LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (GLOVTH00410023) on TOWN HIGHWAY 41, crossing SHERBURNE BROOK, GLOVER, VERMONT

U.S. Geological Survey
Open-File Report 97-388

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

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By SCOTT A. OLSON and ERICK M. BOEHMLER

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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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 23 (GLOVTH00410023) ON TOWN HIGHWAY 41, CROSSING SHERBURNE BROOK, GLOVER, VERMONT

By **Scott A. Olson and Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure GLOVTH00410023 on Town Highway 41 crossing Sherburne Brook, Glover, 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 northern Vermont. The 2.57-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is primarily forest with small areas of lawn and a home on the right overbank and a gravel roadway along the upstream left bank.

In the study area, Sherburne Brook has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 33 ft and an average bank height of 6 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 57.3 mm (0.188 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 24, 1994, indicated that the reach was stable.

The Town Highway 41 crossing of Sherburne Brook is a 24-ft-long, one-lane bridge consisting of one 21-foot steel-beam span with a timber deck (Vermont Agency of Transportation, written communication, August 4, 1994). The opening length of the structure parallel to the bridge face is 20.3 ft. The bridge is supported by vertical, granite block abutments. The channel is skewed approximately 55 degrees to the opening while the measured opening-skew-to-roadway is 30 degrees.

One foot of scour below the mean thalweg depth was observed along the right abutment undermining the abutment by 0.5 feet vertically. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.4 to 0.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.6 to 7.2 ft. The worst-case abutment scour also 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.

Crystal Lake, VT. Quadrangle, 1:24,000, 1986

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 GLOVTH00410023 ***Stream*** Sherburne Brook

County Orleans ***Road*** TH41 ***District*** 9

Description of Bridge

Bridge length 24 ***ft*** ***Bridge width*** 14.5 ***ft*** ***Max span length*** 21 ***ft***

Alignment of bridge to road (on curve or straight) Slight curve on left approach.

Abutment type Vertical, granite ***Embankment type*** None

Stone fill on abutment? No ***Date of inspection*** 10/24/94

Description of stone fill --

Abutments are constructed of granite blocks and extend 11 and 31 ft upstream on the respective left and right sides. The right abutment is undermined 0.5 ft.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 55

There is a severe channel bend at the channel entrance to the bridge. Scour has developed in the location where the bend impacts the right abutment.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	10/24/94	0	0
Level II	10/25/94	0	0

Potential for debris Moderate.

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

10/24/94,--.

Description of the Geomorphic Setting

General topography The channel is located within a narrow, high relief valley. There are no flood plains.

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

Date of inspection 10/24/94

DS left: Steep channel bank and steep valley wall.

DS right: Narrow terrace to steep valley wall.

US left: Steep channel bank, roadway, and steep valley wall.

US right: Steep channel bank, narrow terrace, and steep valley wall.

Description of the Channel

Average top width 33 ***ft*** ***Average depth*** 6 ***ft***

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

Sinuous but stable

with semi- to non-alluvial channel boundaries and no flood plains.

10/24/94

Vegetative co Trees and brush.

DS left: Trees and brush with a small area of lawn on the overbank.

DS right: Trees and brush with a gravel roadway on the immediate channel bank.

US left: Trees and brush with a small area of lawn and a home on the overbank.

US right: Y

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

None, 10/24/94.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 2.57 ***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***: --

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 515 ***ft³/s*** ***Q500*** 700 ***ft³/s***

The 100- and 500-year discharges were the median values from flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled square on top of the abutment footing directly below the upstream right corner of the bridge deck (elev. 93.30 ft, arbitrary survey datum). RM2 is a chiseled square in the top of the abutment footing directly below the downstream right corner of the bridge deck (elev. 93.13 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	-34	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	56	2	Modelled Approach section (Templated from APTEM)
APTEM	66	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.055, and overbank "n" values ranged from 0.035 to 0.095.

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 0.029 ft/ft which was computed from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0038 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the 500-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles, it can be determined that the water surface profile does pass through critical depth within the bridge opening at the 500-year discharge. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 99.6 ***ft***
Average low steel elevation 98.0 ***ft***

100-year discharge 515 ***ft^3/s***
Water-surface elevation in bridge opening 94.4 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 53 ***ft^2***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.4 ***ft/s***

Water-surface elevation at Approach section with bridge 96.9
Water-surface elevation at Approach section without bridge 95.8
Amount of backwater caused by bridge 1.1 ***ft***

500-year discharge 700 ***ft^3/s***
Water-surface elevation in bridge opening 95.1 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 64 ***ft^2***
Average velocity in bridge opening 10.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.7 ***ft/s***

Water-surface elevation at Approach section with bridge 97.9
Water-surface elevation at Approach section without bridge 96.4
Amount of backwater caused by bridge 1.5 ***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 clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). Results are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.4	0.8	--
Depth to armoring	12.7	20.1	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	6.1	7.2	--
Right abutment	4.6	5.7	--
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	1.6	--
Right abutment	1.3	1.6	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

