LEVEL II SCOUR ANALYSIS FOR BRIDGE 9 (BARRUS03020009) on U.S. ROUTE 302, crossing JAIL BRANCH, BARRE, VERMONT

U.S. Geological Survey
Open-File Report 97-109

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

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By SCOTT A. OLSON and MICHAEL A. IVANOFF

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1997

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

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information write to:

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

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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 9 (BARRUS03020009) ON U.S. ROUTE 302, CROSSING JAIL BRANCH, BARRE, VERMONT

By **Scott A. Olson** *and* **Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BARRUS03020009 on U.S. Route 302 crossing Jail Branch, Barre, 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 central Vermont. The 42.8-mi^2 drainage area is in a predominantly rural and forested basin. A flood control reservoir with a usable capacity of 525 million cubic feet is located just upstream of the bridge. In the vicinity of the study site, the surface cover left of the channel consists of trees and brush. Right of the channel, the immediate bank is covered by trees and brush while the overbank is grass covered with several buildings.

In the study area, Jail Branch has an incised, sinuous channel with a slope of approximately 0.008 ft/ft, an average channel top width of 86 ft and an average channel depth of 5 ft. The channel bed material ranged from gravel to boulder with a median grain size (D_{50}) of 73.5 mm (0.241 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 17, 1996, indicated that the reach was laterally unstable due to its sinuosity, cut banks, point bars, and extensive bank protection.

The U.S. Route 302 crossing of Jail Branch is a 74-ft-long, two-lane bridge consisting of one 72-foot steel-beam span (Vermont Agency of Transportation, written communication, October 13, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 30 degrees to the opening while there is no opening-skew-to-roadway.

There is evidence of channel scour along the right bank from 190 feet upstream of the bridge and extending through the bridge along the right abutment. Under the bridge, the scour depth is approximately 0.5 feet below the mean thalweg depth. Scour protection measures at the site include type-3 stone fill (less than 48 inches diameter) along the right bank extending from the bridge to 192 feet upstream. Type-2 stone fill (less than 36 inches diameter) is along the right abutment and the right downstream bank to 205 feet downtream of the bridge. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.2 to 0.5 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.3 to 7.5 ft. The worst-case abutment scour occurred at the 500-year discharge. Computed scour for the 100-year event does not go below the abutment footings. 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.

Barre East, VT. Quadrangle, 1:24,000, 1981

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 U.S. route map.

LEVEL II SUMMARY

Structure Number BARRUS03020009 ***Stream*** Jail Branch

County Washington ***Road*** U.S. 302 ***District*** 6

Description of Bridge

Bridge length 74 ***ft*** ***Bridge width*** 39.0 ***ft*** ***Max span length*** 72 ***ft***

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

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

Stone fill on abutment? On right ***Date of inspection*** 7/17/96

Description of stone fill Type-3 stone-fill along upstream right bank from the bridge to 192 feet upstream. Type-2 stone-fill along the right abutment and the downstream right bank extending from the bridge to 205 feet downstream.

Abutments and wingwalls are concrete. The right abutment is impacted by flows and scour is evident along this abutment.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 30

There is a moderate channel bend through the reach.

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	7/17/96	0	0
Level II	7/17/96	0	0

Potential for debris Moderate. In the reach upstream there are roots exposed in the channel banks and on top of the banks there are some dead trees.

Describe any features near or at the bridge that may affect flow (include observation date) There is a flood control dam approximately 2 miles upstream of the bridge.

Description of the Geomorphic Setting

General topography The channel is located within a 600 foot-wide, flat to slightly irregular flood plain with moderate relief on both sides.

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

Date of inspection 7/17/96

DS left: Moderately sloped overbank.

DS right: Flood plain.

US left: Moderately sloped overbank.

US right: Flood plain.

Description of the Channel

Average top width 86 *ft* ***Average depth*** 5 *ft*

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

Incised and sinuous with alluvial channel boundaries and a narrow flood plain.

7/17/96

Vegetative co Trees and brush.

DS left: Some trees and brush on bank with lawns and buildings on overbank.

DS right: Trees and brush

US left: Some brush on bank with lawns and buildings on overbank.

US right:

Do banks appear stable? No ***If not, describe location and type of instability and date of observation.***

The reach is assessed as laterally unstable. However, the impacted right bank is well protected with type-3 stone-fill upstream of the bridge and type-2 stone-fill downstream.

Describe any obstructions in channel and date of observation.

July 17, 1996. There is a point bar along the left third of the channel under the bridge.

Hydrology

Drainage area 42.8 ***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***: None. The stream runs through the village of East Barre just upstream of the bridge.

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

USGS gage description Jail Branch at East Barre

USGS gage number 04284000

Gage drainage area 38.9 ***mi²***

Is there a lake/p Yes

An Army Corp of Engineers flood control dam is located immediately upstream of the gage location. The capacity of the reservior is 525 million cubic feet.

Calculated Discharges

Q100 2,150 ***ft³/s*** ***Q500*** 2,990 ***ft³/s***

The 100- and 500-year are taken from the Flood Insurance Study for the Town of Barre (Federal Emergency Management Agency, 1977).

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

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

Datum tie between USGS survey and VTAOT plans Subtract 231.6 from the USGS arbitrary survey datum to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 500.01 ft, arbitrary survey datum). RM4 is a survey disk in the upstream end of the left abutment (elev. 501.24 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	-68	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	20	1	Road Grade section
APTEM	93	1	Approach section as surveyed (Used as a template)
APPRO	113	2	Modelled Approach section (Templated from APTEM)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.035 to 0.045, and overbank "n" values ranged from 0.040 to 0.055.

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 0.0083 ft/ft, which is the slope of the 100-year water surface profile downstream of the bridge in the Flood Insurance Study for the Town of Barre (Federal Emergency Management Agency, 1977).

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

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

Bridge Hydraulics Summary

Average bridge embankment elevation 500.7 ***ft***
Average low steel elevation 497.2 ***ft***

100-year discharge 2,150 ***ft³/s***
Water-surface elevation in bridge opening 492.9 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 218 ***ft²***
Average velocity in bridge opening 9.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.0 ***ft/s***

Water-surface elevation at Approach section with bridge 494.9
Water-surface elevation at Approach section without bridge 493.8
Amount of backwater caused by bridge 1.1 ***ft***

500-year discharge 2,990 ***ft³/s***
Water-surface elevation in bridge opening 493.6 ***ft***
Road overtopping? N ***Discharge over road*** --
Area of flow in bridge opening 271 ***ft²***
Average velocity in bridge opening 11.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.5 ***/s***

Water-surface elevation at Approach section with bridge 495.8
Water-surface elevation at Approach section without bridge 494.8
Amount of backwater caused by bridge 1.0

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of the clear-water contraction scour 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. Armoring computations indicate that armoring will not impede contraction scour.

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

Total scour for the 100-year event, as predicted by the scour equations, does not undermine the abutment footings.

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	0.2	0.5	--
Depth to armoring	25.3	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	4.3	6.2	--
Right abutment	5.8	7.5	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

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

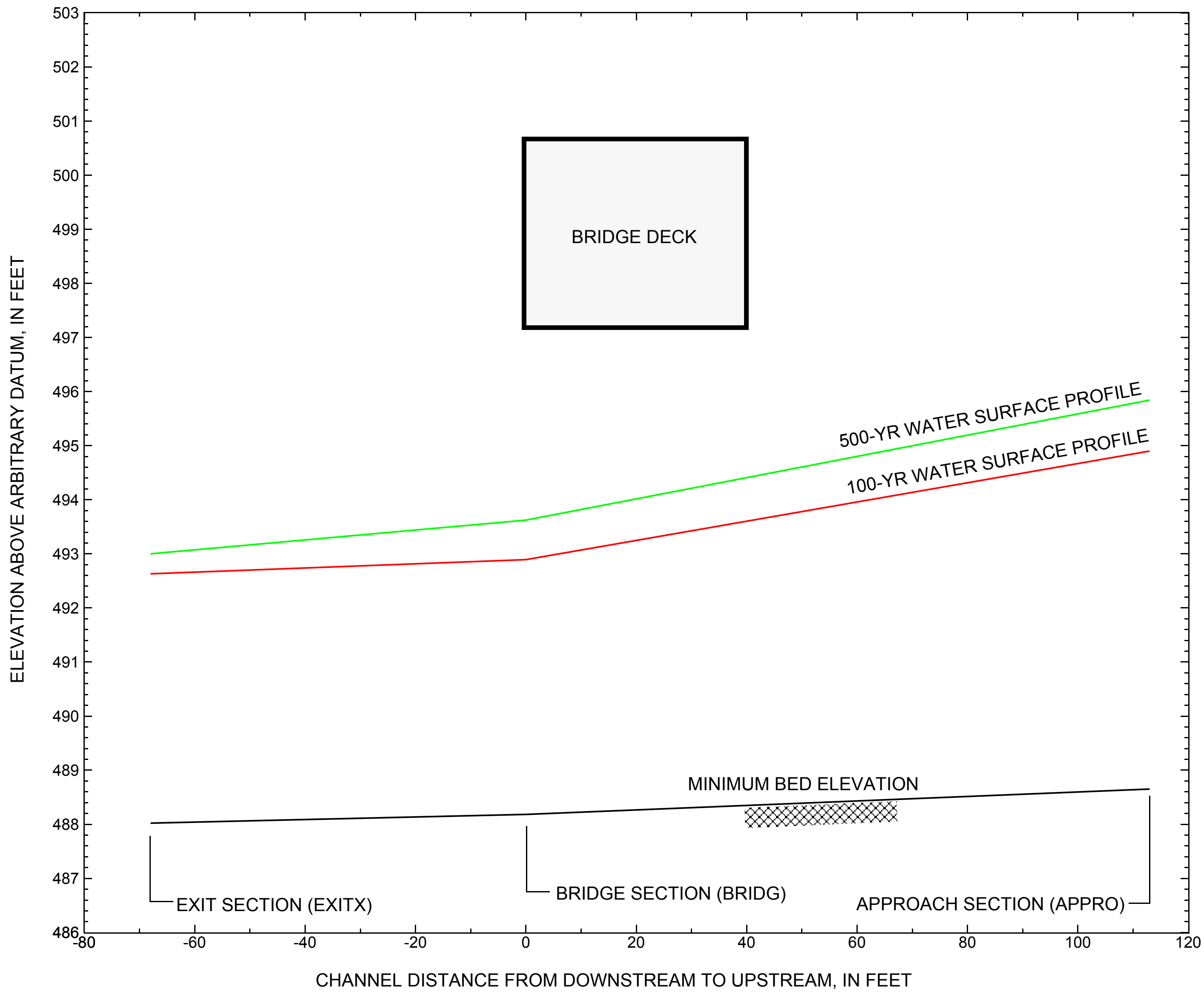

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BARRUS03020009 on U.S. Route 302, crossing Jail Branch, Barre, Vermont.

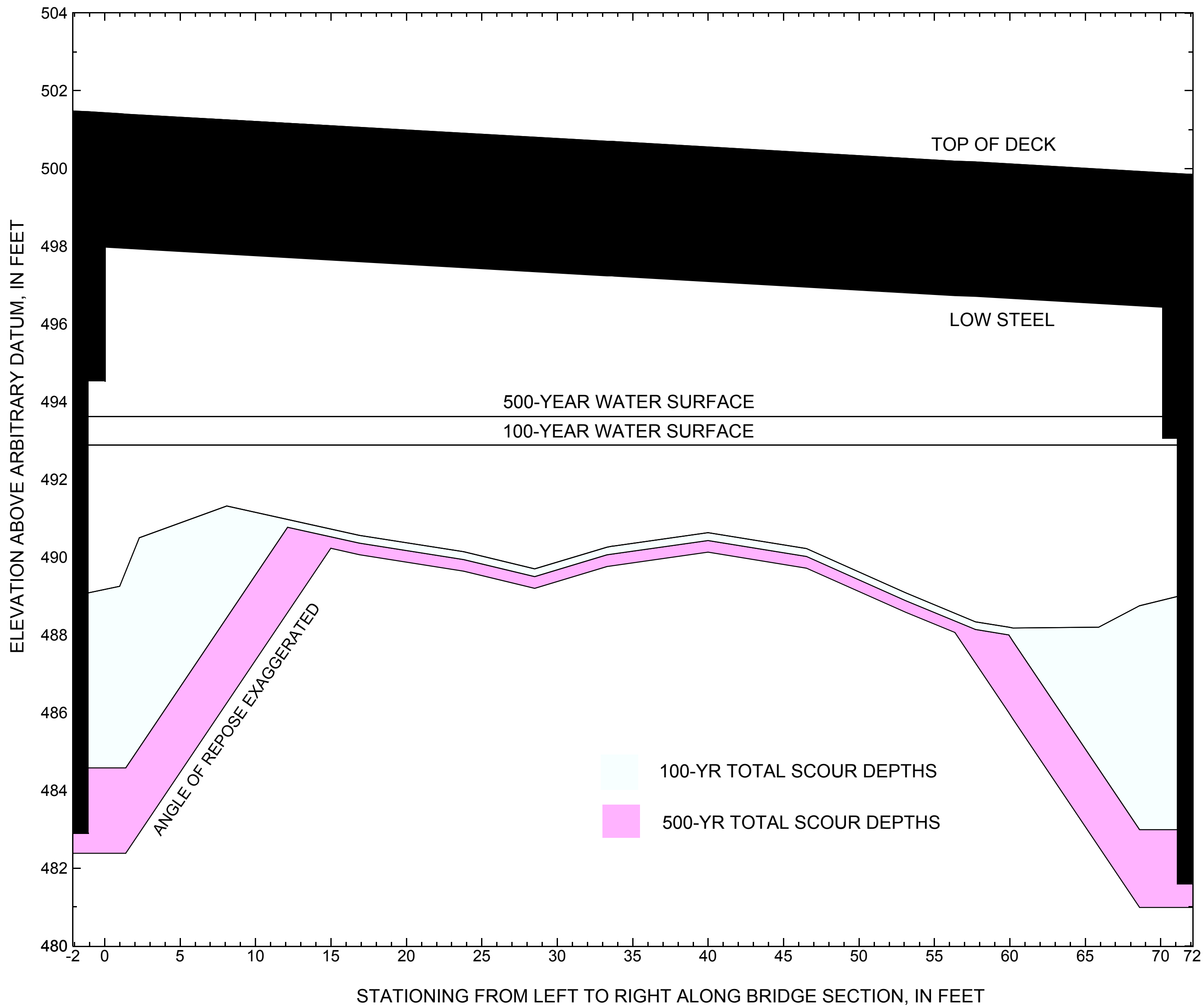

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BARRUS03020009 on U.S. Route 302, crossing Jail Branch, Barre, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BARRUS03020009 on U.S. Route 302, crossing Jail Branch, Barre, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,150 cubic-feet per second											
Left abutment	-1.1	266.0	498.0	482.9	489.1	0.2	4.3	--	4.5	484.6	1.7
Right abutment	71.1	264.6	496.4	481.6	489.0	0.2	5.8	--	6.0	483.0	1.4

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 BARRUS03020009 on U.S. Route 302, crossing Jail Branch, Barre, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,990 cubic-feet per second											
Left abutment	-1.1	266.0	498.0	482.9	489.1	0.5	6.2	--	6.7	482.4	-0.5
Right abutment	71.1	264.6	496.4	481.6	489.0	0.5	7.5	--	8.0	481.0	-0.6

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, 1981, Barre East, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File barr009.wsp
T2        Hydraulic analysis for structure BARRUS03020009   Date: 05-DEC-96
T3        BARRE BRIDGE #9 OVER JAIL BRANCH   SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2150 2990
SK          0.0083 0.0083
*
XS   EXITX    -68
GR          -72.6, 502.20    -43.1, 491.56    -33.0, 489.65    -30.9, 489.03
GR          -26.7, 490.16    -24.8, 490.16    -23.7, 489.02    -22.4, 488.59
GR          -21.2, 488.99    -16.4, 489.83    -11.0, 490.18     -2.4, 489.45
GR            0.0, 488.45     11.3, 488.60     20.6, 488.02     26.0, 488.54
GR           29.2, 489.70     33.9, 493.13     42.6, 494.05    162.3, 493.06
GR          292.2, 492.81    461.2, 491.68    515.7, 492.17    556.0, 491.83
GR          695.7, 492.00    715.1, 504.07    733.1, 506.16
N           0.055        0.045        0.040
SA                 -72.6         42.6
*
XS   FULLV     0 * * * 0.0021
*
BR   BRIDG     0 497.21
GR           -1.1, 494.56     -0.8, 489.08      1.0, 489.25      2.3, 490.50
GR            8.1, 491.32     16.9, 490.56     23.8, 490.14     28.5, 489.70
GR           33.3, 490.26     40.0, 490.63     46.5, 490.22     53.1, 489.08
GR           57.7, 488.34     60.2, 488.18     65.9, 488.20     68.6, 488.75
GR           71.1, 488.99     71.1, 493.20     70.3, 493.13     70.3, 496.41
GR            0.0, 498.00      0.0, 494.70     -1.1, 494.56
N            0.035
CD           1      50.6 * *     45.0      9.7
*
XR   RDWAY    20 39
GR        -374.5, 505.36   -236.6, 504.42      0.0, 501.36      0.3, 502.19
GR            2.0, 502.18     72.4, 500.96     74.3, 500.92     74.5, 499.96
GR          125.4, 499.19    192.6, 497.60    494.8, 493.77    527.3, 493.80
GR          567.3, 503.26    647.1, 512.38
*
XT   APTEM     93
GR          -59.6, 501.98    -34.1, 500.53    -25.2, 496.80     -2.1, 492.54
GR            0.0, 491.27      1.9, 491.06     10.7, 489.86     26.0, 489.22
GR           31.8, 488.65     40.4, 488.91     42.0, 489.52     44.1, 489.53
GR           44.6, 491.03     50.4, 492.93     87.7, 495.58    136.2, 497.81
GR          185.1, 497.37    238.0, 498.09    348.6, 497.14    527.3, 497.20
GR          567.3, 503.26    647.1, 512.38
*
AS   APPRO    113
GT           0.0
N           0.055        0.039        0.040
SA                  -34.1        50.4
*
HP 1 BRIDG   492.89 1 492.89
HP 2 BRIDG   492.89 * * 2150
HP 1 APPRO   494.90 1 494.90
HP 2 APPRO   494.90 * * 2150
*
HP 1 BRIDG   493.62 1 493.62
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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       U.S. Geological Survey WSPRO Input File barr009.wsp
       Hydraulic analysis for structure BARRUS03020009   Date: 05-DEC-96
       BARRE BRIDGE #9 OVER JAIL BRANCH   SAO

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     218.   18090.    72.    81.                       2158.
  492.89          218.   18090.    72.    81.  1.00    -1.    71.   2158.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      492.89    -1.0    71.1   218.5   18090.    2150.   9.84
X STA.       -1.0        4.3       12.5       18.5       23.2       27.2
  A(I)            15.5       14.8       13.3       12.0       11.4
  V(I)            6.94       7.25       8.10       8.95       9.42

X STA.       27.2       30.6       34.8       40.0       45.2       49.2
  A(I)            10.6       11.4       12.4       12.5       11.3
  V(I)           10.11       9.41       8.66       8.57       9.49

X STA.       49.2       52.1       54.5       56.6       58.5       60.3
  A(I)             9.9        9.3        8.8        8.5        8.3
  V(I)           10.89      11.59      12.26      12.62      13.02

X STA.       60.3       62.0       63.8       65.6       67.7       71.1
  A(I)             8.3        8.3        8.4        9.5       14.0
  V(I)           13.03      12.94      12.78      11.32       7.70

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     113.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            2     276.   27032.    65.    68.                       3227.
            3      27.    1006.    28.    28.                        154.
  494.90          304.   28037.    93.    95.  1.09   -15.    78.   2986.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     113.
        WSEL     LEW     REW    AREA        K        Q    VEL
      494.90   -14.9    78.1   303.7   28037.    2150.   7.08
X STA.      -14.9        1.9        6.3        9.8       12.7       15.4
  A(I)            28.3       18.4       16.4       14.7       14.0
  V(I)            3.79       5.84       6.56       7.30       7.66

X STA.       15.4       18.0       20.4       22.8       25.0       27.2
  A(I)            13.6       13.1       13.0       12.4       12.2
  V(I)            7.92       8.18       8.27       8.67       8.78

X STA.       27.2       29.2       31.1       33.0       34.9       36.7
  A(I)            12.1       11.7       11.6       11.5       11.5
  V(I)            8.91       9.19       9.23       9.32       9.38

X STA.       36.7       38.7       40.8       43.2       47.9       78.1
  A(I)            12.1       12.5       13.1       18.2       33.3
  V(I)            8.91       8.63       8.23       5.92       3.22
```

```
        U.S. Geological Survey WSPRO Input File barr009.wsp
        Hydraulic analysis for structure BARRUS03020009   Date: 05-DEC-96
        BARRE BRIDGE #9 OVER JAIL BRANCH   SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     271.   25380.    71.    83.                        2993.
   493.62          271.   25380.    71.    83.  1.00    -1.    71.   2993.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA         K        Q    VEL
       493.62    -1.0    71.1   270.8   25380.    2990.  11.04
X STA.        -1.0         4.4        11.1        16.8        21.2        25.2
  A(I)            19.7        16.9        15.8        14.3        13.7
  V(I)            7.59        8.87        9.47       10.46       10.90

X STA.        25.2        28.7        32.2        36.4        41.1        45.5
  A(I)            13.1        13.0        13.7        14.4        14.1
  V(I)           11.39       11.46       10.92       10.37       10.63

X STA.        45.5        49.2        52.1        54.6        56.8        58.8
  A(I)            13.3        12.0        11.3        11.0        10.7
  V(I)           11.21       12.45       13.28       13.62       13.93

X STA.        58.8        60.7        62.8        64.8        67.1        71.1
  A(I)            10.3        11.0        11.1        12.2        19.1
  V(I)           14.47       13.56       13.49       12.23        7.83

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     113.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     340.   36368.    70.    73.                        4244.
             3      60.    2777.    43.    43.                         401.
   495.84          400.   39145.   113.   116.  1.12   -20.    93.   4021.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     113.
         WSEL     LEW     REW    AREA         K        Q    VEL
       495.84   -20.0    93.4   400.1   39145.    2990.   7.47
X STA.       -20.0        -0.1         4.8         8.7        11.9        14.8
  A(I)            37.2        24.1        20.7        19.2        17.9
  V(I)            4.02        6.20        7.21        7.80        8.37

X STA.        14.8        17.6        20.3        22.8        25.2        27.5
  A(I)            17.3        16.7        16.1        16.1        15.4
  V(I)            8.66        8.96        9.27        9.27        9.68

X STA.        27.5        29.8        31.8        33.9        35.9        38.1
  A(I)            15.2        14.7        14.9        14.4        15.0
  V(I)            9.86       10.19       10.01       10.37        9.94

