LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (WALDTH00020007) on TOWN HIGHWAY 2, crossing COLES BROOK, WALDEN, VERMONT

U.S. Geological Survey
Open-File Report 97-632

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

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By LORA K. STRIKER AND LAURA MEDALIE

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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 7 (WALDTH00020007) ON TOWN HIGHWAY 2, CROSSING COLES BROOK, WALDEN, VERMONT

By **Lora K. Striker and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WALDTH00020007 on Town Highway 2 crossing Coles Brook, Walden, Vermont (figures 1–8). Coles Brook is also referred to as Joes Brook. 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 north-eastern Vermont. The 12.8-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly shrub and brushland.

In the study area, Coles Brook has a sinuous channel with a slope of approximately 0.005 ft/ft, an average channel top width of 37 ft and an average bank height of 4 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 32.9 mm (0.108 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 9, 1995, indicated that the reach was laterally unstable due to cut-banks, point bars, and loose unconsolidated bed material.

The Town Highway 2 crossing of Coles Brook is a 74-ft-long, two-lane bridge consisting of one 71-foot steel-beam span (Vermont Agency of Transportation, written communication, April 5, 1995). The opening length of the structure parallel to the bridge face is 69.3 ft. The bridge is supported by spill-through abutments. The channel is skewed approximately 35 degrees to the opening while the measured opening-skew-to-roadway is 15 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed from 60 ft. to 100 ft. downstream during the Level I assessment. Scour protection measures at the site include: type-1 stone fill (less than 12 inches diameter) along the right bank upstream, at the downstream end of the downstream left wingwall and downstream right wingwall; and type-2 stone fill (less than 36 inches diameter) along the left bank upstream, at the upstream end of the upstream right wingwall, and along the entire base of the left and right abutments. 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 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 0.0 to 0.8 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge. Abutment scour ranged from 5.7 to 12.9 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

St. Johnsbury, VT. Quadrangle, 1:25,000, 1983

NORTH

Figure 1. Location of study area on USGS 1:25,000 scale map.

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

LEVEL II SUMMARY

Structure Number WALDTH00020007 ***Stream*** Coles Brook

County Caledonia ***Road*** TH 2 ***District*** 7

Description of Bridge

Bridge length 74 ***ft*** ***Bridge width*** 21.5 ***ft*** ***Max span length*** 71 ***ft***

Alignment of bridge to road (on curve or straight) Curve, left; Straight, right

Abutment type spill through ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 08/09/95

Description of stone fill Type-2, laid rip rap forming spill through abutments show no evidence of scour. Both abutments have undermined areas.

Brief description of piers/abutments Abutments are spill through. Stub abutments are concrete with sloping spillthroughs composed of fill and large placed rip rap.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 35

There is a mild channel bend at the bridge. A point bar has developed along the right abutment and inside bend of the right abutment.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	08/09/95	0	0
Level II	08/09/95	0	0

Potential for debris Low. There are a few scattered logs in stream from recent flooding. Debris is caught at bridge in I-beams from flood of 08/05/95.

Describe any features near or at the bridge that may affect flow (include observation date) 08/09/95, There is a beaver dam located more than one bridge length downstream of the bridge that may cause backwater to the site.

Description of the Geomorphic Setting

General topography The channel is located within a low relief valley with narrow flood plains. 08/09/95

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

Date of inspection Moderately

DS left: sloped overbank

DS right: Narrow flood plain

US left: Steep channel bank to a narrow flood plain

US right: Moderately sloped overbank

Description of the Channel

Average top width 37 ft ***Average depth*** 4 ft

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

Sinuous and laterally unstable with semi-alluvial channel boundaries and narrow flood plains.

08/09/95

Vegetative co Shrubs and brush

DS left: Shrubs and brush

DS right: Shrubs and brush

US left: Shrubs and brush

US right: No

Do banks appear stable? Lateral instability in the channel is indicated by cut-banks, point bars, and loose unconsolidated bed material, 08/09/95.

date of observation.

None as of 08/09/95,

There is a beaver dam located more than one bridge length downstream of the bridge that may be causing backwater to the site.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 12.8 ***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.

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 2,200 ***ft³/s*** ***Q500*** 3,150 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(12.8/16.4)exp 0.67] with bridge number 83 in Walden. Bridge number 83 crosses Coles Brook downstream of this site and has flood frequency estimates available from the VTAOT database which were graphically extrapolated to the 500-year discharge. The drainage area above bridge number 83 is 16.4 square miles. The discharges used were in the range of empirical methods. (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887)

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the left abutment (elev. 499.04 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the right abutment (elev. 499.76 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	-94	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPRO	90	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 0.040 to 0.055, and overbank "n" values were 0.070.

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 0.0046 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1983).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 500.1 ***ft***
Average low steel elevation 495.7 ***ft***

100-year discharge 2,220 ***ft^3/s***
Water-surface elevation in bridge opening 493.4 ***ft***
Road overtopping? N ***Discharge over road*** 0 ***ft^3/s***
Area of flow in bridge opening 270 ***ft^2***
Average velocity in bridge opening 8.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.9 ***ft/s***

Water-surface elevation at Approach section with bridge 495.3
Water-surface elevation at Approach section without bridge 494.0
Amount of backwater caused by bridge 1.3 ***ft***

500-year discharge 3,150 ***ft^3/s***
Water-surface elevation in bridge opening 496.0 ***ft***
Road overtopping? Y ***Discharge over road*** 107
Area of flow in bridge opening 424 ***ft^2***
Average velocity in bridge opening 7.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.4 ***ft/s***

Water-surface elevation at Approach section with bridge 497.0
Water-surface elevation at Approach section without bridge 494.6
Amount of backwater caused by bridge 2.4 ***ft***

Incipient overtopping discharge 2,540 ***ft^3/s***
Water-surface elevation in bridge opening 493.6 ***ft***
Area of flow in bridge opening 279 ***ft^2***
Average velocity in bridge opening 9.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.0 ***ft/s***

Water-surface elevation at Approach section with bridge 495.9
Water-surface elevation at Approach section without bridge 494.2
Amount of backwater caused by bridge 1.7 ***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 for the 100-year and incipient roadway-overtopping discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for this discharge was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146).

