LEVEL II SCOUR ANALYSIS FOR BRIDGE 15 (BOLTTH00150015) on TOWN HIGHWAY 15, crossing JOINER BROOK, BOLTON, VERMONT

Open-File Report 98-425

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 15 (BOLTTH00150015) on TOWN HIGHWAY 15, crossing JOINER BROOK, BOLTON, VERMONT

By RONDA L. BURNS and EMILY C. WILD

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 15 (BOLTTH00150015) ON TOWN HIGHWAY 15, CROSSING JOINER BROOK, BOLTON, VERMONT

By **Ronda L. Burns and Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BOLTTH00150015 on Town Highway 15 crossing Joiner Brook, Bolton, 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 (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in north central Vermont. The 9.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture (lawn) downstream of the bridge and on the upstream right bank. The surface cover on the upstream left bank is shrub and brushland.

In the study area, Joiner Brook has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 61 ft and an average bank height of 7 ft. The channel bed material ranges from gravel to cobble with a median grain size (D_{50}) of 43.6 mm (0.143 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 27, 1996, indicated that the reach was stable.

The Town Highway 15 crossing of Joiner Brook is a 39-ft-long, two-lane bridge consisting of one 36-foot concrete tee-beam span (Vermont Agency of Transportation, written communication, November 3, 1995). The opening length of the structure parallel to the bridge face is 34.6 ft. The bridge is supported by nearly vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed at the downstream end of the right abutment and along the downstream right wingwall during the Level I assessment. A second scour hole 1.2 ft deeper than the mean thalweg depth was observed at the upstream end of the left abutment and along the upstream left wingwall. The left abutment footing is exposed in the area of the scour hole. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) at the upstream end of the upstream left wingwall and at the downstream end of the downstream right wingwall and type-2 stone fill (less than 36 inches diameter) along the downstream left bank. There is also type-3 stone fill (less than 48 inches diameter) along the upstream left and right banks. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.8 to 3.5 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.9 to 15.1 ft. The worst-case abutment scour occurred at the incipient roadway-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results.” Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number BOLTTH00150015 ***Stream*** Joiner Brook

County Chittenden ***Road*** TH 15 ***District*** 5

Description of Bridge

Bridge length 39 ***ft*** ***Bridge width*** 26.2 ***ft*** ***Max span length*** 36 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 6/27/96

Description of stone fill Type-1, at the upstream end of the upstream left wingwall and at the downstream end of the downstream right wingwall.

Abutments and wingwalls are concrete. There is a 1.2-ft deep scour hole at the upstream end of the left abutment and along the upstream left wingwall and a 1.5-ft deep scour hole at the downstream end of the right abutment and along the downstream right wingwall.

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

There is a moderate channel bend through the bridge. The scour holes have developed in the locations where the bridge constricts the flow.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	6/27/96	0	0
Level II	6/27/96	0	0

Potential for debris Moderate. Some debris is caught along the banks upstream.

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

None were observed on 6/27/96.

Description of the Geomorphic Setting

General topography The channel is located in a high relief valley.

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

Date of inspection 6/27/96

DS left: Steep channel bank to an irregular overbank

DS right: Steep channel bank to an irregular overbank

US left: Steep road embankment for I-89

US right: Steep channel bank to an irregular overbank

Description of the Channel

Average top width 61 ft ***Average depth*** 7 ft

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

Perennial and straight with semi-alluvial channel boundaries and wide point bars.

6/27/96

Vegetative co

Few trees and brush with grass on the overbank

DS left: Few trees and brush with grass on the overbank

DS right: Few trees, shrubs, and brush

US left: Few trees and brush with grass on the overbank

US right:

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

According to the assessment of 6/27/96 a railroad bridge was observed about 190 ft downstream from this bridge.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 9.60 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,900 ***ft³/s*** ***Q500*** 2,800 ***ft³/s***

The 100- and 500-year discharges are the median values of the range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left abutment (elev. 499.29 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream right end of the bridge curb (elev. 500.73 ft, arbitrary survey datum). RM3 is a nail, 5.1 ft above the ground, in an utility pole located 100 ft to the left of the left bank and 15 ft downstream from the road (elev. 504.41 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXTRR	-242	1	Railroad bridge Exit section
FLVRR	-188	2	Railroad bridge Full-valley section (Templated from EXTRR)
RRBRG	-188	1	Railroad bridge section
RRBED	-176	1	Railroad Grade section
APPRR	-110	3	Railroad bridge Approach section (Modified from EXITX)
EXITX	-27	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APPRO	63	1	Approach section

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.035 to 0.066, and overbank "n" values ranged from 0.035 to 0.070.

Normal depth at the railroad bridge exit section (EXTRR) 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 0.0099 ft/ft, which was estimated from thalweg points surveyed downstream of the bridge.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 500.6 ***ft***
Average low steel elevation 496.6 ***ft***

100-year discharge 1,900 ***ft³/s***
Water-surface elevation in bridge opening 495.2 ***ft***
Road overtopping? No ***Discharge over road*** - ***ft³/s***
Area of flow in bridge opening 190 ***ft²***
Average velocity in bridge opening 10.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.5 ***ft/s***

Water-surface elevation at Approach section with bridge 496.7
Water-surface elevation at Approach section without bridge 496.5
Amount of backwater caused by bridge 0.2 ***ft***

500-year discharge 2,800 ***ft³/s***
Water-surface elevation in bridge opening 496.6 ***ft***
Road overtopping? Yes ***Discharge over road*** 188 ***ft³/s***
Area of flow in bridge opening 236 ***ft²***
Average velocity in bridge opening 11.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.5 ***ft/s***

Water-surface elevation at Approach section with bridge 500.2
Water-surface elevation at Approach section without bridge 497.3
Amount of backwater caused by bridge 2.9 ***ft***

Incipient overtopping discharge 2,560 ***ft³/s***
Water-surface elevation in bridge opening 496.6 ***ft***
Area of flow in bridge opening 236 ***ft²***
Average velocity in bridge opening 10.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.0 ***ft/s***

Water-surface elevation at Approach section with bridge 499.7
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 2.1 ***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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 500-year and incipient roadway-overtopping discharges resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow also was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results from these computations are presented in appendix F.

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

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.8	3.5	3.0
Depth to armoring	10.9	22.2	15.6
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	7.6	6.9	9.2
Right abutment	9.9	14.4	15.1
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	1.9	2.4	2.2
Right abutment	1.9	2.4	2.2
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

