LEVEL II SCOUR ANALYSIS FOR BRIDGE 94 (FERDVT01050094) on STATE ROUTE 105, crossing the NULHEGAN RIVER, FERDINAND, VERMONT

U.S. Geological Survey
Open-File Report 96-586

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

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By Erick M. Boehmler and James R. Degnan

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Pembroke, New Hampshire

1996

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 94 (FERDVT01050094) ON STATE ROUTE 105, CROSSING THE NULHEGAN RIVER, FERDINAND, VERMONT

By **Erick M. Boehmler and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure FERDVT01050094 on State Route 105 crossing the Nulhegan River, Ferdinand, 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 White Mountain section of the New England physiographic province in northeastern Vermont. The 38.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is grass and brush with wetlands immediately adjacent to the stream channel.

In the study area, the Nulhegan River has a meandering channel with a slope of approximately 0.002 ft/ft, an average channel top width of 60 ft and an average channel depth of 6 ft. The predominant channel bed material is sand with a median grain size (D_{50}) of 0.465 mm (0.00153 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 5, 1995, indicated that the reach was laterally unstable.

The State Route 105 crossing of the Nulhegan River is a 44-ft-long, two-lane bridge consisting of one 42-foot steel-beam span (Vermont Agency of Transportation, written communication, March 6, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

Scour protection measures at the site were type-2 stone fill (less than 36 inches diameter) on the upstream right bank, the upstream right wingwall, the right abutment, the downstream end of the left abutment and the downstream wingwalls. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 1.2 to 1.9 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.6 to 11.0 ft. The worst-case abutment scour also occurred at the 500-year discharge. Total scour depths computed for this site were not below the bottom of the footings, except for the 500-year discharge model at the left abutment. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number FERDVT01050094 ***Stream*** Nulhegan River

County Essex ***Road*** VT 105 ***District*** 9

Description of Bridge

Bridge length 44 ***ft*** ***Bridge width*** 35.6 ***ft*** ***Max span length*** 42 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 7/5/95

Description of stone fill Type-2 at the downstream end of the left abutment and the entire length of the right abutment. Type-2 stone fill also is present on the upstream right bank and right wingwall, and the downstream wingwalls.

Brief description of piers/abutments Abutments and wingwalls are concrete. The abutment walls slope slightly at an angle closer to 85 degrees than vertical.

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

There is a moderate channel bend in the upstream reach. The right bank at the bend is protected but the stone fill has slumped.

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	7/5/95	0	0
Level II	7/5/95	0	0

Potential for debris Moderate. While there are young trees and shrubs on the banks, the channel reach is meandering and laterally unstable.

Describe any features near or at the bridge that may affect flow (include observation date) None evident on 7/5/95.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with wide, irregular flood plains and moderately sloping valley walls.

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

Date of inspection 7/5/95

DS left: Gradually sloping channel bank to flood plain.

DS right: Moderately sloping channel bank to flood plain.

US left: Gradually sloping channel bank to flood plain.

US right: Moderately sloping channel bank to flood plain.

Description of the Channel

Average top width 60 ***ft*** ***Average depth*** 6 ***ft***

Predominant bed material Sand ***Bank material*** Sand

Perennial and meandering through wetland with alluvial channel boundaries.

7/5/95

Vegetative co Trees and shrubs.

DS left: Shrubs and brush.

DS right: Shrubs and brush.

US left: Shrubs and brush.

US right:

N

Do banks appear stable? There are many channel bends in the reach near this bridge with cut-bank development. Blocks of bank material were noted as having slumped away from the rest of the material. Point bars also were generally coincident on the opposite bank from the cut-banks.

date of observation.

None evident on 7/5/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 38.4 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p - No

Calculated Discharges

Q100 1,530 ***ft³/s*** ***Q500*** 2,200 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates computed by use of several empirical relationships (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957; Talbot, 1887) and those available from the VTAOT database (written communication, May, 1995). Due to the central tendency of the flood frequency curve with the others, the discharges from the Benson (1962) relationship were selected.

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 152.15 feet to USGS survey to obtain VTAOT plans' datum and NGVD.

Description of reference marks used to determine USGS datum. RM2 is the center point of a chisled "X" on top of the concrete curb at the downstream right corner of the bridge deck (elev. 999.95 ft, arbitrary survey datum). RM3 is the center of an engraved triangle in a VTAOT survey mark, brass tablet on top of the upstream end of the left abutment (elev. 1000.08 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	-48	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	79	1	Approach section

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.030 to 0.035, and overbank "n" values ranged from 0.045 to 0.065.

Although the North Branch of the Nulhegan River enters the main stem about 70 feet downstream of this site, the differences in watershed area and characteristics suggest that the peak discharges on each reach are not contemporaneous. Therefore, no backwater effects were assumed and normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0016 ft/ft which was estimated from the topographic map over one contour interval downstream of the site (U.S. Geological Survey, 1988).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 995.8 *ft*
Average low steel elevation 1000.0 *ft*

100-year discharge 1,530 *ft³/s*
Water-surface elevation in bridge opening 991.3 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 185 *ft²*
Average velocity in bridge opening 8.3 *ft/s*
Maximum WSPRO tube velocity at bridge 9.8 *ft/s*

Water-surface elevation at Approach section with bridge 992.1
Water-surface elevation at Approach section without bridge 991.8
Amount of backwater caused by bridge 0.3 *ft*

500-year discharge 2,200 *ft³/s*
Water-surface elevation in bridge opening 992.4 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 226 *ft²*
Average velocity in bridge opening 9.7 *ft/s*
Maximum WSPRO tube velocity at bridge 11.4 *ft/s*

Water-surface elevation at Approach section with bridge 993.6
Water-surface elevation at Approach section without bridge 993.1
Amount of backwater caused by bridge 0.5

Incipient overtopping discharge -- *ft³/s*
Water-surface elevation in bridge opening -- *ft*
Area of flow in bridge opening -- *ft²*
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 live-bed contraction scour equation (Richardson and others, 1995, p. 30, equations 17 and 18). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. In this case, the 500-year discharge resulted in the worst case 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	1.2	1.9	--
Clear-water scour	--	--	--
Depth to armoring	--	--	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	8.3	11.0	--
Right abutment	6.6	7.7	--
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	1.3	1.8	--
Right abutment	1.3	1.8	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

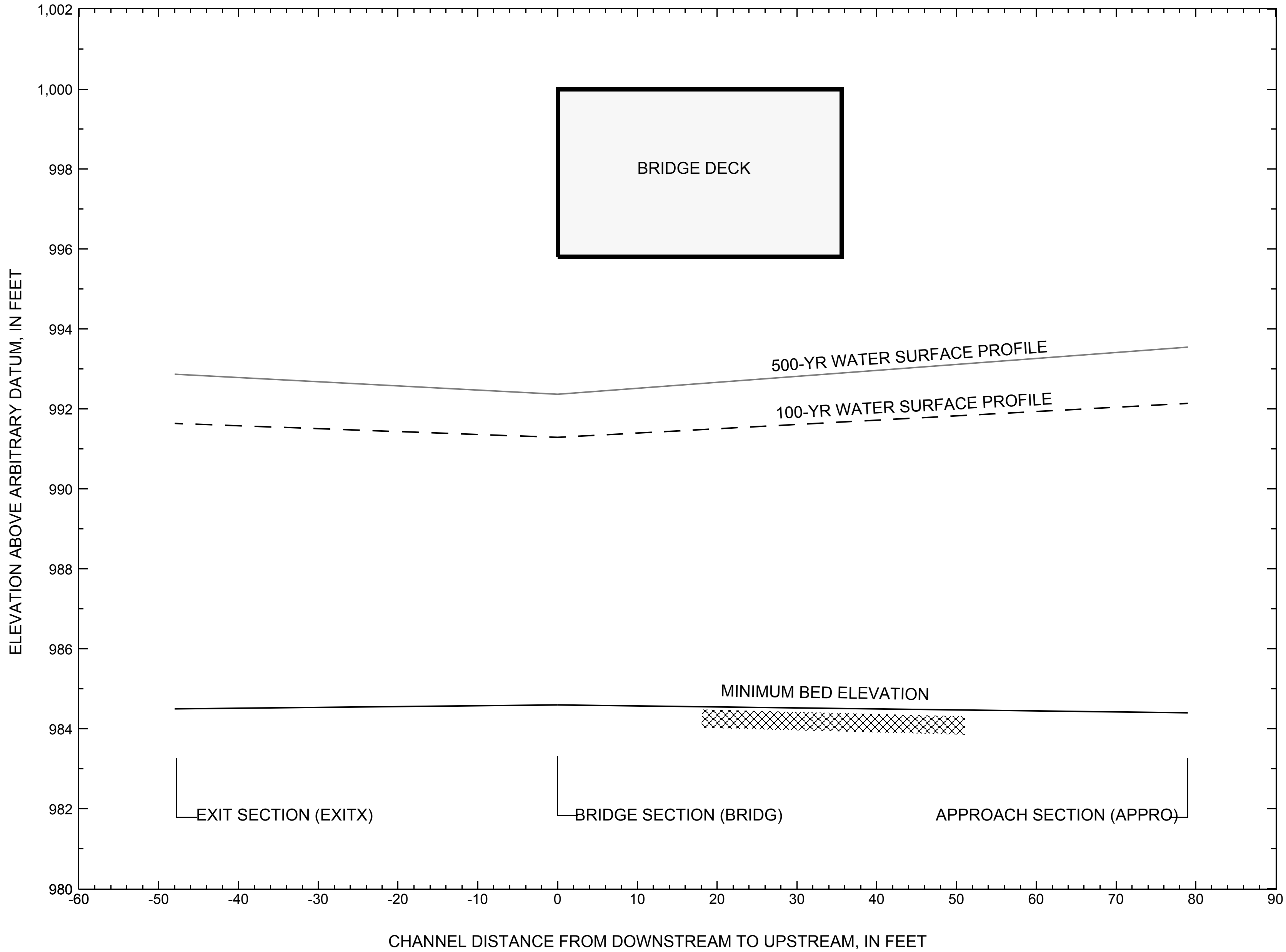

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure FERDVT01050094 on State Route 105, crossing the Nulhegan River, Ferdinand, Vermont.

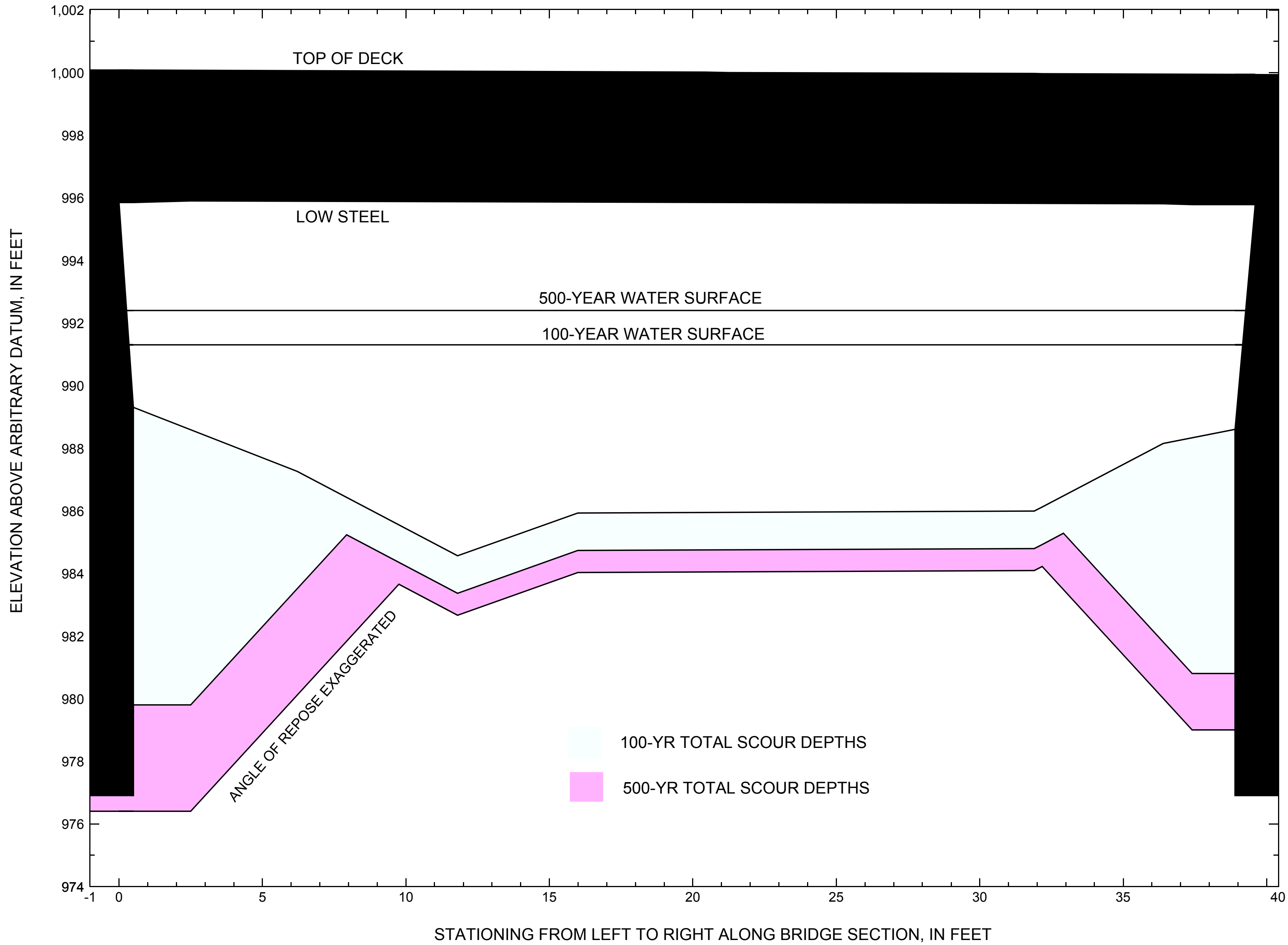

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure FERDVT01050094 on State Route 105, crossing the Nulhegan River, Ferdinand, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure FERDVT01050094 on State Route 105, crossing the Nulhegan River, Ferdinand, Vermont.

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

Description	Station[1]	VTAOT bridge seat 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 1,530 cubic-feet per second											
Left abutment	0.5	1144.3	995.9	976.9	989.3	1.2	8.3	--	9.5	979.8	2.9
Right abutment	38.9	1145.0	995.8	976.9	988.6	1.2	6.6	--	7.8	980.8	3.9

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 FERDVT01050094 on State Route 105, crossing the Nulhegan River, Ferdinand, Vermont.

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

Description	Station[1]	VTAOT bridge seat 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 2,200 cubic-feet per second											
Left abutment	0.5	1144.3	995.9	976.9	989.3	1.9	11.0	--	12.9	976.4	-0.5
Right abutment	38.9	1145.0	995.8	976.9	988.6	1.9	7.7	--	9.6	979.0	2.1

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. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1988, Bloomfield, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1983, Contour interval, 20 feet, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE (continued)

```
T1        U.S. Geological Survey WSPRO Input File ferd094.wsp
T2        Hydraulic analysis for structure FERDVT01050094   Date: 30-AUG-96
T3        State Route 105 Crossing the Nulhegan River, Ferdinand, VT         EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1530.0   2200.0
SK          0.0016   0.0016
*
XS   EXITX    -48
GR         -219.8,1001.82   -211.3,1000.69   -190.7, 995.60   -142.7, 996.25
GR         -110.6, 997.61    -65.4, 996.47    -55.6, 995.57    -53.8, 992.62
GR          -34.1, 991.80    -26.3, 992.55    -12.0, 991.95      0.0, 987.14
GR            6.2, 985.40     12.1, 984.59     19.9, 984.52     26.5, 984.87
GR           34.0, 987.02     38.3, 987.23     46.0, 992.50     84.4, 993.40
GR          104.6, 994.84    151.6, 995.06    284.4,1001.03
*
N           0.065        0.030        0.045
SA                 -12.0         46.0
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    995.81       0.0
GR            0.0, 995.85      0.5, 989.26      6.2, 987.26     11.8, 984.56
GR           16.0, 985.93     25.2, 985.95     31.9, 985.99     36.4, 988.15
GR           38.9, 988.57     39.6, 995.78      0.0, 995.85
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      47.3 * *     44       8.3
N           0.030
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     20      35.6     1
GR         -305.9,1002.90   -231.3,1001.06   -167.4,1000.15   -101.6,1000.39
GR           -2.2,1000.09     -2.1, 1002.13      0.0,1002.13     41.2,1002.05
GR           41.6, 999.93    136.6, 999.50    264.7, 999.98    331.0,1000.76
GR          413.1,1001.57
*
AS   APPRO     79
GR         -275.9,1001.88   -232.0, 998.44   -162.3, 994.95   -124.1, 995.78
GR          -51.9, 995.30    -16.9, 995.59    -13.5, 991.94     -7.1, 989.14
GR            6.3, 988.11     14.0, 987.12     24.0, 985.43     29.6, 984.39
GR           33.6, 985.65     37.3, 987.20     47.8, 993.08     61.3, 995.56
GR          131.9, 996.94    176.8, 997.43
*
N           0.050        0.035        0.050
SA                 -16.9         47.8
BP          0.0
*
HP 1 BRIDG 991.29 1 991.29
HP 2 BRIDG 991.29 * * 1530
HP 1 APPRO 992.14 1 992.14
HP 2 APPRO 992.14 * * 1530
*
HP 1 BRIDG 992.37 1 992.37
HP 2 BRIDG 992.37 * * 2200
HP 1 APPRO 993.55 1 993.55
HP 2 APPRO 993.55 * * 2200
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ferd094.wsp
        Hydraulic analysis for structure FERDVT01050094   Date: 30-AUG-96
        State Route 105 Crossing the Nulhegan River, Ferdinand, VT         EMB
           *** RUN DATE & TIME: 09-17-96  08:25

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      184     23515     39     45                          2282
   991.29           184     23515     39     45  1.00      0     39      2282

  HP 2 BRIDG 991.29 * * 1530

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       991.29     0.3    39.2   184.5   23515.    1530.   8.29

X STA.        0.3        5.6        8.1        9.8       11.2       12.5
  A(I)            15.1       10.9        9.4        8.6        8.1
  V(I)            5.08       7.01       8.17       8.91       9.40

X STA.       12.5       13.7       15.1       16.6       18.0       19.5
  A(I)             7.8        8.0        8.0        8.0        8.0
  V(I)            9.77       9.53       9.59       9.53       9.54

X STA.       19.5       21.0       22.5       24.1       25.6       27.1
  A(I)             8.0        8.0        8.1        8.0        8.4
  V(I)            9.54       9.54       9.44       9.52       9.12

X STA.       27.1       28.7       30.3       32.1       34.3       39.2
  A(I)             8.4        8.5        9.3       10.2       15.5
  V(I)            9.12       9.01       8.19       7.47       4.93

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      79.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             2      263     29101     60     63                          3125
   992.14           263     29101     60     63  1.00    -13     46      3125

  HP 2 APPRO 992.14 * * 1530

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      79.

         WSEL     LEW     REW    AREA        K        Q    VEL
       992.14   -13.7    46.1   262.8   29101.    1530.   5.82

X STA.      -13.7       -3.2        1.5        5.5        9.0       11.9
  A(I)            22.5       16.4       15.4       14.4       13.5
  V(I)            3.40       4.65       4.98       5.33       5.66

X STA.       11.9       14.6       16.9       19.0       20.8       22.5
  A(I)            13.0       12.2       11.8       11.1       10.9
  V(I)            5.87       6.28       6.50       6.91       7.01

X STA.       22.5       24.1       25.7       27.1       28.5       29.8
  A(I)            10.7       10.5       10.2       10.2       10.5
  V(I)            7.14       7.29       7.47       7.52       7.27

X STA.       29.8       31.3       32.9       34.8       37.5       46.1
  A(I)            10.7       11.3       12.2       14.2       21.0
  V(I)            7.15       6.77       6.25       5.37       3.64

  *
  HP 1 BRIDG 992.37 1 992.37
```

```
      U.S. Geological Survey WSPRO Input File ferd094.wsp
      Hydraulic analysis for structure FERDVT01050094   Date: 30-AUG-96
      State Route 105 Crossing the Nulhegan River, Ferdinand, VT          EMB
         *** RUN DATE & TIME: 09-17-96  08:25

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

   WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
           1      227     32080    39     47                          3097
 992.37           227     32080    39     47  1.00      0     39     3097

  HP 2 BRIDG 992.37 * * 2200

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     992.37     0.3    39.3   226.5   32080.    2200.   9.71

X STA.        0.3        5.2        7.7        9.6       11.0       12.3
  A(I)           19.1       13.0       11.7       10.5       10.0
  V(I)           5.77       8.48       9.44      10.44      11.04

X STA.       12.3       13.7       15.1       16.6       18.1       19.6
  A(I)            9.8        9.6        9.9        9.7        9.7
  V(I)          11.18      11.40      11.09      11.39      11.40

X STA.       19.6       21.1       22.6       24.1       25.7       27.2
  A(I)            9.7        9.7        9.8       10.0       10.0
  V(I)          11.30      11.30      11.18      11.04      11.01

X STA.       27.2       28.8       30.5       32.3       34.6       39.3
  A(I)           10.2       10.6       11.4       12.9       19.2
  V(I)          10.79      10.34       9.67       8.53       5.72

  HP 1 APPRO 993.55 1 993.55

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      79.

   WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
           2      350     45010    63     66                          4680
           3        1         7     3      3                             2
 993.55           350     45017    65     69  1.00    -14     50     4593

  HP 2 APPRO 993.55 * * 2200

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      79.

       WSEL     LEW     REW    AREA        K        Q    VEL
     993.55   -15.0    50.4   350.2   45017.    2200.   6.28

X STA.      -15.0       -5.3       -0.7        3.1        6.6        9.7
  A(I)           28.4       21.7       19.2       18.7       17.8
  V(I)           3.87       5.06       5.72       5.88       6.19

X STA.        9.7       12.5       15.1       17.4       19.5       21.4
  A(I)           16.9       16.3       15.6       15.3       14.6
  V(I)           6.50       6.74       7.05       7.17       7.51

X STA.       21.4       23.3       25.0       26.7       28.3       29.8
  A(I)           14.6       14.2       13.9       13.8       14.2
  V(I)           7.55       7.73       7.93       8.00       7.74

X STA.       29.8       31.5       33.3       35.5       38.6       50.4
  A(I)           14.5       15.4       16.6       19.8       28.6
  V(I)           7.57       7.16       6.62       5.57       3.85

  *
  EX
```

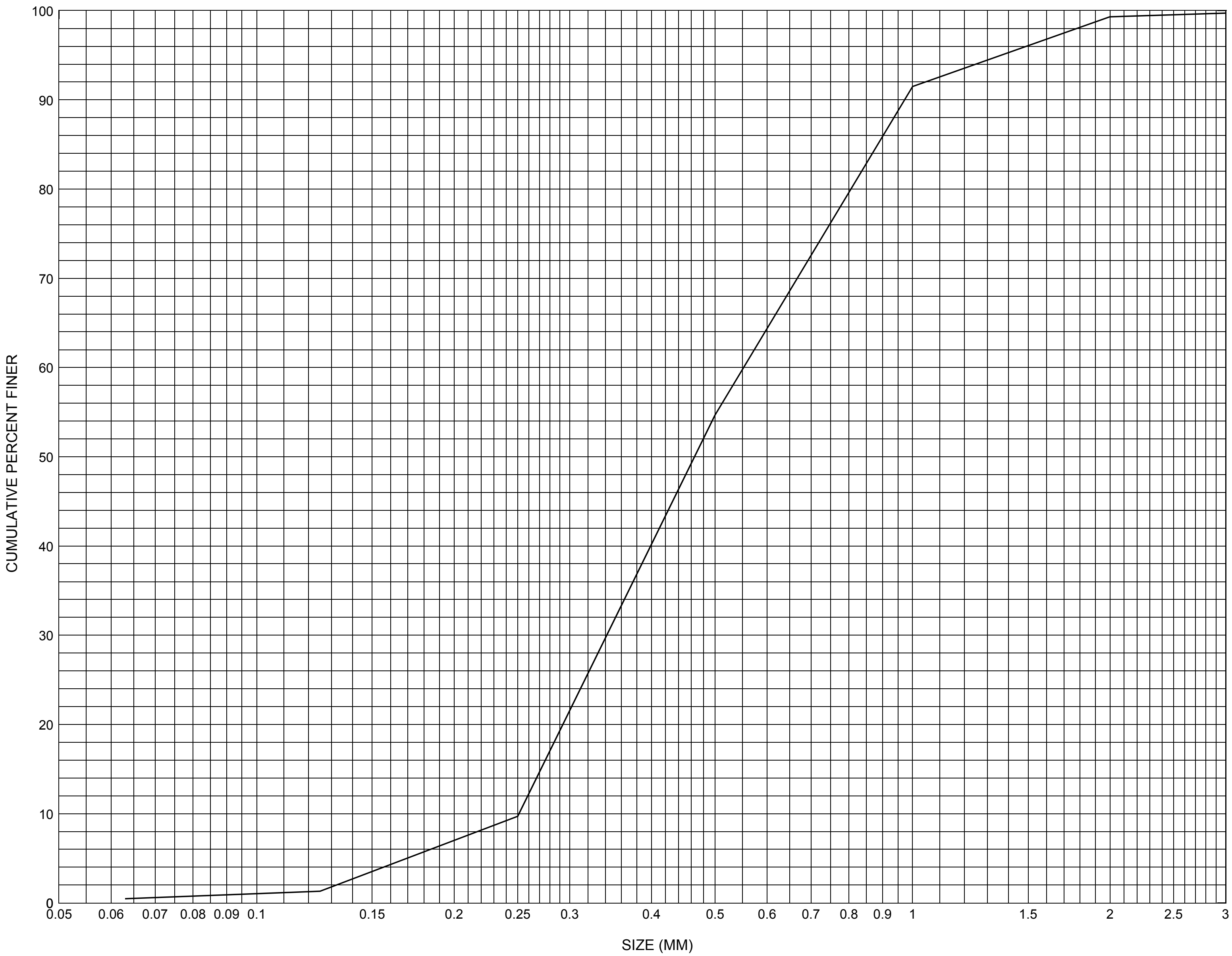
```
+++ BEGINNING PROFILE CALCULATIONS --   2
        U.S. Geological Survey WSPRO Input File ferd094.wsp
        Hydraulic analysis for structure FERDVT01050094   Date: 30-AUG-96
        State Route 105 Crossing the Nulhegan River, Ferdinand, VT         EMB
           *** RUN DATE & TIME: 09-17-96  08:25

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

EXITX:XS   ******    -10      275  0.48 *****  992.12  989.20    1530  991.64
       -47 ******     45    38233  1.00 ***** *******    0.44    5.56

FULLV:FV       48    -10      281  0.46  0.07  992.21 *******    1530  991.75
         0     48     45    39405  1.00  0.00    0.01    0.43    5.44
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.67

APPRO:AS       79    -12      245  0.61  0.18  992.45 *******    1530  991.84
        79     79     46    26236  1.00  0.07   -0.01    0.54    6.24
         <<<<<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       48      0      185  1.07  0.12  992.36  990.18    1530  991.29
         0     48     39    23550  1.00  0.11   -0.01    0.67    8.29

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  995.81 ****** ****** ******

    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       32    -13      263  0.53  0.11  992.67  990.25    1530  992.14
        79     33     46    29090  1.00  0.20    0.02    0.49    5.82

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.339  0.062   27119.     4.    42.   992.02

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -48.   -11.    45.   1530.   38233.     275.    5.56  991.64
   FULLV:FV       0.   -11.    45.   1530.   39405.     281.    5.44  991.75
   BRIDG:BR       0.     0.    39.   1530.   23550.     185.    8.29  991.29
   RDWAY:RG      20.**************      0.******************    1.00********
   APPRO:AS      79.   -14.    46.   1530.   29090.     263.    5.82  992.14

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       4.    42.   27119.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    989.20    0.44  984.52 1001.82************  0.48  992.12  991.64
   FULLV:FV  ********    0.43  984.52 1001.82  0.07  0.00  0.46  992.21  991.75
   BRIDG:BR    990.18    0.67  984.56  995.85  0.12  0.11  1.07  992.36  991.29
   RDWAY:RG  ****************  999.50 1002.90**********************************
   APPRO:AS    990.25    0.49  984.39 1001.88  0.11  0.20  0.53  992.67  992.14
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ferd094.wsp
        Hydraulic analysis for structure FERDVT01050094   Date: 30-AUG-96
        State Route 105 Crossing the Nulhegan River, Ferdinand, VT         EMB
           *** RUN DATE & TIME: 09-17-96  08:25

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

EXITX:XS   ******    -53      376  0.61 *****  993.48  990.15    2200  992.87
       -47 ******     62    54972  1.15 ***** *******    0.61    5.85

FULLV:FV       48    -53      390  0.58  0.07  993.57 *******    2200  992.99
         0     48     67    56999  1.18  0.00    0.02    0.60    5.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  0.69

APPRO:AS       79    -14      320  0.74  0.17  993.81 *******    2200  993.08
        79     79     48    39073  1.00  0.08   -0.01    0.54    6.88
         <<<<<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       48      0      226  1.47  0.13  993.84  991.17    2200  992.37
         0     48     39    32078  1.00  0.22    0.00    0.71    9.71

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  995.81 ****** ****** ******

    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       32    -14      350  0.62  0.11  994.17  991.12    2200  993.55
        79     33     50    45017  1.00  0.22    0.01    0.48    6.28

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.373  0.097   40551.     2.    41.   993.45

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -48.   -54.    62.   2200.   54972.     376.    5.85  992.87
   FULLV:FV       0.   -54.    67.   2200.   56999.     390.    5.64  992.99
   BRIDG:BR       0.     0.    39.   2200.   32078.     226.    9.71  992.37
   RDWAY:RG      20.**************      0.*****************    1.00********
   APPRO:AS      79.   -15.    50.   2200.   45017.     350.    6.28  993.55

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    41.   40551.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    990.15    0.61  984.52 1001.82************  0.61   993.48  992.87
   FULLV:FV  ********    0.60  984.52 1001.82  0.07  0.00  0.58   993.57  992.99
   BRIDG:BR    991.17    0.71  984.56  995.85  0.13  0.22  1.47   993.84  992.37
   RDWAY:RG ***************  999.50 1002.90**********************************
   APPRO:AS    991.12    0.48  984.39 1001.88  0.11  0.22  0.62   994.17  993.55
  ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one channel composite sample at the approach section of structure FERDVT01050094, in Ferdinand, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number FERDVT01050094

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 06 / 95

Highway District Number *(I - 2; nn)* 09

County *(FIPS county code; I - 3; nnn)* 009

Town *(FIPS place code; I - 4; nnnnn)* 25975

Mile marker *(I - 11; nnn.nnn)* 003340

Waterway *(I - 6)* NULHEGAN RIVER

Road Name *(I - 7):* -

Route Number VT105

Vicinity *(I - 9)* 7.6 MI W JCT. VT.102

Topographic Map Bloomfield

Hydrologic Unit Code: 01080101

Latitude *(I - 16; nnnn.n)* 44468

Longitude *(i - 17; nnnnn.n)* 71444

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20003400940509

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

Maximum span length *(I - 48; nnnn)* 0042

Year built *(I - 27; YYYY)* 1979

Structure length *(I - 49; nnnnnn)* 000044

Average daily traffic, ADT *(I - 29; nnnnnn)* 001340

Deck Width *(I - 52; nn.n)* 356

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

Channel & Protection *(I - 61; n)* 8

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

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

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

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

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

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*) 10.0

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

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

Comments:

The structural inspection report of 10/19/93 indicates the structure is a single span, steel stringer type bridge. The abutments are older concrete with newer concrete bearing caps and wingwalls. The older concrete has a couple of minor spalls noted. The waterway takes a slight to moderate turn through the structure. The banks and abutments are well protected with stone fill. The stream bed consists of sand and stone. The structure is in relatively good condition according to the report. No problems are noted for channel scour, bank erosion, or debris.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: 37.8

Terrain character: -

Stream character & type: -

Streambed material: Sand and boulder with some silt

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} 650 Q_{25} 950

Q_{50} 1200 Q_{100} 1450 Q_{500} -

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

Estimated Discharge *(cfs)*: - Velocity at Q 50 *(ft/s)*: 3

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: 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: **Marshy conditions, a slight meander, and beaver activity in the vicinity were noted.**

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*)	-	1139.2	1140.9	1142.3	1143.2
Velocity (*ft / sec*)	-	-	-	3.0	-

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:

No full hydraulics report is available. Just some limited data based on office memoranda. Tail water elevation noted at Q50 of 1142.3. Type 1 stone was recommended as riprap material at this site.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **38.40** mi^2 Lake and pond area **3.07** mi^2

Watershed storage *(ST)* **8.0** %

Bridge site elevation **1149** ft Headwater elevation **3049** ft

Main channel length **11.96** mi

10% channel length elevation **1150** ft 85% channel length elevation **1360** ft

Main channel slope *(S)* **23.41** 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)*: **02** / **1978**

Project Number **F - BHF 034 - 3(5)** Minimum channel bed elevation: **1144.3**

Low superstructure elevation: USLAB **1144.95** DSLAB **1144.31** USRAB **1144.31** DSRAB **1144.95**

Benchmark location description:

Benchmark #1 - a chiseled square on top of a boulder, elevation 1147.58, located 60-70 feet left bankward from the left abutment and approximately 40 feet from the centerline of the road on the downstream left overbank area.

Reference Point (*MSL, Arbitrary, Other*): **MSL** Datum (*NAD27, NAD83, Other*): **NGVD1929**

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **1129.0**

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? **Y** *If no, type ctrl-n bi* Number of borings taken: **2**

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

Briefly describe material at foundation bottom elevation or around piles:

Silt based on the 2 borings, overlain by sand and silty sand.

Comments:

Other points with elevations provided on the plans are: 1) at the corner of upstream end of upstream left wingwall, elevation 1141.0 feet; and 2) at the corner of upstream end of upstream right wingwall, elevation 1140.5 feet. On both wingwalls, elevations refer to points where wingwall goes from slightly sloping to vertical. The channel has been graded to make the channel bed elevation about 2 feet above the top of the spread footings. There is an approximately 2 foot log mat underneath the spread footings.

Cross-sectional Data

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

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

Comments: **Bridge cross section of PREVIOUS STRUCTURE nearest the upstream face at stationing 4 + 86.5, 13.5 feet from the center line of the roadway over the bridge. The channel base line runs along the left bank perpendicular to the bridge, 7 feet from the left abutment face.**

Station	7.0	10.5	13.5	27.0	38.0	43.5	47.0				
Feature	LCL	footing edge	sub-footing	TD	sub-footing	footing edge	LCR				
Low cord elevation	1144	1131	t1129		t1129	t1131	1144				
Bed elevation	1134	b1129	b1127	1132.2	b1127	b1129	1134.3				
Low cord to bed length	10						9.7				

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

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

Comments: **Bridge cross section for PREVIOUS STRUCTURE nearest the downstream face at stationing 5 + 13.60, 13.6 feet from the center line of the roadway over the bridge.**

Station	7.0	10.5	13.5	27.0	38.0	43.5	46.5				
Feature	LCL	footing edge	sub-footing	TD	sub-footing	footing edge	LCR				
Low cord elevation	1144	t1131	t1129		t1129	t1131	1143.5				
Bed elevation	1133	b1129	b1127	1132	b1127	b1129	1133				
Low cord to bed length	11						10.5				

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 3/27/96
Computerized by: EW Date: 2/14/96
Reviewd by: EMB Date: 8/30/96

Structure Number FERDVT01050094

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 07 / 05 / 1995
2. Highway District Number 9 Mile marker 003340
County ESSEX (009) Town FERDINAND (25975)
Waterway *(I - 6)* NULHEGAN RIVER Road Name -
Route Number VT 105 Hydrologic Unit Code: 01080101
3. Descriptive comments:
Located about 7.6 miles west of State Route 105 intersection with State Route 102.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 5 LBDS 5 RBDS 5 Overall 5
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 1 UB 1 DS 1 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 44 *(feet)* Span length 42 *(feet)* Bridge width 35.6 *(feet)*

Road approach to bridge:

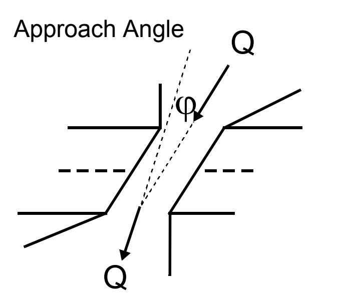
8. LB 0 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 4.4:1 US right 2.8:1

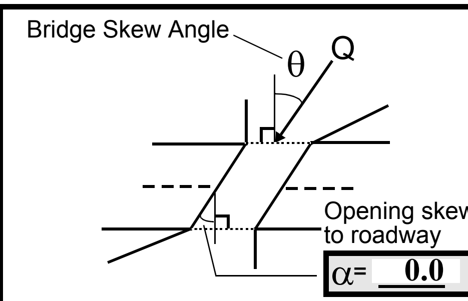
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	2

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

Channel approach to bridge (BF):

15. Angle of approach: 40 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 140 feet US *(US, UB, DS)* to 15 feet US
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 0 feet US *(US, UB, DS)* to 0 feet DS

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

18. Bridge Type: **1a**

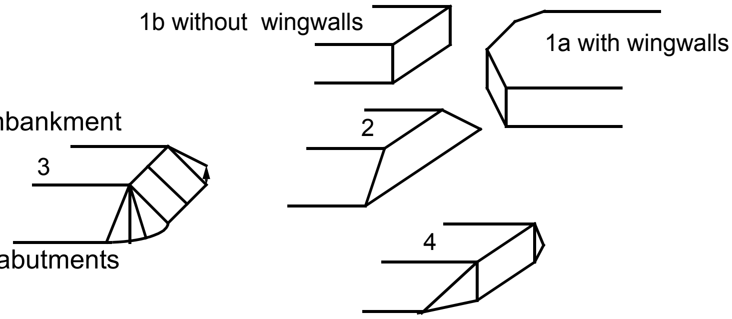
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

Values reported for #7 are from VTAOT files. Measured #7 span length is actually 40 feet.
4. The topographic map has this area marked wetlands but it is currently dry.

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
47.5	**4.0**			**6.0**	**1**	**1**	**21**	**21**	**1**	**2**

23. Bank width **10.0** 24. Channel width **30.0** 25. Thalweg depth **61.0** 29. Bed Material **21**

30 .Bank protection type: LB **0** RB **2** 31. Bank protection condition: LB **-** RB **2**

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.):

The bank protection is heaviest 30 feet US to the corner of the upstream right wingwall and right abutment.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 70 35. Mid-bar width: 15

36. Point bar extent: 25 feet US (US, UB) to 95 feet US (US, UB, DS) positioned 0 %LB to 60 %RB

37. Material: 2

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? RB (LB or RB)

41. Mid-bank distance: 110 42. Cut bank extent: 140 feet US (US, UB) to 50 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.):

The bank condition improves towards the bridge due to stone fill.

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

47. Scour dimensions: Length 65 Width 10 Depth : 3 Position 40 %LB to 90 %RB

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

This hole has developed along the toe of the stone fill along the right bank upstream.

49. Are there major confluences? Y (Y or if N type ctrl-n mc) 50. How many? 1

51. Confluence 1: Distance 140 52. Enters on RB (LB or RB) 53. Type 1 (**1**- perennial; **2**- ephemeral)

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

54. Confluence comments (eg. confluence name):

The confluence (Stevens brook) is wider but with a shallower slope than the Nulhegan River's main channel.

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
31.0		3.0		2	7	7	0

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 90.0 63. Bed Material 0

*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.):

2

-

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

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

The channel meanders and is laterally unstable cutting the banks at most bends. There are mainly young trees, shrubs, and brush on the 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		10	85	2	0	0	0	90.0
RABUT	1	-	85			2	0	39.5

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

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

0

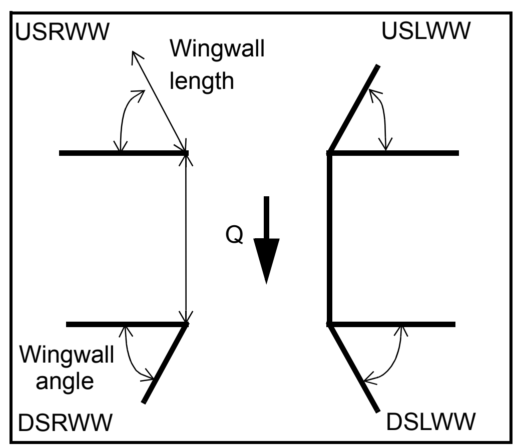
0

1

The abutments protrude from the top of the banks on both sides, but are set back from the bottom of the banks.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						39.5	
USRWW:	Y		1		0	2.0	
DSLWW:	-		-		Y	40.5	
DSRWW:	1		0		-	39.0	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	-	1	1	1
Condition	Y	-	1	-	-	1	3	1
Extent	1	-	0	0	2	2	2	-

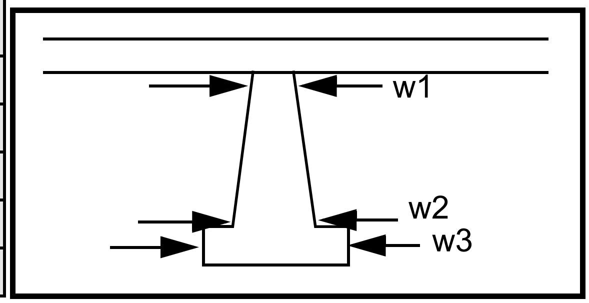
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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		**8.5**		**50.0**	**35.0**	**14.0**
Pier 2		**9.0**		**50.0**	**40.0**	**13.0**
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e left**	**to**		-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**abut**	**DS**		-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**ment**	**as**		-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**pro-**	**the**		-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**tec-**	**chan**		-	*Y- yes; N- no*
91. Attack ∠ (BF)	**tion**	**nel**		-	
92. Pushed	**is**	**cuts**		-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**unde**	**into**		-	
95. Cross-members	**r a**	**the**		-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**bar**	**right**		-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**from**	**bank**	**N**	-	
98. Exposure depth	**US**	**US.**	-	-	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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):

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

Point bar extent: **21** feet **21** *(US, UB, DS)* to **1** feet **1** *(US, UB, DS)* positioned **21** %LB to **0** %RB

Material: **0**

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 _____ 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.):

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

Scour dimensions: Length **-** Width **NO** Depth: **DR** Positioned **OP** %LB to **ST** %RB

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

RUCTURE

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

Confluence 1: Distance **Y** Enters on **10** *(LB or RB)* Type **10** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **0** Enters on **UB** *(LB or RB)* Type **15** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

DS
40

F. Geomorphic Channel Assessment

107. Stage of reach evolution **60**

__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)*:

2

The channel bar dumps right into the middle of the scour hole and is submerged.

N

-

-

-

-

-

-

-

109. G. Plan View Sketch

- N

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: FERDVT01050094 Town: Ferdinand
Road Number: VT 105 County: Essex
Stream: Nulhegan River

Initials EMB Date: 8/30/96 Checked: SAO

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

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

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1530	2200	0
Main Channel Area, ft2	263	350	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	1	0
Top width main channel, ft	60	63	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	3	0
D50 of channel, ft	0.001526	0.001526	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	4.4	5.6	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	0.3	ERR
Total conveyance, approach	29101	45017	0
Conveyance, main channel	29101	45010	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	7	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1530.0	2199.7	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.3	ERR
Vm, mean velocity MC, ft/s	5.8	6.3	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	0.3	ERR
Vc-m, crit. velocity, MC, ft/s	1.7	1.7	N/A
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	0.0	N/A

Results

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

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour

$y2/y1 = (Q2/Q1)^{(6/7)}*(W1/W2)^{(k1)}$

$ys=y2-y\_bridge$

(Richardson and others, 1995, p. 30, eq. 17 and 18)

Characteristic	Approach 100 yr	500 yr	Other Q	Bridge 100 yr	500 yr	Other Q
Q1, discharge, cfs	1530	2200	0	1530	2200	0
Total conveyance	29101	45017	0	23515	32080	0
Main channel conveyance	29101	45010	0	23515	32080	0
Main channel discharge	1530	2200	ERR	1530	2200	ERR
Area - main channel, ft2	263	350	0	184.5	226.5	0
(W1) channel width, ft	60	63	0	38.9	39	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	60	63	0	38.9	39	0
D50, ft	0.001526	0.001526	0			
w, fall velocity, ft/s (p. 32)	0.268	0.268	0			
y, ave. depth flow, ft	4.38	5.56	N/A	4.74	5.81	ERR
S1, slope EGL	0.003	0.003	0			
P, wetted perimeter, MC, ft	63	66	0			
R, hydraulic Radius, ft	4.175	5.303	ERR			
V*, shear velocity, ft/s	0.635	0.716	N/A			
V*/w	2.370	2.671	ERR			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.69	0.69	0			
y2,depth in contraction, ft	5.91	7.74	ERR			
ys, scour depth, ft (y2-y_bridge)	1.17	1.93	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	1530	2200	0	1530	2200	0
a’, abut.length blocking flow, ft	14	15.3	0	6.9	11.1	0
Ae, area of blocked flow ft2	34.7	55.2	0	16.9	26.9	0
Qe, discharge blocked abut.,cfs	133.5	249	0	61.4	103.5	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.85	4.51	ERR	3.63	3.85	ERR
ya, depth of f/p flow, ft	2.48	3.61	ERR	2.45	2.42	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	0	90	90	0
K2	1.00	1.00	0.00	1.00	1.00	0.00
Fr, froude number f/p flow	0.431	0.419	ERR	0.409	0.436	ERR
ys, scour depth, ft	8.29	10.96	N/A	6.58	7.65	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)	14	15.3	0	6.9	11.1	0
y1 (depth f/p flow, ft)	2.48	3.61	ERR	2.45	2.42	ERR
a’/y1	5.65	4.24	ERR	2.82	4.58	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	0.00	1.00	1.00	0.00
Froude no. f/p flow	0.43	0.42	N/A	0.41	0.44	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)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.67	0.71		0.67	0.71	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	4.7	5.8		4.7	5.8	
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.30	1.81	0.00	1.30	1.81	0
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR