   6860.   93261.     712.    9.64  495.33
   FULLV:FV       0.   -14.   140.   6860.  104302.     795.    8.63  495.91
   BRIDG:BR       0.     0.    59.   4482.   64528.     624.    7.19  496.16
   RDWAY:RG      29.*******     0.   2378.       0.*********    1.00  496.88
   APPRO:AS     100.   -26.   375.   6860.  180247.    1704.    4.03  497.23

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      13.    72.  108078.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    492.70    0.82  483.77  500.00************  1.62  496.95  495.33
   FULLV:FV  ********    0.72  483.80  500.03  0.32  0.00  1.35  497.26  495.91
   BRIDG:BR    491.01    0.45  483.48  496.16  0.35  0.09  1.07  497.23  496.16
   RDWAY:RG  ***************  493.37  508.30  0.08******  0.42  497.58  496.88
   APPRO:AS    492.61    0.44  484.59  511.15  0.19  0.23  0.42  497.65  497.23
```

```
        U.S. Geological Survey WSPRO Input File newb106.wsp
        Hydraulic analysis for structure NEWBUS00050106   Date: 19-SEP-96
        Bridge #106 over the Wells River by MAI
           *** RUN DATE & TIME: 10-21-96  12:03

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

EXITX:XS   ******     -7      458  1.15 *****  493.72  490.39    3940  492.57
       -65 ******     61    53580  1.00 ***** *******    0.59    8.61

FULLV:FV       66     -8      488  1.01  0.33  494.05 *******    3940  493.04
         0     66     62    58820  1.00  0.00    0.00    0.54    8.08
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      100      0      536  0.84  0.40  494.45 *******    3940  493.61
       100    100     70    66729  1.00  0.00    0.00    0.47    7.35
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   493.74       0.00     492.79     493.37

 ===260 ATTEMPTING FLOW CLASS 4 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       66      0      432  1.29  0.35  494.08  490.55    3940  492.79
         0     66     59    54297  1.00  0.00   -0.01    0.59    9.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  496.00 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      29.        <<<<<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       52      0      547  0.81  0.22  494.55  490.38    3940  493.74
       100     53    304    68427  1.01  0.25    0.02    0.56    7.20

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.169  0.000   71544.     1.    60. ********

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -66.    -8.    61.   3940.   53580.     458.    8.61  492.57
   FULLV:FV       0.    -9.    62.   3940.   58820.     488.    8.08  493.04
   BRIDG:BR       0.     0.    59.   3940.   54297.     432.    9.11  492.79
   RDWAY:RG      29.**************      0.       0.       0.    1.00********
   APPRO:AS     100.    -1.   304.   3940.   68427.     547.    7.20  493.74