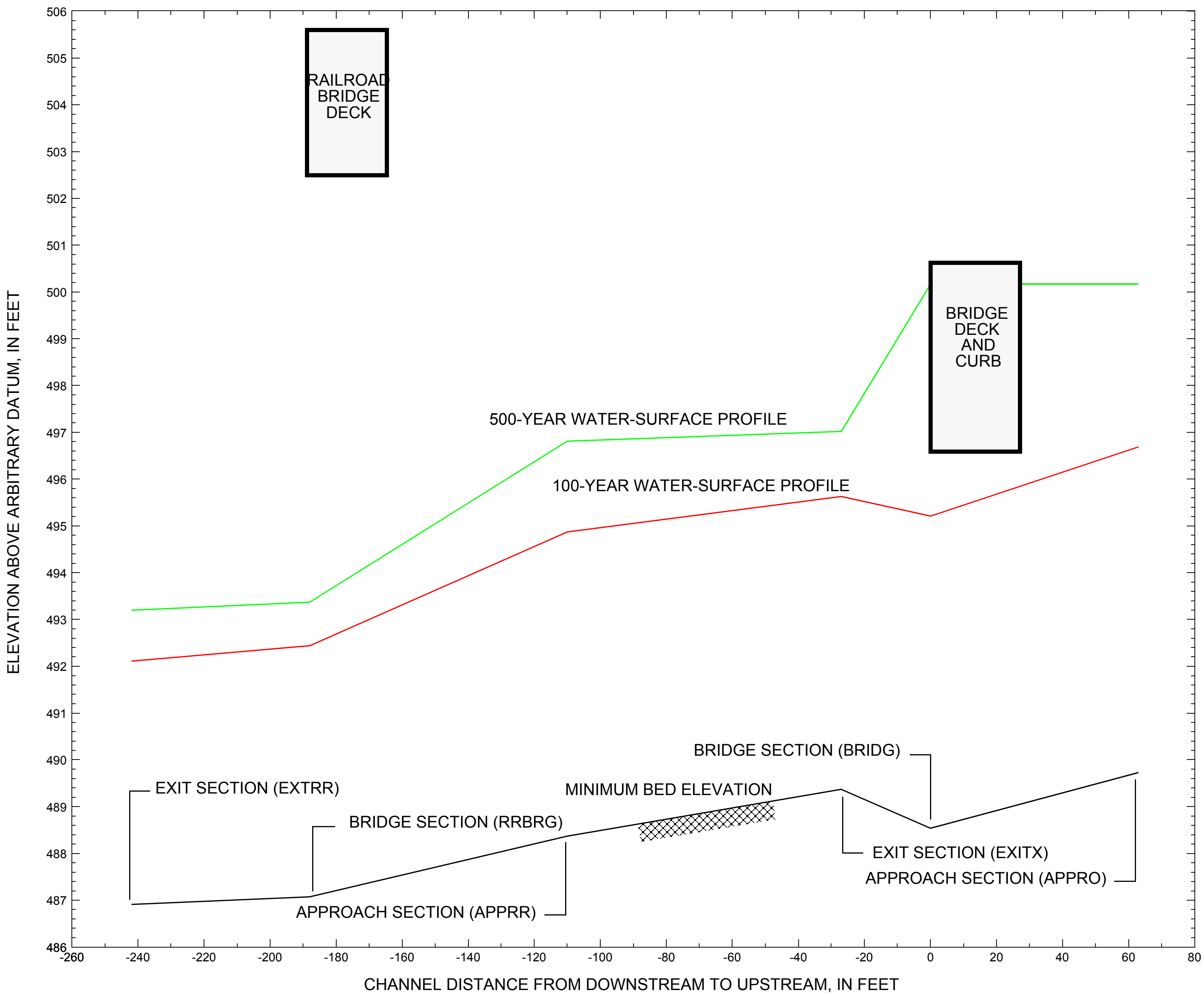

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure BOLTTH00150015 on Town Highway 15, crossing Joiner Brook, Bolton, Vermont.

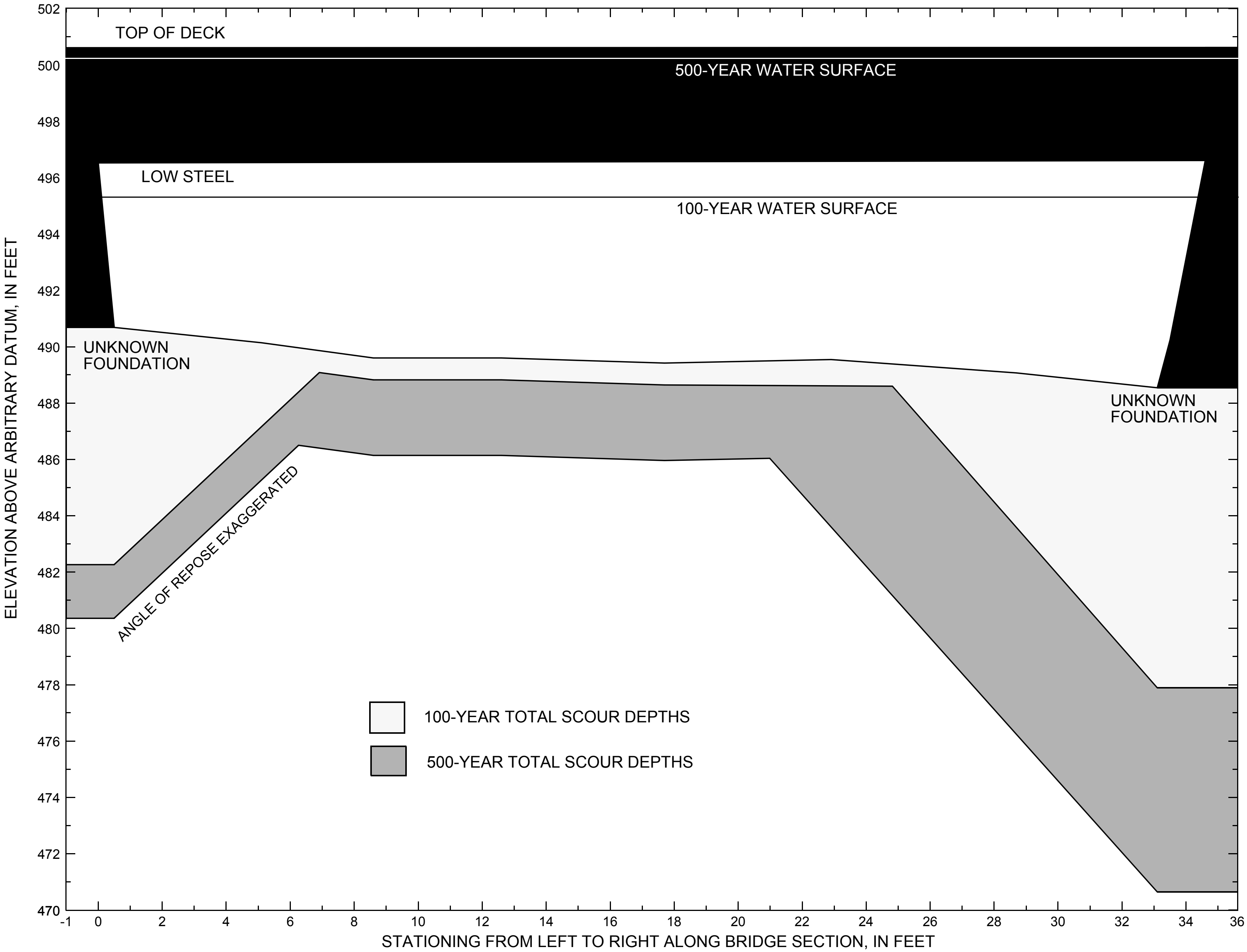

Figure 8. Scour elevations for the 100- and 500-year discharges at structure BOLTTH00150015 on Town Highway 15, crossing Joiner Brook, Bolton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BOLTTH00150015 on Town Highway 15, crossing Joiner Brook, Bolton, 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/pile 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-year discharge is 1,900 cubic-feet per second											
Left abutment	0.0	--	496.5	--	490.7	0.8	7.6	--	8.4	482.3	--
Right abutment	34.6	--	496.6	--	488.5	0.8	9.9	--	10.7	477.8	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure BOLTTH00150015 on Town Highway 15, crossing Joiner Brook, Bolton, 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/pile 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-year discharge is 2,800 cubic-feet per second											
Left abutment	0.0	--	496.5	--	490.7	3.5	6.9	--	10.4	480.3	--
Right abutment	34.6	--	496.6	--	488.5	3.5	14.4	--	17.9	470.6	--

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

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————————, 1948b, Huntington, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1980, Scale 1:24,000.

————————, 1948c, Richmond, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1980, Scale 1:24,000.

————————, 1948d, Waterbury, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1980, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File bolt015.wsp
T2        Hydraulic analysis for structure BOLTTH00150015   Date: 24-FEB-98
T3        TH 15 CROSSING JOINER BROOK IN BOLTON, VT                 RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1900.0  2800.0  2560.0
SK          0.0099  0.0099  0.0099
*
XS   EXTRR   -242             0.
GR            0.0, 493.54      7.5, 488.03      8.9, 487.75
GR           14.9, 487.65     29.2, 487.30     38.0, 487.98     58.7, 487.79
GR           68.3, 486.91     71.1, 487.11     78.9, 491.98     88.2, 493.09
*
N           0.070        0.062        0.035
SA                   0.0          78.9
*
XS   FLVRR   -188  * * *   0.0088
*
*              SRD    LSEL    XSSKEW
BR   RRBRG   -188   502.54     5.0
GR            0.0, 502.50      0.5, 488.76      0.5, 488.49      5.1, 487.65
GR            9.0, 487.27     10.2, 487.07     12.4, 487.37     16.9, 488.01
GR           20.5, 488.50     21.7, 488.41     26.7, 488.77     30.9, 489.37
GR           32.1, 489.23     34.7, 488.95     41.7, 489.58     43.1, 489.49
GR           47.8, 489.63     50.8, 488.46     51.5, 488.04     53.1, 487.67
GR           53.7, 487.62     53.7, 488.41     55.2, 502.57      0.0, 502.50
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      37.9 * *     40.8     16.9
N           0.062
PW 1        487.17, 1.26    487.86, 1.26     487.86, 2.81     488.46, 2.81
PW 1        488.46, 4.05    489.30, 4.05     489.30, 5.22     489.53, 5.22
PW 1        489.53, 6.62    502.54, 6.62     502.54, 0.00
*
*             SRD    EMBWID   IPAVE
XR   RRBED   -176      12.3     2
GR         -165.8, 505.66      0.0, 505.60     56.5, 505.50    288.1, 505.40
*
*    For the 100-year and incipient roadway overtopping discharges, the right
*    overbank was cut off at the top of the bank, station 49.6.
*
AS   APPRR   -110           0.
GR         -176.4, 504.64   -158.1, 497.36   -143.2, 496.30    -84.4, 496.77
GR          -41.7, 497.11    -13.5, 496.04     -6.1, 491.68      0.0, 489.42
GR            5.0, 489.19     12.9, 488.55     13.0, 488.37     19.1, 488.44
GR           26.6, 488.61     32.2, 488.87     37.3, 489.18     42.2, 489.49
GR           45.3, 492.99     49.6, 496.87
GR           69.5, 494.42    111.6, 492.67    154.4, 494.33    171.6, 498.93
*
N           0.035        0.063        0.040
SA                 -13.5          49.6
*
*    For the 100-year and incipient roadway overtopping discharges, the right
*    overbank was cut off at the top of the bank, station 49.6.
*
XS   EXITX    -27           0.
```