X STA.        38.1        40.3        42.8        46.6        55.3        93.4
  A(I)            15.2        16.3        20.4        26.7        46.4
  V(I)            9.82        9.15        7.34        5.60        3.22
```

WSPRO OUTPUT FILE (continued)

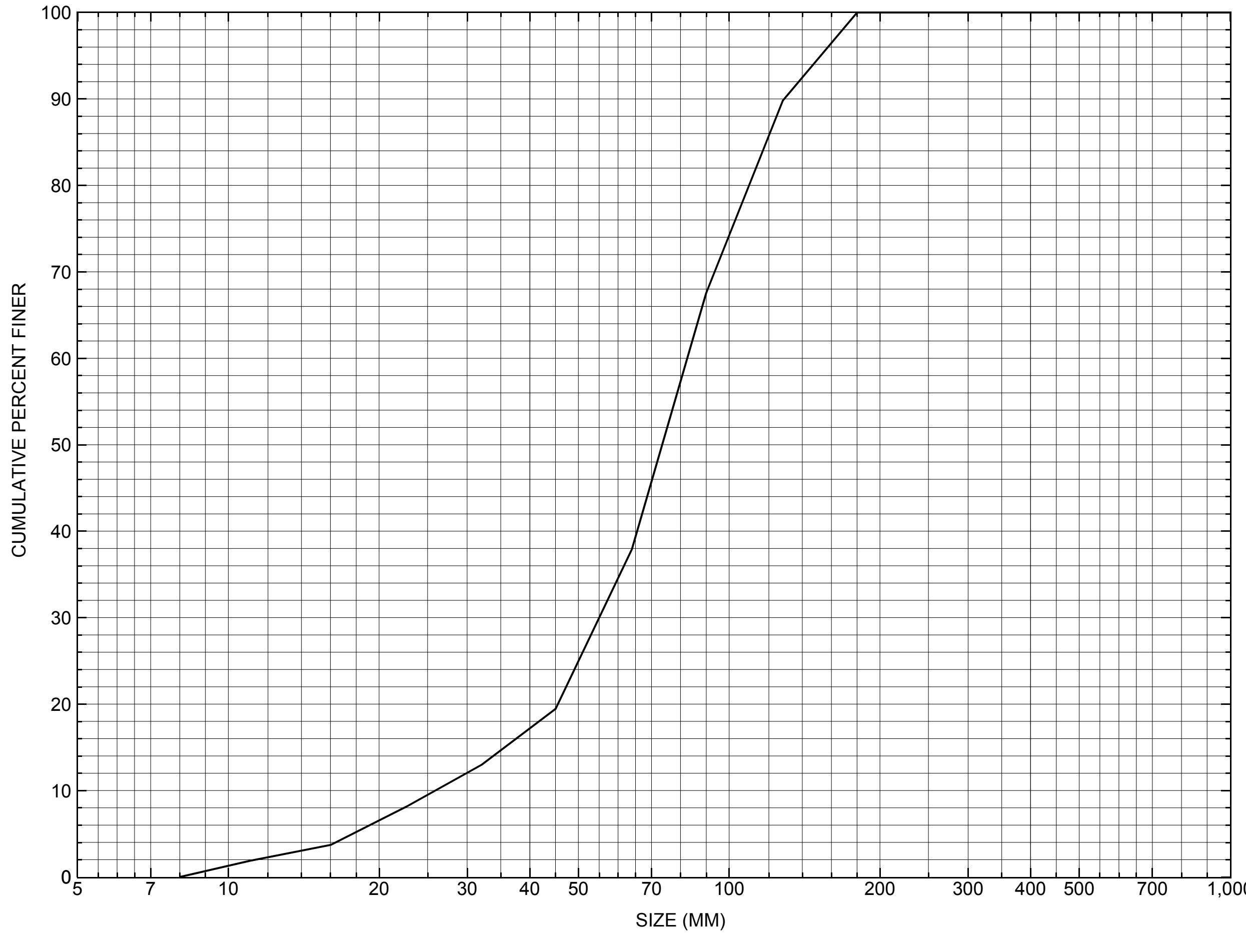
```
        U.S. Geological Survey WSPRO Input File barr009.wsp
        Hydraulic analysis for structure BARRUS03020009   Date: 05-DEC-96
        BARRE BRIDGE #9 OVER JAIL BRANCH   SAO

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

EXITX:XS   ******   -46.      482.  0.48 *****  493.12  492.61   2150.  492.63
      -68. ******   697.   23584.  1.56 ***** *******    0.96    4.46

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.55

FULLV:FV      68.    -47.      741.  0.20  0.36  493.47 *******   2150.  493.26
        0.    68.    698.   36635.  1.55  0.00   -0.01    0.58    2.90
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     1.28     493.21     493.81
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   492.76     512.38    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   492.76     512.38     493.81
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   493.81     512.38     493.81

APPRO:AS     113.     -9.      214.  1.62 *****  495.43  493.81   2150.  493.81
      113.   113.     63.   18101.  1.03 ***** *******    1.04   10.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   494.90       0.00     492.89     493.77
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   496.69         0.      2150.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   497.21         0.      3047.
 ===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      68.     -1.      218.  1.51  0.74  494.40  488.38   2150.  492.89
        0.    68.     71.   18077.  1.00  0.39    0.00    1.00    9.85

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.21 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.        <<<<<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      62.    -15.      303.  0.85  0.63  495.75  493.81   2150.  494.90
      113.    69.     78.   28007.  1.09  0.72    0.00    0.72    7.08

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.033   27064.   -21.    51.  494.46

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -68.   -46.   697.   2150.   23584.     482.    4.46  492.63
   FULLV:FV       0.   -47.   698.   2150.   36635.     741.    2.90  493.26
   BRIDG:BR       0.    -1.    71.   2150.   18077.     218.    9.85  492.89
   RDWAY:RG      20.**************      0.       0.*********    1.00********
   APPRO:AS     113.   -15.    78.   2150.   28007.     303.    7.08  494.90

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -21.    51.   27064.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO   VHD      EGL    WSEL
   EXITX:XS    492.61    0.96  488.02  506.16************  0.48  493.12  492.63
   FULLV:FV  ********    0.58  488.16  506.30  0.36  0.00  0.20  493.47  493.26
   BRIDG:BR    488.38    1.00  488.18  498.00  0.74  0.39  1.51  494.40  492.89
   RDWAY:RG  ****************  493.77  512.38************  0.30  497.41********
   APPRO:AS    493.81    0.72  488.65  512.38  0.63  0.72  0.85  495.75  494.90
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File barr009.wsp
       Hydraulic analysis for structure BARRUS03020009   Date: 05-DEC-96
       BARRE BRIDGE #9 OVER JAIL BRANCH   SAO

