LEVEL II SCOUR ANALYSIS FOR BRIDGE 53 (WILMVT01000053) on STATE ROUTE 100, crossing COLD BROOK, WILMINGTON, VERMONT

U.S. Geological Survey
Open-File Report 97-343

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

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By Erick M. Boehmler

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 53 (WILMVT01000053) ON STATE ROUTE 100, CROSSING COLD BROOK, WILMINGTON, VERMONT

By **Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WILMVT01000053 on State Route 100 crossing Cold Brook, Wilmington, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in south-central Vermont. The 8.38-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover predominantly is pasture except for the immediate channel banks, which are tree covered.

In the study area, Cold Brook has a straight channel with a slope of approximately 0.04 ft/ft, an average channel top width of 63 feet and an average bank height of 9 feet. The channel is constructed with stone fill completely covering both banks for 300 feet upstream of the site. The predominant channel bed materials are gravel and cobbles with a median grain size (D_{50}) of 66.2 mm (0.217 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 7, 1996, indicated that the reach was constructed.

The State Route 100 crossing of Cold Brook is a 23-ft-long, two-lane bridge divided by a median strip consisting of one 20-foot concrete span (Vermont Agency of Transportation, written communication, November 1, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is not skewed to the opening and the opening-skew-to-roadway also is zero degrees.

The scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) on the upstream banks, the upstream wingwalls, and the downstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.6 to 2.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.8 to 10.9 ft. The worst-case abutment scour occurred at the left abutment for 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.

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 WILMVT01000053 ***Stream*** Cold Brook

County Windham ***Road*** VT 100 ***District*** 2

Description of Bridge

Bridge length 23 ***ft*** ***Bridge width*** 59.6 ***ft*** ***Max span length*** 20 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/7/96

Description of stone fill Type-2 on the upstream banks, the upstream wingwalls, and the downstream left wingwall.

Abutments and wingwalls are concrete. The downstream end of the left abutment footing is exposed.

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

No

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	8/7/96	0	0
Level II	8/7/96	0	0

Potential for debris Although there are trees lining the channel banks, the channel is constructed straight and is stable.

Describe any features near or at the bridge that may affect flow (include observation date) None evident on 8/7/96.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with slightly irregular flood plains and moderately sloping valley walls on both sides.

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

Date of inspection 8/7/96

DS left: Steep roadway embankment to VT 100 roadway

DS right: Steep roadway embankment to VT 100 roadway

US left: Moderately sloping channel bank to a narrow flood plain.

US right: Moderately sloping channel bank to a narrow flood plain.

Description of the Channel

Average top width 63

Average depth 9

Predominant bed material Gravel / Cobbles

Bank material Gravel/Cobbles

Constructed straight and stable with non-alluvial channel boundaries.

8/7/96

Vegetative co Grass and brush

DS left: Grass and brush

DS right: Trees and brush with grass on overbank

US left: Trees and brush with short grass on overbank.

US right: Y

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

None evident on 8/7/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 8.38 ***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***:

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 2,350 ***ft³/s*** ***Q500*** 3,400 ***ft³/s***

The 100- and 500-year discharges are based on a range defined by flood frequency curves computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Laraway, unpublished draft, 1972; Johnson and Tasker, 1974; Potter, 1957a&b; Talbot, 1887) and those curves available from the VTAOT database and the flood insurance study for the Town of Wilmington (Federal Emergency Management Agency, 1977).

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

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

Datum tie between USGS survey and VTAOT plans Add 1049.1 to the USGS arbitrary survey datum to obtain the VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is the center point of a chiseled "X" on top of the upstream end of the left abutment concrete (elev. 501.14 ft, arbitrary survey datum). RM2 is a metallic VTAOT survey mark set in the top of the right abutment concrete at the downstream end (elev. 500.40 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	-23	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	31	1	Road Grade section
APPRO	81	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 ranged from 0.035 to 0.040.

Cold Brook enters the North Branch Deerfield River about 20 feet downstream of this site. However, the differences in watershed area and characteristics suggest that the peak discharges on each reach are not contemporaneous. Therefore, no backwater effects were assumed and 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 0.0078 ft/ft, which was estimated from surveyed thalweg points downstream of the site.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 501.8 ***ft***
Average low steel elevation 499.0 ***ft***

100-year discharge 2,350 ***ft³/s***
Water-surface elevation in bridge opening 499.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 6 ***ft³/s***
Area of flow in bridge opening 241 ***ft²***
Average velocity in bridge opening 9.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.5 ***ft/s***

Water-surface elevation at Approach section with bridge 500.9
Water-surface elevation at Approach section without bridge 496.3
Amount of backwater caused by bridge 4.6 ***ft***

500-year discharge 3,400 ***ft³/s***
Water-surface elevation in bridge opening 499.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 678 ***ft³/s***
Area of flow in bridge opening 241 ***ft²***
Average velocity in bridge opening 11.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.5 ***/s***

Water-surface elevation at Approach section with bridge 502.1
Water-surface elevation at Approach section without bridge 497.7
Amount of backwater caused by bridge 4.4

Incipient overtopping discharge 2,330 ***ft³/s***
Water-surface elevation in bridge opening 499.1 ***ft***
Area of flow in bridge opening 241 ***ft²***
Average velocity in bridge opening 9.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.4 ***ft/s***

Water-surface elevation at Approach section with bridge 500.9
Water-surface elevation at Approach section without bridge 496.3
Amount of backwater caused by bridge 4.6 ***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.

At this site, all of the modeled discharges 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 was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Additional estimates of contraction scour also were computed by use of Laursen's clear-water scour equation (Richardson and others, 1995, p. 32, equation 20) and the results are presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting alternative estimates for the depth of flow in the bridge at the downstream face in the Chang equation and Laursen's clear-water equation. Contration scour results with respect to these substitutions also are provided in Appendix F.

Abutment scour was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

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	0.7	2.7	0.6
Depth to armoring	50.0	60.8	49.4
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	7.2	10.9	7.1
Right abutment	6.7	4.8	6.6
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	3.2	3.5	3.2
Right abutment	3.2	3.5	3.2
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