```
GR         -176.4, 505.64   -158.1, 498.36   -143.2, 497.30    -84.4, 497.77
GR          -41.7, 498.11    -13.5, 497.04     -6.1, 492.68      0.0, 490.42
GR            5.0, 490.19     12.9, 489.55     13.0, 489.37     19.1, 489.44
GR           26.6, 489.61     32.2, 489.87     37.3, 490.18     42.2, 490.49
GR           45.3, 493.99     49.6, 497.87
GR          69.5, 495.42    111.6, 493.6      154.4, 495.33    171.6, 499.93
*
N           0.035        0.063        0.040
SA                 -13.5         49.6
*
XS   FULLV      0  * * *   0.0063
*
*              SRD     LSEL    XSSKEW
BR   BRIDG     0    496.57       0.0
GR            0.0, 496.52      0.5, 490.68      5.1, 490.14      8.6, 489.60
GR           12.6, 489.60     17.7, 489.42     22.9, 489.54     28.7, 489.07
GR           33.1, 488.54     33.5, 490.24     34.6, 496.61      0.0, 496.52
*
*          BRTYPE  BRWDTH        WWANGL    WWWID
CD            1      40.8 * *     41.1     14.7
N           0.035
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     14      26.2      1
GR         -105.3, 505.49    -92.3, 501.67    -35.5, 499.99     -1.7, 499.59
GR           -1.6, 500.56      0.0, 500.61     34.9, 500.62     36.4, 500.62
GR           36.8, 499.66     55.3, 499.64    126.9, 499.99    190.9, 500.03
GR          281.7, 500.12    345.6, 500.33    401.6, 502.05    436.7, 505.07
*
AS   APPRO     63           0.
GR          -98.1, 519.93    -60.6, 502.20    -32.7, 500.11    -14.6, 499.89
GR           -5.2, 493.95      0.0, 490.58     10.0, 489.95     15.7, 489.86
GR           22.2, 489.98     26.4, 489.95     30.7, 489.73     33.2, 490.06
GR           37.2, 490.60     41.6, 493.21     43.6, 495.68     60.5, 497.65
GR           75.9, 497.21    139.8, 497.49    139.8, 497.49    170.1, 499.71
GR          290.1, 499.50    385.1, 499.34    409.6, 500.41    434.6, 506.66
*
N           0.050        0.066        0.045
SA                 -14.6         43.6
*
HP 1 BRIDG  495.21 1 495.21
HP 2 BRIDG  495.21 * * 1900
HP 1 APPRO  496.69 1 496.69
HP 2 APPRO  496.69 * * 1900
*
HP 1 BRIDG  496.61 1 496.61
HP 2 BRIDG  496.61 * * 2664
HP 2 RDWAY  500.17 * * 188
HP 1 APPRO  500.17 1 500.17
HP 2 APPRO  500.17 * * 2800
*
HP 1 BRIDG  496.61 1 496.61
HP 2 BRIDG  496.61 * * 2560
HP 1 APPRO  499.72 1 499.72
HP 2 APPRO  499.72 * * 2560
*
EX
```

APPENDIX B:

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File bolt015.wsp
        Hydraulic analysis for structure BOLTTH00150015   Date: 24-FEB-98
        TH 15 CROSSING JOINER BROOK IN BOLTON, VT                    RLB
           *** RUN DATE & TIME: 07-13-98  12:44

    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     190.   21399.    34.    44.                        2536.
   495.21          190.   21399.    34.    44.  1.00     0.    34.   2536.

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.21     0.1    34.4   189.8   21399.    1900.  10.01

 X STA.        0.1        4.9        6.5        8.0        9.5       10.9
   A(I)            21.8        8.5        8.3        8.1        8.1
   V(I)            4.36      11.18      11.48      11.76      11.80

 X STA.       10.9       12.4       13.8       15.2       16.6       18.0
   A(I)             8.1        8.0        8.1        8.2        8.0
   V(I)           11.73      11.92      11.72      11.58      11.84

 X STA.       18.0       19.4       20.9       22.3       23.7       25.1
   A(I)             8.1        8.1        8.1        8.1        8.2
   V(I)           11.69      11.76      11.69      11.80      11.65

 X STA.       25.1       26.4       27.7       29.0       30.2       34.4
   A(I)             7.7        8.0        7.6        7.7       23.2
   V(I)           12.30      11.92      12.54      12.30       4.09

    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =      63.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     302.   20692.    53.    57.                        4076.
             3       4.      91.     9.     9.                          18.
   496.69          306.   20784.    62.    66.  1.02   -10.    52.   3832.

    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =      63.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.69    -9.5    52.3   305.9   20784.    1900.   6.21

 X STA.       -9.5        1.3        3.5        5.6        7.7        9.6
   A(I)            37.2       13.5       13.3       13.5       13.2
   V(I)            2.55       7.02       7.13       7.03       7.21

 X STA.        9.6       11.5       13.4       15.4       17.3       19.2
   A(I)            12.8       12.9       13.1       13.0       12.9
   V(I)            7.41       7.34       7.25       7.32       7.36

 X STA.       19.2       21.1       23.1       25.1       27.1       29.0
   A(I)            13.3       13.2       13.4       13.3       13.1
   V(I)            7.16       7.19       7.10       7.14       7.27

 X STA.       29.0       30.9       32.8       34.9       37.0       52.3
   A(I)            12.9       13.0       13.6       13.5       31.1
   V(I)            7.34       7.29       6.97       7.02       3.06
```

```
        U.S. Geological Survey WSPRO Input File bolt015.wsp
        Hydraulic analysis for structure BOLTTH00150015   Date: 24-FEB-98
        TH 15 CROSSING JOINER BROOK IN BOLTON, VT                 RLB
           *** RUN DATE & TIME: 07-13-98  14:24

    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     236.   20498.     0.    81.                            0.
   496.61          236.   20498.     0.    81.  1.00     0.    35.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.61     0.0    34.6   236.5   20498.    2664.  11.26

X STA.         0.0        4.1        5.8        7.5        9.0       10.6
  A(I)            23.2       11.1       11.1       10.5       10.8
  V(I)            5.74      11.96      12.01      12.70      12.37

X STA.        10.6       12.1       13.6       15.1       16.6       18.1
  A(I)            10.5       10.4       10.5       10.7       10.4
  V(I)           12.63      12.85      12.65      12.50      12.80

X STA.        18.1       19.5       21.0       22.5       24.0       25.4
  A(I)            10.6       10.5       10.6       10.5       10.4
  V(I)           12.62      12.68      12.58      12.66      12.83

X STA.        25.4       26.9       28.2       29.6       30.9       34.6
  A(I)            10.3       10.4        9.8       10.0       24.2
  V(I)           12.92      12.86      13.54      13.29       5.50

    VELOCITY DISTRIBUTION:  ISEQ =  9;  SECID = RDWAY;  SRD =      14.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.17   -41.6   296.9    67.8     909.     188.   2.77

X STA.       -41.6      -23.2      -17.3      -12.3       -6.0       38.3
  A(I)             3.7        2.1        2.1        3.1        3.2
  V(I)            2.57       4.43       4.41       3.02       2.92

X STA.        38.3       44.1       49.8       54.8       59.8       63.0
  A(I)             3.0        3.0        2.6        2.6        1.6
  V(I)            3.16       3.14       3.63       3.62       5.87

X STA.        63.0       64.5       68.7       73.3       78.4       84.0
  A(I)             0.7        2.0        2.1        2.2        2.3
  V(I)           12.57       4.68       4.49       4.32       4.17

X STA.        84.0       90.6       98.3      108.7      130.6      296.9
  A(I)             2.5        2.6        3.0        4.8       18.6
  V(I)            3.82       3.59       3.08       1.98       0.51

    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =      63.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       3.      28.    19.    19.                            7.
             2     496.   44362.    58.    63.                         8216.
             3     476.   18971.   361.   361.                         3105.
   500.17          975.   63361.   438.   443.  1.44   -34.   404.   6886.

    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =      63.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.17   -33.5   404.1   975.2   63361.    2800.   2.87

X STA.       -33.5        1.2        4.4        7.4       10.4       13.3
  A(I)            86.6       30.7       30.4       30.2       29.6
  V(I)            1.62       4.56       4.61       4.63       4.72

X STA.        13.3       16.2       19.1       22.1       25.0       28.0
  A(I)            29.6       30.5       29.8       30.5       30.6
  V(I)            4.72       4.60       4.69       4.59       4.57

X STA.        28.0       31.0       34.0       37.2       42.2       53.2
  A(I)            30.4       30.8       31.5       40.1       45.3
  V(I)            4.61       4.54       4.44       3.49       3.09

X STA.        53.2       71.5       87.2      103.8      121.3      404.1
  A(I)            51.1       46.0       47.6       49.0      244.8
  V(I)            2.74       3.04       2.94       2.86       0.57
```

```
        U.S. Geological Survey WSPRO Input File bolt015.wsp
        Hydraulic analysis for structure BOLTTH00150015   Date: 24-FEB-98
        TH 15 CROSSING JOINER BROOK IN BOLTON, VT                    RLB
           *** RUN DATE & TIME: 07-13-98  12:44

    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     236.   20498.     0.    81.                          0.
   496.61          236.   20498.     0.    81.  1.00     0.    35.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.61     0.0    34.6   236.5   20498.    2560.  10.83

X STA.         0.0         4.1         5.8         7.5         9.0        10.6
  A(I)            23.2        11.1        11.1        10.5        10.8
  V(I)            5.52       11.49       11.54       12.20       11.88

X STA.        10.6        12.1        13.6        15.1        16.6        18.1
  A(I)            10.5        10.4        10.5        10.7        10.4
  V(I)           12.14       12.35       12.16       12.01       12.30

X STA.        18.1        19.5        21.0        22.5        24.0        25.4
  A(I)            10.6        10.5        10.6        10.5        10.4
  V(I)           12.13       12.18       12.09       12.17       12.33

X STA.        25.4        26.9        28.2        29.6        30.9        34.6
  A(I)            10.3        10.4         9.8        10.0        24.2
  V(I)           12.42       12.36       13.01       12.77        5.29

    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = APPRO;  SRD =      63.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     470.   40667.    58.    63.                       7592.
             3     272.   15012.   127.   127.                       2267.
   499.72          742.   55680.   184.   189.  1.12   -14.   170.   7990.

    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = APPRO;  SRD =      63.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.72   -14.3   170.1   742.1   55680.    2560.   3.45

X STA.       -14.3         1.4         4.4         7.3        10.1        12.9
  A(I)            78.3        27.8        27.5        27.4        26.9
  V(I)            1.63        4.61        4.65        4.67        4.76

X STA.        12.9        15.7        18.4        21.2        24.0        26.9
  A(I)            27.4        27.1        27.1        27.6        27.7
  V(I)            4.67        4.72        4.72        4.63        4.62

X STA.        26.9        29.7        32.5        35.4        38.7        47.3
  A(I)            27.6        27.7        28.0        30.0        45.6
  V(I)            4.63        4.61        4.56        4.27        2.81

X STA.        47.3        63.1        83.5       102.4       122.5       170.1
  A(I)            43.1        48.6        46.0        47.4        73.1
  V(I)            2.97        2.63        2.78        2.70        1.75
```

```
        U.S. Geological Survey WSPRO Input File bolt015.wsp
        Hydraulic analysis for structure BOLTTH00150015   Date: 24-FEB-98
        TH 15 CROSSING JOINER BROOK IN BOLTON, VT                  RLB
           *** RUN DATE & TIME: 07-13-98  12:44

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

EXTRR:XS   ******     2.     317.  0.56 *****  492.67  490.57   1900.  492.11
     -242. ******    80.   19093.  1.00 ***** *******    0.52    6.00

FLVRR:FV      54.     2.     322.  0.54  0.52  493.19 *******   1900.  492.65
     -188.    54.    81.   19564.  1.00  0.00    0.00    0.51    5.90
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRR"     KRATIO =  0.66

APPRR:AS      78.    -9.     223.  1.13  1.11  494.60 *******   1900.  493.47
     -110.    78.    46.   12945.  1.00  0.29    0.00    0.75    8.53
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

RRBRG:BR      54.     0.     208.  1.30  0.92  493.74  492.27   1900.  492.44
     -188.    54.    54.   11144.  1.00  0.15    0.00    0.82    9.13

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   1.   1.  1.000  0.127  502.54 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RRBED:RG    -176.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRR:AS      40.   -12.     302.  0.61  0.64  495.48  492.70   1900.  494.87
     -110.    40.    47.   20407.  1.00  1.10   -0.01    0.49    6.29

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.022  0.000   20619.    -4.    50.  494.30

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

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

EXITX:XS      83.   -11.     288.  0.68  0.77  496.30 *******   1900.  495.63
       -27.   83.    47.   19007.  1.00  0.03    0.02    0.52    6.60

FULLV:FV      27.   -11.     296.  0.64  0.26  496.57 *******   1900.  495.93
        0.    27.    47.   19794.  1.00  0.00    0.01    0.50    6.42
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      63.    -9.     295.  0.65  0.58  497.17 *******   1900.  496.52
       63.    63.    51.   19775.  1.01  0.01    0.01    0.51    6.43
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR      27.     0.     190.  1.56  0.28  496.77  494.23   1900.  495.21
        0.    27.    34.   21401.  1.00  0.18   -0.01    0.75   10.01

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.57 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      22.   -10.     306.  0.61  0.22  497.30  494.21   1900.  496.69
       63.    23.    52.   20771.  1.02  0.32    0.01    0.50    6.21

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.426  0.119   18244.     1.    36.  496.38

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

WSPRO OUTPUT FILE (continued)

FIRST USER DEFINED TABLE.

XSID:CODE	SRD	LEW	REW	Q	K	AREA	VEL	WSEL
EXTRR:XS	-242.	2.	80.	1900.	19093.	317.	6.00	492.11
FLVRR:FV	-188.	2.	81.	1900.	19564.	322.	5.90	492.65
RRBRG:BR	-188.	0.	54.	1900.	11144.	208.	9.13	492.44
RRBED:RG	-176.	**************		0.	******************		2.00	********
APPRR:AS	-110.	-12.	47.	1900.	20407.	302.	6.29	494.87

XSID:CODE	XLKQ	XRKQ	KQ
APPRR:AS	-4.	50.	20619.

XSID:CODE	SRD	LEW	REW	Q	K	AREA	VEL	WSEL
EXITX:XS	-27.	-11.	47.	1900.	19007.	288.	6.60	495.63
FULLV:FV	0.	-11.	47.	1900.	19794.	296.	6.42	495.93
BRIDG:BR	0.	0.	34.	1900.	21401.	190.	10.01	495.21
RDWAY:RG	14.	**************		0.	******************		1.00	********
APPRO:AS	63.	-10.	52.	1900.	20771.	306.	6.21	496.69

XSID:CODE	XLKQ	XRKQ	KQ
APPRO:AS	1.	36.	18244.

SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
EXTRR:XS	490.57	0.52	486.91	493.54	************		0.56	492.67	492.11
FLVRR:FV	********	0.51	487.39	494.02	0.52	0.00	0.54	493.19	492.65
RRBRG:BR	492.27	0.82	487.07	502.57	0.92	0.15	1.30	493.74	492.44
RRBED:RG	****************		505.40	505.66	***********************************				
APPRR:AS	492.70	0.49	488.37	504.64	0.64	1.10	0.61	495.48	494.87
EXITX:XS	********	0.52	489.37	505.64	0.77	0.03	0.68	496.30	495.63
FULLV:FV	********	0.50	489.54	505.81	0.26	0.00	0.64	496.57	495.93
BRIDG:BR	494.23	0.75	488.54	496.61	0.28	0.18	1.56	496.77	495.21
RDWAY:RG	****************		499.59	505.49	***********************************				
APPRO:AS	494.21	0.50	489.73	519.93	0.22	0.32	0.61	497.30	496.69

```
        U.S. Geological Survey WSPRO Input File bolt015.wsp
        Hydraulic analysis for structure BOLTTH00150015   Date: 24-FEB-98
        TH 15 CROSSING JOINER BROOK IN BOLTON, VT                 RLB
           *** RUN DATE & TIME: 07-13-98  14:24

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

EXTRR:XS   ******     0.     408.  0.74 *****  493.94  491.41   2800.  493.20
     -242. ******    88.   28132.  1.01 ***** *******    0.56    6.86

 ===140 AT SECID "FLVRR":  END OF CROSS SECTION EXTENDED VERTICALLY.
                             WSEL,YLT,YRT =   493.75     494.02     493.57

FLVRR:FV      54.     0.     414.  0.72  0.52  494.47 *******   2800.  493.75
     -188.    54.    88.   28768.  1.01  0.00    0.00    0.55    6.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRR":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.85     494.60     494.27

 ===110 WSEL NOT FOUND AT SECID "APPRR":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.25     498.93    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRR":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.25     498.93     494.27

APPRR:AS      78.   -11.     376.  0.96  0.96  495.54  494.27   2800.  494.58
     -110.    78.   155.   22188.  1.11  0.12    0.00    0.86    7.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "RRBRG"     Q,CRWS =    2800.     493.37

            <<<<<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

RRBRG:BR      54.     0.     258.  2.06 *****  495.43  493.37   2800.  493.37
     -188.    54.    54.   15625.  1.12 ***** *******    0.93   10.86

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   1.   1.  0.944  0.126  502.54 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RRBED:RG    -176.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRR:AS      40.   -34.     743.  0.22  0.39  497.04  494.27   2800.  496.81
     -110.    44.   164.   56804.  1.02  1.22    0.01    0.35    3.77

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.676  0.471   29989.     1.    55.   496.65

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

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

EXITX:XS      83.   -13.     603.  0.34  0.27  497.36 *******   2800.  497.02
       -27.   83.   161.   42236.  1.02  0.06    0.00    0.43    4.65

FULLV:FV      27.   -13.     595.  0.35  0.12  497.50 *******   2800.  497.15
         0.   27.   161.   41509.  1.02  0.00    0.01    0.44    4.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  0.59

APPRO:AS      63.   -10.     345.  1.07  0.49  498.35 *******   2800.  497.28
       63.    63.    91.   24306.  1.05  0.36    0.00    0.73    8.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   497.15     496.57


            <<<<<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
```

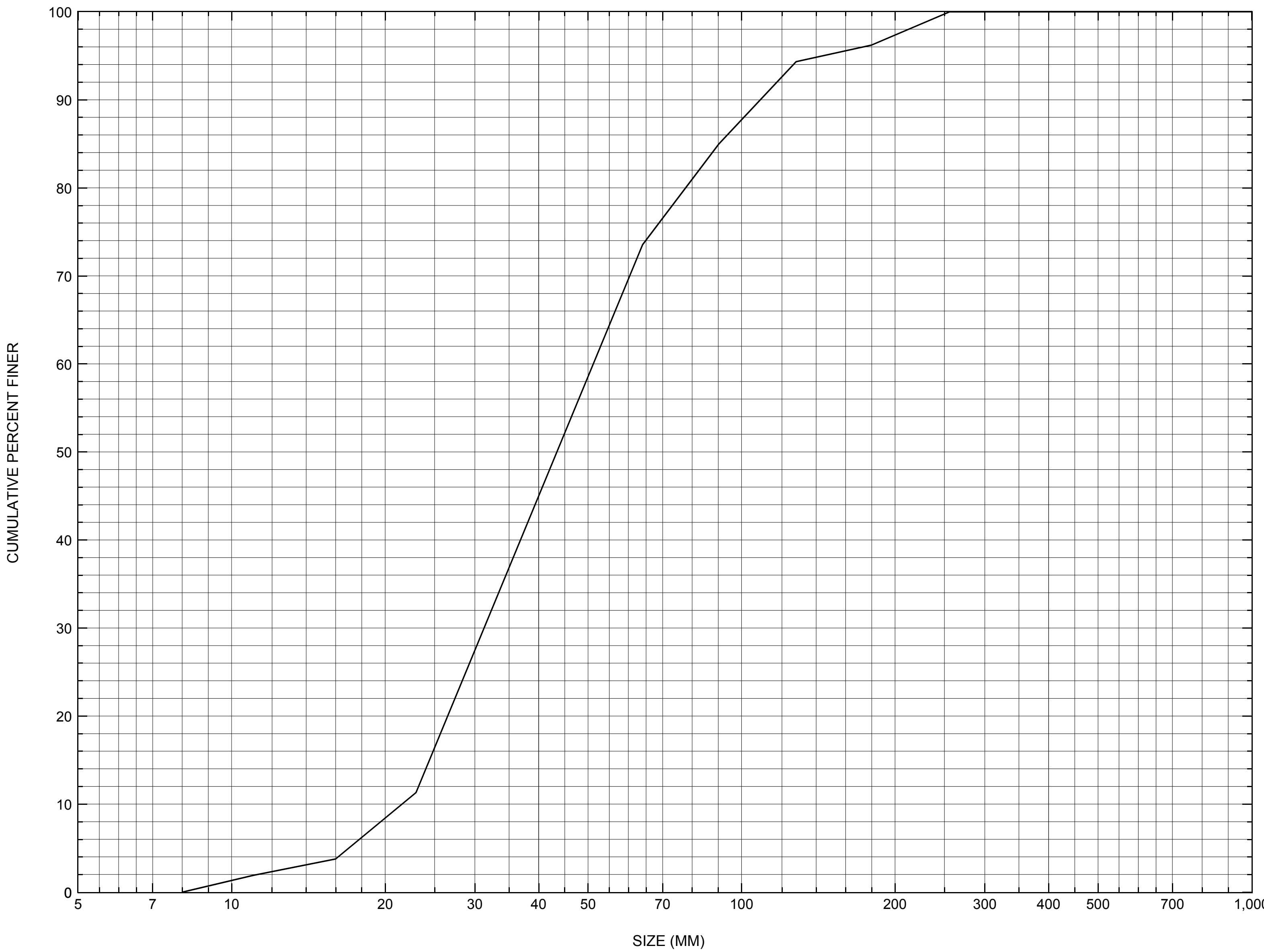
```
BRIDG:BR      27.     0.     236.  1.97 *****  498.58  495.39   2664.  496.61
        0. ******    35.  20498.  1.00 ***** *******    0.76   11.26

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.126  496.57 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      14.    37.  0.07  0.18  500.28    0.02    188.  500.17

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    37.    40.   -42.    -2.   0.6   0.3   3.1   2.8   0.5   3.1
   RT:   151.   245.    37.   282.   0.5   0.2   2.8   2.8   0.3   3.2

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

APPRO:AS      22.   -34.     976.  0.18  0.13  500.36  495.35   2800.  500.17
        63.    23.   404.  63402.  1.44  1.22    0.02    0.41    2.87

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

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXTRR:XS    -242.     0.    88.   2800.   28132.     408.    6.86  493.20
   FLVRR:FV    -188.     0.    88.   2800.   28768.     414.    6.76  493.75
   RRBRG:BR    -188.     0.    54.   2800.   15625.     258.   10.86  493.37
   RRBED:RG    -176.**************      0.*****************    2.00********
   APPRR:AS    -110.   -34.   164.   2800.   56804.     743.    3.77  496.81

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRR:AS       1.    55.   29989.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -27.   -13.   161.   2800.   42236.     603.    4.65  497.02
   FULLV:FV      0.    -13.   161.   2800.   41509.     595.    4.70  497.15
   BRIDG:BR      0.      0.    35.   2664.   20498.     236.   11.26  496.61
   RDWAY:RG      14.*******    37.    188.*****************    1.00  500.17
   APPRO:AS      63.   -34.   404.   2800.   63402.     976.    2.87  500.17

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

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXTRR:XS    491.41    0.56  486.91  493.54************  0.74  493.94  493.20
   FLVRR:FV  ********    0.55  487.39  494.02  0.52  0.00  0.72  494.47  493.75
   RRBRG:BR    493.37    0.93  487.07  502.57************  2.06  495.43  493.37
   RRBED:RG  ****************  505.40  505.66**********************************
   APPRR:AS    494.27    0.35  488.37  498.93  0.39  1.22  0.22  497.04  496.81
   EXITX:XS  ********    0.43  489.37  505.64  0.27  0.06  0.34  497.36  497.02
   FULLV:FV  ********    0.44  489.54  505.81  0.12  0.00  0.35  497.50  497.15
   BRIDG:BR    495.39    0.76  488.54  496.61************  1.97  498.58  496.61
   RDWAY:RG  ****************  499.59  505.49  0.07******  0.18  500.28  500.17
   APPRO:AS    495.35    0.41  489.73  519.93  0.13  1.22  0.18  500.36  500.17
```

```
        U.S. Geological Survey WSPRO Input File bolt015.wsp
        Hydraulic analysis for structure BOLTTH00150015   Date: 24-FEB-98
        TH 15 CROSSING JOINER BROOK IN BOLTON, VT                RLB
           *** RUN DATE & TIME: 07-13-98  12:44

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

EXTRR:XS   ******     1.     384.  0.70 *****  493.63  491.20   2560.  492.93
     -242. ******    87.   25727.  1.01 ***** *******    0.56    6.66

FLVRR:FV      54.     1.     390.  0.68  0.52  494.15 *******   2560.  493.48
     -188.    54.    87.   26311.  1.01  0.00    0.00    0.55    6.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRR"     KRATIO =  0.64

APPRR:AS      78.   -10.     266.  1.44  1.15  495.68 *******   2560.  494.24
     -110.    78.    47.   16896.  1.00  0.38    0.00    0.79    9.62
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

RRBRG:BR      54.     0.     244.  1.72  0.96  494.82  493.09   2560.  493.10
     -188.    54.    54.   14288.  1.00  0.23    0.00    0.87   10.51

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   1.   1.  1.000  0.127  502.54 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RRBED:RG    -176.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRR:AS      40.   -13.     369.  0.75  0.68  496.72  493.50   2560.  495.97
     -110.    40.    49.   27338.  1.00  1.22    0.01    0.50    6.94

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.057  0.000   27325.    -4.    50.  495.39

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

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

EXITX:XS      83.   -13.     354.  0.81  0.77  497.54 *******   2560.  496.72
       -27.    83.    48.   25720.  1.00  0.03    0.01    0.53    7.24

FULLV:FV      27.   -13.     362.  0.78  0.26  497.81 *******   2560.  497.03
        0.    27.    48.   26633.  1.00  0.00    0.01    0.51    7.07
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      63.   -11.     390.  0.76  0.58  498.39 *******   2560.  497.63
       63.    63.   142.   26927.  1.14  0.00    0.01    0.77    6.57
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   497.03     496.57

            <<<<<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      27.     0.     236.  1.76 *****  498.37  495.20   2517.  496.61
        0. ******    35.   20498.  1.00 ***** *******    0.72   10.65

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   3.  0.800  0.127  496.57 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

===140 AT SECID "APPRO":  END OF CROSS SECTION EXTENDED VERTICALLY.
                             WSEL,YLT,YRT =   499.72      519.9      499.7
```

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

APPRO:AS      22.   -14.     741.  0.21  0.14  499.92  495.05   2560.  499.72
       63.    25.   170.   55606.  1.12  1.22   -0.02    0.32    3.45

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
    ****** ****** ******** ****** ******   499.64

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXTRR:XS    -242.     1.    87.   2560.   25727.     384.    6.66  492.93
   FLVRR:FV    -188.     1.    87.   2560.   26311.     390.    6.56  493.48
   RRBRG:BR    -188.     0.    54.   2560.   14288.     244.   10.51  493.10
   RRBED:RG    -176.**************      0.******************    2.00********
   APPRR:AS    -110.   -13.    49.   2560.   27338.     369.    6.94  495.97

    XSID:CODE   XLKQ   XRKQ      KQ
   APPRR:AS      -4.    50.  27325.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -27.   -13.    48.   2560.   25720.     354.    7.24  496.72
   FULLV:FV       0.   -13.    48.   2560.   26633.     362.    7.07  497.03
   BRIDG:BR       0.     0.    35.   2517.   20498.     236.   10.65  496.61
   RDWAY:RG      14.**************      0.       0.       0.    1.00********
   APPRO:AS      63.   -14.   170.   2560.   55606.     741.    3.45  499.72

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

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO   VHD     EGL    WSEL
   EXTRR:XS    491.20    0.56  486.91  493.54************  0.70  493.63  492.93
   FLVRR:FV  ********    0.55  487.39  494.02  0.52  0.00  0.68  494.15  493.48
   RRBRG:BR    493.09    0.87  487.07  502.57  0.96  0.23  1.72  494.82  493.10
   RRBED:RG  ****************  505.40  505.66**********************************
   APPRR:AS    493.50    0.50  488.37  504.64  0.68  1.22  0.75  496.72  495.97
   EXITX:XS  ********    0.53  489.37  505.64  0.77  0.03  0.81  497.54  496.72
   FULLV:FV  ********    0.51  489.54  505.81  0.26  0.00  0.78  497.81  497.03
   BRIDG:BR    495.20    0.72  488.54  496.61************  1.76  498.37  496.61
   RDWAY:RG  ****************  499.59  505.49************  0.21  499.85********
   APPRO:AS    495.05    0.32  489.73  519.93  0.14  1.22  0.21  499.92  499.72
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BOLTTH00150015, in Bolton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BOLTTH00150015

General Location Descriptive

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

Date *(MM/DD/YY)* 11 / 3 / 95

Highway District Number *(I - 2; nn)* 05

County *(FIPS county code; I - 3; nnn)* 007

Town *(FIPS place code; I - 4; nnnnn)* 06550

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

Waterway *(I - 6)* JOINER BROOK

Road Name *(I - 7):* -

Route Number C3015

Vicinity *(I - 9)* 0.08 MI TO JCT W US2

Topographic Map Huntington

Hydrologic Unit Code: 02010003

Latitude *(I - 16; nnnn.n)* 44224

Longitude *(i - 17; nnnnn.n)* 72527

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10040100150401

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

Maximum span length *(I - 48; nnnn)* 0036

Year built *(I - 27; YYYY)* 1919

Structure length *(I - 49; nnnnnn)* 000039

Average daily traffic, ADT *(I - 29; nnnnnn)* 000030

Deck Width *(I - 52; nn.n)* 262

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

Channel & Protection *(I - 61; n)* 5

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) ______

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

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

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

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

Comments:

According to the structural inspection report dated 6/26/95, the structure is a concrete T-beam with an asphalt overlay. The abutments, wingwalls, and backwalls are concrete. Small sections of concrete footing are showing at the upstream end of the left abutment and at the upstream left wingwall and at the downstream end of the right abutment and at the downstream right wingwall. The abutments and wingwalls have a few fine cracks and small leaks overall. A few boulders are present around the ends of the wingwalls, and there are boulders along the US and DS channel embankments. The US-bridge-channel sketch shows a gravel bar near the left abutment.

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: Gravel and stones

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ 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 (*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)* 9.60 mi^2 Lake/pond/swamp area 0 mi^2
Watershed storage *(ST)* 0 %
Bridge site elevation 340 ft Headwater elevation 3660 ft
Main channel length 6.1 mi
10% channel length elevation 500 ft 85% channel length elevation 2640 ft
Main channel slope *(S)* 468 ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? N If no, type ctrl-n pl Date issued for construction (MM / YYYY): - / -

Project Number - Minimum channel bed elevation: -

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:
NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS

Cross-sectional Data

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

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

Comments: **This cross section is the upstream face. The low chord elevations are from the survey log done for this report on 6/27/96. The low chord to bed length data are from the sketch attached to a bridge inspection report dated 6/26/95. The sketch was done on 11/4/93.**

Station	0	22.6	24.6	30.6	34.6	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	496.5	496.6	496.6	496.6	496.6	-	-	-	-	-	-
Bed elevation	488.3	488.9	489.4	489.4	488.6	-	-	-	-	-	-
Low chord to bed	8.2	7.7	7.2	7.2	8.0	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: MS Date: 06/12/97
Computerized by: MS Date: 06/24/97
Reviewd by: RB Date: 07/13/98

Structure Number BOLTTH00150015

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. WILD Date *(MM/DD/YY)* 06 / 27 / 1996

2. Highway District Number 05 Mile marker 000000

County CHITTENDEN (007) Town BOLTON (06550)

Waterway *(I - 6)* JOINER BROOK Road Name -

Route Number C3015 Hydrologic Unit Code: 02010003

3. Descriptive comments:

This bridge is located 0.08 miles from the junction with US 2.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 4 LBDS 4 RBDS 4 Overall 4

*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US 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 39 *(feet)* Span length 36 *(feet)* Bridge width 26.2 *(feet)*

Road approach to bridge:

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

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

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

	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	1	0	0
RBUS	0	-	-	-
RBDS	0	-	-	-
LBDS	1	2	3	2

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

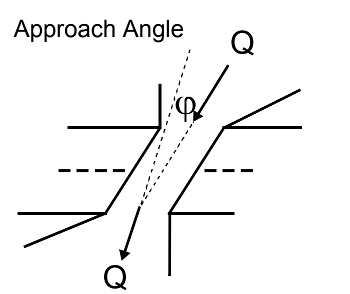
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

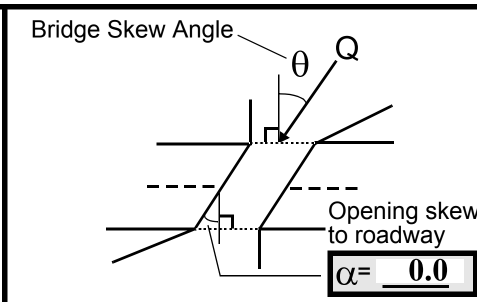
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 5 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*

Where? RB *(LB, RB)* Severity 2

Range? 94 feet US *(US, UB, DS)* to 0 feet UB

Channel impact zone 2: Exist? Y *(Y or N)*

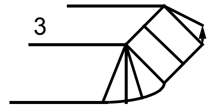
Where? LB *(LB, RB)* Severity 1

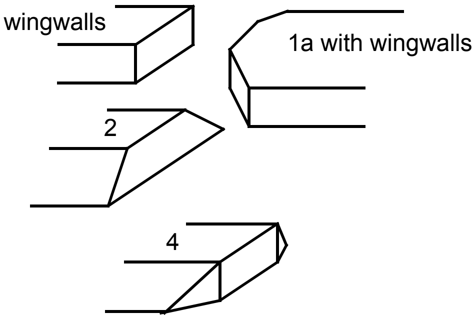
Range? 8 feet DS *(US, UB, DS)* to 152 feet DS

*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 parallel 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. The US left bank surface cover is brush with a few trees along the bank. The DS left bank has trees along the bank, a lawn, and a medium size house. The US right bank has a few trees along the bank, grass, and one house. The DS right bank has trees along the bank, a large lawn and a house.
7. The measured deck width, bridge length, and span length are 25.82 ft, 39 ft, and 36 ft, respectively.
17. Channel impact zone 1 has moderate impact severity due to lack of protection along the right bank. Channel impact zone 2 has low impact severity due to extensive protection on the left bank.
18. The DS left wingwall is parallel with the left abutment and can be considered type 1b.

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
40.0	9.5			5.0	1	1	234	234	1	2

23. Bank width **30.0** 24. Channel width **40.0** 25. Thalweg depth **58.5** 29. Bed Material **34**

30 .Bank protection type: LB **3** RB **3** 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.):
28. There is extensive erosion from 94 ft US to 75 ft US along the right bank.
30. The right bank protection extends from 114 ft US to 94 ft US. There is type 2 protection on the right bank that extends from 75 ft US to 60 ft US. The left bank protection extends from 114 ft US to 57 ft US.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 8.5 35. Mid-bar width: 4.75

36. Point bar extent: 20 feet US (US, UB) to 0 feet UB (US, UB, DS) positioned 90 %LB to 100 %RB

37. Material: 3

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

There is an additional side bar located 42 ft US to 3 ft US. The mid-bar distance is 38 ft US, the mid-bar width is 5.6 ft, and the material is gravel. There is a channel bar that has formed behind a boulder located 58.5 ft US to 40.8 ft US. It is comprised of gravel, the mid-bar distance is 53 ft US, and the mid-bar width is 4.75 ft. It is positioned 50% LB to 80% RB.