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

EXITX:XS   ******   -47.     668.  0.49 *****  493.49  492.81   2990.  493.00
      -68. ******   697.   32790.  1.57 ***** *******    0.93    4.47

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.58

FULLV:FV      68.   -48.     988.  0.19  0.36  493.84 *******   2990.  493.64
        0.    68.   698.   51928.  1.36  0.00   -0.01    0.51    3.03
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   493.14     512.38    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   493.14     512.38     494.80
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
            ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                 WSBEG,WSEND,CRWS =   494.80     512.38     494.80

APPRO:AS     113.   -14.     294.  1.74 *****  496.54  494.80   2990.  494.80
      113.   113.    77.   26992.  1.08 ***** *******    1.04   10.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
         WS1,WSSD,WS3,RGMIN =   495.84       0.00     493.62     493.77
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                 WS,QBO,QRD =   497.05         0.      2990.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                 WS,QBO,QRD =   497.21         0.      3409.
 ===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      68.    -1.     271.  1.90  0.73  495.52  488.38   2990.  493.62
        0.    68.    71.   25361.  1.00  0.61    0.00    1.00   11.05

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.21 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.        <<<<<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      62.   -20.     400.  0.98  0.60  496.82  494.80   2990.  495.84
      113.    67.    93.   39188.  1.13  0.70    0.00    0.74    7.47

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.208  0.052   37094.   -19.    53.   495.41

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -68.   -47.   697.   2990.   32790.     668.    4.47  493.00
   FULLV:FV      0.   -48.   698.   2990.   51928.     988.    3.03  493.64
   BRIDG:BR      0.    -1.    71.   2990.   25361.     271.   11.05  493.62
   RDWAY:RG     20.**************      0.       0.*********    1.00********
   APPRO:AS    113.   -20.    93.   2990.   39188.     400.    7.47  495.84

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -19.    53.   37094.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    492.81    0.93  488.02  506.16************  0.49  493.49  493.00
   FULLV:FV  ********    0.51  488.16  506.30  0.36  0.00  0.19  493.84  493.64
   BRIDG:BR    488.38    1.00  488.18  498.00  0.73  0.61  1.90  495.52  493.62
   RDWAY:RG  ****************  493.77  512.38************  0.58  497.59********
   APPRO:AS    494.80    0.74  488.65  512.38  0.60  0.70  0.98  496.82  495.84
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BARRUS03020009, in Barre, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BARRUS03020009

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)* 03250

Mile marker *(I - 11; nnn.nnn)* 001050

Waterway *(I - 6)* JAIL BRANCH BROOK

Road Name *(I - 7)*:

Route Number US 302

Vicinity *(I - 9)* 1.5 MI W JCT. 110

Topographic Map Barre East

Hydrologic Unit Code: 2010003

Latitude *(I - 16; nnnn.n)* 44106

Longitude *(i - 17; nnnnn.n)* 72280

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20002600091202

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

Maximum span length *(I - 48; nnnn)* 0072

Year built *(I - 27; YYYY)* 1928

Structure length *(I - 49; nnnnnn)* 000074

Average daily traffic, ADT *(I - 29; nnnnnn)* 006280

Deck Width *(I - 52; nn.n)* 390

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

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

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

Waterway adequacy *(I - 71; n)* 5

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

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

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

Year Reconstructed *(I - 106)* 1972

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

Clear span (*nnn.n ft*) 69.17

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

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

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

Waterway of full opening (*nnn.n ft*^{2}) 553.4

Comments:

According to the structural inspection report dated 8/2/93, the structure is a single-span rolled-beam bridge. The channel takes a minor turn into the structure and is flowing along the right side. There is a sand and stone point bar along the left side of the channel. There is heavy stone fill on the right banks, US and DS. Abutment footings are not exposed. Minor channel scour is noted along right side. Minor embankment erosion is noted. Overall structure is in good condition. There are minor cracks, scaling and spalling of the abutments and wingwalls.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: 43.1

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} 1490

Q_{50} 1670 Q_{100} ____ Q_{500} ____

Record flood date *(MM / DD / YY)*: 11 / 4 / 27 Water surface elevation *(ft)*: 266.3

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: **38.8 square miles of the drainage area are controlled by the East Barre Dam.**

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*)				262	
Velocity (*ft / sec*)					

Long term stream bed changes:

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

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

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

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

Highway No. : ____ Structure No. : ____ Structure Type: ____

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

Downstream distance (*miles*): ___________ Town: ____________________ Year Built: ______

Highway No. : _________________ Structure No. : ______ Structure Type: ______________________

Clear span (*ft*): _____ Clear Height (*ft*): ______ Full Waterway (ft^2): _______

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **42.8** mi^2 Lake and pond area **1.65** mi^2

Watershed storage *(ST)* **3.85** %

Bridge site elevation **780** ft Headwater elevation **2267** ft

Main channel length **11.42** mi

10% channel length elevation **940** ft 85% channel length elevation **1510** ft

Main channel slope *(S)* **66.55** 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 **BP-026-1-7101** Minimum channel bed elevation: **256**

Low superstructure elevation: USLAB **265.98** DSLAB **265.98** USRAB **264.59** DSRAB **264.59**

Benchmark location description:

BM #1A, Power Pole elev. 267.32, approx. 60' upstream and 60' to right of the bridge
BM #1, Nickel Monel Nail at corner of the upstream right abutment, elev. 268.31
BM #1B, 24" Pine elev. 263.97, approx. 20' downstream and 120' to right of bridge
BM #1C, Power Pole elev. 273.67 approx. 20' from west side of U.S. Rte 302 and 300' to left of bridge

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

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

If 1: Footing Thickness **2** Footing bottom elevation: **250****

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: ____ (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:

Comments:

****Footing bottom elev of right abutment is 250.00 feet; left abutment is 251.25 feet.**
The low superstructure elevations are the bridge seat elevations from the bridge plans.
The US right abutment-wingwall top corner elevation is 268.42 feet, the US left abutment-wingwall top coner elevation is 269.69 feet.