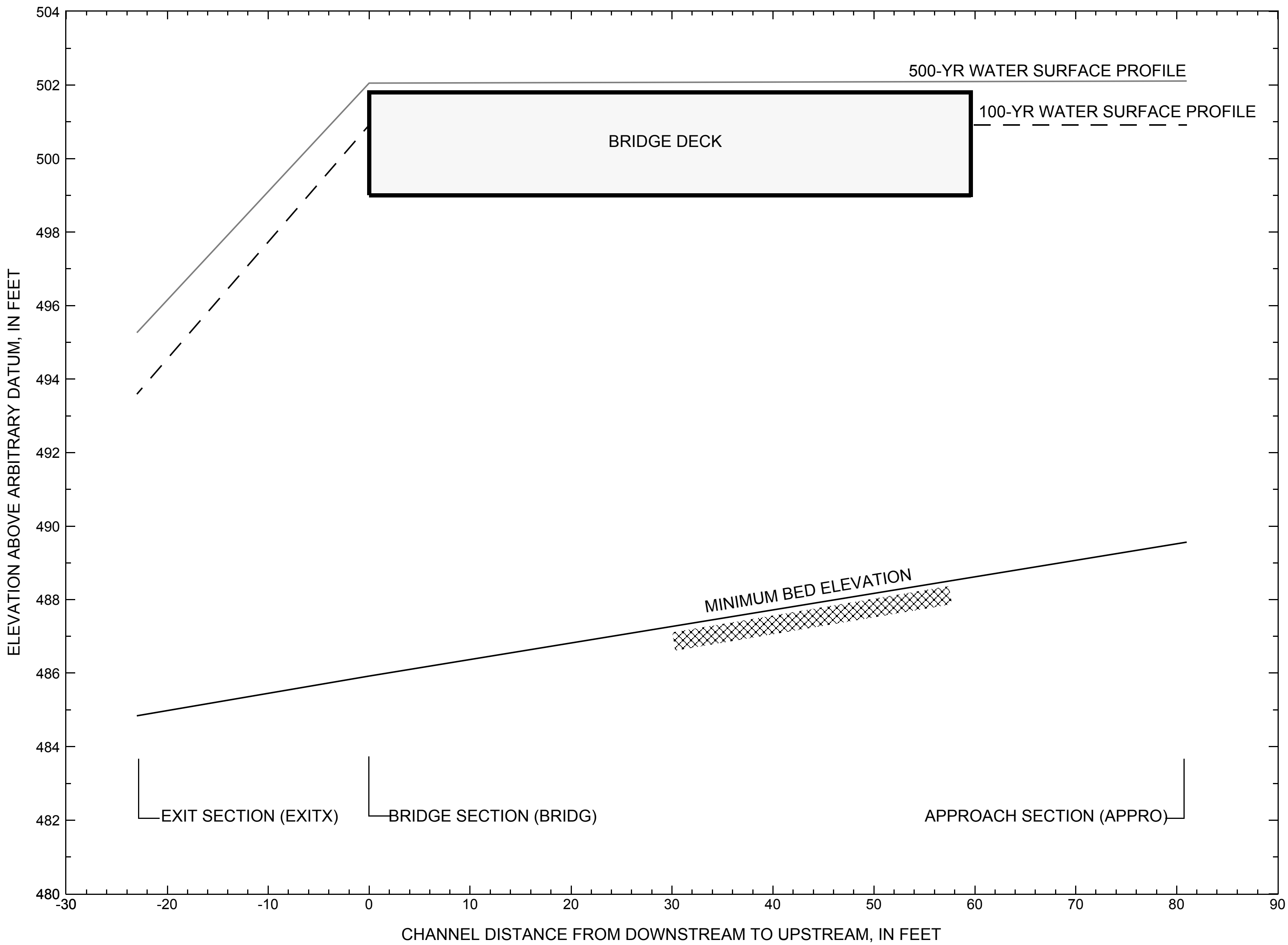

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WILMVT01000053 on State Route 100, crossing Cold Brook, Wilmington, Vermont.

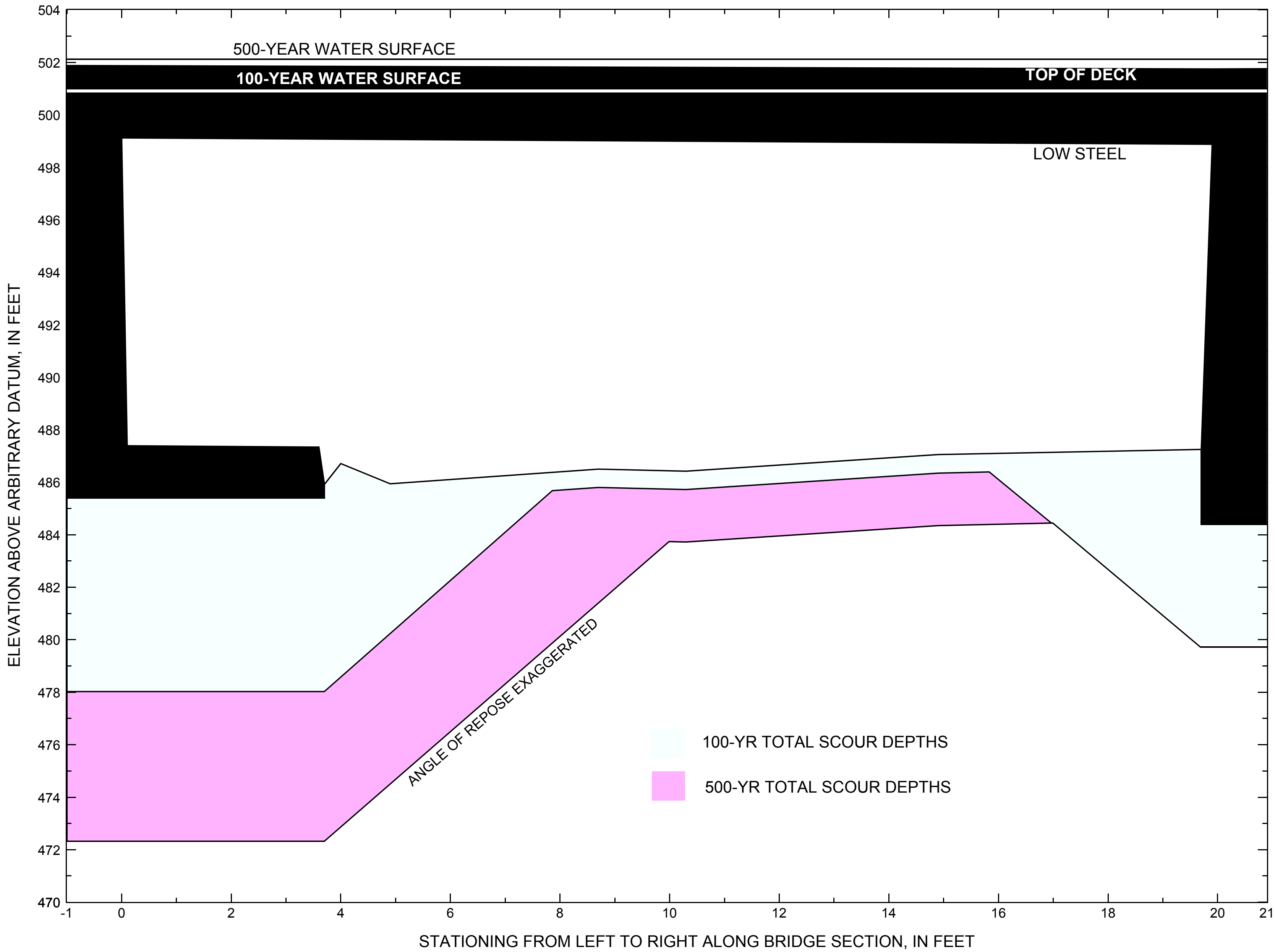

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WILMVT01000053 on State Route 100, crossing Cold Brook, Wilmington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WILMVT01000053 on State Route 100, crossing Cold Brook, Wilmington, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,350 cubic-feet per second											
Left abutment	0.0	1548.1	499.1	485.4	485.9	0.7	7.2	--	7.9	478.0	-7.4
Right abutment	19.9	1548.0	498.9	484.4	487.2	0.7	6.7	--	7.4	479.8	-4.6

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 WILMVT01000053 on State Route 100, crossing Cold Brook, Wilmington, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 3,400 cubic-feet per second											
Left abutment	0.0	1548.1	499.1	485.4	485.9	2.7	10.9	--	13.6	472.3	-13.1
Right abutment	19.9	1548.0	498.9	484.4	487.2	2.7	4.8	--	7.5	479.7	-4.7

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, 1986, West Dover, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1981; Contour interval, 6 meters; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File wilm053.wsp
T2        Hydraulic analysis for structure WILMVT01000053   Date: 30-JAN-97
T3        State Route 100 crossing Cold Brook, Wilmington, VT               EMB
*
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2350.0   3400.0   2330.0
SK          0.0078   0.0078   0.0078
*
XS   EXITX    -23
GR         -309.8, 511.24   -280.4, 507.35   -249.2, 502.13    -30.9, 500.68
GR          -17.4, 493.84     -6.3, 488.18      0.0, 486.40      4.1, 485.16
GR            9.9, 484.84     13.4, 484.87     18.7, 485.35     22.1, 486.39
GR           32.9, 490.20     42.3, 496.99    133.3, 497.67    236.6, 496.74
GR          356.1, 500.25    496.5, 501.92    730.9, 505.59    903.5, 509.87
*
N           0.040        0.055        0.035
SA                 -30.9         42.3
*
XS   FULLV      0   * * *  0.0451
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    499.00       0.0
GR            0.0, 499.12      0.1, 487.39      3.6, 487.34      3.7, 485.92
GR            4.0, 486.71      4.9, 485.94      6.2, 486.15      8.7, 486.50
GR           10.3, 486.42     14.9, 487.05     19.7, 487.25     19.9, 498.88
GR            0.0, 499.12
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD            4     61.3     3.5     501.8     45.5
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     31      59.6      1
GR         -305.6, 513.90   -274.8, 507.91   -180.4, 502.47    -92.2, 502.29
GR            0.0, 501.87     20.2, 501.75    190.4, 500.85    223.9, 501.72
GR          288.9, 502.48    403.5, 503.61
*           192.9, 500.57    222.5, 501.30
*
AS   APPRO     81
GR         -300.2, 513.39   -242.4, 505.80   -192.3, 504.19   -168.3, 500.53
GR          -95.9, 499.78    -12.1, 497.88      0.0, 490.67      1.5, 489.95
GR            5.1, 489.56      9.8, 490.04     14.3, 490.01     20.3, 490.11
GR           21.4, 490.77     40.1, 499.57    118.1, 500.48    254.8, 502.41
*
N           0.040        0.045        0.040
SA                 -12.1         40.1
*
HP 1 BRIDG 499.12 1 499.12
HP 2 BRIDG 499.12 * * 2345
HP 2 RDWAY 500.91 * * 6
HP 1 APPRO 500.91 1 500.91
HP 2 APPRO 500.91 * * 2350
*
HP 1 BRIDG 499.12 1 499.12
HP 2 BRIDG 499.12 * * 2724
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File wilm053.wsp
        Hydraulic analysis for structure WILMVT01000053   Date: 30-JAN-97
        State Route 100 crossing Cold Brook, Wilmington, VT                EMB
           *** RUN DATE & TIME: 03-12-97  13:25

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

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      241     21456     0     65                            0
   499.12           241     21456     0     65  1.00      0     20        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.12     0.0    19.9   240.8   21456.    2345.   9.74

 X STA.        0.0        2.1        3.2        4.4        5.3        6.1
   A(I)            23.5       13.7       14.5       11.2       10.6
   V(I)            4.99       8.57       8.09      10.48      11.03

 X STA.        6.1        6.9        7.6        8.4        9.1        9.9
   A(I)            10.0        9.7        9.7        9.5        9.6
   V(I)           11.71      12.04      12.06      12.29      12.28

 X STA.        9.9       10.7       11.4       12.2       13.0       13.8
   A(I)             9.4        9.6        9.5        9.9       10.1
   V(I)           12.45      12.16      12.32      11.79      11.66

 X STA.       13.8       14.7       15.6       16.6       17.8       19.9
   A(I)            10.3       10.9       11.8       13.8       23.4
   V(I)           11.34      10.78       9.95       8.52       5.00

THE HP TABLES FOR THE RDWAY SECTION WERE NOT PROPERLY COMPUTED AND HENCE WERE
OMMITTED FROM THIS OUTPUT.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      81.

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      229     10925   159    159                         1565
             2      421     53256    52     57                         6796
             3       76      2213   108    108                          358
   500.91           727     66394   319    324  1.58   -170    149     4945

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      81.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.91  -170.8   148.6   726.5   66394.    2350.   3.23

 X STA.     -170.8      -67.2      -37.7      -16.8       -6.0       -2.1
   A(I)            96.9       62.5       56.1       43.8       29.9
   V(I)            1.21       1.88       2.09       2.68       3.93

 X STA.       -2.1        0.5        2.6        4.6        6.5        8.4
   A(I)            25.7       22.9       21.8       21.8       21.4
   V(I)            4.57       5.14       5.38       5.39       5.48

 X STA.        8.4       10.4       12.4       14.5       16.5       18.6
   A(I)            21.9       21.9       22.1       22.0       23.4
   V(I)            5.35       5.37       5.30       5.35       5.02

 X STA.       18.6       20.9       23.6       27.3       33.6      148.6
   A(I)            24.1       26.6       30.4       37.0       94.3
   V(I)            4.87       4.41       3.87       3.17       1.25
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wilm053.wsp
        Hydraulic analysis for structure WILMVT01000053   Date: 30-JAN-97
        State Route 100 crossing Cold Brook, Wilmington, VT                EMB
           *** RUN DATE & TIME: 03-12-97  13:25

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      241     21456      0     65                            0
   499.12           241     21456      0     65  1.00      0     20        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.12     0.0    19.9   240.8   21456.    2724.  11.31

X STA.         0.0         2.1         3.2         4.4         5.3         6.1
  A(I)             23.5        13.7        14.5        11.2        10.6
  V(I)             5.80        9.95        9.39       12.17       12.82

X STA.         6.1         6.9         7.6         8.4         9.1         9.9
  A(I)             10.0         9.7         9.7         9.5         9.6
  V(I)            13.60       13.99       14.01       14.28       14.26

X STA.         9.9        10.7        11.4        12.2        13.0        13.8
  A(I)              9.4         9.6         9.5         9.9        10.1
  V(I)            14.46       14.13       14.31       13.69       13.54

X STA.        13.8        14.7        15.6        16.6        17.8        19.9
  A(I)             10.3        10.9        11.8        13.8        23.4
  V(I)            13.18       12.53       11.56        9.89        5.81

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      31.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.05   -39.5   252.1   166.3    5266.     678.   4.08

X STA.       -39.5        51.5        70.8        85.3        97.6       108.1
  A(I)             20.4        10.0         8.8         8.3         7.7
  V(I)             1.66        3.40        3.85        4.07        4.38

X STA.       108.1       117.5       126.2       134.1       141.4       148.3
  A(I)              7.4         7.3         7.0         6.7         6.6
  V(I)             4.56        4.67        4.84        5.03        5.15

X STA.       148.3       154.9       161.1       167.1       173.0       178.7
  A(I)              6.6         6.4         6.4         6.4         6.4
  V(I)             5.17        5.32        5.30        5.27        5.29

X STA.       178.7       184.5       190.3       196.9       206.7       252.1
  A(I)              6.7         6.8         7.4         8.9        14.2
  V(I)             5.07        4.99        4.57        3.82        2.39

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      81.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      425     29497    167    167                         3847
             2      484     67089     52     57                         8366
             3      257     11547    193    193                         1678
   502.11          1165    108133    412    417  1.56   -178    234     8897

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      81.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.11  -178.7   233.5  1165.4  108133.    3400.   2.92

X STA.      -178.7      -116.3       -79.8       -54.7       -35.0       -18.6
  A(I)            104.3        86.0        74.6        68.8        63.7
  V(I)             1.63        1.98        2.28        2.47        2.67

X STA.       -18.6        -6.5        -1.7         1.5         4.2         6.9
  A(I)             60.3        43.2        36.4        33.4        32.8
  V(I)             2.82        3.93        4.67        5.09        5.18

X STA.         6.9         9.5        12.2        14.9        17.8        20.7
  A(I)             32.3        32.9        32.8        33.9        35.0
  V(I)             5.26        5.16        5.18        5.02        4.86

X STA.        20.7        24.2        29.3        44.6        90.1       233.5
  A(I)             38.2        44.8        66.5       101.2       144.3
  V(I)             4.45        3.79        2.56        1.68        1.18
```

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         U.S. Geological Survey WSPRO Input File wilm053.wsp
         Hydraulic analysis for structure WILMVT01000053   Date: 30-JAN-97
         State Route 100 crossing Cold Brook, Wilmington, VT               EMB
            *** RUN DATE & TIME: 03-12-97  13:25

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      241     21456      0     65                            0
   499.12            241     21456      0     65  1.00      0     20        0

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

          WSEL     LEW     REW    AREA        K        Q     VEL
        499.12     0.0    19.9   240.8   21456.    2330.   9.68

 X STA.        0.0        2.1        3.2        4.4        5.3        6.1
   A(I)            23.5       13.7       14.5       11.2       10.6
   V(I)            4.96       8.51       8.04      10.41      10.96

 X STA.        6.1        6.9        7.6        8.4        9.1        9.9
   A(I)            10.0        9.7        9.7        9.5        9.6
   V(I)           11.63      11.97      11.98      12.21      12.20

 X STA.        9.9       10.7       11.4       12.2       13.0       13.8
   A(I)             9.4        9.6        9.5        9.9       10.1
   V(I)           12.37      12.08      12.24      11.71      11.58

 X STA.       13.8       14.7       15.6       16.6       17.8       19.9
   A(I)            10.3       10.9       11.8       13.8       23.4
   V(I)           11.27      10.71       9.89       8.46       4.97

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      81.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      225     10559    158    159                         1518
              2      420     52926     52     57                         6759
              3       72      2085    106    106                          339
   500.88            717     65570    317    321  1.58   -170    146     4870

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      81.

          WSEL     LEW     REW    AREA        K        Q     VEL
        500.88  -170.6   146.4   717.0   65570.    2330.   3.25

 X STA.     -170.6      -65.7      -36.1      -15.9       -5.6       -2.0
   A(I)            96.5       62.6       54.2       43.2       28.9
   V(I)            1.21       1.86       2.15       2.70       4.04

 X STA.       -2.0        0.6        2.7        4.6        6.6        8.5
   A(I)            25.6       22.7       21.6       21.5       21.2
   V(I)            4.55       5.14       5.39       5.41       5.50

 X STA.        8.5       10.4       12.4       14.4       16.5       18.6
   A(I)            21.5       21.5       21.7       22.4       22.7
   V(I)            5.41       5.43       5.36       5.19       5.14

 X STA.       18.6       20.8       23.6       27.1       33.3      146.4
   A(I)            23.8       27.0       28.8       37.1       92.3
   V(I)            4.89       4.31       4.04       3.14       1.26
1
   *
   EX
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        U.S. Geological Survey WSPRO Input File wilm053.wsp
        Hydraulic analysis for structure WILMVT01000053   Date: 30-JAN-97
        State Route 100 crossing Cold Brook, Wilmington, VT                EMB
           *** RUN DATE & TIME: 03-12-97  13:25

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

 EXITX:XS   ******    -16      317  0.85 *****  494.44  491.30    2350  493.59
       -22 ******     38    26596  1.00 ***** *******    0.54    7.41

 FULLV:FV       23    -14      264  1.23  0.23  494.85 *******    2350  493.62
         0     23     36    20523  1.00  0.19   -0.01    0.69    8.91
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =    493.12     513.39    0.50

  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.12     513.39      496.30

  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   496.30     513.39     496.30

 APPRO:AS       81     -8      194  2.27 *****  498.57  496.30    2350  496.30
        81     81     33    16876  1.00 ***** *******    1.00   12.09
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
            WS3,WSIU,WS1,LSEL =   494.45     499.47     499.65     499.00

  ===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       23      0      241  1.47 *****  500.59  494.43    2345  499.12
         0 ******     20    21456  1.00 ***** *******    0.49    9.74

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        4. ****   5.  0.426  0.000  499.00 ****** ****** ******

     XSID:CODE     SRD   FLEN    HF    VHD     EGL     ERR      Q    WSEL
    RDWAY:RG      31.    21.  0.03  0.26  501.14    0.00      6.  500.91

             Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:      0.   135.  -125.    10.   0.5   0.2   3.4   5.2   0.5   3.1
    RT:      6.    14.   179.   193.   0.1   0.0   2.3  13.0   0.3   3.0

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

 APPRO:AS       20   -170      727  0.26  0.08  501.17  496.30    2350  500.91
        81     20    149    66426  1.58  1.80    0.00    0.48    3.23

        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      -23.    -17.     38.   2350.   26596.      317.    7.41  493.59
    FULLV:FV        0.    -15.     36.   2350.   20523.      264.    8.91  493.62
    BRIDG:BR        0.      0.     20.   2345.   21456.      241.    9.74  499.12
    RDWAY:RG       31.*******      0.      6.        0.*********    1.00  500.91
    APPRO:AS       81.   -171.    149.   2350.   66426.      727.    3.23  500.91

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

  SECOND USER DEFINED TABLE.

     XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
    EXITX:XS     491.30    0.54  484.84  511.24************  0.85  494.44  493.59
    FULLV:FV    ********   0.69  485.88  512.28  0.23  0.19  1.23  494.85  493.62
    BRIDG:BR     494.43    0.49  485.92  499.12************  1.47  500.59  499.12
    RDWAY:RG    ****************  500.85  513.90  0.03******  0.26  501.14  500.91
    APPRO:AS     496.30    0.48  489.56  513.39  0.08  1.80  0.26  501.17  500.91
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wilm053.wsp
        Hydraulic analysis for structure WILMVT01000053   Date: 30-JAN-97
        State Route 100 crossing Cold Brook, Wilmington, VT                EMB
           *** RUN DATE & TIME: 03-12-97  13:25

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

EXITX:XS   ******    -19      413  1.05 *****  496.32  492.57    3400  495.26
       -22 ******     40    38481  1.00 ***** *******    0.55    8.23

FULLV:FV       23    -17      354  1.44  0.22  496.72 *******    3400  495.28
         0     23     38    30995  1.00  0.19   -0.01    0.68    9.62
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.78     513.39    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.78     513.39     497.72

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   497.72     513.39     497.72

APPRO:AS       81    -11      259  2.69 *****  500.41  497.72    3400  497.72
        81     81     36    24986  1.00 ***** *******    1.00   13.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   503.40       0.00     496.58     500.85

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===225 NO ENERGY BALANCE IN 15 ITERATIONS.
                   FLOW,Q =    4      2322.
             WS1,WSSD,WS3 =   498.30       0.00     494.49

 ===235 CONTINUE FLOW CLASS 4 COMPUTATIONS.
                   ITER,QRD =    3      1078.
             WS,WSMIN,WSMAX =   502.42     500.85     503.98

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.71     501.74     501.86     499.00

 ===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       23      0      241  1.99 *****  501.11  495.23    2724  499.12
         0 ******     20    21456  1.00 ***** *******    0.57   11.31

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.463  0.000  499.00 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      31.    21.  0.02  0.21  502.29    0.00    678.  502.05

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     32.    50.   -40.    10.   0.2   0.1   2.7   5.6   0.4   3.0
   RT:    646.   242.    10.   252.   1.2   0.7   4.4   4.0   0.9   3.1

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

APPRO:AS       20   -178     1164  0.21  0.08  502.31  497.72    3400  502.11
        81     21    233   107950  1.56  1.67    0.00    0.38    2.92

       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      -23.   -20.    40.   3400.   38481.      413.    8.23  495.26
   FULLV:FV        0.   -18.    38.   3400.   30995.      354.    9.62  495.28
   BRIDG:BR        0.     0.    20.   2724.   21456.      241.   11.31  499.12
   RDWAY:RG       31.*******    32.    678.       0.*********    1.00  502.05
   APPRO:AS       81.  -179.   233.   3400.  107950.     1164.    2.92  502.11

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS     492.57    0.55  484.84  511.24************  1.05  496.32  495.26
   FULLV:FV   ********    0.68  485.88  512.28  0.22  0.19  1.44  496.72  495.28
   BRIDG:BR     495.23    0.57  485.92  499.12************  1.99  501.11  499.12
   RDWAY:RG   ****************  500.85  513.90  0.02******  0.21  502.29  502.05
   APPRO:AS     497.72    0.38  489.56  513.39  0.08  1.67  0.21  502.31  502.11
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File wilm053.wsp
        Hydraulic analysis for structure WILMVT01000053   Date: 30-JAN-97
        State Route 100 crossing Cold Brook, Wilmington, VT               EMB
           *** RUN DATE & TIME: 03-12-97  13:25

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

EXITX:XS   ******    -16      315  0.85 *****  494.40  491.26    2330  493.55
       -22 ******     38    26370  1.00 ***** *******    0.54    7.40

FULLV:FV       23    -14      262  1.23  0.23  494.81 *******    2330  493.58
         0     23     36    20326  1.00  0.19   -0.01    0.69    8.89
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   493.08     513.39    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   493.08     513.39     496.27

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
            ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                 WSBEG,WSEND,CRWS =   496.27     513.39     496.27

APPRO:AS       81     -8      193  2.26 *****  498.54  496.27    2330  496.27
        81     81     33    16737  1.00 ***** *******    1.00   12.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.39     499.41     499.60     499.00

 ===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       23      0      241  1.46 *****  500.58  494.41    2333  499.12
         0 ******     20    21456  1.00 ***** *******    0.49    9.69

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   2.  0.424  0.000  499.00 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      31.         <<<<<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       20   -170      718  0.26  0.08  501.14  496.27    2330  500.88
        81     20    147    65654  1.58  1.82    0.00    0.48    3.25

       M(G)   M(K)       KQ   XLKQ   XRKQ     OTEL
     ****** ****** ******** ****** ******   500.86

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -23.   -17.    38.   2330.   26370.     315.    7.40  493.55
   FULLV:FV      0.   -15.    36.   2330.   20326.     262.    8.89  493.58
   BRIDG:BR      0.     0.    20.   2333.   21456.     241.    9.69  499.12
   RDWAY:RG     31.**************      0.       0.       0.    1.00********
   APPRO:AS     81.  -171.   147.   2330.   65654.     718.    3.25  500.88

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL     WSEL
   EXITX:XS    491.26    0.54  484.84  511.24************  0.85  494.40  493.55
   FULLV:FV  ********    0.69  485.88  512.28  0.23  0.19  1.23  494.81  493.58
   BRIDG:BR    494.41    0.49  485.92  499.12************  1.46  500.58  499.12
   RDWAY:RG ****************  500.85  513.90************  0.26  501.11********
   APPRO:AS    496.27    0.48  489.56  513.39  0.08  1.82  0.26  501.14  500.88
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```
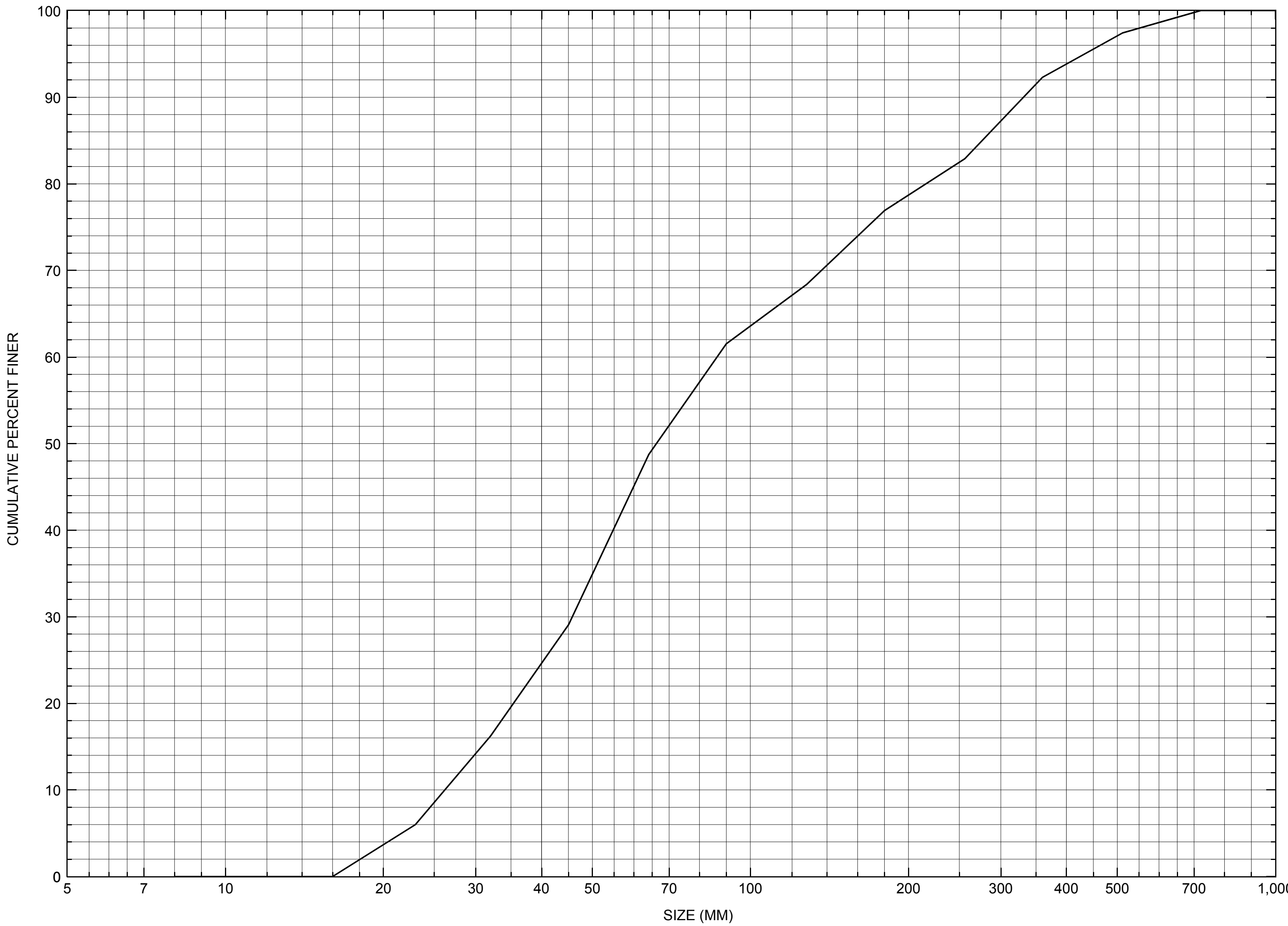

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WILMVT01000053, in Wilmington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WILMVT01000053

General Location Descriptive

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

Date *(MM/DD/YY)* 11 / 01 / 95

Highway District Number *(I - 2; nn)* 01

County *(FIPS county code; I - 3; nnn)* 025

Town *(FIPS place code; I - 4; nnnnn)* 84700

Mile marker *(I - 11; nnn.nnn)* 005020

Waterway *(I - 6)* Cold Brook

Road Name *(I - 7)*: -

Route Number VT 100

Vicinity *(I - 9)* 2.6 MI N JCT. VT.9 W

Topographic Map West.Dover

Hydrologic Unit Code: 1080203

Latitude *(I - 16; nnnn.n)* 42538

Longitude *(i - 17; nnnnn.n)* 72513

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001300531322

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

Maximum span length *(I - 48; nnnn)* 0020

Year built *(I - 27; YYYY)* 1967

Structure length *(I - 49; nnnnnn)* 000023

Average daily traffic, ADT *(I - 29; nnnnnn)* 005850

Deck Width *(I - 52; nn.n)* 596

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 22.5

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

Vertical clearance from streambed (*nnn.n ft*) 10

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

Waterway of full opening (*nnn.n ft*^{2}) 225

Comments:

According to the structural inspection report dated 7/14/93, the structure is a single span at-grade concrete slab bridge. The abutment walls and wingwalls are concrete, which is in good condition except some minor cracking and scaling. The left abutment footing is exposed for the DS half of the abutment. There is some minor undermining noted at the right corner of the right abutment footing. This undermining is approximately 3 feet long, extends 8 inches under the footing and is about 6 inches deep. Buildup of gravel and stones is noted for the US 3/4ths under the bridge. A scour hole is noted at the outlet. The channel is straight through the structure. Cold Brook empties into the North Branch of the **(Continued, page 33)**

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:
Deerfield River approx 50' DS from the bridge.

From plans, maximum high water is 1547.5'; ordinary high water is 1544.5'.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **8.38** mi^2 Lake and pond area **0.052** mi^2
Watershed storage *(ST)* **0.62** %
Bridge site elevation **1595** ft Headwater elevation **3586** ft
Main channel length **5.89** mi
10% channel length elevation **1673** ft 85% channel length elevation **2822** ft
Main channel slope *(S)* **260** ft / mi

Watershed Precipitation Data

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

Bridge Plan Data

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

Project Number S0117(4) Minimum channel bed elevation: 1538

Low superstructure elevation: USLAB 1548.76 DSLAB 1548.12 USRAB 1548.79 DSRAB 1547.98

Benchmark location description:
TBM-1-B, square on boulder, 1550.61.

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

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

If 1: Footing Thickness 2 Footing bottom elevation: 1533.5

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

If 3: Footing bottom elevation: -

Is boring information available? Y *If no, type ctrl-n bi* Number of borings taken: 9

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

Briefly describe material at foundation bottom elevation or around piles:
Abut #1 in loose to very dense sand, some silt, trace of gravel
Abut #2 in loose to very dense sand, some silt, little gravel

Comments:
Footing bottom elevation for right abutment is 1533.5; for left abutment is 1534.5
The low superstructure elevations are the bridge seat elevations from the bridge plans.
According to the plans, the channel for Cold Brook was relocated and WILM BR53 goes over this relocated channel.

Cross-sectional Data

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

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

Comments: **The station and elevation measurements are in feet.**

Station	**990**	**1000**	**1010**	-	-	-	-	-	-	-	-
Feature	**LAB**		**RAB**	-	-	-	-	-	-	-	-
Low cord elevation	**1554.3**	**1554.3**	**1554.3**	-	-	-	-	-	-	-	-
Bed elevation	**1544.3**	**1543.6**	**1544.3**	-	-	-	-	-	-	-	-
Low cord to bed length	**10**	**10.7**	**10**	-	-	-	-	-	-	-	-

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: 10/08/96
Computerized by: RB Date: 10/10/96
Reviewd by: EMB Date: 2/10/97

Structure Number WILMVT01000053

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. BOEHMLER Date *(MM/DD/YY)* 08 / 07 / 1996

2. Highway District Number 01 Mile marker 005020

County Windham (025) Town Wilmington (84700)

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

Route Number VT 100 Hydrologic Unit Code: 01080203

3. Descriptive comments:

Located 2.6 miles north of the intersection with VT 9 west and 0.1 mile north of the Cold Brook intersection with VT 100.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 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 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 23 *(feet)* Span length 20 *(feet)* Bridge width 59.6 *(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)*

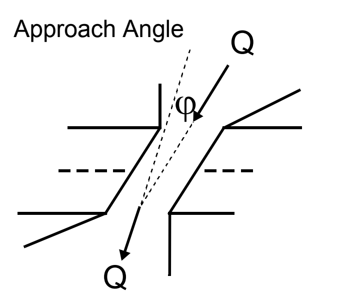
10. Embankment slope *(run / rise in feet / foot)*:
US left -- US right --

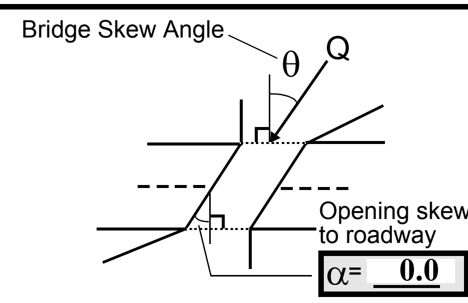
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	3	2	1	2
LBDS	2	1	1	1

*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: 0 16. Bridge skew: 0





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

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: **4**

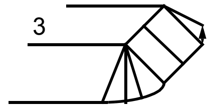
1a- Vertical abutments with wingwalls

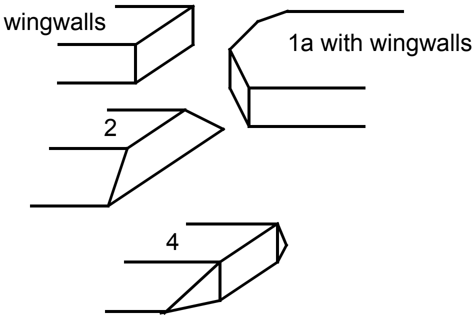
1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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





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

Pasture cover on the DS left and right banks is actually grass on the embankments of VT 100 which are the right bank of the Deerfield River. The left bank US is lawn with a house and driveway. The US right bank surface cover is also pasture except for a strip of trees and shrubs along the tributary. It is 40 ft. wide.
Values are from the VT AOT files. Measured values are the same.
The bridge is wider than it is long.

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
22.5	**7.0**			**9.0**	**1**	**3**	**7**	**7**	**0**	**0**

23. Bank width **30.0** 24. Channel width **25.0** 25. Thalweg depth **52.0** 29. Bed Material **435**

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

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

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

Both banks are heavily covered with stone fill. The stone fill extends about 300 ft. US on both banks and covers the US ends of the wingwalls. Beyond 300 ft. US the banks return to their native material of cobble and boulder with some sand and gravel.
The bed material has more gravel above 300 ft. US but many boulders are also clearly visible.
The US reach is moderately steep and artificially straight. Beyond 300 ft. US the channel begins to bend.
There is bedrock across the channel from 145 ft. to 200 ft. US.

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

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

37. Material: -

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

NO POINT BARS

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

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB **2** RB ____ *(**1**- natural bank; **2**- abutment; **3**- artificial levee)*

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
21.5		**1.0**		**2**	**7**	**7**	**-**

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

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

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

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

453

The channel through the bridge has nearly the same gradient as US from the upstream face to 45 feet under the bridge. Then the bed steepens quickly to the confluence with the Deerfield River about 20 ft. DS. Water is pooled at the confluence.

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

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

Constructed channel reach is stable.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**2**	**2**	**0**	**1.5**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**0**	**20.0**

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

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

0

0

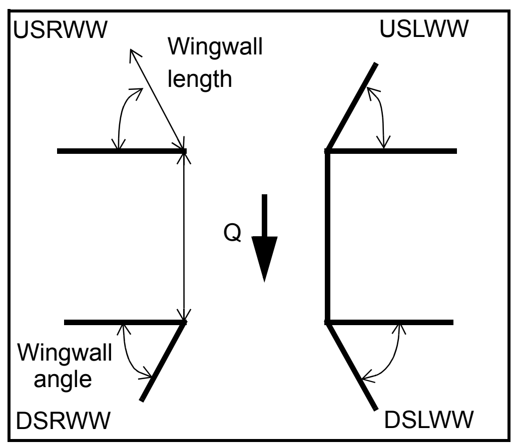
1

The DS end of the left abutment is exposed for 25 ft. from the DS face under the bridge. The exposure ranges from 0 to 1.5 ft. from the US end to the DS end.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**20.0**	
USRWW:	**Y**		**1**		**0**	**1.0**	
DSLWW:	**0**		**0**		**Y**	**61.5**	
DSRWW:	**1**		**0**		**0**	**61.5**	

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

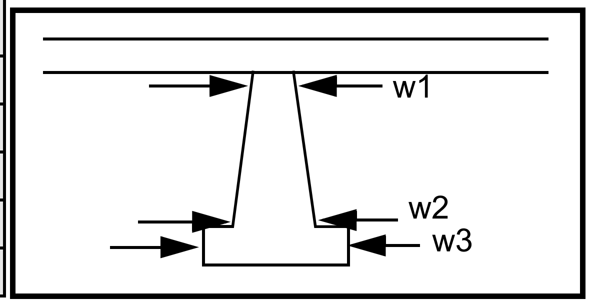
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
3
0
-
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				45.0	14.0	45.0
Pier 2				15.5	45.0	14.5
Pier 3			-	45.0	15.5	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e DS	alon	and		LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	left	g the	the		1- Solid pier, 2- column, 3- bent
88. Material	wing	wing	left		1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	wall	wall	abut		1- Round; 2- Square; 3- Pointed
90. Inclined?	foot-	from	ment	N	Y- yes; N- no
91. Attack ∠ (BF)	ing is	the	foot-	-	
92. Pushed	expo	cor-	ing.	-	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	sed 0	ner		-	
95. Cross-members	to 1	of		-	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	ft.	the		-	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	for 7	wing		-	
98. Exposure depth	ft.	wall		-	

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	RB	Bank angle (BF) LB	RB	% Veg. cover (BF) LB	RB	Bank material (BF) LB	RB	Bank erosion (BF) LB	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: - *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

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

NO PIERS

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

Point bar extent: ______ feet ____ *(US, UB, DS)* to ______ feet ____ *(US, UB, DS)* positioned **1** %LB to **1** %RB

Material: **7**

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

324
0
2
324

Is a cut-bank present? **2** *(Y or if N type ctrl-n cb)* Where? **0** *(LB or RB)* Mid-bank distance: **1**

Cut bank extent: **-** feet **Th** *(US, UB, DS)* to **e left** feet **ba** *(US, UB, DS)*

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

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

is the US right bank of the Deerfield River and the right bank is the DS right bank of the Deerfield River. On the right bank, a point bar has developed that is about 4 ft. high.

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 **NO** Enters on **DR** *(LB or RB)* Type **OP** *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

RE

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
120
35
0
DS
250
DS
60
100
324

109. G. Plan View Sketch

\- Ba

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:	WILMVT01000053	Town:	Wilmington
Road Number:	VT 100	County:	Windham
Stream:	Cold Brook		

Initials EMB   Date: 4/1/97   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	2350	3400	2330
Main Channel Area, ft2	421	484	420
Left overbank area, ft2	229	425	225
Right overbank area, ft2	76	257	72
Top width main channel, ft	52	52	52
Top width L overbank, ft	159	167	158
Top width R overbank, ft	108	193	106
D50 of channel, ft	0.2173	0.2173	0.2173
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.1	9.3	8.1
y1, average depth, LOB, ft	1.4	2.5	1.4
y1, average depth, ROB, ft	0.7	1.3	0.7
Total conveyance, approach	66394	108133	65570
Conveyance, main channel	53256	67089	52926
Conveyance, LOB	10925	29497	10559
Conveyance, ROB	2213	11547	2085
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1885.0	2109.5	1880.7
Ql, discharge, LOB, cfs	386.7	927.5	375.2
Qr, discharge, ROB, cfs	78.3	363.1	74.1
Vm, mean velocity MC, ft/s	4.5	4.4	4.5
Vl, mean velocity, LOB, ft/s	1.7	2.2	1.7
Vr, mean velocity, ROB, ft/s	1.0	1.4	1.0
Vc-m, crit. velocity, MC, ft/s	9.6	9.8	9.5
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

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	2345	2724	2330
Main channel area (DS), ft2	150.1	166	149.8
Main channel width (normal), ft	19.9	19.9	19.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	19.9	19.9	19.9
D90, ft	1.0860	1.0860	1.0860
D95, ft	1.4210	1.4210	1.4210
Dc, critical grain size, ft	1.2484	1.3170	1.2386
Pc, Decimal percent coarser than Dc	0.070	0.061	0.070
Depth to armoring, ft	49.99	60.82	49.37

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	2350	3400	2330
(Q) discharge thru bridge, cfs	2345	2724	2330
Main channel conveyance	21456	21456	21456
Total conveyance	21456	21456	21456
Q2, bridge MC discharge,cfs	2345	2724	2330
Main channel area, ft2	241	241	241
Main channel width (normal), ft	19.9	19.9	19.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.9	19.9	19.9
y_bridge (avg. depth at br.), ft	12.11	12.11	12.11
Dm, median (1.25*D50), ft	0.271625	0.271625	0.271625
y2, depth in contraction,ft	10.71	12.18	10.65
ys, scour depth (y2-ybridge), ft	-1.40	0.06	-1.46

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	2350	3400	2330
Q, thru bridge MC, cfs	2345	2724	2330
Vc, critical velocity, ft/s	9.55	9.77	9.55
Va, velocity MC approach, ft/s	4.48	4.36	4.48
Main channel width (normal), ft	19.9	19.9	19.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.9	19.9	19.9
qbr, unit discharge, ft2/s	117.8	136.9	117.1
Area of full opening, ft2	241.0	241.0	241.0
Hb, depth of full opening, ft	12.11	12.11	12.11
Fr, Froude number, bridge MC	0.49	0.57	0.49
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	150.1	166	149.8
**Hb, depth at downstream face, ft	7.54	8.34	7.53
**Fr, Froude number at DS face	1.00	1.00	1.00
**Cf, for downstream face (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	499	499	499
Elevation of Bed, ft	486.89	486.89	486.89
Elevation of Approach, ft	500.91	502.11	500.88
Friction loss, approach, ft	0.08	0.08	0.08
Elevation of WS immediately US, ft	500.83	502.03	500.80
ya, depth immediately US, ft	13.94	15.14	13.91
Mean elevation of deck, ft	501.81	501.81	501.81
w, depth of overflow, ft (>=0)	0.00	0.22	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.95	0.97
**Cc, for downstream face (<=1.0)	0.97	0.95	0.97
Ys, scour w/Chang equation, ft	0.67	2.65	0.58
Ys, scour w/Umbrell equation, ft	-2.38	-1.95	-2.40

**=for UNsubmerged orifice flow only.

**Ys, scour w/Chang equation, ft	5.18	6.40	5.12
**Ys, scour w/Umbrell equation, ft	2.19	1.82	2.18

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	10.71	12.18	10.65
WSEL at downstream face, ft	493.62	495.28	493.58
Depth at downstream face, ft	6.73	8.39	6.69
Ys, depth of scour (Laursen), ft	3.98	3.78	3.96

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	2350	3400	2330	2350	3400	2330
a', abut.length blocking flow, ft	170.8	178.7	170.6	128.7	213.6	126.5
Ae, area of blocked flow ft2	310	511.4	305.1	198.8	257.5	194.9
Qe, discharge blocked abut.,cfs	682.4	--	672.1	--	--	513.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.20	2.46	2.20	2.62	2.22	2.64
ya, depth of f/p flow, ft	1.81	2.86	1.79	1.54	1.21	1.54
--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	0.288	0.256	0.290	0.372	0.284	0.374
ys, scour depth, ft	12.97	16.59	12.90	12.08	10.85	12.02

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)	170.8	178.7	170.6	128.7	213.6	126.5
y1 (depth f/p flow, ft)	1.81	2.86	1.79	1.54	1.21	1.54
a'/y1	94.11	62.44	95.39	83.32	177.18	82.10
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.29	0.26	0.29	0.37	0.28	0.37
Ys w/ corr. factor K1/0.55:						
vertical	8.75	13.28	8.65	8.11	5.79	8.10
vertical w/ ww's	7.18	10.89	7.09	6.65	4.75	6.64
spill-through	4.81	7.30	4.76	4.46	3.18	4.46

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 (DS)	1	1	1	1	1	1
y, depth of flow in bridge (DS), ft	7.54	8.34	7.53	7.54	8.34	7.53
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	3.15	3.49	3.15	3.15	3.49	3.15