Since the 500-year discharge resulted in unsubmerged orifice flow, estimates of contraction scour were also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144). Furthermore, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results are provided in Appendix F.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.2	0.0	0.8
Depth to armoring	2.2	3.9	0.1
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour	10.5	12.9	11.6 5.7
Left abutment	7.5–	6.4–	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	1.9
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:	1.4	2.0	1.9
Left abutment	1.4	2.0	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	
Pier 2			

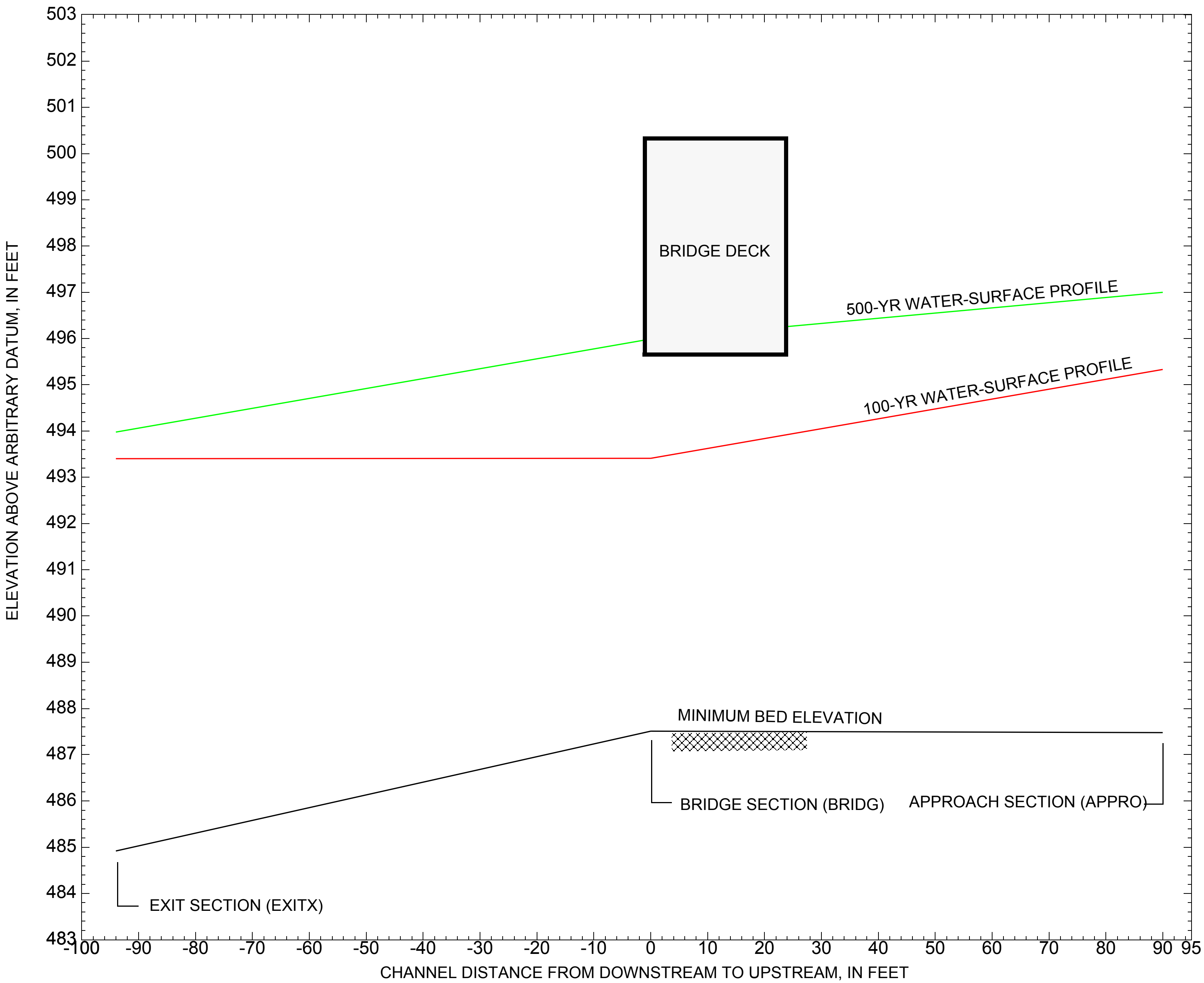

Figure 7. Water-surface profiles for the 100-year and 500-year discharges at structure WALDTH00020007 on Town Highway 2, crossing Coles Brook, Walden, Vermont.