Cross-sectional Data

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

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	--	--	--	--	--	--	--	--	--	--	--

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: **RB** Date: **11/01/96**
Computerized by: **RB** Date: **11/05/96**
Reviewd by: **SAO** Date: **1/17/97**

Structure Number **BARRUS03020009**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **07** / **17** / 19**96**
2. Highway District Number **06** Mile marker **001050**
County **WASHINGTON 023** Town **BARRE 03250**
Waterway *(I - 6)* **JAIL BRANCH BROOK** Road Name **US 302**
Route Number **US 302** Hydrologic Unit Code: **2010003**
3. Descriptive comments:
Located 1.5 miles from the junction with VT110.

B. Bridge Deck Observations

4. Surface cover... LBUS **5** RBUS **5** LBDS **6** RBDS **2** 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 **74** *(feet)* Span length **72** *(feet)* Bridge width **39** *(feet)*

Road approach to bridge:

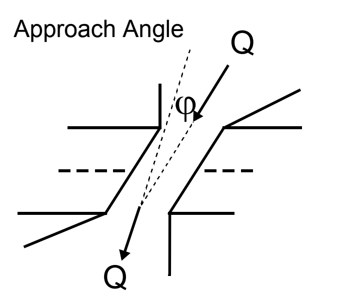
8. LB **2** RB **1** *(**0** even, **1**- lower, **2**- higher)*
9. LB **1** RB **1** *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

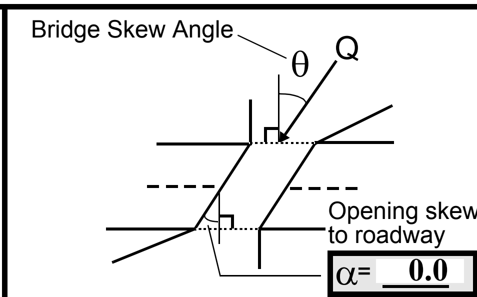
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: **40** 16. Bridge skew: **30**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **70** feet **US** *(US, UB, DS)* to **100** 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: 1a

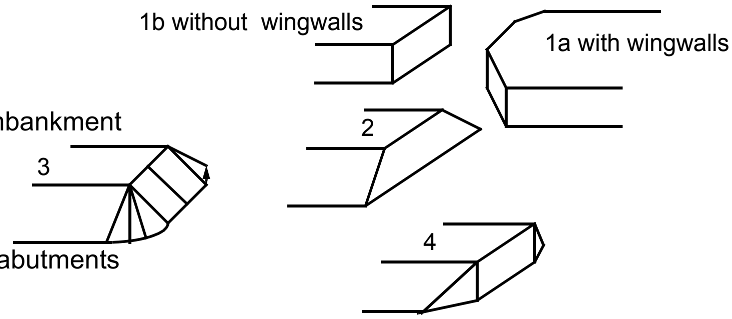
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

7. Values are from the VT AOT files. Measured bridge dimensions are the same.

4. There is a house on the right bank US beyond the trees along the immediate bank.

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
58.0	9.5			3.5	2	2	31	531	1	0

23. Bank width 15.0 24. Channel width 30.0 25. Thalweg depth 85.5 29. Bed Material 435

30 .Bank protection type: LB - RB 3 31. Bank protection condition: LB - RB 2

*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.):

27. The left bank consists of gravels and silt. The right bank is composed of boulders, gravel and silt.

29. The bed material is cobble, gravel and boulder.

30. The right bank protection extends 192 ft. US of the bridge.

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

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

37. Material: -

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

NO POINT BARS

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

41. Mid-bank distance: 250 42. Cut bank extent: 170 feet US (US, UB) to 310 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.):

The cut bank begins at about 310 ft. US to the bend in the channel 170 ft. US of the bridge.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 93

47. Scour dimensions: Length 125 Width 10 Depth : 3.5 Position 75 %LB to 100 %RB

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

Average thalweg depth is 1.5 ft. US and DS. Scour runs along the right bank from 65 ft. US to 190 ft. US.

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
44.0		2.5		2	7	7	0

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 90.0 63. Bed Material 0

*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*

*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*

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

345

63. The bed material is gravel, cobble and boulder.

The stream flow is along the right abutment.

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? 1___ (Y or N) Ice Blockage Potential N____ (1- Low; 2- Moderate; 3- High)

70. Debris and Ice Comments:

1

There is a low flood plain along the US right bank from 200 ft. US to 500 ft. US with dead trees. There are exposed roots along the upstream left cut bank.

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	90	2	0	0	0	90.0
RABUT	1	30	90			2	1	71.5

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

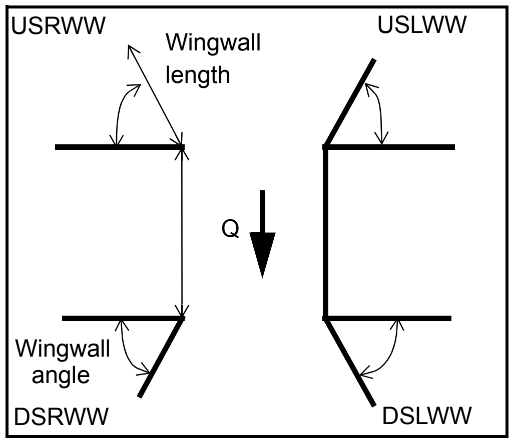
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0.5
0
1
The flow is along the right abutment as it is at the outside bank of a meander.
75. The right abutment scour is just beyond the slumped and eroded stone fill.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						71.5	
USRWW:	Y		1		0	2.0	
DSLWW:	-		-		Y	40.5	
DSRWW:	1		0		-	41.0	

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



82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	-	2	-	3
Condition	Y	-	1	-	-	1	-	1
Extent	1	-	0	0	3	0	2	-

