LEVEL II SCOUR ANALYSIS FOR BRIDGE 10 (WNDHTH00020010) on TOWN HIGHWAY 2, crossing the MIDDLE BRANCH WILLIAMS RIVER WINDHAM, VERMONT

U.S. Geological Survey
Open-File Report 97-387

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

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By LORA K. STRIKER and EMILY C. WILD

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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Denver, CO 80225-0286

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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 10 (WNDHTH00020010) ON TOWN HIGHWAY 2, CROSSING the MIDDLE BRANCH WILLIAMS RIVER, WINDHAM, VERMONT

***By* Lora K. Striker and Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WNDHTH00020010 on Town Highway 2 crossing the Middle Branch Williams River, Windham, 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 1.44-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the predominate surface cover upstream of the bridge is pasture on the left bank and forest on the right bank. Downstream of the bridge the surface cover consists of forest on the right bank and grass on the left bank.

In the study area, the Middle Branch Williams River has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 28 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 61.4 mm (0.201 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 22, 1996, indicated that the reach was stable.

The Town Highway 2 crossing of the Middle Branch Williams River is a 25-ft-long, two-lane bridge consisting of one 22-foot concrete slab span (Vermont Agency of Transportation, written communication, March 31, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 60 degrees to the opening while the opening-skew-to-roadway is 50 degrees.

The scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along both upstream banks. The scour protection measures downstream were type -1 stone fill (less than 12 inches diameter) on the left bank and type-3 stone fill (less than 48 inches diameter) on the right bank. Scour protection measures do not exist underneath the bridge. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for modelled flows ranged from 0.9 to 2.2 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.5 to 8.8 ft along the right abutment and from 8.7 to 10.1 ft along the left abutment. The worst-case abutment scour at the right abutment occurred at the 100-year discharge and at the left abutment 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.

Saxtons River, VT. Quadrangle, 1:25,000, 1984

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 WNDHTH00020010 ***Stream*** Middle Branch Williams River

County Windham ***Road*** TH 2 ***District*** 2

Description of Bridge

Bridge length 25 ***ft*** ***Bridge width*** 35.5 ***ft*** ***Max span length*** 22 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 08/22/96

Description of stone fill Type-2 along both upstream banks. Type-1 on downstream left bank and type-3 on downstream right bank.

Abutments and wingwalls are concrete.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 60

There is a moderate channel bend in the upstream and downstream reach. (mild, moderate, severe)

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	08/22/96	0	0
Level II	08/22/96	0	0

Potential for debris The potential for debris is moderate. There is some debris caught in the vegetation along both upstream banks.

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

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with steep valley walls on both sides.

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

Date of inspection 08/22/96

DS left: Moderately sloped overbank to narrow flood plain

DS right: Narrow flood plain to steep valley wall

US left: Moderately sloped overbank

US right: Moderately sloped overbank

Description of the Channel

Average top width 28 ***ft***

Average depth 5 ***ft***

Predominant bed material Cobbles

Bank material Cobble/Boulder

The stream is sinuous but stable with semi-alluvial channel boundaries and a narrow flood plain.

08/22/96

Vegetative co Grass with trees and brush.

DS left: Trees and brush.

DS right: Trees and brush with pasture beyond tree line

US left: Trees and brush.

US right:

Do banks appear stable? Yes

If not, describe location and type of instability and date of observation.

The banks are stable due to upstream and downstream protection. There is evidence of slight lateral instability indicated by three cut-banks at the site. There is one cut-bank along the upstream left bank from 29 ft to 10 ft upstream and two along the downstream right bank from 6 ft to 23 ft downstream and 45 ft to 73 ft downstream.

Describe any obstructions in channel and date of observation.

The assessment of 08/22/96 noted some debris caught on both banks upstream.

Hydrology

Drainage area 1.44 ***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 630 ***ft³/s*** ***Q500*** 920 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(1.44/1.7)exp 0.67] with bridge number 23 in Windham. Bridge number 23 crosses the Middle Branch Williams River downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 23 is 1.7 square miles.

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 1,037.26 feet to arbitrary survey datum to obtain NGVD of 1929

Description of reference marks used to determine USGS datum. RM1 is a VTAOT benchmark brass disc on top of the upstream left abutment (elev. 500.80 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream right abutment (elev. 498.32 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	-25	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	28	1	Road Grade section
APPRO	68	2	Modelled Approach section (Templated from APTEM)
APTEM	89	1	Approach section as surveyed (Used as a template)

[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 0.055 to 0.060, and overbank "n" values ranged from 0.035 to 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 0.0289 ft/ft which was estimated from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0287 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.1 *ft*
Average low steel elevation 496.24 *ft*

100-year discharge 630 *ft^3/s*
Water-surface elevation in bridge opening 496.2 *ft*
Road overtopping? Y *Discharge over road* 2 *ft^3/s*
Area of flow in bridge opening 71 *ft^2*
Average velocity in bridge opening 8.9 *ft/s*
Maximum WSPRO tube velocity at bridge 12.6 *ft/s*

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 496.6
Amount of backwater caused by bridge 2.7 *ft*

500-year discharge 920 *ft^3/s*
Water-surface elevation in bridge opening 496.6 *ft*
Road overtopping? Y *Discharge over road* 186 *ft^3/s*
Area of flow in bridge opening 72 *ft^2*
Average velocity in bridge opening 10.2 *ft/s*
Maximum WSPRO tube velocity at bridge 12.4 *ft/s*

Water-surface elevation at Approach section with bridge 500.8
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 3.2

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

All modelled flows resulted in unsubmerged orifice flow with road overflow. Although there is 2 cfs over the road, the 100-year discharge is approximately equivalent to the incipient roadway overtopping discharge. 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 the 100-year a 500-year discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions 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	0.9	2.2	--
Depth to armoring	33.7	27.8	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
Abutment scour	8.9	10.1	--
Left abutment	8.8	8.5	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	2.3	2.4	--
Left abutment	2.3	2.4	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

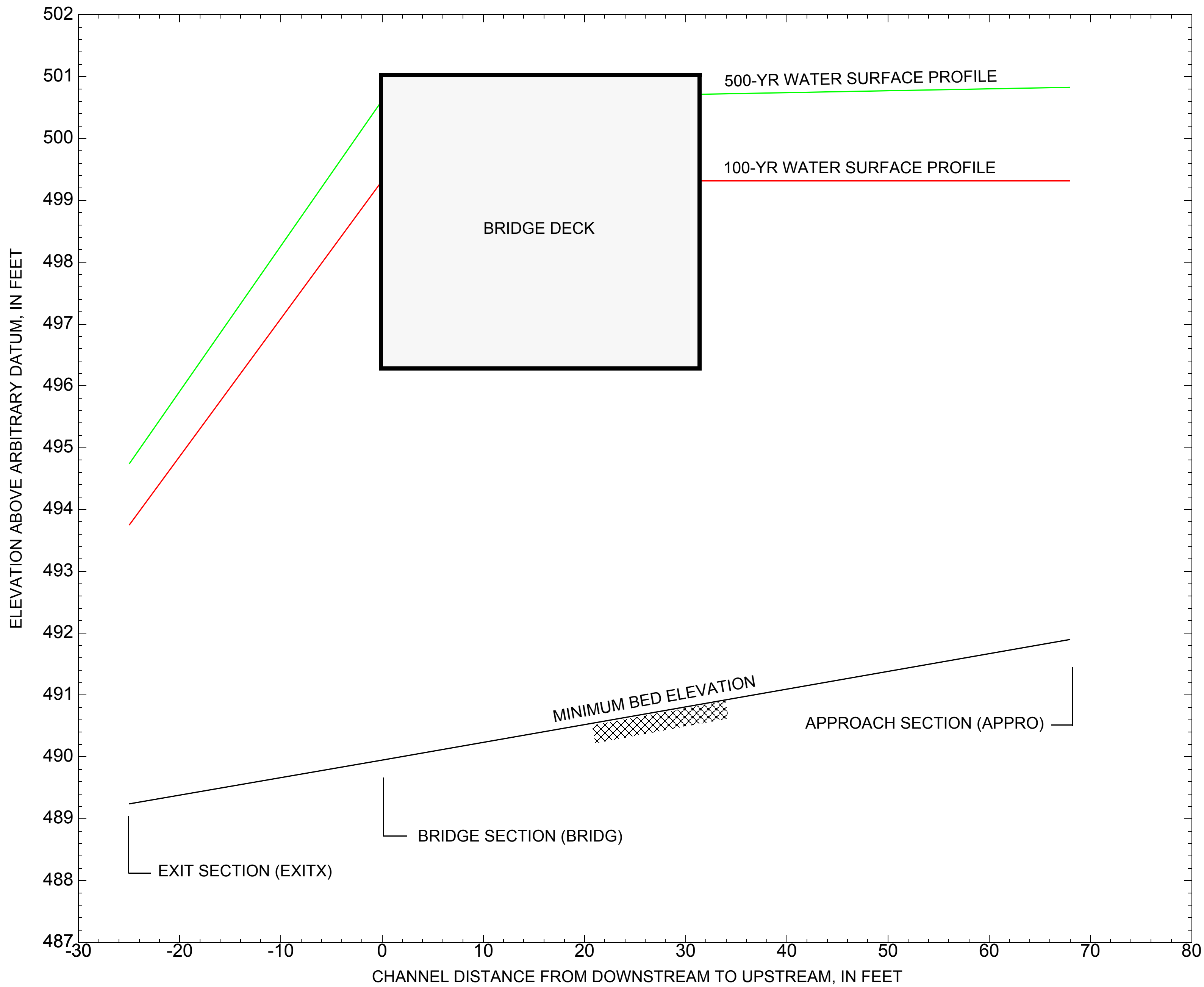

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WNDHTH00020010 on Town Highway 2, crossing the Middle Branch Williams River, Windham, Vermont.

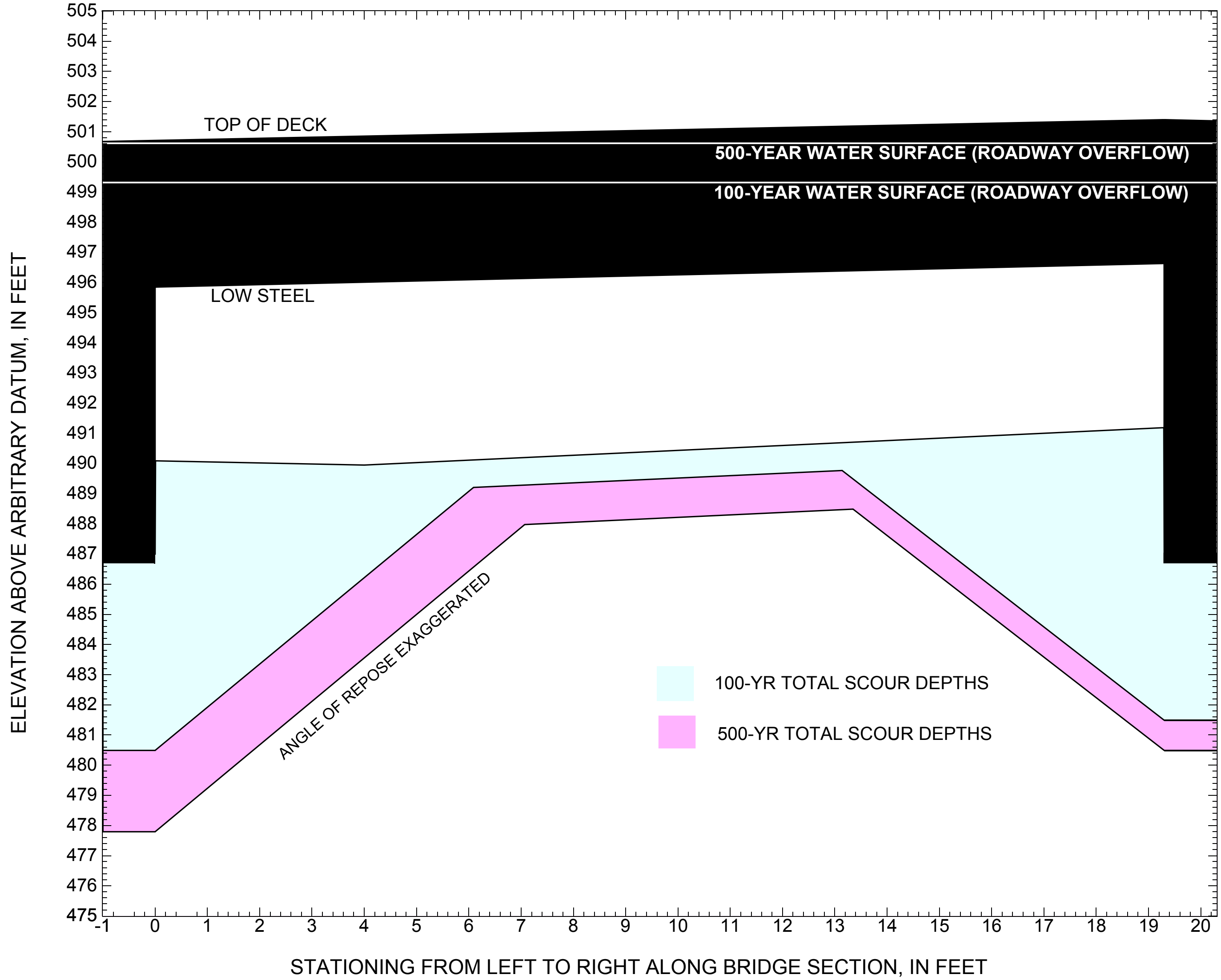

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WNDHTH00020010 on Town Highway 2, crossing the Middle Branch Williams River, Windham, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WNDHTH00020010 on Town Highway 2, crossing the Middle Branch of the Williams River, Windham, 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 630 cubic-feet per second											
Left abutment	0.0	--	495.9	486.7	490.1	0.9	8.9	--	9.8	480.3	-6.4
Right abutment	19.3	--	496.6	486.7	491.2	0.9	8.8	--	9.7	481.5	-5.2

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure WNDHTH00020010 on Town Highway 2, crossing the Middle Branch of the Williams River, Windham, 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 920 cubic-feet per second											
Left abutment	0.0	--	495.9	486.7	490.1	2.2	10.1	--	12.3	477.8	-8.9
Right abutment	19.3	--	496.6	486.7	491.2	2.2	8.5	--	10.7	480.5	-6.2

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, 1984, Saxtons River, Vermont 7.5 x 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1      U.S. Geological Survey WSPRO Input File wndh010.wsp
T2      Hydraulic analysis for structure wndhth00020010   Date: 28-JAN-97
T3      Bridge is located 0.3 miles south of VT 11 over Middle Br Williams River
*
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            630.0    920.0
SK           0.0289   0.0289
*
XS   EXITX    -25           0.
GR          -137.7 501.00    -105.6, 497.98    -34.0, 498.34     -8.7, 496.65
GR            -2.9, 493.94      0.0, 491.04      6.0, 489.69      8.5, 489.24
GR            12.4, 489.39     14.4, 489.78     17.4, 491.10     21.2, 495.36
GR            61.4, 495.61     82.7, 499.75
*
N           0.035        0.060   0.070
SA                  -8.7     21.2
*
*
XS   FULLV      0  * * *   0.0317
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.24      50.0
GR             0.0, 495.85      0.0, 490.09      4.0, 489.95     10.8, 490.47
GR            19.3, 491.19     19.3, 496.63     0.0, 495.85
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      55.1      4.3    501.1     60.1
N           0.055
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     28      35.5     1
GR         -70.0, 501.70     -41.51 499.02    -38.0, 499.35      0.0, 500.72
GR           21.7, 501.49     71.6, 503.28    206.3, 508.51
*
*
*
XT   APTEM     89
GR          -38.1, 501.70    -22.6, 500.24    -22.6, 498.02      0.0, 496.74
GR             7.7, 492.98      9.4, 492.90     12.9, 492.50     16.2, 492.96
GR            19.8, 493.80     25.1, 498.01     29.3, 500.76    181.0, 505.44
GR          191.4, 508.43
*
AS   APPRO     68   * * * 0.0287
GT
SA                   0.0   29.3
N           0.055    0.060  0.07
*
HP 1 BRIDG   496.24 1 496.24
HP 2 BRIDG   496.24 * *  630
HP 1 BRIDG   494.75 1 494.75
HP 1 APPRO   499.32 1 499.32
HP 2 APPRO   499.32 * *  630
*
HP 1 BRIDG   496.63 1 496.63
HP 2 BRIDG   496.63 * *  733
HP 1 BRIDG   495.46 1 495.46
HP 2 RDWAY   500.62 * *  186
HP 1 APPRO   500.83 1 500.83
HP 2 APPRO   500.83 * *  920
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File wndh010.wsp
        Hydraulic analysis for structure wndhth00020010   Date: 28-JAN-97
        Bridge is located 0.3 miles south of VT 11 over Middle Br Williams River
           *** RUN DATE & TIME: 06-17-97  09:42
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       71      3429      6     30                         1354
   496.24            71      3429      6     30  1.00      0     19     1354

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.24     0.0    19.3    70.7    3429.     630.   8.91

X STA.         0.0         2.0         3.2         4.2         5.1         6.0
  A(I)              7.5         4.4         3.9         3.7         3.6
  V(I)             4.19        7.09        8.14        8.52        8.83

X STA.         6.0         6.9         7.8         8.7         9.5        10.3
  A(I)              3.4         3.4         3.3         3.2         2.7
  V(I)             9.22        9.33        9.44        9.74       11.83

X STA.        10.3        10.9        11.6        12.3        13.0        13.8
  A(I)              2.5         2.5         2.5         2.6         2.6
  V(I)            12.45       12.57       12.55       12.27       11.96

X STA.        13.8        14.5        15.3        16.2        17.3        19.3
  A(I)              2.7         2.8         3.1         3.6         6.5
  V(I)            11.65       11.12       10.04        8.65        4.82

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       53      2722     12     21                          629
   494.75            53      2722     12     21  1.00      0     19      629

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      68.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       57      2745     23     25                          520
             2      148     10345     28     31                         1921
   499.32           205     13090     51     56  1.07    -22     28     2262

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      68.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.32   -22.6    28.0   205.0   13090.     630.   3.07

X STA.       -22.6       -14.5        -9.3        -4.7        -0.7         2.5
  A(I)             17.2        13.3        12.8        12.2        11.6
  V(I)             1.83        2.37        2.47        2.58        2.71

X STA.         2.5         4.5         6.1         7.4         8.5         9.6
  A(I)             10.0         9.0         8.4         7.9         7.7
  V(I)             3.16        3.52        3.75        4.00        4.08

X STA.         9.6        10.7        11.8        12.8        13.9        15.0
  A(I)              7.6         7.7         7.7         7.8         8.2
  V(I)             4.16        4.09        4.11        4.05        3.86

X STA.        15.0        16.2        17.5        19.0        21.0        28.0
  A(I)              8.5         8.8         9.7        11.7        17.4
  V(I)             3.71        3.59        3.24        2.68        1.81
```

```
       U.S. Geological Survey WSPRO Input File wndh010.wsp
       Hydraulic analysis for structure wndhth00020010   Date: 28-JAN-97
       Bridge is located 0.3 miles south of VT 11 over Middle Br Williams River
          *** RUN DATE & TIME: 06-17-97  09:42
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       72      3083      0     36                      3543156
  496.63            72      3083      0     36  1.00      0     19  3543156

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
       WSEL     LEW     REW    AREA        K        Q    VEL
     496.63     0.0    19.3    71.9    3083.     733.  10.19
X STA.        0.0        1.8        2.9        3.8        4.6        5.4
  A(I)            6.9        3.9        3.5        3.3        3.2
  V(I)           5.35       9.32      10.37      11.06      11.62

X STA.        5.4        6.2        7.0        7.8        8.6        9.4
  A(I)            3.1        3.0        3.0        3.0        2.9
  V(I)          11.93      12.22      12.18      12.38      12.44

X STA.        9.4       10.2       11.0       11.8       12.6       13.5
  A(I)            3.0        3.0        3.0        3.1        3.2
  V(I)          12.26      12.32      12.24      11.91      11.57

X STA.       13.5       14.3       15.3       16.3       17.4       19.3
  A(I)            3.2        3.4        3.6        4.0        6.7
  V(I)          11.52      10.69      10.21       9.10       5.47

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       62      3359     12     22                          791
  495.46            62      3359     12     22  1.00      0     19      791

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      28.

       WSEL     LEW     REW    AREA        K        Q    VEL
     500.62   -58.5    -2.8    41.0    1496.     186.   4.54
X STA.      -58.5      -50.1      -47.6      -45.9      -44.4      -43.2
  A(I)            3.3        2.3        1.9        1.8        1.6
  V(I)           2.80       4.11       4.77       5.12       5.69

X STA.      -43.2      -42.2      -41.2      -40.2      -39.1      -37.8
  A(I)            1.6        1.5        1.6        1.6        1.6
  V(I)           5.81       6.03       6.00       6.00       5.73

X STA.      -37.8      -36.5      -35.1      -33.5      -31.8      -29.9
  A(I)            1.7        1.7        1.8        1.8        1.9
  V(I)           5.59       5.48       5.27       5.10       4.78

X STA.      -29.9      -27.8      -25.2      -22.0      -17.6       -2.8
  A(I)            2.0        2.2        2.4        2.7        3.9
  V(I)           4.67       4.24       3.85       3.42       2.36

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      68.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       99      5129     35     38                          943
            2      191     15441     29     33                         2772
            3        7        75     22     22                           24
  500.83           298     20645     86     92  1.15    -34     51     2922

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      68.
       WSEL     LEW     REW    AREA        K        Q    VEL
     500.83   -35.3    51.1   297.7   20645.     920.   3.09
```

WSPRO OUTPUT FILE (continued)

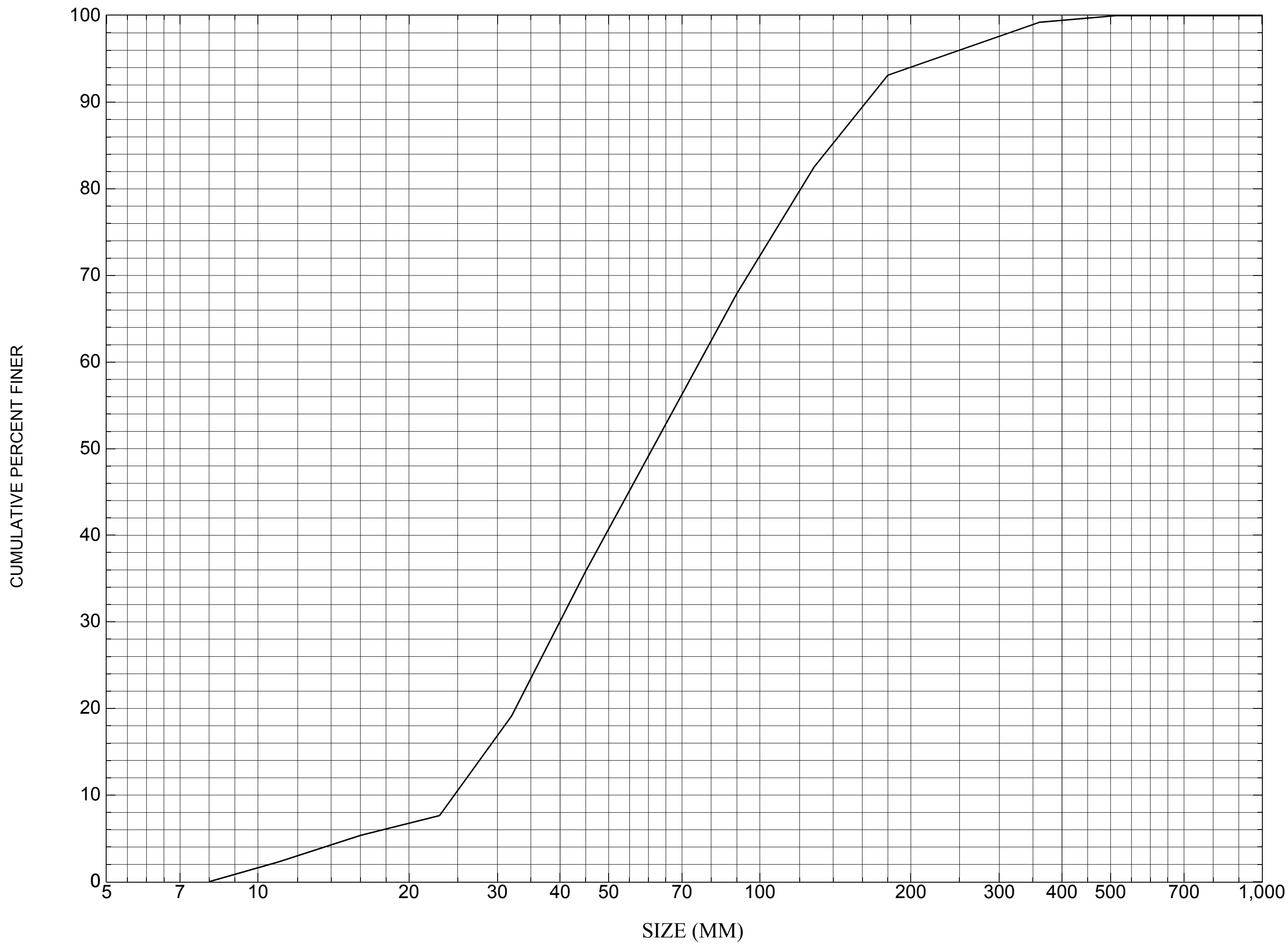
```
X STA.       -35.3      -16.1      -11.1       -6.9       -3.2        0.1
  A(I)            31.1       19.6       17.4       16.5       14.9
  V(I)            1.48       2.35       2.64       2.80       3.08

X STA.         0.1        2.8        4.8        6.4        7.8        9.0
  A(I)            14.7       13.0       11.8       11.4       10.5
  V(I)            3.13       3.53       3.91       4.02       4.37

X STA.         9.0       10.2       11.5       12.7       13.9       15.2
  A(I)            10.5       10.6       10.6       10.8       11.3
  V(I)            4.39       4.32       4.36       4.27       4.07

X STA.        15.2       16.5       18.0       19.7       22.2       51.1
  A(I)            11.5       12.5       13.1       16.6       29.4
  V(I)            4.01       3.69       3.51       2.77       1.57
```

```
        U.S. Geological Survey WSPRO Input File wndh010.wsp
        Hydraulic analysis for structure wndhth00020010   Date: 28-JAN-97
        Bridge is located 0.3 miles south of VT 11 over Middle Br Williams River
           *** RUN DATE & TIME: 06-17-97  09:42

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******     -2       73  1.15 *****  494.90  493.34     630  493.75
       -24 ******     20     3706  1.00 ***** *******    0.84    8.59

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.86     494.47     494.13
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.25     501.79    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.25     501.79     494.13

FULLV:FV       25     -2       72  1.18  0.74  495.67  494.13     630  494.49
         0     25     20     3620  1.00  0.02    0.02    0.86    8.73
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.93     496.57     496.15
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.99     507.83    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.99     507.83     496.15

APPRO:AS       68     -7       78  1.05  1.93  497.62  496.15     630  496.57
        68     68     24     3865  1.03  0.00    0.02    0.92    8.09
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   500.10       0.00     494.77     499.02
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   502.01         0.       630.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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       25      0       71  1.23 *****  497.47  494.75     629  496.24
         0 ******     19     3429  1.00 ***** *******    0.82    8.89

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.500  0.000  496.24 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      28.    33.  0.08  0.16  499.40    0.00      2.  499.32
```

```
            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
  LT:      2.     6.   -45.   -38.   0.3   0.1   2.1   2.2   0.2   3.0
  RT:      0.    15.     9.    24.   0.5   0.3   4.0   7.9   0.8   3.0

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
 APPRO:AS       13    -22       205  0.16  0.15  499.48  496.15     630  499.32
        68     17     28    13080  1.07  0.00    0.00    0.28    3.08

       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     -25.    -3.    20.    630.    3706.      73.    8.59  493.75
   FULLV:FV       0.    -3.    20.    630.    3620.      72.    8.73  494.49
   BRIDG:BR       0.     0.    19.    629.    3429.      71.    8.89  496.24
   RDWAY:RG      28.*******     2.      2.       0.       0.    1.00  499.32
   APPRO:AS      68.   -23.    28.    630.   13080.     205.    3.08  499.32

  SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.34    0.84  489.24  501.00************  1.15  494.90  493.75
   FULLV:FV    494.13    0.86  490.03  501.79  0.74  0.02  1.18  495.67  494.49
   BRIDG:BR    494.75    0.82  489.95  496.63************  1.23  497.47  496.24
   RDWAY:RG  ****************  499.02  508.51  0.08******  0.16  499.40  499.32
   APPRO:AS    496.15    0.28  491.90  507.83  0.15  0.00  0.16  499.48  499.32




       U.S. Geological Survey WSPRO Input File wndh010.wsp
       Hydraulic analysis for structure wndhth00020010   Date: 28-JAN-97
       Bridge is located 0.3 miles south of VT 11 over Middle Br Williams River
          *** RUN DATE & TIME: 06-17-97  09:42

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******     -4       97  1.40 *****  496.14  494.28     920  494.74
       -24 ******     21     5410  1.00 ***** *******    0.85    9.49

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.88     495.45     495.07
 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.24     501.79    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.24     501.79     495.07

FULLV:FV       25     -3       95  1.45  0.74  496.92  495.07     920  495.46
         0     25     21     5279  1.00  0.03    0.01    0.87    9.67
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.92     497.58     497.29
 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.96     507.83    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.96     507.83     497.29

APPRO:AS       68    -22      119  1.07  1.73  498.64  497.29     920  497.57
        68     68     25     6309  1.14  0.00   -0.01    0.93    7.75
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   502.22       0.00     495.89     499.02
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.28     500.62     500.79     496.24
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WNDHTH00020010, in Windham, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WNDHTH00020010

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 31 / 95

Highway District Number *(I - 2; nn)* 02

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

Town *(FIPS place code; I - 4; nnnnn)* 84850

Mile marker *(I - 11; nnn.nnn)* 006780

Waterway *(I - 6)* The Middle Branch Williams River

Road Name *(I - 7):* FAS 123

Route Number TH002

Vicinity *(I - 9)* 0.3 MI S JCT. VT.11

Topographic Map Saxtons River

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43128

Longitude *(i - 17; nnnnn.n)* 72443

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20012300101323

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

Maximum span length *(I - 48; nnnn)* 0022

Year built *(I - 27; YYYY)* 1961

Structure length *(I - 49; nnnnnn)* 000025

Average daily traffic, ADT *(I - 29; nnnnnn)* 000450

Deck Width *(I - 52; nn.n)* 355

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

Channel & Protection *(I - 61; n)* 7

Opening skew to Roadway *(I - 34; nn)* 45

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

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*) 21.46

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

Vertical clearance from streambed (*nnn.n ft*) 6

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

Waterway of full opening (*nnn.n* ft^2) 128.8

Comments:

The structural inspection report states that the structure is a concrete slab bridge. Both concrete abutments are relatively clean. The right abutment stem has a 1/8 inch wide vertical crack extending up through the third weep hole down from the upstream end. The downstream ends of both stems have minor scaling along the flow line. All four wingwalls are in good condition. The waterway has a moderate turn through structure. The streambed consists of stone and gravel with some random boulders. The banks are well protected. There are no footings in view. There was no channel scour or embankment erosion noted in the VTAOT files.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

-

Streambed material: Stones and gravel

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 1.443 mi^2 Lake and pond area 0 mi^2
Watershed storage *(ST)* 0 %
Bridge site elevation 1538.4 ft   Headwater elevation 2893.7 ft
Main channel length 1.635 mi
10% channel length elevation 1555.1 ft   85% channel length elevation 2263.8 ft
Main channel slope *(S)* 577.91 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 a VTAOT brass disc on top of the US left abutment (elev. 1538.058).

-

Reference Point (*MSL, Arbitrary, Other*): **MSL** Datum (*NAD27, NAD83, Other*): **NGVD 1929**

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **1524.0**

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

If 3: Footing bottom elevation: ______

Is boring information available? **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 information available on the foundation material.

Comments:
The elevations were taken from a plan copy in the structural folder.

Cross-sectional Data

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

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

Comments: **There is no cross section information available.**

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

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

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

Comments: **There is no cross section information available.**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **09/30/96**

Computerized by: **RB** Date: **09/30/96**

Reviewd by: **LKS** Date: **04/15/97**

Structure Number **WNDHTH00020010**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. WILD** Date *(MM/DD/YY)* **08** / **22** / 19**96**

2. Highway District Number **02** Mile marker **006780**

County **025 WINDHAM** Town **84850 WINDHAM**

Waterway *(I - 6)* **Middle Branch of the Williams River** Road Name **FAS 123**

Route Number **TH002** Hydrologic Unit Code: **01080107**

3. Descriptive comments:

The bridge is located 0.3 miles south of the junction with VT 11. The structure is a concrete slab bridge. The bridge is located on the town line between Windham (on the right bank) and Londonderry (on the left bank).

B. Bridge Deck Observations

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

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

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

7. Bridge length **25** *(feet)* Span length **22** *(feet)* Bridge width **35.5** *(feet)*

Road approach to bridge:

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

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

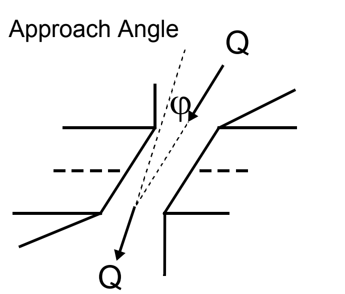
10. Embankment slope (*run / rise in feet / foot*):
US left **6.1:1** US right **2.4:1**

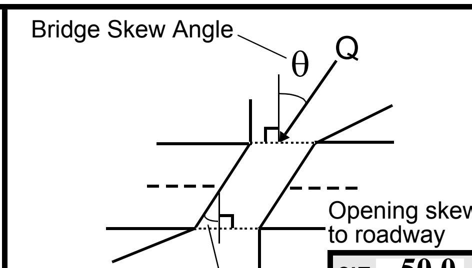
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	-
RBUS	2	1	0	-
RBDS	0	-	2	1
LBDS	1	1	0	-

*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: **5** 16. Bridge skew: **60**





α= **50.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **55** feet **US** *(US, UB, DS)* to **4** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **4** feet **DS** *(US, UB, DS)* to **32** feet **DS**

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

18. Bridge Type: **4**

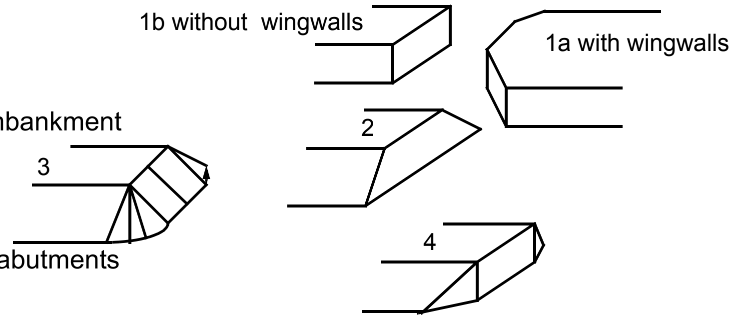
1a- Vertical abutments with wingwalls

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.)

7. The values are from the VTAOT files. The measured bridge dimensions are the same.
4. TH 2 runs along the right bank US with a forested hill beyond. The left bank US is an open field with a few buildings on it and trees along the immediate bank. The right bank DS is forested with a small cottage on the hillside. TH 2 again runs parallel to the stream on the DS left bank for about 100 ft at this point the stream bends.

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
34.0	**4.0**			**4.0**	**2**	**1**	**45**	**45**	**1**	**1**

23. Bank width **25.0** 24. Channel width **35.0** 25. Thalweg depth **25.5** 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.):

30. The left bank protection extends from 106 ft US to the end of the US left wingwall. The right bank protection extends from greater than 300 ft US to the end of the US right wingwall.
27. Bank protection on both banks consists of placed cobbles and boulders.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **3UB** 35. Mid-bar width: **10.5**

36. Point bar extent: **35** feet **US** (US, UB) to **30** feet **UB** (US, UB, DS) positioned **50** %LB to **100** %RB

37. Material: **32**

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

-

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: **27** 42. Cut bank extent: **29** feet **US** (US, UB) to **10** 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.):

There is less bank protection at the cut-bank along the left bank. The protection in the cut-bank area has failed from the impact.

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 08/22/96.

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 at the 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
12.0		**0.5**		**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.):

43

-

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

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

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

70. Debris and Ice Comments:

1

65. There is debris caught in the vegetation along both banks.

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		30	90	2	0	-	-	90.0
RABUT	1	0	90			2	0	14.0

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.):

-

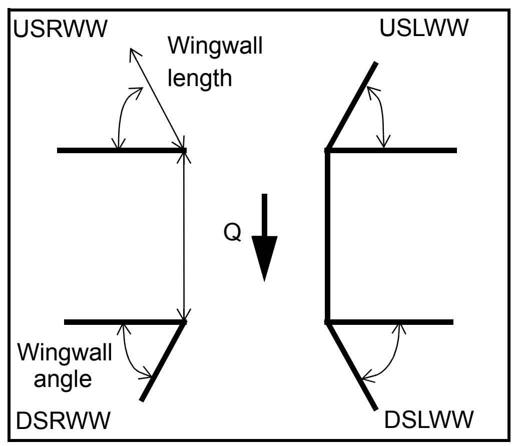
-

1

The main channel flow is along the left abutment.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						14.0	
USRWW:	Y		1		0	0.5	
DSLWW:	-		-		Y	55.5	
DSRWW:	1		0		-	54.5	



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

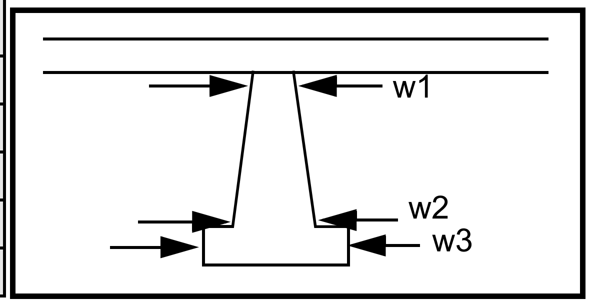
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	**110.0**			**7.0**	**10.0**	**15.5**
Pier 2			**110.0**	**10.0**	**11.5**	**7.5**
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	The	re	are	no	pier

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

Bank protection type (Qmax): LB the RB bri Bank protection condition: LB dge. 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.):

1
3
342
5432
1
2
453

101. Is a drop structure present? **1** *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

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

105. Drop structure comments (eg. downstream scour depth):
1
1
The right bank protection extends from 17 ft DS to 45 ft DS. After 45 ft DS, the right bank is moderately eroded. In this area there are trees leaning into the channel. The right bank protection is slumped into the channel from 6 ft DS to 23 ft DS at the cut-bank. The right bank material includes boulder protection. The left bank protection extends from the end of the wingwall at 26 ft DS to 42 ft DS. The left bank erosion

106. Point/Side bar present? ext (Y or N. if N type ctrl-n pb) Mid-bar distance: ends Mid-bar width: from

Point bar extent: 53 ft feet DS (US, UB, DS) to to 69 feet ft (US, UB, DS) positioned DS %LB to . %RB

Material: _____

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

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

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

Bank damage: NO (1- eroded and/or creep; 2- slip failure; 3- block failure)

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

DROP STRUCTURE

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

Scour dimensions: Length Y Width 27 Depth: 5.2 Positioned 14 %LB to DS %RB

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

38
DS
0
45

Are there major confluences? 32 (Y or if N type ctrl-n mc) How many? 4

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

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

Confluence comments (eg. confluence name):

13
6

F. Geomorphic Channel Assessment

107. Stage of reach evolution DS

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)*:

23

DS

2

The bank protection has failed and is slumped into the channel. An additional cut bank is from 45 ft DS to 73 ft DS on the right bank. Mid-bank distance is at 60 ft DS. The bank in this area has been eroded.

N

-

-

-

-

-

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: WNDHTH00020010 Town: WINDHAM
Road Number: FAS 123 County: WINDHAM
Stream: Middle Branch Williams River

Initials LKS Date: 06/17/97 Checked: RF

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	630	920	0
Main Channel Area, ft2	148	191	0
Left overbank area, ft2	57	99	0
Right overbank area, ft2	0	7	0
Top width main channel, ft	28	29	0
Top width L overbank, ft	23	35	0
Top width R overbank, ft	0	22	0
D50 of channel, ft	0.20135	0.20135	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.3	6.6	ERR
y1, average depth, LOB, ft	2.5	2.8	ERR
y1, average depth, ROB, ft	ERR	0.3	ERR
Total conveyance, approach	13090	20645	0
Conveyance, main channel	10345	15441	0
Conveyance, LOB	2745	5129	0
Conveyance, ROB	0	75	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	497.9	688.1	ERR
Ql, discharge, LOB, cfs	132.1	228.6	ERR
Qr, discharge, ROB, cfs	0.0	3.3	ERR
Vm, mean velocity MC, ft/s	3.4	3.6	ERR
Vl, mean velocity, LOB, ft/s	2.3	2.3	ERR
Vr, mean velocity, ROB, ft/s	ERR	0.5	ERR
Vc-m, crit. velocity, MC, ft/s	8.7	9.0	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

 Bridge Section                      Q100     Q500     Other Q

   (Q) total discharge, cfs          630      920      0
   (Q) discharge thru bridge, cfs    630      733      0
   Main channel conveyance           3429     3083     0
   Total conveyance                  3429     3083     0
 Q2, bridge MC discharge,cfs         630      733      ERR
   Main channel area, ft2            71       72       0
   Main channel width (normal), ft   12.4     12.4     0.0
   Cum. width of piers in MC, ft     0.0      0.0      0.0
 W, adjusted width, ft               12.4     12.4     0
 y_bridge (avg. depth at br.), ft    5.73     5.81     ERR
 Dm, median (1.25*D50), ft           0.251688 0.251688 0
 y2, depth in contraction,ft           5.32     6.06   ERR

 ys, scour depth (y2-ybridge), ft    -0.40    0.25     N/A


 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  630      733      N/A
   Main channel area (DS), ft2       53       62       0
   Main channel width (normal), ft   12.4     12.4     0.0
   Cum. width of piers, ft           0.0      0.0      0.0
   Adj. main channel width, ft       12.4     12.4     0.0
 D90, ft                             0.5344   0.5344   0.0000
 D95, ft                             0.7327   0.7327   0.0000
 Dc, critical grain size, ft         0.6789   0.6279   ERR
 Pc, Decimal percent coarser than Dc 0.057    0.063    0.000

 Depth to armoring, ft               33.70    27.84    ERR
```

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	630	920	0
Q, thru bridge MC, cfs	630	733	N/A
Vc, critical velocity, ft/s	8.67	9.00	N/A
Va, velocity MC approach, ft/s	3.36	3.60	N/A
Main channel width (normal), ft	12.4	12.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	12.4	12.4	0.0
qbr, unit discharge, ft2/s	50.8	59.1	ERR
Area of full opening, ft2	71.0	72.0	0.0
Hb, depth of full opening, ft	5.73	5.81	ERR
Fr, Froude number, bridge MC	0.82	0.93	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	53	62	N/A
**Hb, depth at downstream face, ft	4.27	5.00	ERR
**Fr, Froude number at DS face	1.01	0.93	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	496.24	496.24	0
Elevation of Bed, ft	490.51	490.43	N/A
Elevation of Approach, ft	499.32	500.83	0
Friction loss, approach, ft	0.15	0.17	0
Elevation of WS immediately US, ft	499.17	500.66	0.00
ya, depth immediately US, ft	8.66	10.23	N/A
Mean elevation of deck, ft	501.11	501.11	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.89	0.82	ERR
**Cc, for downstream face (<=1.0)	0.79	0.79	ERR
Ys, scour w/Chang equation, ft	0.85	2.23	N/A
Ys, scour w/Umbrell equation, ft	-0.34	0.68	N/A

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

**Ys, scour w/Chang equation, ft	3.14	3.32	N/A
**Ys, scour w/Umbrell equation, ft	1.11	1.49	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	5.32	6.06	0.00
WSEL at downstream face, ft	494.49	495.46	--
Depth at downstream face, ft	4.27	5.00	N/A
Ys, depth of scour (Laursen), ft	1.05	1.06	N/A

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	630	920	0	630	920	0
a', abut.length blocking flow, ft	26	38.7	0	12.2	35.3	0
Ae, area of blocked flow ft2	71.6	108.3	0	50.43	77.8	0
Qe, discharge blocked abut.,cfs	171.67	--	0	136.5	211.04	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.40	2.48	ERR	2.71	2.71	ERR
ya, depth of f/p flow, ft	2.75	2.80	ERR	4.13	2.20	ERR
--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	140	140	140	50	50	50
K2	1.06	1.06	1.06	0.93	0.93	0.93
Fr, froude number f/p flow	0.255	0.250	ERR	0.235	0.322	ERR
ys, scour depth, ft	8.94	10.13	N/A	8.82	8.48	N/A

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

a'(abut length blocked, ft)	26	38.7	0	12.2	35.3	0
y1 (depth f/p flow, ft)	2.75	2.80	ERR	4.13	2.20	ERR
a'/y1	9.44	13.83	ERR	2.95	16.02	ERR

Skew correction (p. 49, fig. 16)	1.11	1.11	1.11	0.83	0.83	0.83
Froude no. f/p flow	0.25	0.25	N/A	0.23	0.32	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship

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

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.82	0.93	0	0.82	0.93	0
y, depth of flow in bridge, ft	5.70	5.80	0.00	5.70	5.80	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	2.25	2.38	ERR	2.25	2.38	ERR
Fr<=0.8 (spillthrough abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (spillthrough abut.)	1.99	2.10	ERR	1.99	2.10	ERR