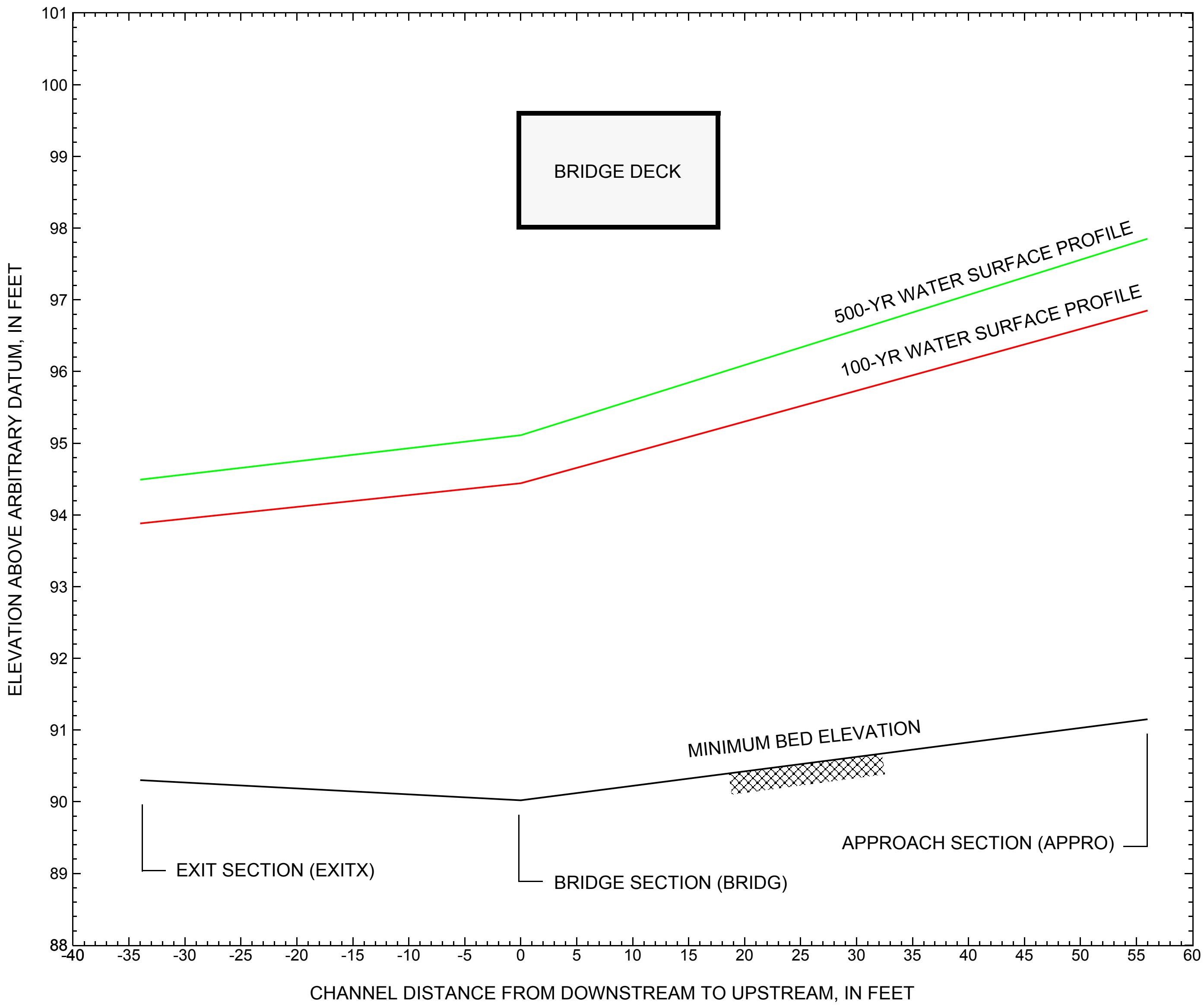

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure GLOVTH00410023 on Town Highway 41, crossing Sherburne Brook, Glover, Vermont.

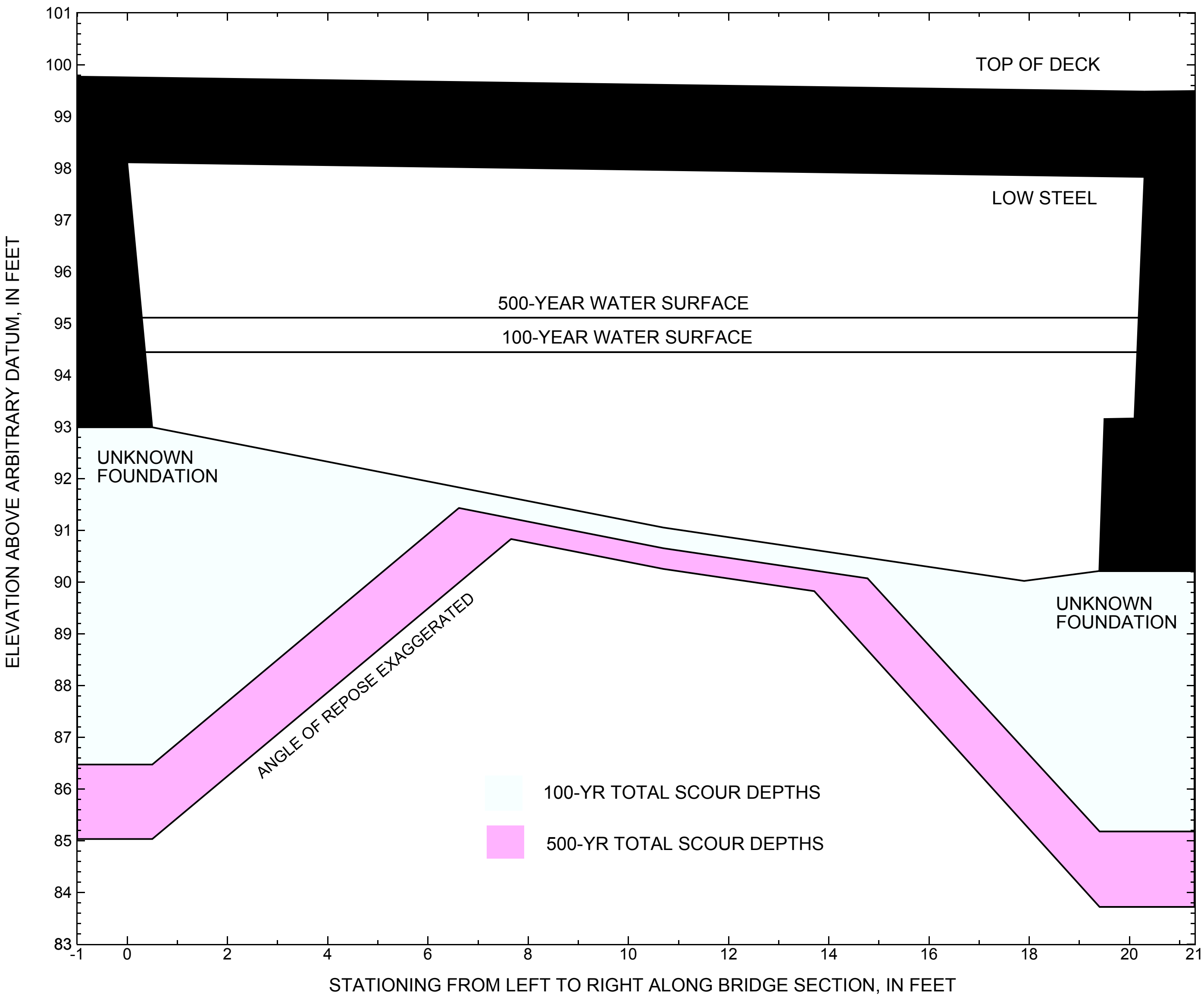

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure GLOVTH00410023 on Town Highway 41, crossing Sherburne Brook, Glover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure GLOVTH00410023 on Town Highway 41, crossing Sherburne Brook, Glover, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 515 cubic-feet per second											
Left abutment	0.0	--	98.1	--	93.0	0.4	6.1	--	6.5	86.5	--
Right abutment	20.3	--	97.8	--	90.2	0.4	4.6	--	5.0	85.2	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure GLOVTH00410023 on Town Highway 41, crossing Sherburne Brook, Glover, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 700 cubic-feet per second											
Left abutment	0.0	--	98.1	--	93.0	0.8	7.2	--	8.0	85.0	--
Right abutment	20.3	--	97.8	--	90.2	0.8	5.7	--	6.5	83.7	--

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

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U.S. Geological Survey, 1986, Crystal Lake, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File glov023.wsp
T2        Hydraulic analysis for structure GLOVTH00410023   Date: 08-MAY-97
T3        Bridge 23 crossing Sherburne Brook in Glover, Vt    SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q             515      700
SK          0.029   0.029
*
XS   EXITX    -34
GR          -33.6, 109.31    -22.5,  99.53     -6.1,  94.16      0.0,  91.10
GR            7.0,  90.72     10.2,  90.43     12.2,  90.30     14.6,  90.56
GR           20.2,  93.96     23.3,  95.24     30.1,  95.46     53.7,  98.43
GR           76.2,  98.00     86.2,  98.71
N            0.055       0.045
SA                  23.3
*
XS   FULLV      0  * * *   0.0107
*
BR   BRIDG     0     97.97      30.0
GR            0.0,  98.11      0.5,  92.99     10.7,  91.05     17.9,  90.02
GR           19.5,  90.21     19.5,  93.15     20.1,  93.16     20.3,  97.83
GR            0.0,  98.11
N            0.045
CD           1      38.8
*
XR   RDWAY      8      14.5     2
GR         -260.2, 104.20   -166.4, 102.08    -83.2, 100.85    -31.0,  99.96
GR            0.0,  99.76     20.0,  99.48     68.4,  98.42
*                           142.5,  96.42
*
XT   APTEM     66
GR          -56.3, 108.73    -49.5,  99.19    -46.7,  98.77    -28.6,  99.65
GR           -7.4,  99.73     -4.0,  98.34     -1.6,  94.02      0.0,  93.09
GR            3.2,  91.90      3.2,  91.89      5.0,  91.19      7.5,  91.54
GR           10.3,  91.46     11.6,  91.86     16.8,  94.57     28.7, 100.50
GR           59.0,  99.39
*
AS   APPRO     56 * * * 0.0038
GT
N            0.035     0.055       0.095
SA                -7.4        28.7
*
HP 1 BRIDG    94.44 1 94.44
HP 2 BRIDG    94.44 * * 515
HP 1 APPRO    96.85 1 96.85
HP 2 APPRO    96.85 * * 515
*
HP 1 BRIDG    95.11 1 95.11
HP 2 BRIDG    95.11 * * 700
HP 1 APPRO    97.85 1 97.85
HP 2 APPRO    97.85 * * 700
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File glov023.wsp
        Hydraulic analysis for structure GLOVTH00410023   Date: 08-MAY-97
        Bridge 23 crossing Sherburne Brook in Glover, Vt    SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      53.    3018.    17.    23.                        521.
    94.44           53.    3018.    17.    23.  1.00     0.    20.    521.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
        94.44     0.4    20.2    52.5    3018.     515.   9.81
X STA.         0.4         3.4         5.1         6.4         7.6         8.6
  A(I)             4.4         3.2         2.9         2.6         2.5
  V(I)            5.87        8.10        8.98        9.83       10.18

X STA.         8.6         9.5        10.3        11.0        11.8        12.4
  A(I)             2.4         2.3         2.2         2.2         2.1
  V(I)           10.85       11.29       11.56       11.95       11.99

X STA.        12.4        13.1        13.7        14.4        15.0        15.6
  A(I)             2.1         2.1         2.1         2.1         2.2
  V(I)           12.33       12.42       12.22       12.26       11.97

X STA.        15.6        16.2        16.8        17.5        18.3        20.2
  A(I)             2.2         2.3         2.5         3.0         5.2
  V(I)           11.66       11.08       10.23        8.72        4.93

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2      91.    5427.    25.    28.                       1000.
    96.85           91.    5427.    25.    28.  1.00    -3.    21.   1000.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
         WSEL     LEW     REW    AREA        K        Q    VEL
        96.85    -3.2    21.5    91.5    5427.     515.   5.63
X STA.        -3.2         0.1         1.3         2.4         3.2         4.0
  A(I)             7.9         5.0         4.6         4.2         3.9
  V(I)            3.24        5.11        5.60        6.12        6.53

X STA.         4.0         4.7         5.3         6.0         6.6         7.3
  A(I)             3.8         3.7         3.6         3.6         3.6
  V(I)            6.77        6.97        7.14        7.09        7.21

X STA.         7.3         8.0         8.7         9.3        10.1        10.8
  A(I)             3.6         3.7         3.7         3.8         4.0
  V(I)            7.07        7.05        6.94        6.69        6.49

X STA.        10.8        11.6        12.6        13.8        15.5        21.5
  A(I)             4.2         4.6         5.1         5.8         8.9
  V(I)            6.20        5.57        5.03        4.41        2.89
```

```
        U.S. Geological Survey WSPRO Input File glov023.wsp
        Hydraulic analysis for structure GLOVTH00410023   Date: 08-MAY-97
        Bridge 23 crossing Sherburne Brook in Glover, Vt    SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      64.    4043.    17.    24.                        700.
    95.11           64.    4043.    17.    24.  1.00     0.    20.    700.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
        95.11     0.3    20.2    64.0    4043.     700.  10.93
X STA.         0.3         3.1         4.7         5.9         7.1         8.0
  A(I)             5.5         3.7         3.3         3.2         2.9
  V(I)            6.38        9.33       10.55       10.86       12.09

X STA.         8.0         8.9         9.8        10.6        11.3        12.0
  A(I)             2.9         2.8         2.7         2.6         2.6
  V(I)           12.11       12.68       13.04       13.47       13.56

X STA.        12.0        12.7        13.4        14.0        14.7        15.3
  A(I)             2.6         2.5         2.6         2.6         2.6
  V(I)           13.62       13.74       13.55       13.63       13.33

X STA.        15.3        16.0        16.7        17.4        18.2        20.2
  A(I)             2.7         2.9         3.1         3.7         6.5
  V(I)           13.01       12.00       11.40        9.38        5.35

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     117.    7627.    27.    32.                       1384.
    97.85          117.    7627.    27.    32.  1.00    -4.    23.   1384.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.
         WSEL     LEW     REW    AREA        K        Q    VEL
        97.85    -3.7    23.5   117.4    7627.     700.   5.96
X STA.        -3.7        -0.1         1.2         2.2         3.1         4.0
  A(I)            10.4         6.4         5.8         5.3         5.1
  V(I)            3.35        5.45        6.02        6.62        6.93

X STA.         4.0         4.7         5.4         6.1         6.8         7.5
  A(I)             4.9         4.7         4.6         4.6         4.5
  V(I)            7.22        7.46        7.66        7.59        7.71

X STA.         7.5         8.3         9.0         9.7        10.5        11.3
  A(I)             4.6         4.6         4.7         4.9         5.2
  V(I)            7.55        7.53        7.42        7.16        6.77

X STA.        11.3        12.2        13.3        14.7        16.7        23.5
  A(I)             5.4         5.9         6.7         7.8        11.3
  V(I)            6.43        5.95        5.23        4.48        3.11
```

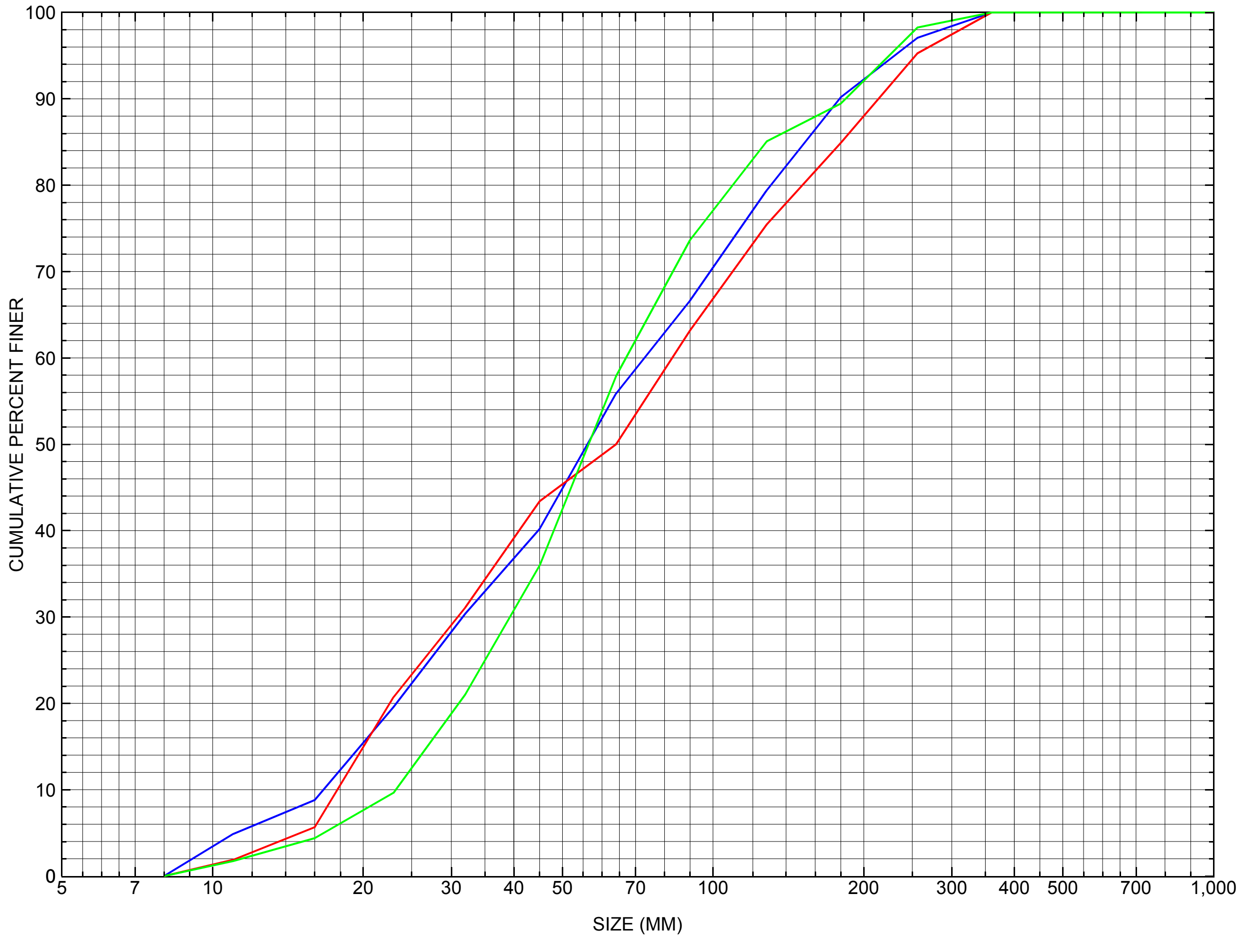
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File glov023.wsp
        Hydraulic analysis for structure GLOVTH00410023   Date: 08-MAY-97
        Bridge 23 crossing Sherburne Brook in Glover, Vt    SAO

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

EXITX:XS   ******    -6.      63.  1.02 *****   94.90   93.70    515.   93.88
      -34. ******    20.    3023.  1.00 ***** *******    0.91    8.11

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.46

FULLV:FV      34.    -8.      84.  0.58  0.68   95.58 *******    515.   95.00
        0.    34.    22.    4403.  1.00  0.00    0.00    0.64    6.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      56.    -3.      67.  0.92  0.96   96.71 *******    515.   95.79
       56.    56.    19.    3518.  1.00  0.17    0.00    0.78    7.71
         <<<<<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      34.     0.      53.  1.49  0.99   95.94   94.42    515.   94.44
        0.    34.    20.    3022.  1.00  0.04    0.00    0.99    9.80

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******   97.97 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<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      17.    -3.      91.  0.49  0.29   97.34   95.25    515.   96.85
       56.    18.    21.    5425.  1.00  1.12    0.02    0.52    5.63

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.094  0.000    5400.    -5.    15.    96.47

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q        K      AREA     VEL    WSEL
   EXITX:XS     -34.    -6.    20.    515.    3023.      63.    8.11   93.88
   FULLV:FV       0.    -8.    22.    515.    4403.      84.    6.12   95.00
   BRIDG:BR       0.     0.    20.    515.    3022.      53.    9.80   94.44
   RDWAY:RG       8.**************      0.*****************    2.00********
   APPRO:AS      56.    -3.    21.    515.    5425.      91.    5.63   96.85

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -5.    15.    5400.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS     93.70    0.91   90.30  109.31************  1.02   94.90   93.88
   FULLV:FV  ********    0.64   90.66  109.67  0.68  0.00  0.58   95.58   95.00
   BRIDG:BR     94.42    0.99   90.02   98.11  0.99  0.04  1.49   95.94   94.44
   RDWAY:RG  ****************   98.42  104.20********************************
   APPRO:AS     95.25    0.52   91.15  108.69  0.29  1.12  0.49   97.34   96.85
```

```
       U.S. Geological Survey WSPRO Input File glov023.wsp
       Hydraulic analysis for structure GLOVTH00410023   Date: 08-MAY-97
       Bridge 23 crossing Sherburne Brook in Glover, Vt    SAO

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

EXITX:XS   ******    -7.      80.  1.20 *****   95.68   94.32    700.   94.49
      -34. ******    21.    4109.  1.00 ***** *******    0.93    8.77

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "FULLV"     KRATIO =  1.45

FULLV:FV      34.   -10.     105.  0.69  0.68   96.36 *******    700.   95.68
        0.    34.    26.    5940.  1.00  0.00    0.00    0.68    6.64
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81      96.44      95.93

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =    95.18     108.69    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =    95.18     108.69      95.93

APPRO:AS      56.    -3.      81.  1.15  1.00   97.58   95.93    700.   96.43
       56.    56.    21.    4619.  1.00  0.23   -0.02    0.82    8.60
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =     700.      95.11

           <<<<<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      34.     0.      64.  1.86 *****   96.97   95.11    700.   95.11
        0.    34.    20.    4050.  1.00 ***** *******    1.00   10.92

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******   97.97 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG       8.        <<<<<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      17.    -4.     117.  0.55  0.28   98.40   95.93    700.   97.85
       56.    18.    23.    7631.  1.00  1.16    0.01    0.51    5.96

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.153  0.015    7490.    -4.    16.    97.50

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -34.    -7.    21.    700.    4109.      80.    8.77   94.49
   FULLV:FV       0.   -10.    26.    700.    5940.     105.    6.64   95.68
   BRIDG:BR       0.     0.    20.    700.    4050.      64.   10.92   95.11
   RDWAY:RG       8.**************      0.******************    2.00********
   APPRO:AS      56.    -4.    23.    700.    7631.     117.    5.96   97.85

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -4.    16.    7490.

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS      94.32    0.93   90.30  109.31************  1.20   95.68   94.49
   FULLV:FV   ********    0.68   90.66  109.67  0.68  0.00  0.69   96.36   95.68
   BRIDG:BR      95.11    1.00   90.02   98.11************  1.86   96.97   95.11
   RDWAY:RG   ****************   98.42  104.20**********************************
   APPRO:AS      95.93    0.51   91.15  108.69  0.28  1.16  0.55   98.40   97.85
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for three pebble count transects in the channel approach of structure GLOVTH00410023, in Glover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number GLOVTH00410023

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 04 / 94

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

County *(FIPS county code; I - 3; nnn)* 019

Town *(FIPS place code; I - 4; nnnnn)* 28075

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

Waterway *(I - 6)* SHERBURNE BROOK

Road Name *(I - 7)*: TH041

Route Number 0.1 MI

Vicinity *(I - 9)* TO JCT W VT16

Topographic Map Crystal.Lake

Hydrologic Unit Code: 01110000

Latitude *(I - 16; nnnn.n)* 44408

Longitude *(i - 17; nnnnn.n)* 72113

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10100800231008

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

Maximum span length *(I - 48; nnnn)* 0021

Year built *(I - 27; YYYY)* 1919

Structure length *(I - 49; nnnnnn)* 000024

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 145

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

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

Opening skew to Roadway *(I - 34; nn)* 40

Waterway adequacy *(I - 71; n)* 8

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*) 007.5

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

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

Comments:

Structural inspection of 7/9/93 indicates a steel stringer with timber deck bridge. A minor amount of mortar is missing on both abutment walls. The footing is exposed at the right abutment. No undermining or settlement. No embankment erosion. The channel makes sharp bend through bridge. A point bar along left abutment blocks 50% of the flow. The deck is in poor condition. Some scour at the right abutment if any.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: 1.4

Terrain character: -

Stream character & type: -

Streambed material: Stones and boulders with gravel and mud

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} 290 Q_{25} 350

Q_{50} 420 Q_{100} 500 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)* : Light Debris *(Heavy, Moderate, Light)*: Moderate

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*)	-	5.6	6.6	7.6	9.1
Velocity (*ft / sec*)	-	-	12.1	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): Y Frequency: Q50

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

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

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

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

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

Downstream distance (*miles*): - ___________ Town: - ___________________ Year Built: - ______
Highway No. : - ________________ Structure No. : - ______ Structure Type: - ______________________
Clear span (*ft*): - _____ Clear Height (*ft*): - ______ Full Waterway (ft^2): - _______

Comments:

The above high water elevations are measured up from the ambient channel bed.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **2.57** mi^2 Lake/pond/swamp area **0.10** mi^2

Watershed storage *(ST)* **3.4** %

Bridge site elevation **1221** ft Headwater elevation **2188** ft

Main channel length **2.80** mi

10% channel length elevation **1270** ft 85% channel length elevation **1850** ft

Main channel slope *(S)* **276.32** ft / mi

Watershed Precipitation Data

Average site precipitation __________ in Average headwater precipitation __________ in

Maximum 2yr-24hr precipitation event *(I24,2)* ________ in

Average seasonal snowfall *(Sn)* _________ ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS.

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

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

Comments: NO CROSS SECTION INFORMATION

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **DLS** Date: **2/6/95**
Computerized by: **EMB** Date: **2/27/95**
Reviewd by: **SAO** Date: **5/23/97**

Structure Number **GLOVTH00410023**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. BOEHMLER** Date *(MM/DD/YY)* **10** / **24** / 19**94**

2. Highway District Number **09**
Mile marker **-**
County **ORLEANS (019)**
Town **GLOVER (28075)**
Waterway *(I - 6)* **SHERBURNE BROOK**
Road Name **-**
Route Number **TH41**
Hydrologic Unit Code: **01110000**

3. Descriptive comments:
The structure is a steel stringer type bridge located about 0.2 miles from the intersection of TH41 with VT16. The bridge has a timber deck with grey painted steel pipe guard rails.

B. Bridge Deck Observations

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

5. Ambient water surface... US **2** UB **1** 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 **24.0** *(feet)* Span length **21.0** *(feet)* Bridge width **14.5** *(feet)*

Road approach to bridge:

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

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

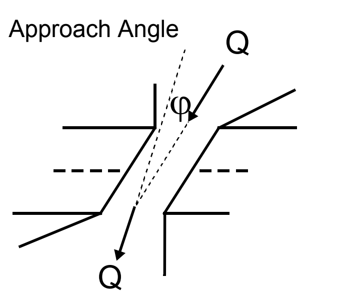
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

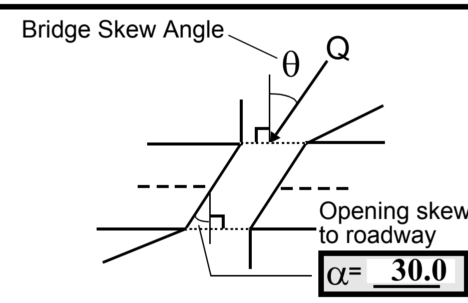
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	1	2
RBUS	0	-	0	0
RBDS	0	-	2	2
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: **20** 16. Bridge skew: **55**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **3**
Range? **25** feet **US** *(US, UB, DS)* to **10** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **80** feet **US** *(US, UB, DS)* to **55** feet **US**

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

18. Bridge Type: **1b**

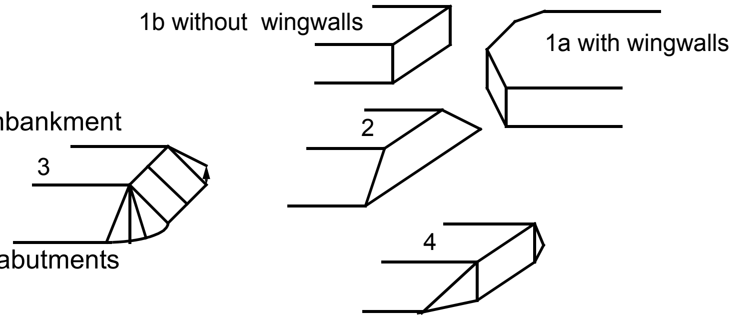
1a- Vertical abutments with wingwalls

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.)

The measured bridge length is 23.0 feet, while the other dimensions are the same as those indicated on the historical form.
Surface cover on the immediate left bank upstream is the gravel roadway with forest further away from the channel. On the right bank upstream, there is a home surrounded by a lawn, but the predominant surface cover is still forest. The downstream right bank has a grass plot, otherwise it is forested. The downstream left bank surface cover is brush to about 25 feet downstream where it changes to forest cover.
The upstream left bank is impacted moderately as the channel bends and runs along the immediate edge of the roadway for 150 feet before turning sharply to proceed under the bridge. The upstream end of the bridge has vertical retaining walls extending upstream from both abutment walls.

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
27.0	8.0			8.5	1	4	4	4	1	0

23. Bank width	24. Channel width	25. Thalweg depth	29. Bed Material
30.0	25.0	37.0	4

30 .Bank protection type: LB **5** RB **5**

31. Bank protection condition: LB **1** RB **1**

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

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

The banks are composed of cobble and boulder material with fill for the roadway on top on the left bank upstream. Cobble and boulder material in the right bank is in a sand matrix with a lot of organics (leaves, branches, etc.) on top and a thin topsoil layer. The bed material appears to have a high fraction of coarse gravel, cobbles, and some boulders embedded in a coarse sand and fine gravel.

30. The abutments extend upstream 31 feet on the right and 11 feet on the left. These abutment extensions are being considered as bank protection in this case. The right abutment is experiencing undermining.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **0** 35. Mid-bar width: **10**

36. Point bar extent: **13** feet **US** (US, UB) to **25** feet **DS** (US, UB, DS) positioned **0** %LB to **70** %RB

37. Material: **3**

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

The point bar material ranges from coarse gravel at the upstream end to fine gravel and coarse to medium sand under the bridge, to coarse gravel and cobbles at the downstream end.

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

41. Mid-bank distance: **65** 42. Cut bank extent: **80** feet **US** (US, UB) to **50** feet **US** (US, UB, DS)

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

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

The entire left bank upstream is moderately eroded with only small (1 to 2 year old) trees. The roots are exposed on some of the young trees and some are leaning toward the channel. Some slight bank undercutting is evident in various places along the bank. The bank material here is very steep and loose and eroding and creeping down the embankment.

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
8.5		0.5		2	7	7	-

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

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

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

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

4

The streambed is covered with cobbles and boulders at the thalweg which runs along the right abutment but is fine gravel and coarse to medium sand along the left abutment.

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? 3 ___ *(Y or N)* Ice Blockage Potential N ___ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

2

A fallen tree is in the channel along the downstream left bank parallel with the direction of flow. Remnants of the tree are too long to have flowed through the bridge. There are a lot of small branches and small trees that have accumulated along the banks upstream. However, no distinct zones are apparent where debris has piled up.

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		-	90	0	0	-	-	90.0
RABUT	2	15	90			2	3	20.5

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

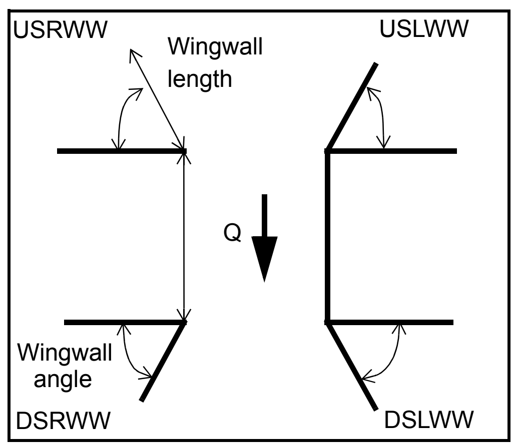
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

1.0
3.5
2

The right abutment footing is undermined about 0.5 feet (vertical) and a rangepole penetrates in some spots to a maximum of one foot (horizontal). The exposure depth above (3.5 ft) refers to the maximum measurement from the top of the footing to the stream bed. The retaining wall footing on the right bank upstream also is exposed at least by 2 to 3.5 feet, with the undermining restricted to the location of the wall just upstream of the abutment wall. On the left bank, the retaining wall is in good condition except for the extreme upstream end where it is being eroded from behind the wall probably by both channel and roadwash processes. The attack angle shown is focused primarily on the right bank retaining wall/upstream end of abutment. The right abut-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	ment		foot-		ing is	8.5	
USRWW:	con-		crete		with	1.0	
DSLWW:	one		or		mul-	33.5	
DSRWW:	tiple		sub-		foot-	50.0	



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	ing(	ed	peri	cha	sion	the	wall	viou
Condition	s)	afte	ods	nnel	belo	ston	or	sly
Extent	plac	r	of	ero-	w	e	pre-	inst

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

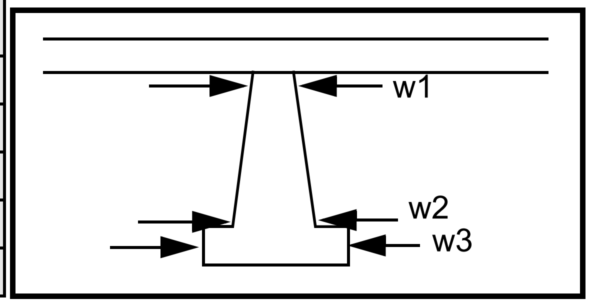
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
alled subfooting.

N
-
-
-
-
N
-
-
-

Piers:

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

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



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

106. Point/Side bar present? **-** (Y or N. if N type ctrl-n pb) Mid-bar distance: **-** Mid-bar width: **NO**

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

Material: _____

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

Is a cut-bank present? **2** (Y or if N type ctrl-n cb) Where? **1** (LB or RB) Mid-bank distance: **3**

Cut bank extent: **3** feet **2** (US, UB, DS) to **1** feet **4** (US, UB, DS)

Bank damage: **0** (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)

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

0

-

-

The bank material is composed of more coarse gravel downstream than upstream with some cobbles and

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

Scour dimensions: Length **emb** Width **edde** Depth: **d in** Positioned **a** %LB to **me** %RB

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

dium to coarse sand and fine gravel.

The bed material is similar, but has more cobble material.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution **N**

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)*:

-

NO DROP STRUCTURE

Y

90

8

65

DS

105

109. G. Plan View Sketch

D

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: GLOVTH00410023 Town: GLOVER
Road Number: TH41 County: ORLEANS
Stream: SHELBURNE BROOK

Initials SAO Date: 5/20/97 Checked: RB

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	515	700	0
Main Channel Area, ft2	91.5	117	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	24.7	27.2	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.188	0.188	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	3.7	4.3	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	5427	7627	0
Conveyance, main channel	5427	7627	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	515.0	700.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	5.6	6.0	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	8.0	8.2	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	515	700	0
(Q) discharge thru bridge, cfs	515	700	0
Main channel conveyance	3018	4043	0
Total conveyance	3018	4043	0
Q2, bridge MC discharge,cfs	515	700	ERR
Main channel area, ft2	52.5	64.0	0
Main channel width (normal), ft	17.1	17.2	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	17.1	17.2	0
y_bridge (avg. depth at br.), ft	3.07	3.72	ERR
Dm, median (1.25*D50), ft	0.235	0.235	0
y2, depth in contraction,ft	3.47	4.49	ERR
ys, scour depth (y2-ybridge), ft	0.40	0.77	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	515	700	N/A
Main channel area (DS), ft2	52.5	64	0
Main channel width (normal), ft	17.1	17.2	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	17.1	17.2	0.0
D90, ft	0.6352	0.6352	0.0000
D95, ft	0.7779	0.7779	0.0000
Dc, critical grain size, ft	0.5835	0.6616	ERR
Pc, Decimal percent coarser than Dc	0.121	0.090	0.000
Depth to armoring, ft	12.73	20.08	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	515	700	0	515	700	0
a', abut.length blocking flow, ft	3.6	4.0	0	4.0	6.0	0
Ae, area of blocked flow ft2	9.2	12.4	0	5.9	10.0	0
Qe, discharge blocked abut.,cfs	32.2	45.8	0	17.2	30.9	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.50	3.69	ERR	2.92	3.09	ERR
ya, depth of f/p flow, ft	2.56	3.10	ERR	1.48	1.67	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	0	1	1	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	60	60	0	120	120	0
K2	0.95	0.95	0.00	1.04	1.04	0.00
Fr, froude number f/p flow	0.386	0.370	ERR	0.423	0.422	ERR
ys, scour depth, ft	6.12	7.16	N/A	4.63	5.69	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)	3.6	4	0	4	6	0
y1 (depth f/p flow, ft)	2.56	3.10	ERR	1.48	1.67	ERR
a'/y1	1.41	1.29	ERR	2.71	3.60	ERR
Skew correction (p. 49, fig. 16)	0.90	0.90	0.90	1.07	1.07	1.07
Froude no. f/p flow	0.39	0.37	N/A	0.42	0.42	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.99	1	0	0.99	1	0
y, depth of flow in bridge, ft	3.07	3.72	0.00	3.07	3.72	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.)	1.28	1.56	ERR	1.28	1.56	ERR
Fr<=0.8 (spillthrough abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (spillthrough abut.)	1.13	1.38	ERR	1.13	1.38	ERR