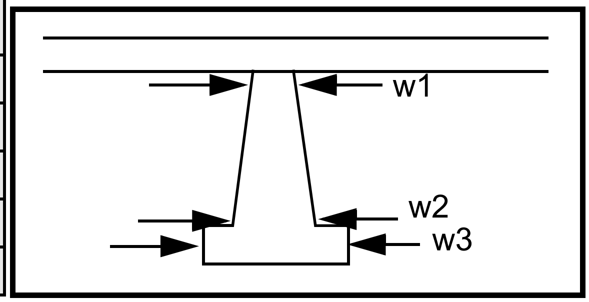
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
3
2
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				**45.0**	**17.0**	**45.0**
Pier 2				**10.0**	**45.0**	**13.5**
Pier 3			-	**45.0**	**10.0**	-
Pier 4	-	-	-	-	-	-



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

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

2
1
45
45

101. Is a drop structure present? **2** *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

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

105. Drop structure comments (eg. downstream scour depth):
345
0
2
-
2
The bank material consists of cobbles and boulders in silt material. The bed consists of gravel, cobbles, and

106. Point/Side bar present? so (Y or N. if N type ctrl-n pb) Mid-bar distance: me Mid-bar width: boul-

Point bar extent: ders. feet Th (US, UB, DS) to e feet rig (US, UB, DS) positioned ht %LB to ba %RB

Material: nk

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

protection extends 205 ft. DS.
At 190 ft. DS the channel anabranches and then merges back at 275 ft.
At 320 ft. DS on the left bank there is mass wasting of the bank with some downed live trees.

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

Cut bank extent: ____ feet ____ (US, UB, DS) to ____ feet ____ (US, UB, DS)

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

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

N
-
NO DROP STRUCTURE

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

Scour dimensions: Length ____ Width ____ Depth: ____ Positioned Y %LB to 0 %RB

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

50
12
US
109

Are there major confluences? DS (Y or if N type ctrl-n mc) How many? 0

Confluence 1: Distance 65 Enters on 32 (LB or RB) Type This (1- perennial; 2- ephemeral)

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

Confluence comments (eg. confluence name):

and sand point bar with vegetation at mid-bar and DS of the bridge with some flow through the middle of the bar.

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
RB
180
150
DS
220
DS
1
There is slight erosion of the fines from the bank and slumping protection. There is mass wasting/block failure at 320 ft. DS on the left bank.

109. G. Plan View Sketch

\- N

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: BARRUS03020009 Town: Barre
Road Number: County: Washington
Stream: Jail Branch Brook

Initials SAO Date: 12/19/96 Checked: EMB

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	2150	2990	0
Main Channel Area, ft2	276	340	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	27	60	0
Top width main channel, ft	65	70	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	28	43	0
D50 of channel, ft	0.241	0.241	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	4.2	4.9	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	1.0	1.4	ERR
Total conveyance, approach	28037	39145	0
Conveyance, main channel	27032	36368	0
Conveyance, LOB	0	2777	0
Conveyance, ROB	1006	0	0
Percent discrepancy, conveyance	-0.0036	0.0000	ERR
Qm, discharge, MC, cfs	2072.9	2777.9	ERR
Ql, discharge, LOB, cfs	0.0	212.1	ERR
Qr, discharge, ROB, cfs	77.1	0.0	ERR
Vm, mean velocity MC, ft/s	7.5	8.2	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.9	0.0	ERR
Vc-m, crit. velocity, MC, ft/s	8.9	9.1	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Main Channel	0	0	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	276	340	0
Main channel width, ft	65	70	0
y1, main channel depth, ft	4.25	4.86	ERR

Bridge Section			
(Q) total discharge, cfs	2150	2990	0
(Q) discharge thru bridge, cfs	2150	2990	0
Main channel conveyance	18090	25380	0
Total conveyance	18090	25380	0
Q2, bridge MC discharge,cfs	2150	2990	ERR
Main channel area, ft2	218	271	0
Main channel width (skewed), ft	72.1	72.1	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	72.1	72.1	0
y_bridge (avg. depth at br.), ft	3.02	3.76	ERR
Dm, median (1.25*D50), ft	0.30125	0.30125	0
y2, depth in contraction,ft	3.20	4.25	ERR
ys, scour depth (y2-ybridge), ft	0.18	0.49	N/A

ARMORING			
D90	0.423	0.423	0
D95	0.500	0.500	0
Critical grain size,Dc, ft	0.4911	0.5590	ERR
Decimal-percent coarser than Dc	0.0551	0.0164	0
Depth to armoring,ft	25.27	N/A	ERR

Abutment Scour

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

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	2150	2990	0	2150	2990	0
a', abut.length blocking flow, ft	2.9	8	0	18	33.3	0
Ae, area of blocked flow ft2	4.9	15	0	19.9	40.6	0
Qe, discharge blocked abut.,cfs	18.6	60.1	0	64.1	130.7	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.80	4.01	ERR	3.22	3.22	ERR
ya, depth of f/p flow, ft	1.69	1.88	ERR	1.11	1.22	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	0	90	90	0
K2	1.00	1.00	0.00	1.00	1.00	0.00
Fr, froude number f/p flow	0.515	0.516	ERR	0.540	0.514	ERR
ys, scour depth, ft	4.34	6.22	N/A	5.80	7.49	N/A

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

a'(abut length blocked, ft)	2.9	8	0	18	33.3	0
y1 (depth f/p flow, ft)	1.69	1.88	ERR	1.11	1.22	ERR
a'/y1	1.72	4.27	ERR	16.28	27.31	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.51	0.52	N/A	0.54	0.51	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	7.12	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	5.84	ERR

spill-through	ERR	ERR	ERR	ERR	3.91	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	1	1	0	1	1	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	3.02	3.76	0.00	3.02	3.76	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	1.26	1.57	ERR	1.26	1.57	ERR
Fr<=0.8 (spillthrough abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (spillthrough abut.)	1.12	1.39	ERR	1.12	1.39	ERR