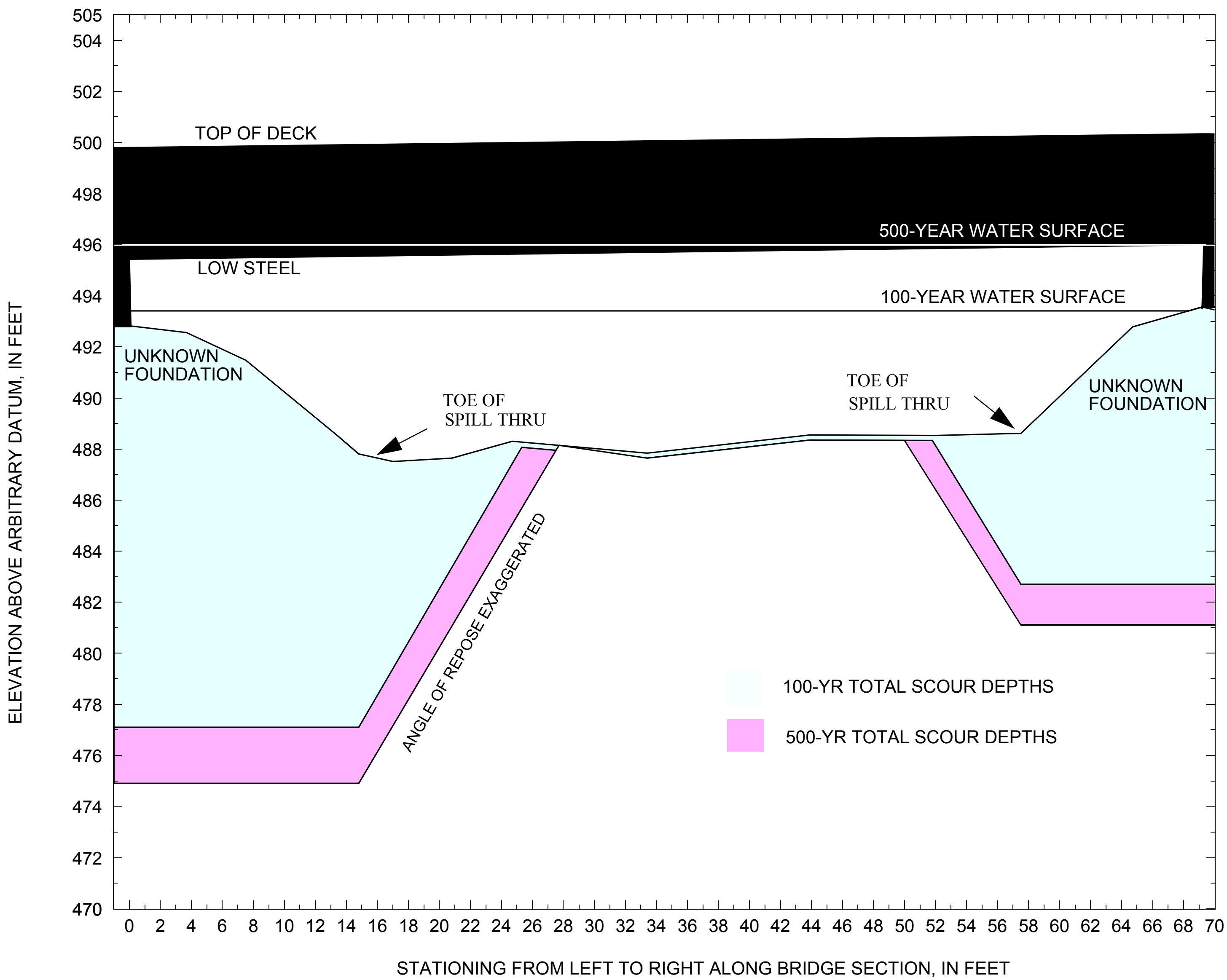

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure WALDTH00020007 on Town Highway 2, crossing Coles Brook, Walden, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WALDTH00020007 on Town Highway 2, crossing Coles Brook, Walden, 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-yr. discharge is 2,200 cubic-feet per second											
Left abutment	0.0	--	495.4	--	492.8	--	--	--	--	--	--
Spill-through toe	14.8	--	--	--	487.8	0.2	10.5	--	10.7	477.1	--
Spill-through toe	57.5	--	--	--	488.6	0.2	5.7	--	5.9	482.7	--
Right abutment	69.3	--	496.0	--	493.6	--	--	--	--	--	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure WALDTH00020007 on Town Highway 2, crossing Coles Brook, Walden, 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-yr. discharge is 3,150 cubic-feet per second											
Left abutment	0.0	--	495.4	--	492.8	--	--	--	--	--	--
Spill-through toe	14.8	--	--	--	487.8	0.0	12.9	--	12.9	474.9	--
Spill-through toe	57.5	--	--	--	488.6	0.0	7.5	--	7.5	481.1	--
Right abutment	69.3	--	496.0	--	493.6	--	--	--	--	--	--

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, 1983, St. Johnsbury, Vermont 7.5 x 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File wald007.wsp
T2        Hydraulic analysis for structure WALDTH00020007   Date: 05-JUN-97
T3        TH 2 crossing Coles Brook, 0.85 miles to the junction VT 15
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2220.0   3150.0  2540.0
SK          0.0046   0.0046  0.0046
*
*    Points removed from the left overbank area, that were not representative of*    the exit section
*
XS   EXITX    -94           0.
GR         -368.0, 500.42   -284.9, 492.85   -245.7, 490.65    -241.6, 490.38
GR          -44.1, 492.12      0.0, 492.89      2.7, 491.31      5.7, 488.30
GR            6.4, 487.38      8.1, 486.69     15.0, 485.66     20.6, 484.92
GR           22.0, 485.16     28.2, 488.29     31.9, 492.12     34.4, 493.23
GR          133.9, 492.93    158.7, 494.33    179.2, 497.37    228.3, 498.79
GR          311.1, 504.44    367.0, 517.36
*
N           0.070        0.055        0.070
SA                   0.0         34.4
*
*
XS   FULLV      0  * * *   0.0024
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    495.71      15.0
GR            0.0, 495.43      0.1, 492.82      3.7, 492.56      7.5, 491.48
GR           13.3, 488.58     14.8, 487.81     17.0, 487.51     20.8, 487.64
GR           24.7, 488.30     33.4, 487.84     43.9, 488.55     52.0, 488.53
GR           57.5, 488.61     64.7, 492.78     69.2, 493.56     69.3, 495.99
GR            0.0, 495.43
*
*        BRTYPE  BRWDTH    EMBSS   EMBELV
CD          3      23.4      2.4    500.1
N           0.040
*
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     12      21.5     2
GR         -478.6, 504.20   -458.7, 501.46   -307.5, 497.01   -213.9, 496.24
GR          -91.3, 497.96      0.0, 499.80     69.5, 500.34    131.2, 500.67
GR          213.3, 502.18    349.4, 506.35    467.6, 511.70    621.3, 516.33
*
*
AS   APPRO     90           0.
GR         -361.7, 498.85   -335.8, 494.31   -323.5, 492.09   -272.9, 491.83
GR         -251.0, 491.45   -155.3, 492.01    -44.4, 493.38      0.0, 494.51
GR           17.1, 493.26     23.9, 488.70     29.5, 487.80     38.1, 487.48
GR           44.1, 487.54     50.9, 488.56     58.6, 488.55     62.0, 490.88
GR           70.4, 492.53    114.4, 493.83    125.5, 494.57    142.1, 493.34
GR          147.3, 494.42    172.5, 498.93    226.1, 499.79    364.2, 504.92
GR          420.5, 511.60    581.2, 512.25
*
N           0.070       0.04     0.07
SA               17.1       62.1
*
HP 1 BRIDG   493.41 1 493.41
HP 2 BRIDG   493.41 * * 2200
HP 1 APPRO   495.33 1 495.33
HP 2 APPRO   495.33 * * 2200
*
HP 1 BRIDG   495.99 1 495.99
HP 2 BRIDG   495.99 * * 3055
*  fullvalley wsel
HP 1 BRIDG   494.41 1 494.41
HP 2 RDWAY   496.90 * * 107
HP 1 APPRO   497.00 1 497.00
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File wald007.wsp
        Hydraulic analysis for structure WALDTH00020007   Date: 05-JUN-97
        TH 2 crossing Coles Brook, 0.85 miles to the junction VT 15
           *** RUN DATE & TIME: 06-25-97  09:12
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      270     24970     66     69                          3097
  493.41            270     24970     66     69  1.00      0     68     3097

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       493.41     0.1    68.3   269.8   24970.    2200.   8.15
X STA.        0.1        12.7        15.7        18.0        20.2        22.4
  A(I)            23.7        15.3        13.1        12.4        12.1
  V(I)            4.65        7.18        8.43        8.89        9.11

X STA.       22.4        24.7        27.1        29.3        31.6        33.6
  A(I)            11.7        11.9        11.6        11.6        11.1
  V(I)            9.41        9.26        9.52        9.46        9.87

X STA.       33.6        35.8        38.0        40.4        42.8        45.4
  A(I)            11.4        11.5        11.9        11.8        12.1
  V(I)            9.63        9.59        9.25        9.29        9.06

X STA.       45.4        48.1        50.8        53.7        56.8        68.3
  A(I)            12.8        12.6        13.7        14.4        23.2
  V(I)            8.60        8.70        8.05        7.66        4.75

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      90.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     1003     42375    359    359                          9523
             2      303     39054     45     47                          4472
             3      170      5491     90     91                          1322
  495.33           1477     86920    494    497  2.42   -341    152     9318

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      90.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.33  -341.6   152.4  1476.8   86920.    2200.   1.49
X STA.     -341.6      -299.0      -272.7      -249.0      -226.3      -202.5
  A(I)           110.1        90.4        87.5        86.6        87.1
  V(I)            1.00        1.22        1.26        1.27        1.26

X STA.     -202.5      -177.1      -149.0      -115.6       -69.3        22.1
  A(I)            89.6        94.1       101.5       117.7       157.6
  V(I)            1.23        1.17        1.08        0.93        0.70

X STA.       22.1        27.6        31.9        35.9        39.7        43.6
  A(I)            36.6        32.1        30.6        30.2        30.2
  V(I)            3.01        3.43        3.59        3.65        3.65

X STA.       43.6        47.6        52.3        57.2        68.9       152.4
  A(I)            30.1        32.7        33.4        54.5       144.1
  V(I)            3.66        3.36        3.29        2.02        0.76
```

```
      U.S. Geological Survey WSPRO Input File wald007.wsp
      Hydraulic analysis for structure WALDTH00020007   Date: 05-JUN-97
      TH 2 crossing Coles Brook, 0.85 miles to the junction VT 15
         *** RUN DATE & TIME: 06-25-97  09:12

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW      QCR
           1      423    32818     0    141                            0
 495.99           423    32818     0    141  1.00      0     69        0

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL     LEW     REW    AREA       K        Q    VEL
     495.99     0.0    69.3   423.5  32818.    3055.   7.21
X STA.         0.0       10.1       14.1       16.9       19.4       21.9
  A(I)            34.3       24.0       21.2       19.3       19.2
  V(I)            4.45       6.35       7.22       7.89       7.97

X STA.        21.9       24.5       27.2       29.7       32.2       34.6
  A(I)            19.0       19.3       18.7       18.2       18.5
  V(I)            8.06       7.92       8.16       8.38       8.26

X STA.        34.6       37.1       39.6       42.3       45.0       47.8
  A(I)            18.4       18.6       18.8       19.4       19.5
  V(I)            8.31       8.21       8.13       7.88       7.83

X STA.        47.8       50.6       53.4       56.4       59.8       69.3
  A(I)            19.8       19.7       21.0       22.8       33.8
  V(I)            7.72       7.76       7.28       6.71       4.51

 *  fullvalley wsel
           CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW      QCR
           1      337    35178    67     72                         4285
 494.41           337    35178    67     72  1.00      0     69     4285

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      12.
       WSEL     LEW     REW    AREA       K        Q    VEL
     496.90  -294.1  -166.9    42.0     427.     107.   2.55
X STA.      -294.1     -262.5     -252.9     -246.3     -241.1     -236.6
  A(I)             4.1        2.9        2.4        2.2        2.0
  V(I)            1.30       1.87       2.21       2.45       2.65

X STA.      -236.6     -232.7     -229.3     -226.1     -223.2     -220.4
  A(I)             1.9        1.8        1.7        1.7        1.6
  V(I)            2.79       2.98       3.08       3.21       3.28

X STA.      -220.4     -217.9     -215.4     -213.0     -210.4     -207.6
  A(I)             1.6        1.6        1.6        1.6        1.7
  V(I)            3.37       3.36       3.43       3.29       3.22

X STA.      -207.6     -204.4     -200.6     -196.0     -189.5     -166.9
  A(I)             1.8        1.9        2.0        2.4        3.6
  V(I)            3.05       2.82       2.65       2.26       1.49

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      90.
   WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW      QCR
           1     1610    91590   368    369                        19111
           2      379    56468    45     47                         6232
           3      328    15423   100    100                         3383
 497.00          2317   163481   513    516  1.95   -350    162    20020

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      90.
       WSEL     LEW     REW    AREA       K        Q    VEL
     497.00  -351.1   161.7  2317.5  163481.    3150.   1.36

X STA.      -351.1     -303.7     -276.4     -252.2     -229.8     -205.8
  A(I)           165.8      138.4      129.1      122.9      128.2
  V(I)            0.95       1.14       1.22       1.28       1.23

X STA.      -205.8     -181.0     -154.9     -126.3      -93.8      -54.6
  A(I)           129.3      132.5      137.4      143.9      156.3
  V(I)            1.22       1.19       1.15       1.09       1.01

X STA.       -54.6        5.8       26.0       31.7       37.1       42.3
  A(I)           189.1       96.0       51.8       50.4       49.5
  V(I)            0.83       1.64       3.04       3.12       3.18

X STA.        42.3       47.7       53.8       60.8       92.4      161.7
  A(I)            50.1       52.6       57.4      143.4      193.3
  V(I)            3.14       2.99       2.75       1.10       0.81
```

```
        U.S. Geological Survey WSPRO Input File wald007.wsp
        Hydraulic analysis for structure WALDTH00020007   Date: 05-JUN-97
        TH 2 crossing Coles Brook, 0.85 miles to the junction VT 15
           *** RUN DATE & TIME: 06-25-97  09:12
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      279     26183     67     70                         3239
   493.55           279     26183     67     70  1.00      0     69     3239

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       493.55     0.1    69.1   279.1   26183.    2540.   9.10
X STA.         0.1        12.5        15.5        17.8        20.1        22.2
  A(I)            24.6        15.6        13.4        12.7        12.2
  V(I)            5.16        8.15        9.49        9.98       10.44

X STA.        22.2        24.5        26.9        29.2        31.4        33.5
  A(I)            12.2        12.3        11.9        12.0        11.5
  V(I)           10.44       10.35       10.64       10.58       11.03

X STA.        33.5        35.7        38.0        40.3        42.8        45.4
  A(I)            11.7        12.1        11.9        12.7        12.6
  V(I)           10.89       10.51       10.65       10.03       10.08

X STA.        45.4        48.1        50.9        53.7        56.9        69.1
  A(I)            12.9        13.4        13.7        15.3        24.4
  V(I)            9.82        9.44        9.25        8.28        5.21

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      90.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     1216     58008    362    362                        12646
             2      330     44913     45     47                         5072
             3      224      8506     94     94                         1967
   495.92          1770    111428    501    504  2.21   -344    156    12704

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      90.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.92  -345.0   155.7  1770.2  111428.    2540.   1.43

X STA.      -345.0      -300.4      -274.4      -250.3      -227.8      -204.4
  A(I)           130.6       104.6       102.8        99.3        99.8
  V(I)            0.97        1.21        1.24        1.28        1.27

X STA.      -204.4      -178.9      -151.8      -121.4       -83.5       -28.2
  A(I)           105.0       107.5       112.0       123.4       146.7
  V(I)            1.21        1.18        1.13        1.03        0.87

X STA.       -28.2        24.4        29.6        34.3        38.6        43.1
  A(I)           122.1        40.1        38.0        36.6        37.5
  V(I)            1.04        3.17        3.34        3.47        3.39

X STA.        43.1        47.7        52.9        58.3        79.6       155.7
  A(I)            37.5        39.2        39.8        88.4       159.4
  V(I)            3.38        3.24        3.19        1.44        0.80
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wald007.wsp
        Hydraulic analysis for structure WALDTH00020007   Date: 05-JUN-97
        TH 2 crossing Coles Brook, 0.85 miles to the junction VT 15
           *** RUN DATE & TIME: 06-25-97  09:12

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

EXITX:XS   ******   -290      769  0.24 *****  493.64  492.60    2220  493.40
       -93 ******    142    32713  1.82 ***** *******    0.52    2.89

FULLV:FV       94   -292      860  0.18  0.38  494.02 *******    2220  493.84
         0     94    146    37385  1.76  0.00    0.00    0.43    2.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       90   -333      855  0.30  0.26  494.33 *******    2220  494.03
        90     90    145    45069  2.84  0.06   -0.01    0.55    2.60
         <<<<<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       94      0      270  1.51  0.57  494.92  492.40    2220  493.41
         0     94     68    24948  1.43  0.71    0.00    0.86    8.23

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.836 ******  495.71 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<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       67   -341     1477  0.08  0.23  495.42  493.09    2220  495.33
        90     99    152    86975  2.42  0.28    0.01    0.24    1.50

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.856  0.532   40486.    -2.    66.   495.29

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -94.  -291.   142.   2220.   32713.     769.    2.89  493.40
   FULLV:FV       0.  -293.   146.   2220.   37385.     860.    2.58  493.84
   BRIDG:BR       0.     0.    68.   2220.   24948.     270.    8.23  493.41
   RDWAY:RG      12.**************       0.******************    2.00********
   APPRO:AS      90.  -342.   152.   2220.   86975.    1477.    1.50  495.33

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    492.60    0.52  484.92  517.36************  0.24  493.64  493.40
   FULLV:FV  ********    0.43  485.15  517.59  0.38  0.00  0.18  494.02  493.84
   BRIDG:BR    492.40    0.86  487.51  495.99  0.57  0.71  1.51  494.92  493.41
   RDWAY:RG  ****************  496.24  516.33**********************************
   APPRO:AS    493.09    0.24  487.48  512.25  0.23  0.28  0.08  495.42  495.33
```

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File wald007.wsp
       Hydraulic analysis for structure WALDTH00020007   Date: 05-JUN-97
       TH 2 crossing Coles Brook, 0.85 miles to the junction VT 15
          *** RUN DATE & TIME: 06-25-97  09:12

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

EXITX:XS   ******   -296     1021  0.25 *****  494.22  493.07    3150  493.98
       -93 ******    152    46419  1.67 ***** *******    0.47    3.09

FULLV:FV       94   -299     1116  0.20  0.39  494.61 *******    3150  494.41
         0     94    156    52181  1.61  0.00    0.00    0.40    2.82
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       90   -337     1125  0.33  0.28  494.95 *******    3150  494.61
        90     90    148    61108  2.74  0.07   -0.01    0.54    2.80
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   497.11       0.00     493.75     496.24

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   493.83     496.69     496.91     495.71

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

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

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

BRIDG:BR       94      0      423  0.81 *****  496.80  493.38    3055  495.99
         0 ******     69    32818  1.00 ***** *******    0.51    7.21

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   5.  0.438 ******  495.71 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG      12.    69.  0.03  0.06  497.03    0.00    107.  496.90

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    107.   127.  -294.  -167.   0.7   0.3   2.7   2.5   0.5   2.7
   RT:      0.   196.    34.   230.   2.6   1.7   7.9   9.3   3.0   3.0

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

APPRO:AS       67   -350     2319  0.06  0.18  497.06  493.67    3150  497.00
        90    101    162   163593  1.95  0.35    0.00    0.16    1.36

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -94.  -297.   152.  3150.  46419.    1021.    3.09  493.98
   FULLV:FV       0.  -300.   156.  3150.  52181.    1116.    2.82  494.41
   BRIDG:BR       0.     0.    69.  3055.  32818.     423.    7.21  495.99
   RDWAY:RG      12.*******   107.   107.*********       0.    2.00  496.90
   APPRO:AS      90.  -351.   162.  3150. 163593.    2319.    1.36  497.00

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    493.07    0.47  484.92  517.36************  0.25  494.22  493.98
   FULLV:FV  ********    0.40  485.15  517.59  0.39  0.00  0.20  494.61  494.41
   BRIDG:BR    493.38    0.51  487.51  495.99************  0.81  496.80  495.99
   RDWAY:RG  ****************  496.24  516.33  0.03******  0.06  497.03  496.90
   APPRO:AS    493.67    0.16  487.48  512.25  0.18  0.35  0.06  497.06  497.00
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wald007.wsp
        Hydraulic analysis for structure WALDTH00020007   Date: 05-JUN-97
        TH 2 crossing Coles Brook, 0.85 miles to the junction VT 15
           *** RUN DATE & TIME: 06-25-97  09:12

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

EXITX:XS   ******   -292      861  0.24 *****  493.85  492.75    2540  493.61
       -93 ******    146    37423  1.76 ***** *******    0.49    2.95

FULLV:FV       94   -295      953  0.19  0.38  494.24 *******    2540  494.05
         0     94    150    42517  1.71  0.00    0.00    0.42    2.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       90   -334      951  0.31  0.27  494.56 *******    2540  494.24
        90     90    146    50518  2.82  0.06   -0.01    0.55    2.67
         <<<<<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       94      0      279  1.91  0.62  495.46  492.84    2540  493.55
         0     94     69    26157  1.48  0.98    0.00    0.96    9.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  0.822 ******  495.71 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.         <<<<<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       67   -344     1771  0.07  0.22  495.99  493.30    2540  495.92
        90    100    156   111526  2.21  0.32    0.01    0.20    1.43

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.856  0.576   47115.    -3.    66.   495.89

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

  FIRST USER DEFINED TABLE.

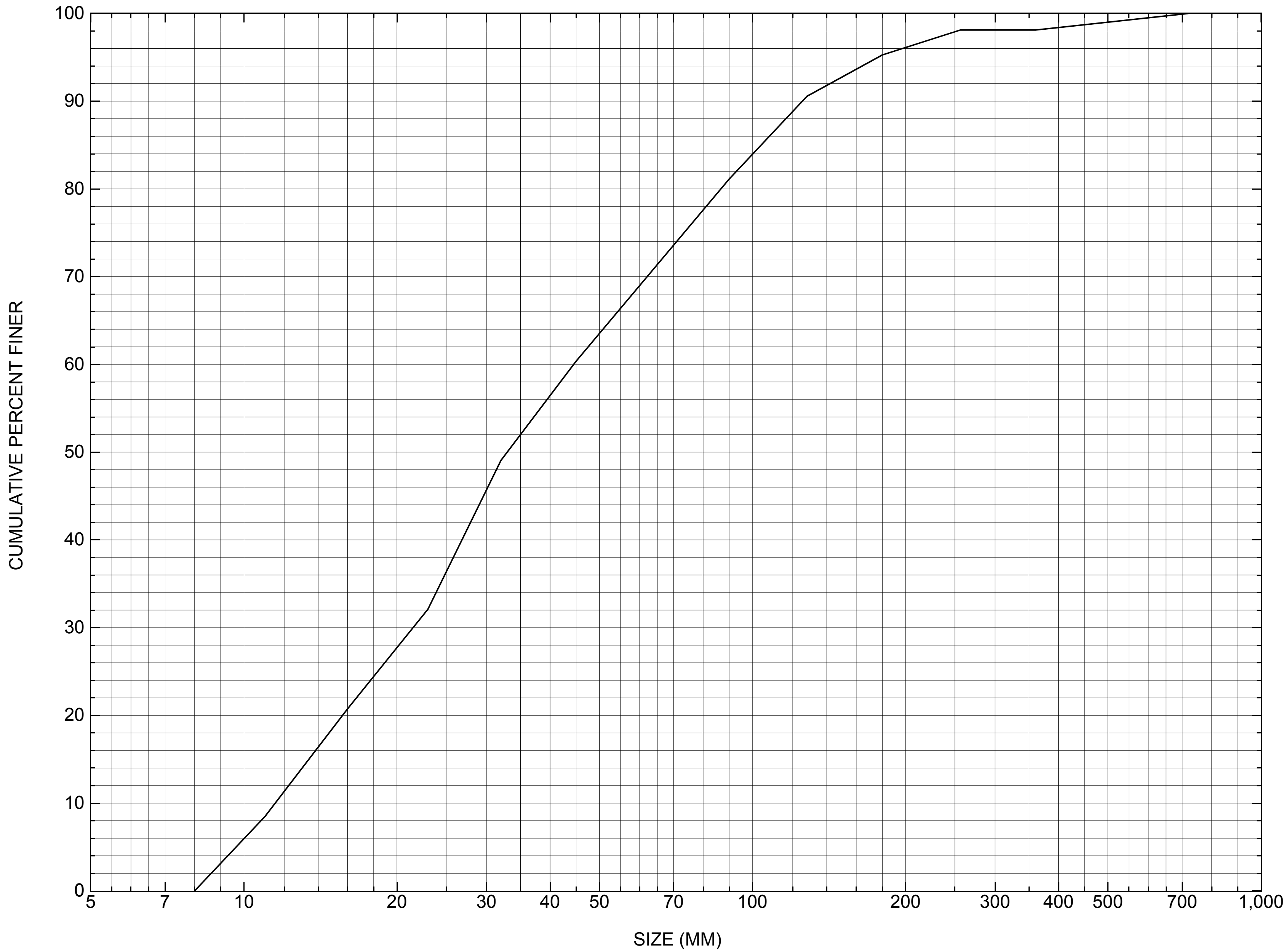
    XSID:CODE    SRD    LEW     REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -94.  -293.   146.   2540.   37423.     861.    2.95  493.61
   FULLV:FV       0.  -296.   150.   2540.   42517.     953.    2.66  494.05
   BRIDG:BR       0.     0.    69.   2540.   26157.     279.    9.11  493.55
   RDWAY:RG      12.**************       0.******************    2.00********
   APPRO:AS      90.  -345.   156.   2540.  111526.    1771.    1.43  495.92

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    492.75    0.49  484.92  517.36************  0.24  493.85  493.61
   FULLV:FV  ********    0.42  485.15  517.59  0.38  0.00  0.19  494.24  494.05
   BRIDG:BR    492.84    0.96  487.51  495.99  0.62  0.98  1.91  495.46  493.55
   RDWAY:RG  ****************  496.24  516.33**********************************
   APPRO:AS    493.30    0.20  487.48  512.25  0.22  0.32  0.07  495.99  495.92
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WALDTH00020007, in Weston, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WALDTH00020007

General Location Descriptive

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

Date *(MM/DD/YY)* 04 / 05 / 95

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

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 75700

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

Waterway *(I - 6)* COLES BROOK

Road Name *(I - 7):* -

Route Number TH002

Vicinity *(I - 9)* 0.85 MI TO JCT W VT15

Topographic Map Saint Johnsbury

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44276

Longitude *(i - 17; nnnnn.n)* 72133

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10031500070315

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

Maximum span length *(I - 48; nnnn)* 0071

Year built *(I - 27; YYYY)* 1945

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000160

Deck Width *(I - 52; nn.n)* 215

Year of ADT *(I - 30; YY)* 91

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

Opening skew to Roadway *(I - 34; nn)* 05

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

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

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

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

Year Reconstructed *(I - 106)* 1975

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:

The structural inspection report of 06/07/93 indicates the structure is a steel stringer type bridge with a concrete deck and an asphalt road surface. There are concrete skeleton abutments. They have minor cracks and spalls reported overall. Boulder riprap has been laid on the flow through embankments in front of and around the ends of each abutment, with boulders showing in the up and downstream banks. A low, fine gravel point bar is present in the channel on the right abutment side, and presently covers two thirds of the channel.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **12.77** mi^2 Lake/pond/swamp area **.325** mi^2

Watershed storage *(ST)* **2.54** %

Bridge site elevation **1637** ft Headwater elevation **2500** ft

Main channel length **7.747** mi

10% channel length elevation **1686** ft 85% channel length elevation **2169** ft

Main channel slope *(S)* **83.1** 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:

There is no benchmark information available.

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:

There is no foundation material information available.

Comments:

There were no bridge plans available.

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 of the upstream face. The low cord elevation is from the survey log done for this report on 08/09/95. The low cord to bed length data is from the sketch attached to a bridge inspection report dated 06/07/93.**

Station	0.0	26.3	36.3	57.3	69.3	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low cord elevation	495.4	495.6	495.7	495.9	496	-	-	-	-	-	-
Bed elevation	492.4	487.3	488.4	488.6	493.2	-	-	-	-	-	-
Low cord to bed length	3.0	8.3	7.3	7.3	2.8	-	-	-	-	-	-
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: 3/26/96
Computerized by: RB Date: 4/4/96
Reviewd by: LKS Date: 06/13/97

Structure Number WALDTH00020007

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 8 / 9 / 1995

2. Highway District Number 7 Mile marker 000

County CALENDONIA 005 Town WALDEN 75700

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

Route Number TH02 Hydrologic Unit Code: 01080102

3. Descriptive comments:

The bridge is located 0.85 miles from the junction of TH 2 and VT 15.

B. Bridge Deck Observations

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

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

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

7. Bridge length 74 *(feet)* Span length 71 *(feet)* Bridge width 21.5 *(feet)*

Road approach to bridge:

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

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

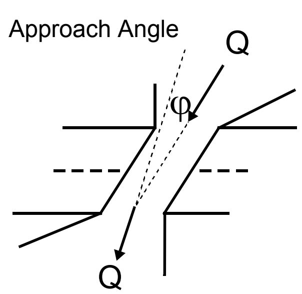
10. Embankment slope (*run / rise in feet / foot*):
US left 2.3:1 US right 2.6:1

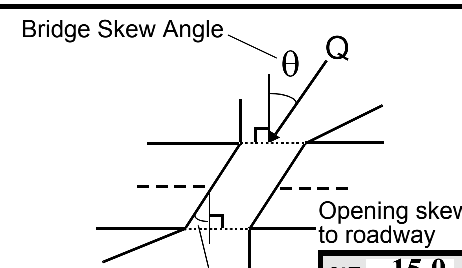
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 40 16. Bridge skew: 35





α= 15.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 9 feet US *(US, UB, DS)* to 38 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: 3

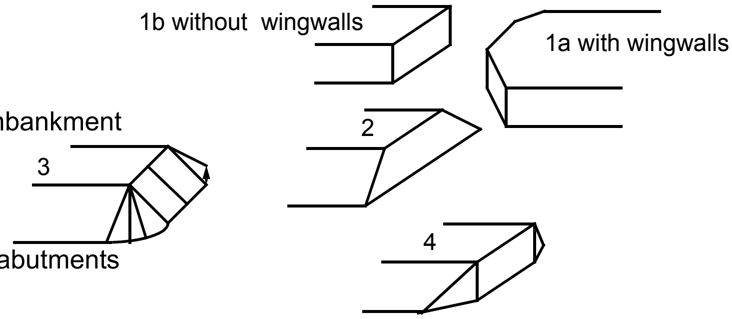
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. All areas have large shrubs on the banks and some spruce trees above the banks.
7. Values are from the VT AOT files. Measured bridge dimensions are the same as the historical form.
8. The left bank road approach is even for 50 feet and then it gets lower.
5. Riffles begin about 50 feet US.
18. The abutments are vertical concrete with sloping stone slabs placed below them. Wingwalls protrude as extensions from the abutment face.

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
67.0	4.5			2.5	4	3	21	245	1	1

23. Bank width 35.0 24. Channel width 35.0 25. Thalweg depth 45.0 29. Bed Material 342

30 .Bank protection type: LB 2 RB 1 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.):

26. The percent vegetation cover for the left and right banks are based on the 10 feet tall shrubs on the banks. No trees are on the bank until 150 feet US.
29. There are occasional boulders at 74 feet US. Within 55 feet of the bridge there is only gravel and nothing larger.
30. The left bank protection is only within 10 feet of the bridge and is a continuation of the under bridge sloping stone protection. The right bank protection extends to 35 feet US.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **36** 35. Mid-bar width: **12**

36. Point bar extent: **83** feet **US** (US, UB) to **33** feet **DS** (US, UB, DS) positioned **55** %LB to **100** %RB

37. Material: **3**

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

The point bar material is very well sorted.

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: **40** 42. Cut bank extent: **11** feet **US** (US, UB) to **85** 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 damage is very slight.

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

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

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

There was no channel scour present as of 08/09/95. The flow just US and under the bridge flows towards the left bank because of the gravel bar. Within this flow zone, the average thalweg is about 1 foot and gets as deep as 1.5 feet, but variation in the channel bottom does not justify noting channel scour.

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

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

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

54. Confluence comments (eg. confluence name):

There are no major confluences located at this site.

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
34.5		**1.0**		**2**	**7**	**7**	**-**

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

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

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

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

32

63. The bed material grades from sand to gravel from left to right. The material is very loose and it is easy to penetrate 1 foot.

61. The placed stone slabs that form the spill through abutments are boulder size though flat. These stones have slumped away from the vertical concrete abutment slightly and act as protection.

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

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

Some logs and branches are in the stream from recent flooding, there is also some debris caught at the bridge in the I-beams. There is a debris accumulation from slip failure of the right bank at 165 feet DS.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		10	90	0	1	-	-	90.0
RABUT	1	0	90			0	1	67.0

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

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

-

-

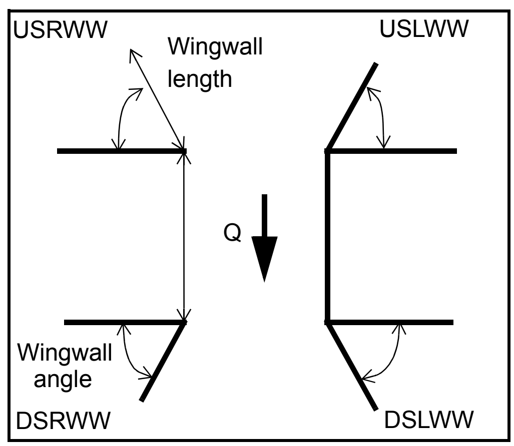
1

The concrete abutment walls are about 3 feet high. The sloping stone slabs on the spill-through slope are at a 30 degree angle.
On the left and right abutments the bottom of the concrete is exposed up to 2 feet for a length of eight feet.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						67.0	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	23.5	
DSRWW:	1		0		-	23.5	

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



82. **Bank / Bridge Protection**:

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

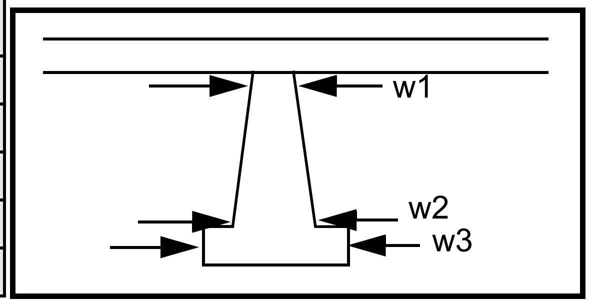
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

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	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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.):

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

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

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

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

ere are no piers at this site.

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

Point bar extent: ______ feet **4** *(US, UB, DS)* to **3** feet **2** *(US, UB, DS)* positioned **2** %LB to **2** %RB

Material: **2**

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

324
2
2
1

Is a cut-bank present? **1** *(Y or if N type ctrl-n cb)* Where? **The** *(LB or RB)* Mid-bank distance: **left**

Cut bank extent: **bank** feet **pro** *(US, UB, DS)* to **tec-** feet **tio** *(US, UB, DS)*

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

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

extends DS 55 feet. The right bank protection extends from 60 feet to 118 feet DS. Moderate fluvial erosion on the left bank begins at the end of the protected area.

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

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

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

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

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

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

Confluence comments (eg. confluence name):

structures present at this site.

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
170
10
130
DS
185
DS
10
25
23

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: WALDTH00020007   Town: WALDEN
Road Number: TH 2   County: CALENDONIA
Stream: COLES (JOES) BROOK

Initials LKS   Date: 06/10/97 Checked: SAO

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2200	3150	2540
Main Channel Area, ft2	303	379	330
Left overbank area, ft2	1003	1610	1216
Right overbank area, ft2	170	328	224
Top width main channel, ft	45	45	45
Top width L overbank, ft	359	368	632
Top width R overbank, ft	90	100	94
D50 of channel, ft	0.10801	0.10801	0.10801
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.7	8.4	7.3
y1, average depth, LOB, ft	2.8	4.4	1.9
y1, average depth, ROB, ft	1.9	3.3	2.4
Total conveyance, approach	86920	163481	111428
Conveyance, main channel	39054	56468	44913
Conveyance, LOB	42375	91590	58008
Conveyance, ROB	5491	15423	8506
Percent discrepancy, conveyance	0.0000	0.0000	0.0009
Qm, discharge, MC, cfs	988.5	1088.0	1023.8
Ql, discharge, LOB, cfs	1072.5	1764.8	1322.3
Qr, discharge, ROB, cfs	139.0	297.2	193.9
Vm, mean velocity MC, ft/s	3.3	2.9	3.1
Vl, mean velocity, LOB, ft/s	1.1	1.1	1.1
Vr, mean velocity, ROB, ft/s	0.8	0.9	0.9
Vc-m, crit. velocity, MC, ft/s	7.3	7.6	7.4
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 others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	2200	3150	2540
(Q) discharge thru bridge, cfs	2200	3055	2540
Main channel conveyance	24970	32818	26183
Total conveyance	24970	32818	26183
Q2, bridge MC discharge,cfs	2200	3055	2540
Main channel area, ft2	270	423	279
Main channel width (normal), ft	50.8	50.8	50.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	50.8	50.8	50.8
y_bridge (avg. depth at br.), ft	5.31	8.33	5.49
Dm, median (1.25*D50), ft	0.135013	0.135013	0.135013
y2, depth in contraction,ft	5.54	7.35	6.27
ys, scour depth (y2-ybridge), ft	**0.23**	-0.98	**0.78**

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	2200	3055	2540
Main channel area (DS), ft2	270	337	279
Main channel width (normal), ft	50.8	50.8	50.8
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	50.8	50.8	50.8
D90, ft	0.4112	0.4112	0.4112
D95, ft	0.5786	0.5786	0.5786
Dc, critical grain size, ft	0.2614	0.2970	0.3222
Pc, Decimal percent coarser than Dc	0.261	0.187	0.165

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	2200	3150	2540
Q, thru bridge MC, cfs	2200	3055	2540
Vc, critical velocity, ft/s	7.34	7.61	7.44
Va, velocity MC approach, ft/s	3.26	2.87	3.10
Main channel width (normal), ft	50.8	50.8	50.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	50.8	50.8	50.8
qbr, unit discharge, ft2/s	43.3	60.1	50.0
Area of full opening, ft2	270.0	423.0	279.0
Hb, depth of full opening, ft	5.31	8.33	5.49
Fr, Froude number, bridge MC	0	0.51	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	337	N/A
**Hb, depth at downstream face, ft	N/A	6.63	N/A
**Fr, Froude number at DS face	ERR	0.62	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	495.71	0
Elevation of Bed, ft	-5.31	487.38	-5.49
Elevation of Approach, ft	0	497	0
Friction loss, approach, ft	0	0.18	0
Elevation of WS immediately US, ft	0.00	496.82	0.00
ya, depth immediately US, ft	5.31	9.44	5.49
Mean elevation of deck, ft	0	500.07	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.97	1.00
**Cc, for downstream face (<=1.0)	ERR	0.909574	ERR
Ys, scour w/Chang equation, ft	N/A	**-0.18**	N/A
Ys, scour w/Umbrell equation, ft	N/A	-2.55	N/A

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

**Ys, scour w/Chang equation, ft	N/A	2.05	N/A

**Ys, scour w/Umbrell equation, ft	ERR	-0.86	ERR

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

y2, from Laursen's equation, ft	5.54	7.35	6.27
WSEL at downstream face, ft	--	494.41	--
Depth at downstream face, ft	N/A	6.63	N/A
Ys, depth of scour (Laursen), ft	N/A	0.71	N/A
Depth to armoring, ft	**2.22**	**3.87**	**0.14**

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	2200	3150	2540	2200	3150	2540
a', abut.length blocking flow, ft	350.9	360.4	354.3	92.3	101.6	95.6
Ae, area of blocked flow ft2	1000.1	1547.4	1218.75	185.1	342.4	240.3
Qe, discharge blocked abut.,cfs	1084.6	--	1360.5	192.7	330.8	243.3
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.08	1.19	1.12	1.04	0.97	1.01
ya, depth of f/p flow, ft	2.85	4.29	3.44	2.01	3.37	2.51
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.113	0.093	0.106	0.130	0.093	0.113
ys, scour depth, ft	**10.46**	**12.92**	**11.62**	**5.65**	**7.54**	**6.38**

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)	350.9	360.4	354.3	92.3	101.6	95.6
y1 (depth f/p flow, ft)	2.85	4.29	3.44	2.01	3.37	2.51
a'/y1	123.12	83.94	103.00	46.03	30.15	38.03
Skew correction (p. 49, fig. 16)	1.03	1.03	1.03	0.95	0.95	0.95
Froude no. f/p flow	0.11	0.09	0.11	0.13	0.09	0.11
Ys w/ corr. factor K1/0.55:						
vertical	10.43	14.73	12.32	7.06	10.62	8.45
vertical w/ ww's	8.56	12.08	10.11	5.79	8.71	6.93
spill-through	5.74	8.10	6.78	3.88	5.84	4.65

Abutment riprap Sizing

Isbash Relationship

D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)

(Richardson and others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.86	0.62	0.96	0.87	0.62	0.96
y, depth of flow in bridge, ft	5.31	6.63	5.49	5.31	6.63	5.49

Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	1.58	ERR	ERR	1.58	ERR
Fr>0.8 (vertical abut.)	2.13	ERR	2.27	2.14	ERR	2.27
Fr<=0.8 (spillthrough abut.)	ERR	**1.37**	ERR	ERR	**1.37**	ERR
Fr>0.8 (spillthrough abut.)	**1.88**	ERR	**2.01**	**1.89**	ERR	**2.01**