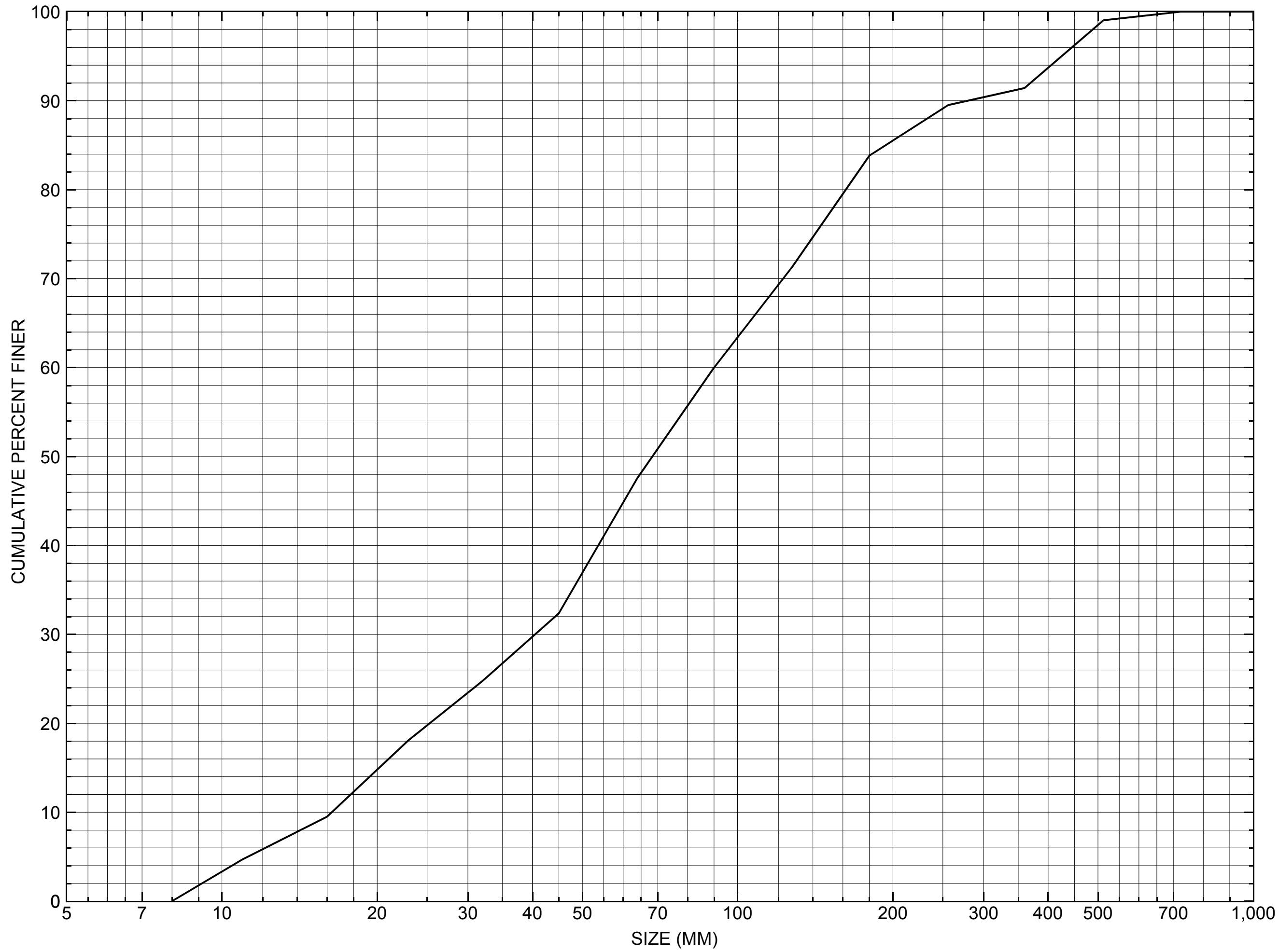
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    60.   71544.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     490.39    0.59  483.77  500.00************  1.15  493.72  492.57
   FULLV:FV   ********    0.54  483.80  500.03  0.33  0.00  1.01  494.05  493.04
   BRIDG:BR     490.55    0.59  483.48  496.16  0.35  0.00  1.29  494.08  492.79
   RDWAY:RG   ****************  493.37  508.30  0.18******  0.82  494.35********
   APPRO:AS     490.38    0.56  484.59  511.15  0.22  0.25  0.81  494.55  493.74
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure NEWBUS00050106, in Newbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number NEWBUS00050106

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 27 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 48175

Mile marker *(I - 11; nnn.nnn)* 009560

Waterway *(I - 6)* WELLS RIVER

Road Name *(I - 7):* -

Route Number US 5

Vicinity *(I - 9)* 0.1 MI N JCT. U.S.302 W

Topographic Map Woodsville

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 44093

Longitude *(i - 17; nnnnn.n)* 72028

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20011301060907

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0064

Year built *(I - 27; YYYY)* 1929

Structure length *(I - 49; nnnnnn)* 000070

Average daily traffic, ADT *(I - 29; nnnnnn)* 002040

Deck Width *(I - 52; nn.n)* 465

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

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

Opening skew to Roadway *(I - 34; nn)* 09

Waterway adequacy *(I - 71; n)* 7

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

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

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

Year Reconstructed *(I - 106)* 1969

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*) 11.0

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

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

Comments:

The structural inspection report of 8/30/93 indicates the structure is a single span, steel stringer type bridge with an asphalt roadway surface. The upstream ends of both abutments consist of older mortared granite block walls with newer concrete caps. The downstream sections consist of concrete. The footings are reportedly not in view. Some boulder and granite block fill is noted along both abutments extending beyond the upstream ends. The waterway has a slightly skewed alignment through the structure. The streambed material is stone and gravel, with a few random boulders.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **100.55** mi^2 Lake and pond area **2.47** mi^2
Watershed storage *(ST)* **2.4** %
Bridge site elevation **420** ft Headwater elevation **2369** ft
Main channel length **23.69** mi
10% channel length elevation **540** ft 85% channel length elevation **1280** ft
Main channel slope *(S)* **42** 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)*: **05** / **1968**

Project Number **BP041-4-6674** Minimum channel bed elevation: **485.0**

Low superstructure elevation: USLAB **496.31** DSLAB **496.71** USRAB **496.12** DSRAB **495.43**

Benchmark location description:

Spot at the upstream end of the right abutment concrete, elevation 500.0.

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

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

If 1: Footing Thickness **2.33** Footing bottom elevation: **479.0***

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

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

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

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

Briefly describe material at foundation bottom elevation or around piles:

The footings of abutment extensions were set in rock fill, or boulders, with some sand and gravel.

Comments:

***The left abutment footing bottom elevation is 481.70 as constructed; right as shown above. Plans are for widening the existing bridge. The bottom of the footing elevation is representative of the abutment extensions. The original footings are shown on plans with a bottom elevation about 2 feet above that of the extensions.**

Cross-sectional Data

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

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

Comments: **Surveyed channel cross section 1.5 feet under the bridge from the upstream bridge face from left to right bank.**

Station	0.5	1.5	1.5	9.0	14.0	33.0	48.0	53.0	59.5	60.0	60.0
Feature	LCL	stone	bed	LEW		TD		REW	bed	stone	LCR
Low cord elevation	496.3										
Bed elevation	494.0	494.0	488.5	486.7	485.0	485.0	485.0	486.4	488.8	492.8	496.1
Low cord to bed length											

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

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

Comments: **The surveyed channel cross section of the downstream bridge face is not reproducible due to the curve in the bridge deck. Other channel cross sections may be available.**

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: **EW** Date: **3/12/96**
Computerized by: **EW** Date: **3/12/96**
Reviewd by: **MAI** Date: **12/2/96**

Structure Number **NEWBUS00050106**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **08** / **30** / 19**95**

2. Highway District Number **07**
Mile marker **009560**
County **ORANGE (017)**
Town **NEWBURY (48175)**
Waterway *(I - 6)* **WELLS RIVER**
Road Name **US 5**
Route Number **US 5**
Hydrologic Unit Code: **01080104**

3. Descriptive comments:
Located 0.1 miles north of junction with US 302 west

B. Bridge Deck Observations

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

5. Ambient water surface... US **2** UB **1** DS **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 **70** *(feet)* Span length **64** *(feet)* Bridge width **46.5** *(feet)*

Road approach to bridge:

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

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

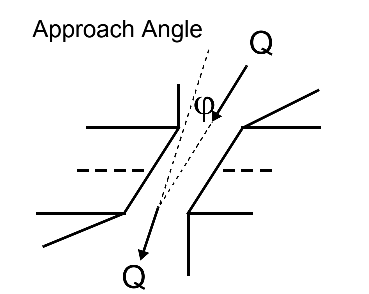
10. Embankment slope (*run / rise in feet / foot*):
US left **7.1:1** US right **3.1:1**

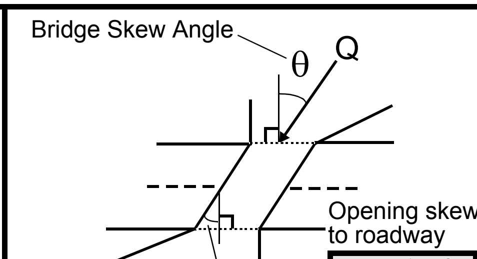
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	5	1	0	0
RBUS	5	2	2	1
RBDS	5	1	0	0
LBDS	5	1	0	0

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





α= **15.0**

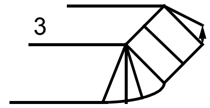
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **0**
Range? **20** feet **UB** *(US, UB, DS)* to **0** feet **DS**

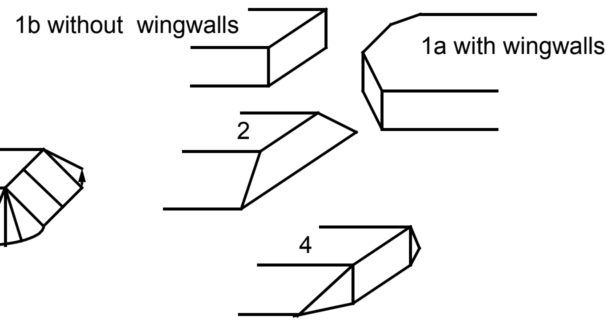
Channel impact zone 2: Exist? **N** *(Y or N)*
Where? _____ *(LB, RB)* Severity _____
Range? _____ feet _____ *(US, UB, DS)* to _____ feet _____

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

18. Bridge Type: 1b, 4

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.





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

#4: Suburban surface cover with U.S. 5 along the downstream left bank.
#7: Values are from VTAOT. The measured bridge span was 58.5 ft at the US face and 61 ft at the DS face.
#12: The retaining wall on the right bank DS for the sidewalk and road approach is cracked and protruding 0.5 ft US at the US end of the right abutment.

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
53.0	10.0			9.0	3	3	745	745	0	0

23. Bank width 30.0 24. Channel width 20.0 25. Thalweg depth 74.0 29. Bed Material 453

30 .Bank protection type: LB 5 RB 5 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.):
Right and left bank retaining walls extend 180 feet upstream from the bridge.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 52 35. Mid-bar width: 22

36. Point bar extent: 10 feet US (US, UB) to 100 feet US (US, UB, DS) positioned 0 %LB to 30 %RB

37. Material: 45

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

Side bar consists of cobbles and boulders. A second side bar was located 125 to 205 ft US. The mid-bar distance was 180 ft. The bar was positioned 30% LB to 100% RB. The bar width was 30 feet with gravel, cobble, some boulder material.

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

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB 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
44.5		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.):

453

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

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

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

70. Debris and Ice Comments:

1

Debris potential was moderate due to some trees leaning into the upstream reach in a forested area. Capture efficiency was low due to a span 80% of the US bank width.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		10	90	2	0	0	0	90.0
RABUT	12	0	90			2	0	57.0

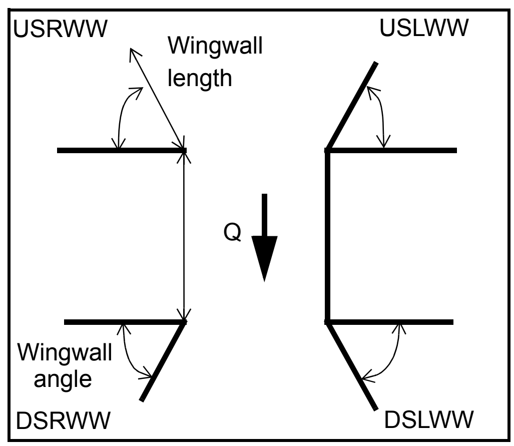
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1*- Concrete; *2*- Stone masonry or drywall; *3*- steel or metal; *4*- wood

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

0
0
12
#77: US end of both abutments consists of large block stone masonry with concrete caps. The newer DS half of the abutments is all concrete

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						57.0	
USRWW:	N		-		-	1.5	
DSLWW:	-		-		N	66.5	
DSRWW:	-		-		-	48.0	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	N	-	-	-	1	1
Condition	Y	0	-	-	-	-	1	1
Extent	1	0	-	-	-	3	3	-

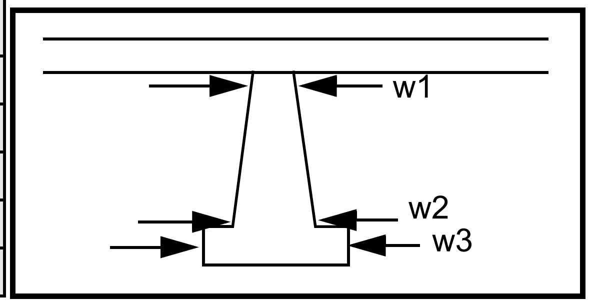
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
3
1
1
-
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-		-	-	**70.0**
Pier 2		-	-	**20.5**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

2
4
453
547
0
0
453
32
25
1
1
LB protection extends 400 feet DS with the greatest protection near bridge
RB protection consists of a concrete wall extending 230 feet DS with stone fill sloping from the toe of the wall

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

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

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

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 **N** %LB to **-** %RB

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **72** feet **16** *(US, UB, DS)* to **0** feet **DS** *(US, UB, DS)*

Bank damage: **125** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
25
54

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

Scour dimensions: Length **tiona** Width **l side** Depth: **bar** Positioned **was** %LB to **loca** %RB

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

ted 136 feet to 300 feet DS. The bar was 27 feet wide with a mid-bar distance of 257 feet, positioned 40% LB to 100% RB, and the material was cobble

Are there major confluences? **N** *(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 **-** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

NO 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)*:

Y
20
100
15
1.0
10
80
Scour extends from 10 feet US to 66 feet DS. Scour was 0.5 feet deep at US face and 1.0 foot deep just beyond DS face. The maximum scour under the bridge was 1 foot at the DS face.

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: NEWBUS00050106   Town: Newbury
Road Number: US 5   County: Orange
Stream: Wells River

Initials MAI   Date: 10/21/96 Checked: EB

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	5110	6860	3940
Main Channel Area, ft2	647	797	545
Left overbank area, ft2	0	26	0
Right overbank area, ft2	289	880	0
Top width main channel, ft	72	72	71
Top width L overbank, ft	1	25	0
Top width R overbank, ft	263	303	0
D50 of channel, ft	0.2242	0.2242	0.2242
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	9.0	11.1	7.7
y1, average depth, LOB, ft	0.0	1.0	ERR
y1, average depth, ROB, ft	1.1	2.9	ERR
Total conveyance, approach	98348	180157	68482
Conveyance, main channel	89191	126031	68482
Conveyance, LOB	0	814	0
Conveyance, ROB	9157	53313	0
Percent discrepancy, conveyance	0.0000	-0.0006	0.0000
Qm, discharge, MC, cfs	4634.2	4799.0	3940.0
Ql, discharge, LOB, cfs	0.0	31.0	0.0
Qr, discharge, ROB, cfs	475.8	2030.0	0.0
Vm, mean velocity MC, ft/s	7.2	6.0	7.2
Vl, mean velocity, LOB, ft/s	ERR	1.2	ERR
Vr, mean velocity, ROB, ft/s	1.6	2.3	ERR
Vc-m, crit. velocity, MC, ft/s	9.8	10.2	9.6
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	N/A
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	N/A

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	647	797	545
Main channel width, ft	72	72	71
y1, main channel depth, ft	8.99	11.07	7.68

Bridge Section			
(Q) total discharge, cfs	5110	6860	3940
(Q) discharge thru bridge, cfs	4539	4482	3940
Main channel conveyance	71505	64528	54288
Total conveyance	71505	64528	54288
Q2, bridge MC discharge,cfs	4539	4482	3940
Main channel area, ft2	519	624	432
Main channel width (skewed), ft	58.0	58.2	57.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	58	58.2	57.9
y_bridge (avg. depth at br.), ft	8.94	10.71	7.47
Dm, median (1.25*D50), ft	0.28025	0.28025	0.28025
y2, depth in contraction,ft	7.47	7.37	6.63
ys, scour depth (y2-ybridge), ft	-1.47	-3.34	-0.84

ARMORING			
D90	0.9146	0.9146	0.9146
D95	1.393	1.393	1.393
Critical grain size,Dc, ft	0.3377	0.2115	0.3954
Decimal-percent coarser than Dc	0.356	0.521	0.305
Depth to armoring,ft	1.83	0.58	2.70

Abutment Scour

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

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	5110	6860	3940	5110	6860	3940
a', abut.length blocking flow, ft	2.1	26.1	1.3	276.1	316	11.7
Ae, area of blocked flow ft2	15.6	83.9	8.8	257.3	612.5	45.6
Qe, discharge blocked abut.,cfs	69.7	276.3	40	--	--	193.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.47	3.29	4.55	2.15	2.46	4.25
ya, depth of f/p flow, ft	7.43	3.21	6.77	0.93	1.94	3.90
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	100	100	100	80	80	80
K2	1.01	1.01	1.01	0.98	0.98	0.98
Fr, froude number f/p flow	0.289	0.324	0.308	0.335	0.248	0.379
ys, scour depth, ft	12.08	12.36	10.50	13.29	18.48	11.63

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)	2.1	26.1	1.3	276.1	316	11.7

y1 (depth f/p flow, ft)	7.43	3.21	6.77	0.93	1.94	3.90
a’/y1	0.28	8.12	0.19	296.27	163.03	3.00
Skew correction (p. 49, fig. 16)	1.022	1.022	1.022	0.967	0.967	0.967
Froude no. f/p flow	0.29	0.32	0.31	0.34	0.25	0.38
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	4.72	8.90	ERR
vertical w/ ww’s	ERR	ERR	ERR	3.87	7.30	ERR
spill-through	ERR	ERR	ERR	2.60	4.89	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.52	0.45	0.59	0.52	0.45	0.59
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	8.81	10.55	7.35	8.81	10.55	7.35
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.47	1.32	1.58	1.47	1.32	1.58