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

41. Mid-bank distance: 25 42. Cut bank extent: 94 feet US (US, UB) to 0 feet UB (US, UB, DS)

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

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

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 25

47. Scour dimensions: Length 12.5 Width 4.75 Depth : 1.5 Position 85 %LB to 100 %RB

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

The scour depth is 1.5 ft assuming a 0.5 ft thalweg. There is another scour hole located 65 ft US to 30 ft US. It is positioned between the right bank and the channel bar. The scour depth is 1 ft assuming a 0.5 ft thalweg. The position is 85% from the left bank to 95% right bank.

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
37.5		1.0		2	7	7	-

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

3

-

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

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

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

70. Debris and Ice Comments:

2

-

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**	**85**	**2**	**2**	**1.2**	**0.4**	**90.0**
RABUT	**1**	**15**	**75**			**2**	**1**	**34.5**

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

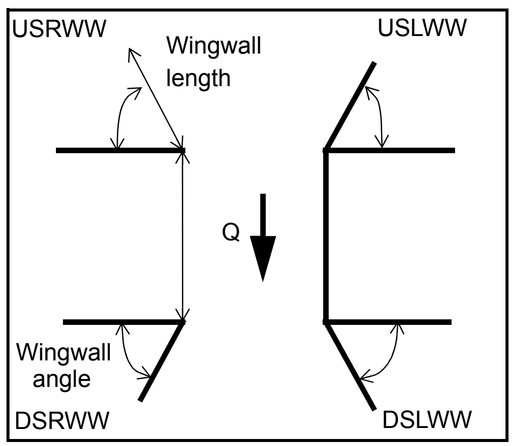
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

1.5
0
1
74. The left abutment footing is exposed for 3.8 ft (horizontally) at the US end.
75. The scour of the left abutment is located at the US end of the abutment. The scour of the right abutment is located at the DS end of the abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**34.5**	
USRWW:	**Y**		**1**		**2**	**0.5**	
DSLWW:	**1.2**		**0.1**		**Y**	**28.0**	
DSRWW:	**1**		**0**		**-**	**28.0**	

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**	**1.5**	**1**	**-**	**-**	**-**
Condition	**Y**	**-**	**1**	**-**	**2**	**-**	**-**	**-**
Extent	**1**	**-**	**1**	**1**	**0**	**0**	**0**	**-**

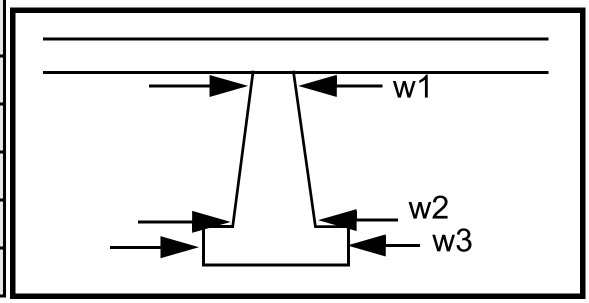
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
1
1
3

Piers:

84. Are there piers? **80.** *(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				**40.0**	**20.5**	**45.0**
Pier 2			**3.5**	**18.5**	**100.0**	**30.0**
Pier 3		-	-	**10.0**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The 1.2**	**assum-**	**out 3.5**		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**ft**	**ing a**	**ft**		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**scou**	**0.5**	**from**		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**r**	**thal-**	**the**		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**dept**	**weg.**	**left**		*Y- yes; N- no*
91. Attack ∠ (BF)	**h on**	**The**	**abut**		
92. Pushed	**the**	**DS**	**ment**		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**US**	**left**	**and**		
95. Cross-members	**left**	**wing**	**slope**		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**wing**	**wall**	**s**	**N**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**wall**	**exte**	**dow**	-	
98. Exposure depth	**is**	**nds**	**n.**	-	

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

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width - Thalweg depth - 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.):
-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

106. Point/Side bar present? - (Y or N. if N type ctrl-n pb) Mid-bar distance: - Mid-bar width: NO

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

Material: _____

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

Is a cut-bank present? 2 (Y or if N type ctrl-n cb) Where? 2 (LB or RB) Mid-bank distance: 23

Cut bank extent: 23 feet 2 (US, UB, DS) to 2 feet 34 (US, UB, DS)

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

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

0
1
-
The left bank protection extends from 32 ft DS to 152 ft DS.

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

Scour dimensions: Length road Width brid Depth: ge, Positioned con %LB to sist- %RB

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

ing of five piers each with six piles, is located 191 ft DS of this bridge.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution N

__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)*:

-

NO DROP STRUCTURE

Y
16
5.4
9.5
UB
36

109. G. Plan View Sketch

\- D

point bar (pb)
cut-bank (cb)
scour hole
debris
rip rap or stone fill
flow (Q)
cross-section
ambient channel
stone wall
other wall

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: BOLTTH00150015 Town: BOLTON
Road Number: TH 15 County: CHITTENDEN
Stream: JOINER BROOK

Initials RLB Date: 7/2/98 Checked: ECW

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1900	2800	2560
Main Channel Area, ft2	302	496	470
Left overbank area, ft2	0	3	0
Right overbank area, ft2	4	476	272
Top width main channel, ft	53	58	58
Top width L overbank, ft	0	19	0
Top width R overbank, ft	9	361	127
D50 of channel, ft	0.1431	0.1431	0.1431
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.7	8.6	8.1
y1, average depth, LOB, ft	ERR	0.2	ERR
y1, average depth, ROB, ft	0.4	1.3	2.1
Total conveyance, approach	20784	63361	55680
Conveyance, main channel	20692	44362	40667
Conveyance, LOB	0	28	0
Conveyance, ROB	91	18971	15012
Percent discrepancy, conveyance	0.0048	0.0000	0.0018
Qm, discharge, MC, cfs	1891.6	1960.4	1869.7
Ql, discharge, LOB, cfs	0.0	1.2	0.0
Qr, discharge, ROB, cfs	8.3	838.4	690.2
Vm, mean velocity MC, ft/s	6.3	4.0	4.0
Vl, mean velocity, LOB, ft/s	ERR	0.4	ERR
Vr, mean velocity, ROB, ft/s	2.1	1.8	2.5
Vc-m, crit. velocity, MC, ft/s	7.8	8.4	8.3
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1900	2800	2560
(Q) discharge thru bridge, cfs	1900	2664	2560
Main channel conveyance	21399	20498	20498
Total conveyance	21399	20498	20498
Q2, bridge MC discharge,cfs	1900	2664	2560
Main channel area, ft2	190	237	237
Main channel width (normal), ft	34.3	34.6	34.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.3	34.6	34.6
y_bridge (avg. depth at br.), ft	5.53	6.84	6.84
Dm, median (1.25*D50), ft	0.178875	0.178875	0.178875
y2, depth in contraction,ft	6.32	8.38	8.10
ys, scour depth (y2-ybridge), ft	0.78	1.54	1.26

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	1900	2800	2560
Q, thru bridge MC, cfs	1900	2664	2560
Vc, critical velocity, ft/s	7.84	8.38	8.31
Va, velocity MC approach, ft/s	6.26	3.95	3.98
Main channel width (normal), ft	34.3	34.6	34.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.3	34.6	34.6
qbr, unit discharge, ft2/s	55.4	77.0	74.0
Area of full opening, ft2	189.8	236.5	236.5
Hb, depth of full opening, ft	5.53	6.84	6.84
Fr, Froude number, bridge MC	0	0.76	0.72
Cf, Fr correction factor (<=1.0)	0.00	1.00	1.00
**Area at downstream face, ft2	0	0	0
**Hb, depth at downstream face, ft	0.00	0.00	0.00
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	0	496.57	496.57

Elevation of Bed, ft	-5.53	489.73	489.73
Elevation of Approach, ft	0	500.17	499.72
Friction loss, approach, ft	0	0.13	0.14
Elevation of WS immediately US, ft	0.00	500.04	499.58
ya, depth immediately US, ft	5.53	10.31	9.85
Mean elevation of deck, ft	0	500.62	500.62
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.89	0.91
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	N/A	3.46	2.99
Ys, scour w/Umbrell equation, ft	N/A	0.38	0.12

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

**Ys, scour w/Chang equation, ft	N/A	ERR	ERR
**Ys, scour w/Umbrell equation, ft	ERR	7.22	6.96

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1900	2664	2560
Main channel area (DS), ft2	189.8	236.5	236.5
Main channel width (normal), ft	34.3	34.6	34.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	34.3	34.6	34.6
D90, ft	0.3571	0.3571	0.3571
D95, ft	0.4732	0.4732	0.4732
Dc, critical grain size, ft	0.3678	0.4303	0.3974
Pc, Decimal percent coarser than Dc	0.092	0.055	0.071
Depth to armoring, ft	10.89	22.18	15.60

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1900	2800	2560	1900	2800	2560
a', abut.length blocking flow, ft	9.6	33.5	14.3	17.9	369.5	135.5
Ae, area of blocked flow ft2	33.07	73.95	71.32	47.84	495.8	341.52
Qe, discharge blocked abut.,cfs	84.44	--	116.59	212.62	--	931.31
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.55	1.62	1.63	4.44	1.99	2.73
ya, depth of f/p flow, ft	3.44	2.21	4.99	2.67	1.34	2.52
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.242	0.180	0.129	0.479	0.288	0.303
ys, scour depth, ft	7.64	6.86	9.17	9.87	14.43	15.08

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

a'(abut length blocked, ft)	9.6	33.5	14.3	17.9	369.5	135.5
y1 (depth f/p flow, ft)	3.44	2.21	4.99	2.67	1.34	2.52
a'/y1	2.79	15.18	2.87	6.70	275.37	53.76
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.24	0.18	0.13	0.48	0.29	0.30
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	6.47	12.36
vertical w/ ww's	ERR	ERR	ERR	ERR	5.31	10.13
spill-through	ERR	ERR	ERR	ERR	3.56	6.80

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.75	0.76	0.72	0.75	0.76	0.72
y, depth of flow in bridge, ft	5.53	6.84	6.84	5.53	6.84	6.84
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.92	2.44	2.19	1.92	2.44	2.19
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR