LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (RYEGTH00050004) on TOWN HIGHWAY 5, crossing the WELLS RIVER, RYEGATE, VERMONT

Open-File Report 97-765

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

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By MICHAEL A. IVANOFF AND ROBERT E. HAMMOND

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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 4 (RYEGTH00050004) ON TOWN HIGHWAY 5, CROSSING THE WELLS RIVER, RYEGATE, VERMONT

By **Michael A. Ivanoff and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure RYEGTH00050004 on Town Highway 5 crossing the Wells River, Ryegate, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in eastern Vermont. The 84.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover includes shrubs and brush on the upstream left bank and downstream right bank of the bridge. The upstream right bank and downstream left bank of the bridge is forested.

In the study area, the Wells River has an incised, sinuous channel with a slope of approximately 0.008 ft/ft, an average channel top width of 107 ft and an average bank height of 11 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 67.4 mm (0.221 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 21, 1995, indicated that the reach was laterally unstable with mass wasting along the upstream right bank.

The Town Highway 5 crossing of the Wells River is a 108-ft-long, two-lane bridge consisting of a 100-foot steel-beam span (Vermont Agency of Transportation, written communication, March 27, 1995). The opening length of the structure parallel to the bridge face is 93.4 ft. The bridge is supported by vertical, stone block abutments with wingwalls. The channel is skewed approximately 50 degrees to the opening while the opening-skew-to-roadway is 45 degrees.

The scour protection counter-measures at the site included type-1 stone fill (less than 12 inches diameter) along the downstream left road embankment. Also, type-2 stone fill (less than 36 inches diameter) along the upstream right wingwall, extending 30 feet upstream along the right bank, along the downstream end of the downstream right wingwall, along the downstream right road embankment, and along the downstream left bank below the old railroad bed. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. 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 1.8 to 2.6 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 10.2 to 22.6 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Groton, VT. Quadrangle, 1:24,000, 1973.
Woodsville, VT. Quadrangle, 1:24,000, 1973

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 RYEGTH00050004 ***Stream*** Wells River

County Caledonia ***Road*** TH 5 ***District*** 7

Description of Bridge

Bridge length 108 ***ft*** ***Bridge width*** 21.2 ***ft*** ***Max span length*** 100 ***ft***

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

Abutment type Vertical, stone blocks ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 8/21/95

Description of stone fill Type-2, around the upstream right wingwall, the downstream end of the downstream right wingwall, and the downstream left bank.

Abutments and wingwalls are grouted stone blocks.

Yes

Is bridge skewed to flood flow according to ___ survey? 50 ***Angle***

No

8/21/95

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	0	0	8/21/
Level II	95	0	0

Potential for debris Low. There is some debris caught on old pilings three feet streamward of the right abutment footing and upstream along the right cut bank.

Describe any features near or at the bridge that may affect flow (include observation date) A scour hole was observed on the streamward side of a few large boulders on the upstream right bank as of 8/21/95.

Description of the Geomorphic Setting

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

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

Date of inspection 8/21/95

DS left: Steep channel bank to a moderately sloped overbank.

DS right: Steep channel bank to a moderately sloped overbank.

US left: Steep channel bank to a narrow flood plain

US right: Steep valley wall

Description of the Channel

Average top width 107 *ft* ***Average depth*** 11 *ft*

Predominant bed material Gravel / Boulder ***Bank material*** Gravel/Boulder

Sinuous with semi-alluvial channel boundaries and a narrow flood plain.

8/21/95

Vegetative co Trees and brush.

DS left: Trees and brush.

DS right: Trees and brush with pasture on the flood plain.

US left: Trees and brush.

US right: No

Do banks appear stable? Severe fluvial erosion is occurring along the upstream right bank. ***If not, describe location and type of instability and date of observation.***

The assessment of 8/21/95 noted some debris is caught on the boulders in the channel upstream.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 84.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description Wells River at Wells River, VT

USGS gage number 01139000

Gage drainage area 98.4 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 5,720 ***ft³/s*** ***Q500*** 7,210 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(84.7/98.4)exp 0.7] with gage 01139000 at Wells River, VT. The 100- and 500- year discharges at the gage were developed using a log-Pearson type-III analysis of annual peak-flow data (Interagency Advisory Committee on Water Data, 1982). These discharge values are within a range of several flood frequency curves based on empirical relationships for this site (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans Subtract 595.9 ft from the USGS arbitrary survey datum to obtain VTAOT plans' datum. Subtract 0.4 ft from the USGS arbitrary survey datum to obtain National Geodetic Vertical Datum of 1929.

Description of reference marks used to determine USGS datum. RM1 is a USGS brass tablet marked MR8-1933 on top of the downstream end of the right abutment (elev. 698.04 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 699.36 ft, arbitrary survey datum).

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-94	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	20	1	Road Grade section
APPRO	109	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.

[2] Cross-section development: (1) survey at SRD, (2) shift of survey data to SRD, (3) modification of survey data, (4) composite bridge section, (5) other.

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 0.050, and the overbank "n" value was 0.050.

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 0.008 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1988).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 699.2 *ft*
Average low steel elevation 695.6 *ft*

100-year discharge 5,720 *ft*^{3}*/s*
Water-surface elevation in bridge opening 690.0 *ft*
Road overtopping? No *Discharge over road* -- *ft*^{3}*/s*
Area of flow in bridge opening 425 *ft*^{2}
Average velocity in bridge opening 13.5 *ft/s*
Maximum WSPRO tube velocity at bridge 16.4 *ft/s*

Water-surface elevation at Approach section with bridge 693.3
Water-surface elevation at Approach section without bridge 693.0
Amount of backwater caused by bridge 0.3 *ft*

500-year discharge 7,210 *ft*^{3}*/s*
Water-surface elevation in bridge opening 690.9 *ft*
Road overtopping? No *Discharge over road* -- *ft*^{3}*/s*
Area of flow in bridge opening 485 *ft*^{2}
Average velocity in bridge opening 14.9 *ft/s*
Maximum WSPRO tube velocity at bridge 18.1 *ft/s*

Water-surface elevation at Approach section with bridge 694.7
Water-surface elevation at Approach section without bridge 694.3
Amount of backwater caused by bridge 0.4 *ft*

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.

Contraction scour was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

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

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	1.8	2.6	--
Depth to armoring	18.6	28.8	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	10.2	11.8	--
Right abutment	20.6	22.6	--
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	2.6	3.1	--
Right abutment	2.6	3.1	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

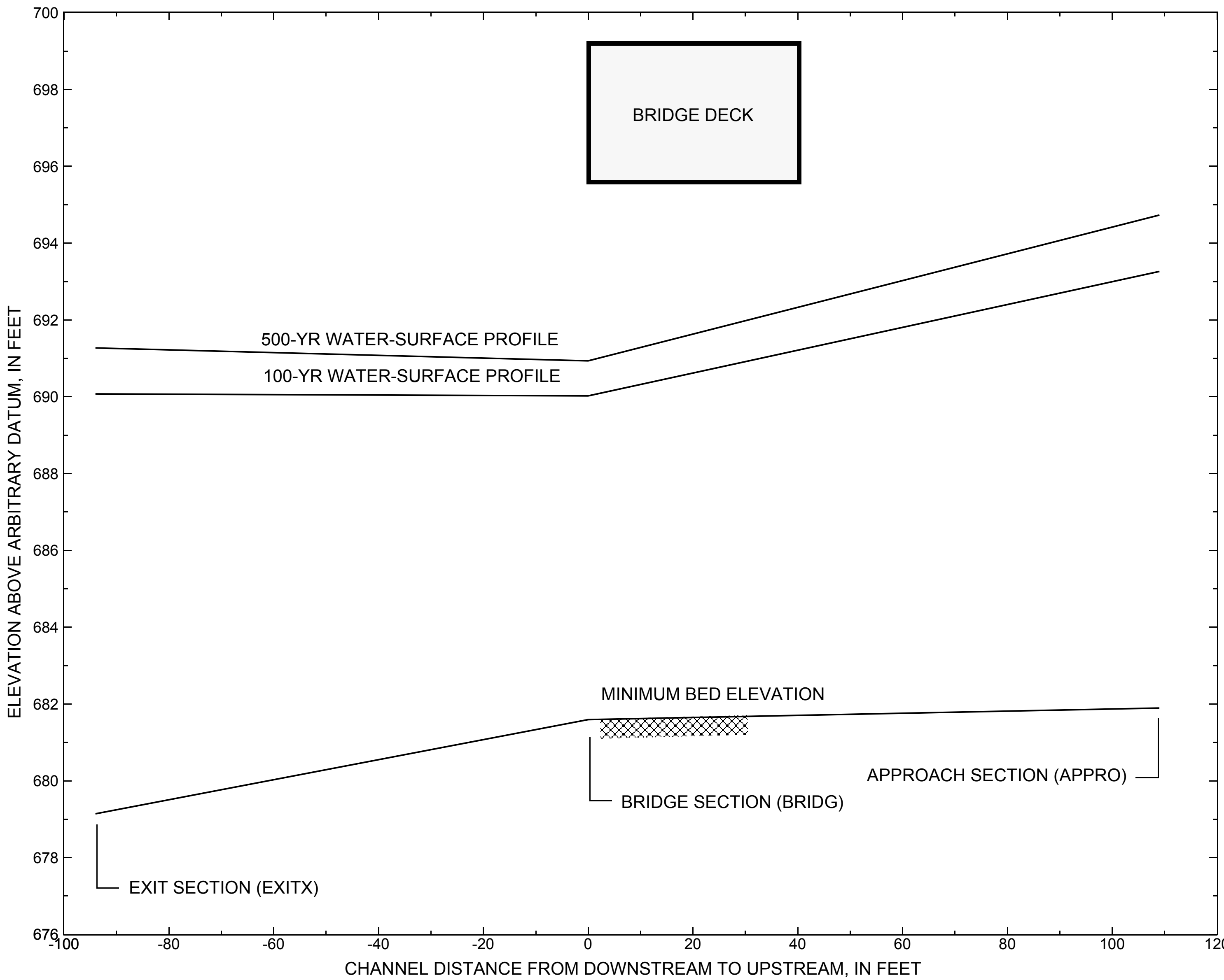

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RYEGTH00050004 on Town Highway 5, crossing the Wells River, Ryegate, Vermont.

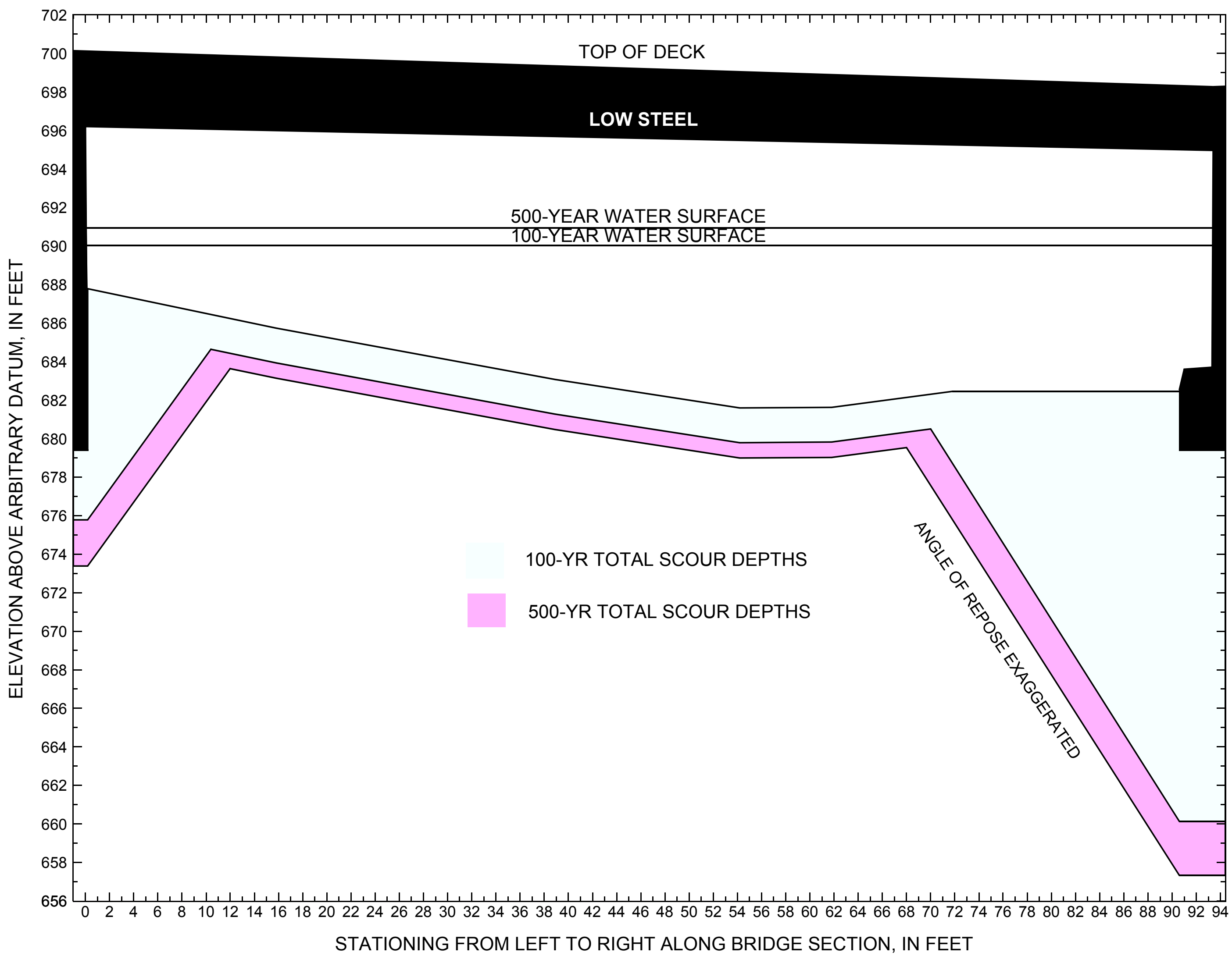

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RYEGTH00050004 on Town Highway 5, crossing the Wells River, Ryegate, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RYEGTH00050004 on Town Highway 5, crossing the Wells River, Ryegate, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 5,720 cubic-feet per second											
Left abutment	0.0	98.6	696.2	679.4	687.8	1.8	10.2	--	12.0	675.8	-3.6
Right abutment	93.4	97.3	695.0	679.4	682.5	1.8	20.6	--	22.4	660.1	-19.3

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 RYEGTH00050004 on Town Highway 5, crossing the Wells River, Ryegate, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 7,210 cubic-feet per second											
Left abutment	0.0	98.6	696.2	679.4	687.8	2.6	11.8	--	14.4	673.4	-6.0
Right abutment	93.4	97.3	695.0	679.4	682.5	2.6	22.6	--	25.2	657.3	-22.1

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, 1973, Woodsville, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1988, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ryeg004.wsp
T2        Hydraulic analysis for structure RYEGTH00050004   Date: 13-JUN-97
T3        Bridge 4 on Town Highway 5 over the Wells River, Ryegate, VT  by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5720.0   7210.0
SK          0.008    0.008
*
XS   EXITX    -94
GR         -788.7, 710.27   -630.0, 703.71   -523.5, 698.01   -389.9, 695.88
GR         -245.0, 695.10   -134.4, 696.75      0.0, 692.92     22.1, 687.11
GR           25.9, 684.28     38.7, 681.55     62.5, 679.14     72.6, 681.57
GR           81.6, 684.63     87.9, 686.06     98.9, 695.28    129.7, 695.11
GR          175.9, 694.82    185.6, 694.65    267.6, 723.73
N           0.050        0.045        0.050
SA                   0.0          98.9
*
XS   FULLV       0  * * *   0.0183
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    695.58      45.0
GR            0.0, 696.20      0.2, 687.78     15.8, 685.73     38.9, 683.07
GR           54.2, 681.59     61.8, 681.62     71.8, 682.45     90.6, 682.52
GR           91.0, 683.60     93.3, 683.71     93.4, 694.96      0.0, 696.20
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      49.1 * *     55.5      7.8
N           0.040
*
*              SRD    EMBWID   IPAVE
XR   RDWAY      20      21.2     1
GR         -853.5, 725.23   -497.4, 704.53   -262.3, 699.27   -105.3, 700.73
GR           -5.4, 700.12     -5.3, 700.71     -3.9, 700.86     -2.1, 704.64
GR            0.0, 704.62     92.7, 703.42     95.4, 703.30     97.4, 699.37
GR          101.0, 699.31    101.2, 698.27    159.0, 697.68    351.1, 723.73
*
AS   APPRO    109
GR         -642.9, 723.77   -467.6, 707.49   -333.2, 700.65   -245.5, 695.86
GR         -138.0, 694.83    -11.4, 694.51      0.0, 690.08     12.8, 688.14
GR           14.4, 686.24     18.3, 686.21     26.7, 686.09     44.3, 683.89
GR           50.7, 682.71     59.6, 682.38     65.1, 681.89     75.1, 683.34
GR           83.8, 682.56     90.6, 683.96    137.2, 724.13
N           0.050        0.050
SA                 -11.4
*
HP 1 BRIDG   690.02 1 690.02
HP 2 BRIDG   690.02 * * 5720
HP 1 APPRO   693.26 1 693.26
HP 2 APPRO   693.26 * * 5720
*
HP 1 BRIDG   690.93 1 690.93
HP 2 BRIDG   690.93 * * 7210
HP 1 APPRO   694.73 1 694.73
HP 2 APPRO   694.73 * * 7210
*
EX
```

APPENDIX B:

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File ryeg004.wsp
     Hydraulic analysis for structure RYEGTH00050004   Date: 13-JUN-97
     Bridge 4 on Town Highway 5 over the Wells River, Ryegate, VT  by MAI
        *** RUN DATE & TIME: 07-18-97  09:56
 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     425.   50045.    66.    76.                        6132.
690.02          425.   50045.    66.    76.  1.00     0.    93.   6132.




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

      WSEL     LEW     REW    AREA        K        Q    VEL
    690.02     0.1    93.4   425.4   50045.    5720.  13.45

X STA.        0.1       15.9       23.7       29.8       35.0       39.3
  A(I)            36.3       26.4       23.8       22.5       20.9
  V(I)            7.87      10.83      11.99      12.70      13.68

X STA.       39.3       43.2       46.8       50.1       53.2       56.1
  A(I)            19.6       19.1       18.3       18.1       17.4
  V(I)           14.56      14.97      15.66      15.84      16.40

X STA.       56.1       59.1       62.0       65.0       68.2       71.5
  A(I)            17.5       17.5       17.4       17.8       18.4
  V(I)           16.30      16.33      16.42      16.06      15.54

X STA.       71.5       75.0       78.6       82.4       86.5       93.4
  A(I)            18.5       19.2       20.2       22.1       34.1
  V(I)           15.45      14.90      14.15      12.94       8.39

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          2     843.   94714.   110.   115.                       13272.
693.26          843.   94714.   110.   115.  1.00    -8.   101.  13272.




 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

      WSEL     LEW     REW    AREA        K        Q    VEL
    693.26    -8.2   101.4   843.2   94714.    5720.   6.78

X STA.       -8.2       14.7       22.2       28.9       34.7       39.6
  A(I)            77.7       52.9       48.7       44.7       42.2
  V(I)            3.68       5.41       5.87       6.39       6.78

X STA.       39.6       44.1       48.1       51.7       55.0       58.3
  A(I)            40.9       38.5       37.0       35.6       34.9
  V(I)            6.99       7.42       7.72       8.04       8.20

X STA.       58.3       61.5       64.5       67.5       70.8       74.2
  A(I)            35.1       33.7       34.1       34.7       35.2
  V(I)            8.16       8.48       8.38       8.24       8.12

X STA.       74.2       77.8       81.4       85.0       89.3      101.4
  A(I)            36.8       36.3       38.7       42.4       62.8
  V(I)            7.77       7.87       7.39       6.74       4.55
```

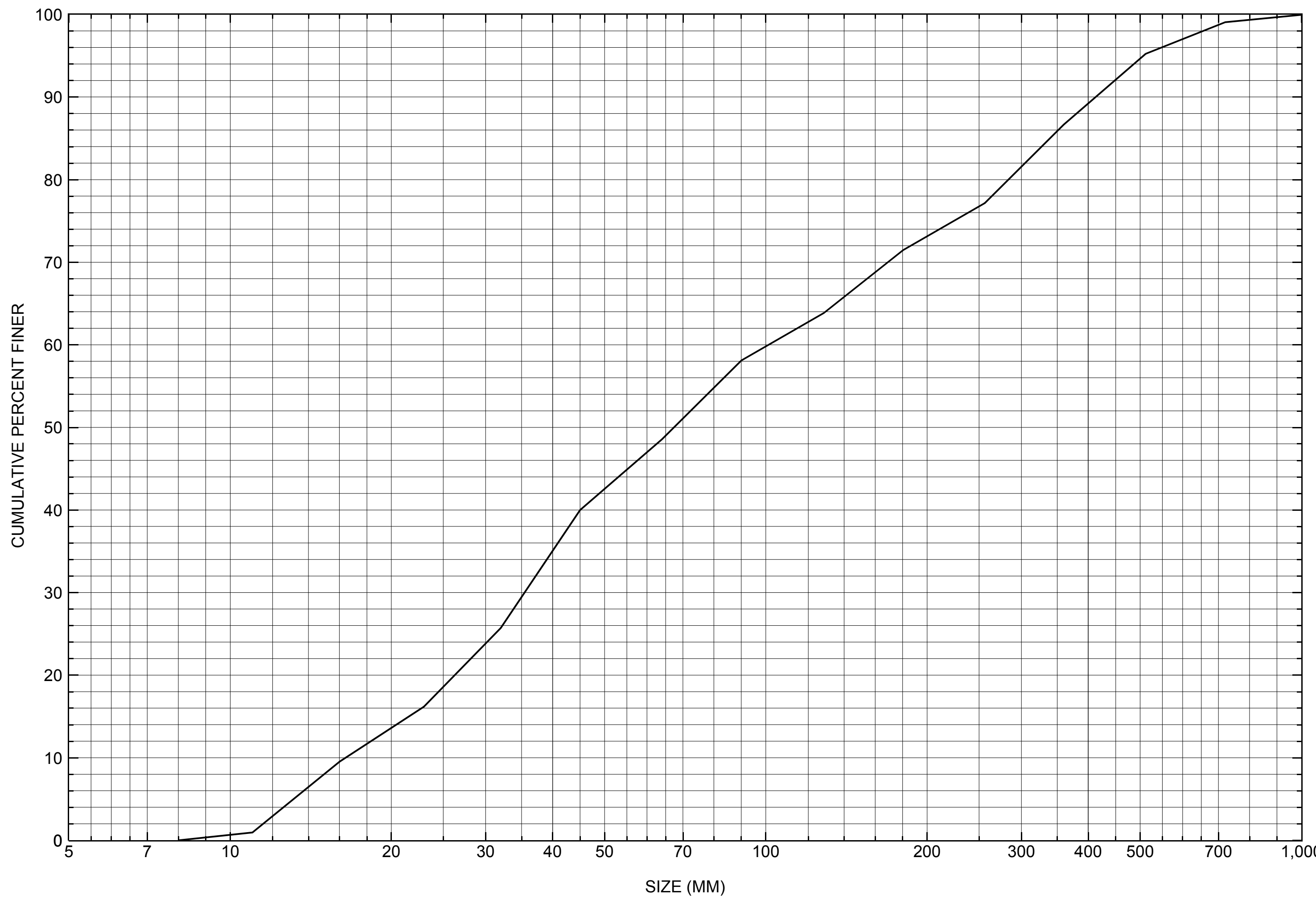
```
      U.S. Geological Survey WSPRO Input File ryeg004.wsp
      Hydraulic analysis for structure RYEGTH00050004   Date: 13-JUN-97
      Bridge 4 on Town Highway 5 over the Wells River, Ryegate, VT  by MAI
         *** RUN DATE & TIME: 07-18-97  09:56
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     485.  61373.    66.    78.                        7472.
 690.93          485.  61373.    66.    78.  1.00     0.    93.   7472.




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

      WSEL     LEW     REW    AREA        K        Q    VEL
    690.93     0.1    93.4   485.3   61373.    7210.  14.86

X STA.        0.1       14.3       22.0       28.0       33.1       37.7
  A(I)           40.7       29.6       27.0       24.8       24.0
  V(I)           8.85      12.19      13.38      14.55      15.01

X STA.       37.7       41.7       45.4       48.8       52.1       55.1
  A(I)           22.6       21.6       21.0       20.7       20.1
  V(I)          15.99      16.72      17.19      17.42      17.96

X STA.       55.1       58.2       61.2       64.2       67.4       70.9
  A(I)           20.0       20.0       20.0       20.1       21.2
  V(I)          18.04      18.06      18.02      17.92      17.02

X STA.       70.9       74.4       78.1       81.9       86.2       93.4
  A(I)           21.2       22.0       23.2       25.3       40.5
  V(I)          16.98      16.39      15.56      14.23       8.91

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1      10.      65.    87.    87.                          18.
           2     1008.  123543.   114.   121.                       16977.
 694.73          1018.  123608.   202.   208.  1.02   -98.   103.  12867.




  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

      WSEL     LEW     REW    AREA        K        Q    VEL
    694.73   -98.4   103.1  1017.8  123608.    7210.   7.08

X STA.      -98.4       10.8       19.3       25.8       31.9       37.1
  A(I)           96.5       66.4       55.5       54.3       50.9
  V(I)           3.74       5.43       6.49       6.64       7.08

X STA.       37.1       41.8       46.1       50.0       53.5       56.9
  A(I)           47.5       46.8       44.9       42.5       41.6
  V(I)           7.59       7.71       8.03       8.49       8.66

X STA.       56.9       60.3       63.6       66.8       70.2       73.8
  A(I)           41.9       41.4       40.2       42.3       42.0
  V(I)           8.60       8.70       8.96       8.53       8.58

X STA.       73.8       77.6       81.4       85.1       89.6      103.1
  A(I)           43.5       45.0       45.1       51.0       78.4
  V(I)           8.29       8.02       8.00       7.06       4.60
```

```
        U.S. Geological Survey WSPRO Input File ryeg004.wsp
        Hydraulic analysis for structure RYEGTH00050004   Date: 13-JUN-97
        Bridge 4 on Town Highway 5 over the Wells River, Ryegate, VT  by MAI
           *** RUN DATE & TIME: 07-18-97  09:56

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

EXITX:XS   ******    11.     556.  1.64 *****  691.71  688.32   5720.  690.07
      -94. ******    93.   63949.  1.00 ***** *******    0.70   10.28

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.87     690.68     690.04

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   689.57     725.45    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   689.57     725.45     690.04

FULLV:FV      94.    15.     469.  2.31  0.95  693.00  690.04   5720.  690.68
        0.    94.    91.   50503.  1.00  0.34    0.00    0.87   12.20
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            “APPRO”     KRATIO =  1.79

APPRO:AS     109.    -8.     816.  0.76  0.78  693.78 *******   5720.  693.01
      109.   109.   101.   90261.  1.00  0.00    0.00    0.45    7.01
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR      94.     0.     425.  2.82  0.96  692.83  689.72   5720.  690.02
        0.    94.    93.   49986.  1.00  0.16   -0.01    0.93   13.46

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  695.58 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      60.    -8.     843.  0.72  0.51  693.97  689.49   5720.  693.26
      109.    73.   101.   94639.  1.00  0.64    0.01    0.43    6.79

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.142  0.000   98978.     3.    96.   692.93


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -94.    11.    93.   5720.   63949.     556.   10.28  690.07
   FULLV:FV       0.    15.    91.   5720.   50503.     469.   12.20  690.68
   BRIDG:BR       0.     0.    93.   5720.   49986.     425.   13.46  690.02
   RDWAY:RG      20.**************       0.******************    1.00********
   APPRO:AS     109.    -8.   101.   5720.   94639.     843.    6.79  693.26

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    96.   98978.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS      FR#    YMIN    YMAX    HF    HO   VHD      EGL     WSEL
   EXITX:XS    688.32     0.70  679.14  723.73************  1.64  691.71  690.07
   FULLV:FV    690.04     0.87  680.86  725.45  0.95  0.34  2.31  693.00  690.68
   BRIDG:BR    689.72     0.93  681.59  696.20  0.96  0.16  2.82  692.83  690.02
   RDWAY:RG  ****************  697.68  725.23**********************************
   APPRO:AS    689.49     0.43  681.89  724.13  0.51  0.64  0.72  693.97  693.26
```

```
        U.S. Geological Survey WSPRO Input File ryeg004.wsp
        Hydraulic analysis for structure RYEGTH00050004   Date: 13-JUN-97
        Bridge 4 on Town Highway 5 over the Wells River, Ryegate, VT  by MAI
           *** RUN DATE & TIME: 07-18-97  09:56

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

EXITX:XS   ******     6.     658.  1.87 *****  693.13  689.40   7210.  691.27
      -94. ******    94.   80541.  1.00 ***** *******    0.71   10.96

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.87     691.85     691.12

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   690.77     725.45    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   690.77     725.45     691.12

FULLV:FV      94.    11.     561.  2.56  0.94  694.41  691.12   7210.  691.85
        0.    94.    93.   64785.  1.00  0.35    0.00    0.87   12.84
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.77

APPRO:AS     109.   -11.     959.  0.88  0.76  695.18 *******   7210.  694.30
      109.   109.   103.  114453.  1.00  0.00    0.00    0.46    7.52
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR      94.     0.     485.  3.44  0.99  694.36  690.76   7210.  690.93
        0.    94.    93.   61317.  1.00  0.24   -0.01    0.97   14.86

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  695.58 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      60.  -100.    1018.  0.79  0.49  695.53  690.37   7210.  694.73
      109.    72.   103.  123685.  1.02  0.68    0.01    0.56    7.08

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.178  0.000  128744.     3.    97.   694.43


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -94.     6.    94.   7210.   80541.     658.   10.96  691.27
   FULLV:FV       0.    11.    93.   7210.   64785.     561.   12.84  691.85
   BRIDG:BR       0.     0.    93.   7210.   61317.     485.   14.86  690.93
   RDWAY:RG      20.**************      0.******************     1.00********
   APPRO:AS     109.  -100.   103.   7210.  123685.    1018.    7.08  694.73

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    97.  128744.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF    HO   VHD      EGL    WSEL
   EXITX:XS    689.40    0.71  679.14  723.73************  1.87  693.13  691.27
   FULLV:FV    691.12    0.87  680.86  725.45  0.94  0.35  2.56  694.41  691.85
   BRIDG:BR    690.76    0.97  681.59  696.20  0.99  0.24  3.44  694.36  690.93
   RDWAY:RG  ****************  697.68  725.23**********************************
   APPRO:AS    690.37    0.56  681.89  724.13  0.49  0.68  0.79  695.53  694.73
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure RYEGTH00050004, in Ryegate, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number RYEGTH00050004

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 27 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 61525

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

Waterway *(I - 6)* WELLS RIVER

Road Name *(I - 7)*: -

Route Number TH05

Vicinity *(I - 9)* 0.2 MI JCT TH 5 + US 302

Topographic Map Woodsville

Hydrologic Unit Code: 01080103

Latitude *(I - 16; nnnn.n)* 44111

Longitude *(i - 17; nnnnn.n)* 72051

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10031000040310

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

Maximum span length *(I - 48; nnnn)* 0100

Year built *(I - 27; YYYY)* 1929

Structure length *(I - 49; nnnnnn)* 000108

Average daily traffic, ADT *(I - 29; nnnnnn)* 000270

Deck Width *(I - 52; nn.n)* 212

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 303

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 12.7

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

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

Comments:

Structural inspection report of 6/7/93 indicates that the structure is a single span concrete deck type bridge with an asphalt surface. Abutments and wings are grouted stone blocks with concrete caps and backwalls. The caps have alligator cracks and leaks with spalling extending up to but not under each masonry plate except on the downstream right abutment. Right abutment and wings have an exposed concrete footing with some overall spalling. Some stone and boulder fill is present along left abutment, wings, and the up and downstream channel embankments. Some signs of erosion from past flooding are present along the embankments. **(Continued, page 33)**

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: -

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} (*ft³/ 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 (*ft²*): -

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

Comments:

There is about 1 foot of channel scour along right abutment. Minor accumulation of debris. It was suggested, in the comments, to patch or replace the concrete caps on abutments.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **84.72** mi^2 Lake/pond/swamp area **2.22** mi^2
Watershed storage *(ST)* **2.6** %
Bridge site elevation **680** ft Headwater elevation **2369** ft
Main channel length **17.34** mi
10% channel length elevation **720** ft 85% channel length elevation **1417** ft
Main channel slope *(S)* **53.59** 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)*: 05 / 1928

Project Number FR 4B Minimum channel bed elevation: 87.5

Low superstructure elevation: USLAB 98.63 DSLAB 98.53 USRAB 97.33 DSRAB *

Benchmark location description:

Chiseled 'X' on top of stone of the upstream left wingwall at the corner of granite stone abutment wall, elevation 100.0.

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

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

If 1: Footing Thickness 4.33 Footing bottom elevation: 83.5

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION.

Comments:

Bottom of concrete footing of abutments planned at elevation 83.5 with a thickness of 4.33 ft. Note the footings may be exposed upon construction. Another point with elevation shown is on the top streamward edge of the right abutment on the upstream end where the concrete slope changes from horizontal to sloping downward, elevation 103.75 ft. At the above described location on the downstream end, elevation 102.81.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **03/15/96**
Computerized by: **EW** Date: **03/15/96**
Reviewd by: **MAL** Date: **8/4/97**

Structure Number **RYEGTH00050004**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R**. **HAMMOND** Date *(MM/DD/YY)* **08** / **21** / 19**95**

2. Highway District Number **07** Mile marker **-**

County **ESSEX 005** Town **RYEGATE 61525**

Waterway *(I - 6)* **WELLS RIVER** Road Name **-**

Route Number **TH5** Hydrologic Unit Code: **01080103**

3. Descriptive comments:

The site is located 0.2 miles from the junction with US 302

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **6** LBDS **6** RBDS **5** 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 **108** *(feet)* Span length **100** *(feet)* Bridge width **21.2** *(feet)*

Road approach to bridge:

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

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

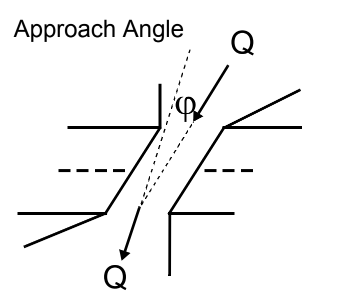
10. Embankment slope (*run / rise in feet / foot*):
US left **2.0:1** US right **2.5:1**

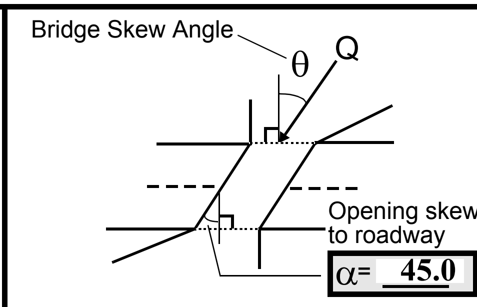
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	0
RBDS	2	1	2	1
LBDS	1	1	2	0

*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: **20** 16. Bridge skew: **50**





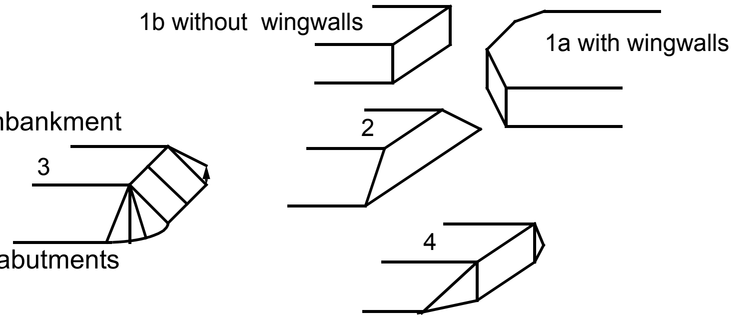
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **30** feet **US** *(US, UB, DS)* to **150** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **10** feet **DS** *(US, UB, DS)* to **30** feet **DS**

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

18. Bridge Type: 1a

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

#7: The bridge dimension values are from the VTAOT. The measured values were: bridge length of 108 feet; bridge span at 97 feet; bridge width of 21.2 feet between the steel braces.
#18: The slope of the wingwalls end above the low cord.

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
69.5	9.5			10.0	3	2	2	23	0	3

23. Bank width 25.0 24. Channel width 40.0 25. Thalweg depth 115.0 29. Bed Material 543

30 .Bank protection type: LB 0 RB 2 31. Bank protection condition: LB - 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 right bank protection is from 120 feet to 300 feet upstream with large boulders placed to protect highway 302 embankment.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **100** 35. Mid-bar width: **20**

36. Point bar extent: **200** feet **US** (US, UB) to **50** feet **US** (US, UB, DS) positioned **0** %LB to **80** %RB

37. Material: **54**

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

The point bar includes a soil capped area near the left bank. There are some small trees on top of the bar.

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

41. Mid-bank distance: **90** 42. Cut bank extent: **30** feet **US** (US, UB) to **125** feet **US** (US, UB, DS)

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

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

Channel migrates towards the right bank and cuts into a steep bank.
Large diameter trees (>6 inches) are also a part of block slump

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

47. Scour dimensions: Length **25** Width **8** Depth : **2.5** Position **80** %LB to **90** %RB

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

The scour is in the channel next to two large boulders (each with 2 meter diameters)

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
76.5		2.0		2	7	7	0

58. Bank width (BF) **-** 59. Channel width **-** 60. Thalweg depth **90.0** 63. Bed Material **1**

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.):

543

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

67. Debris Potential **2** ____ *(**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

There is debris caught on old pilings 3 feet streamside of RB footing

<u>Abutments</u>	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**10**	**90**	**2**	**0**	**-**	**0**	**90.0**
RABUT	**2**	**0**	**90**			**2**	**2**	**66.0**

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.):

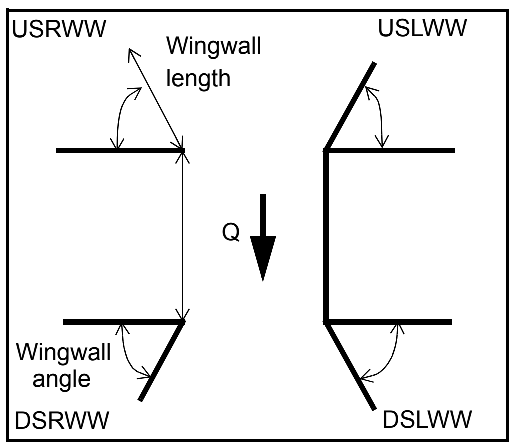
-

2

2

80. <u>Wingwalls</u>:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**66.0**	
USRWW:	**Y**		**2**		**0**	**1.0**	
DSLWW:	**-**		**-**		**Y**	**40.5**	
DSRWW:	**2**		**0**		**-**	**39.5**	



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

82. <u>Bank / Bridge Protection</u>:

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

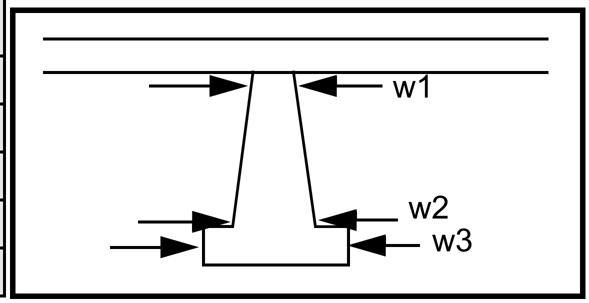
*Protection extent: **1**- entire base length; **2**- US end; **3**- DS end; **4**- other*

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**10.0**	**19.0**	**100.0**
Pier 2				**15.5**	**140.0**	**15.0**
Pier 3			**-**	**15.0**	**29.5**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



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

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

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width - Thalweg depth - Bed Material -

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB -

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

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
-
-
-
-
-
-
NO PIERS

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):

1
1
543
513

106. Point/Side bar present? **1** (Y or N. if N type ctrl-n pb) Mid-bar distance: **0** Mid-bar width: **543**

Point bar extent: **2** feet **23** (US, UB, DS) to **1** feet **1** (US, UB, DS) positioned **Th** %LB to **e** %RB

Material: **left**

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

bank material consist of fill base for old railroad bed (quarry debris) which runs adjacent to the channel on the left bank downstream.

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

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

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

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

N

Is channel scour present? **-** *(Y or if N type ctrl-n cs)* Mid-scour distance: **NO**

Scour dimensions: Length **DRO** Width **P** Depth: **STR** Positioned **UC** %LB to **TU** %RB

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

RE

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

Confluence 1: Distance **Y** Enters on **160** *(LB or RB)* Type **20** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **120** Enters on **DS** *(LB or RB)* Type **250** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

DS
50

F. Geomorphic Channel Assessment

107. Stage of reach evolution **100**

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)*:

543

Y

LB

20

0

DS

30

DS

1

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: RYEGTH00050004 Town: Ryegate
Road Number: TH 5 County: Caledonia
Stream: Wells River

Initials MAI Date: 07/18/97 Checked: ECW

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	5720	7210	0
Main Channel Area, ft2	843	1008	0
Left overbank area, ft2	0	10	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	109.6	114	0
Top width L overbank, ft	0	87	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.221	0.221	0.221
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.7	8.8	ERR
y1, average depth, LOB, ft	ERR	0.1	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	94714	123608	0
Conveyance, main channel	94714	123543	0
Conveyance, LOB	0	65	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	5720.0	7206.2	ERR
Ql, discharge, LOB, cfs	0.0	3.8	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	6.8	7.1	ERR
Vl, mean velocity, LOB, ft/s	ERR	0.4	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.5	9.7	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	5720	7210	0
(Q) discharge thru bridge, cfs	5720	7210	0
Main channel conveyance	50045	61373	0
Total conveyance	50045	61373	0
Q2, bridge MC discharge,cfs	5720	7210	ERR
Main channel area, ft2	425	485	0
Main channel width (normal), ft	66.0	66.0	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	66	66	0
y_bridge (avg. depth at br.), ft	6.44	7.35	ERR
Dm, median (1.25*D50), ft	0.27625	0.27625	0.27625
y2, depth in contraction,ft	8.19	9.99	ERR
ys, scour depth (y2-ybridge), ft	1.75	2.63	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	5720	7210	N/A
Main channel area (DS), ft2	425	485.3	0
Main channel width (normal), ft	66.0	66	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	66.0	66.0	0.0
D90, ft	1.3545	1.3545	0.0000
D95, ft	1.6634	1.6634	0.0000
Dc, critical grain size, ft	1.1073	1.2654	ERR
Pc, Decimal percent coarser than Dc	0.151	0.117	0.000
Depth to armoring, ft	18.63	28.77	ERR

Abutment Scour

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

	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	5720	7210	0	5720	7210	0
a', abut.length blocking flow, ft	22	112.2	0	21.6	23.3	0
Ae, area of blocked flow ft2	74.6	119.9	0	160	193.4	0
Qe, discharge blocked abut.,cfs	274.8	487.7	0	985.1	1233.3	0

(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)

Ve, (Qe/Ae), ft/s	3.68	4.07	ERR	6.16	6.38	ERR
ya, depth of f/p flow, ft	3.39	1.07	ERR	7.41	8.30	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	45	45	45	135	135	135
K2	0.91	0.91	0.91	1.05	1.05	1.05
Fr, froude number f/p flow	0.353	0.693	ERR	0.399	0.390	ERR
ys, scour depth, ft	10.21	11.82	N/A	20.55	22.60	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)	22	112.2	0	21.6	23.3	0
y1 (depth f/p flow, ft)	3.39	1.07	ERR	7.41	8.30	ERR
a'/y1	6.49	104.99	ERR	2.92	2.81	ERR
Skew correction (p. 49, fig. 16)	0.80	0.80	0.80	1.10	1.10	1.10
Froude no. f/p flow	0.35	0.69	N/A	0.40	0.39	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	5.51	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	4.52	ERR	ERR	ERR	ERR
spill-through	ERR	3.03	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)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.93	0.97	0	0.93	0.97	0
y, depth of flow in bridge, ft	6.44	7.35	0.00	6.44	7.35	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.)	2.64	3.05	ERR	2.64	3.05	ERR