LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (STOWTH00160039) on TOWN HIGHWAY 16, crossing MOSS GLEN BROOK, STOWE, VERMONT

Open-File Report 97-794

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (STOWTH00160039) on TOWN HIGHWAY 16, crossing MOSS GLEN BROOK, STOWE, VERMONT

By MICHAEL A. IVANOFF AND ROBERT E. HAMMOND

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Pembroke, New Hampshire

1997

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (STOWTH00160039) ON TOWN HIGHWAY 16, CROSSING MOSS GLEN BROOK, STOWE, VERMONT

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

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure STOWTH00160039 on Town Highway 16 crossing Moss Glen Brook, Stowe, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in north-central Vermont. The 4.75-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream and on the right bank downstream. The downstream left bank is pasture while the immediate bank has dense woody vegetation.

In the study area, Moss Glen Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 52 ft and an average bank height of 7 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 56.5 mm (0.185 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 10, 1996, indicated that the reach was stable.

The Town Highway 16 crossing of Moss Glen Brook is a 22-ft-long galvanized plate arch culvert with an opening span width of 21 ft (Vermont Agency of Transportation, written communication, October 13, 1995). The opening length of the structure parallel to the culvert face is 20.6 ft. The culvert is supported by vertical, concrete abutments with no wingwalls. The channel is skewed approximately zero degrees to the opening. The opening skew-to-roadway value from the VTAOT database is 5 degrees while zero degrees was computed from surveyed points.

The only scour counter measure at the site was type-3 stone fill (less than 48 inches diameter) at the upstream and downstream ends of the left and right abutments and extending along the banks upstream and downstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 1.2 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 12.6 to 16.2 ft. Right abutment scour ranged from 12.1 to 14.3 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Stowe and Mount Worcester, VT. Quadrangle, 1:24,000, 1968

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 STOWTH00160039 ***Stream*** Moss Glen Brook

County Lamoille ***Road*** TH 16 ***District*** 6

Description of Bridge

Bridge length 22 ***ft*** ***Bridge width*** 50.5 ***ft*** ***Max span length*** 21 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 7/10/96

Description of stone fill Type-3, around the upstream and downstream ends of the left and right abutments.

Brief description of piers/abutments Abutments are concrete. The concrete abutments are supporting a corrugated galvanized plate pipe arch.

Is bridge skewed to flood flow according to Yes ***survey?*** No ***Angle*** 0

Is there a channel bend in the ... If so, describe (mild, moderate, severe) There is a moderate channel bend in the upstream reach.

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	7/10/96	0	0
Level II	7/10/96	0	0

Potential for debris High. There is debris caught on concrete blocks along the upstream left bank and trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 7/10/96.

Description of the Geomorphic Setting

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

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

Date of inspection 7/10/96

DS left: Steep channel bank to a narrow flood plain.

DS right: Steep channel bank to a narrow flood plain.

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

US right: Steep channel bank to a narrow flood plain.

Description of the Channel

Average top width 52 ft ***Average depth*** 7 ft

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

Sinuous but stable with non-alluvial channel boundaries and a narrow flood plain.

7/10/96

Vegetative co Trees and brush with cut grass on the overbank.

DS left: Trees and brush.

DS right: Trees and brush.

US left: Trees and brush.

US right: Yes

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

None, 7/10/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 4.75 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: -

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/p No

-

-

Calculated Discharges

Q100 1,190 ***ft***^{3}***/s*** ***Q500*** 1,700 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on the flood frequency estimates for this site available from the VTAOT database. The drainage area above bridge number 39 in the VTAOT database is 4.57 square miles. The discharge values are within a range defined by several empirical flood frequency curves (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 nail 6 ft high in a telephone pole by the edge of TH 16 on the right bank in line with the road over the culvert (elev. 502.62 ft, arbitrary survey datum). RM2 is a bolt on the top left center of the downstream end of the culvert (elev. 496.61 ft, arbitrary survey datum). RM3 is a bolt on the top right center on the upstream end of the culvert (elev. 496.21 ft, arbitrary survey datum).

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-22	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
APPRO	75	1	Approach section

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

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.035 to 0.070, and overbank "n" values ranged from 0.040 to 0.055.

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 0.0153 ft/ft, which was estimated from surveyed thalweg points downstream of the culvert.

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

The unconstricted channel was modeled for each discharge by use of WSPRO. Then the water surface elevation computed at the full valley section (FULLV) for each discharge under the unconstricted channel condition was applied as the starting water surface elevation for modeling the culvert hydraulics for each discharge.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.8 *ft*
Average low steel elevation 496.7 *ft*

100-year discharge 1,190 *ft^3/s*
Water-surface elevation in bridge opening 492.1 *ft*
Road overtopping? No *Discharge over road* -- *ft^3/s*
Area of flow in bridge opening 110 *ft^2*
Average velocity in bridge opening 10.8 *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge 495.4
Water-surface elevation at Approach section without bridge 493.3
Amount of backwater caused by bridge 2.1 *ft*

500-year discharge 1,700 *ft^3/s*
Water-surface elevation in bridge opening 493.1 *ft*
Road overtopping? No *Discharge over road* -- *ft^3/s*
Area of flow in bridge opening 126 *ft^2*
Average velocity in bridge opening 13.5 *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge 498.0
Water-surface elevation at Approach section without bridge 494.3
Amount of backwater caused by bridge 3.7 *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 for the 100-year and 500-year discharges were computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). 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	0.0	1.2	--
Depth to armoring	10.8	23.6	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	12.6	16.2	--
Right abutment	12.1	14.3	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.2	2.9	--
Right abutment	2.2	2.9	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

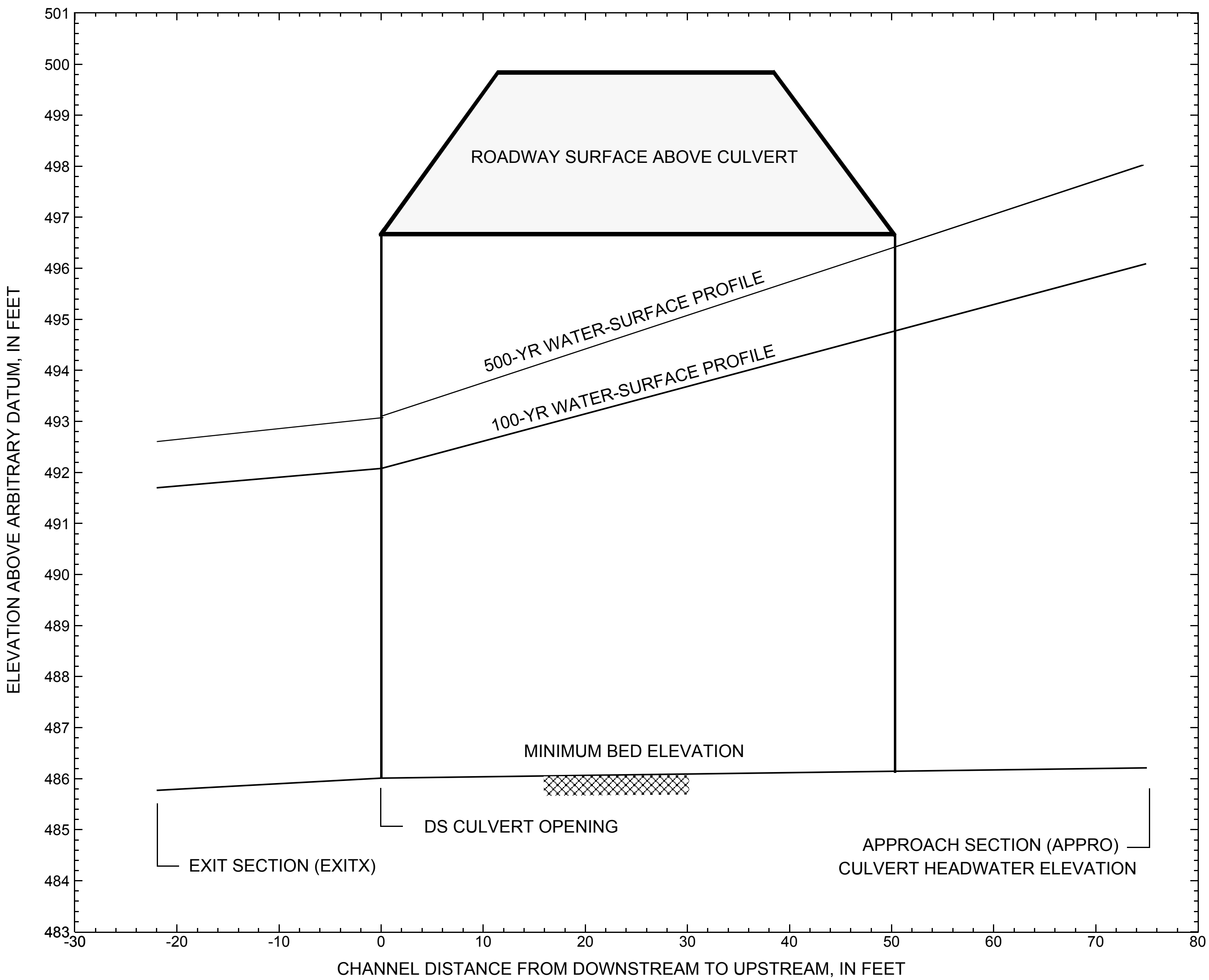

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure STOWTH00160039 on Town Highway 16, crossing Moss Glen Brook, Stowe, Vermont.

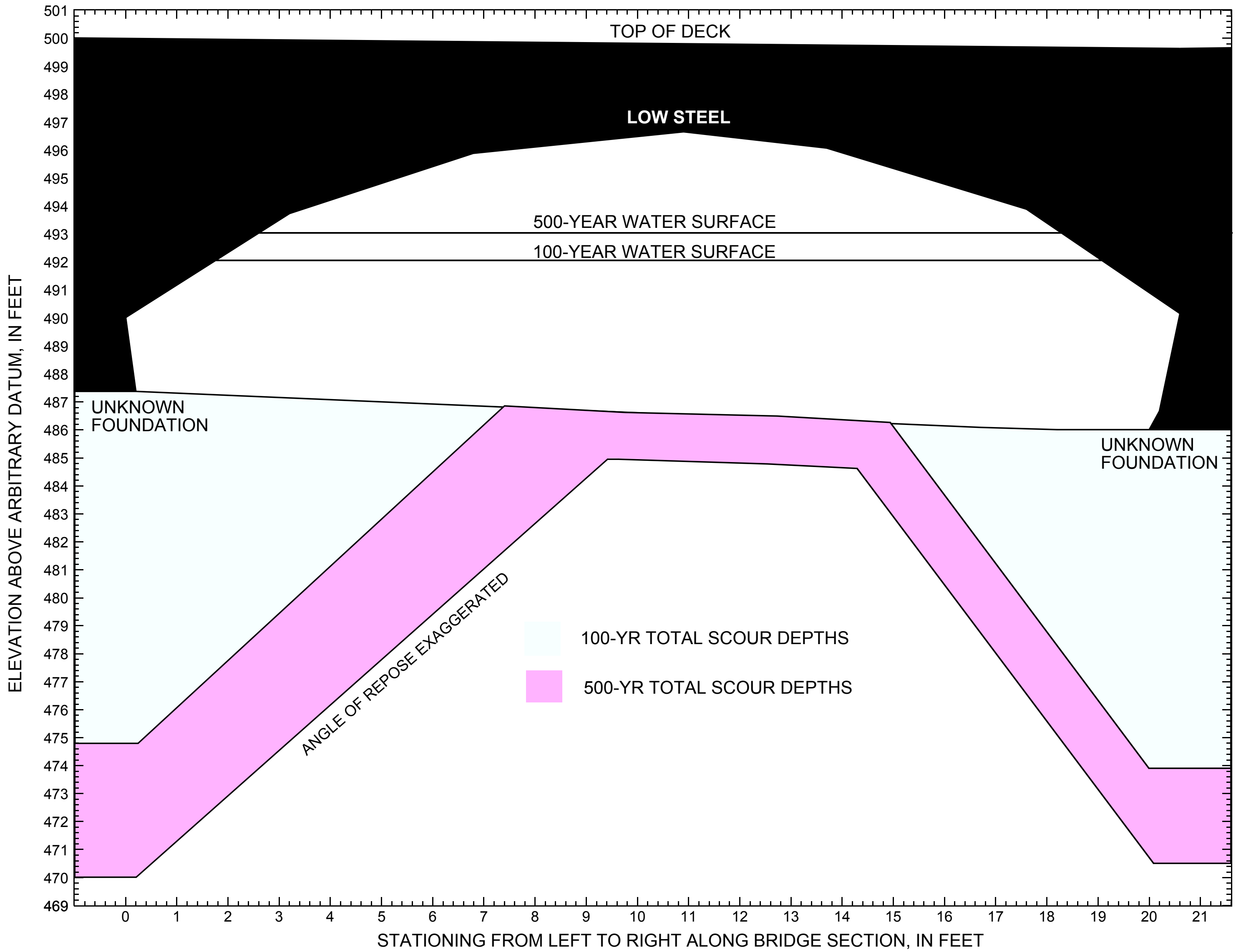

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure STOWTH00160039 on Town Highway 16, crossing Moss Glen Brook, Stowe, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure STOWTH00160039 on Town Highway 16, crossing Moss Glen Brook, Stowe, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,190 cubic-feet per second											
Left abutment	0.0	--	496.7	--	487.4	0.0	12.6	--	12.6	474.8	--
Right abutment	20.6	--	496.7	--	486.0	0.0	12.1	--	12.1	473.9	--

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 STOWTH00160039 on Town Highway 16, crossing Moss Glen Brook, Stowe, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 1,700 cubic-feet per second											
Left abutment	0.0	--	496.7	--	487.4	1.2	16.2	--	17.4	470.0	--
Right abutment	20.6	--	496.7	--	486.0	1.2	14.3	--	15.5	470.5	--

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, 1968, Stowe, 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 stow039.wsp
T2        Hydraulic analysis for structure STOWTH00160039   Date: 15-AUG-97
T3        Arch Culvert 39 on Town Highway 16 over Moss Glen Brook Stowe, VT  MAI
*
*          6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1190.0   1700.0
SK          0.0153   0.0153
*
XS   EXITX    -22
GR         -211.6, 508.15   -182.1, 501.52   -145.5, 494.82    -77.1, 494.18
GR          -55.9, 492.59     -8.7, 491.73      0.0, 489.63      5.2, 486.64
GR            5.6, 485.96      8.1, 486.06     11.5, 486.07     15.1, 485.77
GR           18.6, 485.84     21.9, 486.48     28.5, 489.45     38.2, 495.96
GR           49.8, 497.11     62.3, 498.01     80.2, 497.93    114.5, 499.41
GR          142.7, 502.29
N           0.040        0.054        0.045
SA                  -8.7         38.2
*
XS   FULLV      0  * * *   0.0109
*
XS   APPRO     75
GR         -201.3, 505.20   -135.7, 501.56    -73.4, 499.98    -46.0, 497.70
GR          -29.5, 492.95    -11.3, 491.23     -4.5, 490.39      0.0, 487.44
GR            2.1, 487.27      7.0, 486.21     10.1, 486.27     14.6, 486.62
GR           19.0, 486.77     22.2, 487.33     26.5, 488.30     32.0, 491.62
GR           41.7, 498.05     51.5, 499.16     96.3, 498.61    114.3, 499.94
GR          121.6, 502.43
*
N           0.055        0.070        0.045
SA                 -4.5          51.5
*
HP 1 APPRO 495.37 1 495.37
HP 2 APPRO 495.37 * * 1190
*
HP 1 APPRO 498.01 1 498.01
HP 2 APPRO 498.01 * * 1700
*
EX
ER
```

Culvert Analysis

```
T1        Culvert bridge # 39 on Moss Glen Brook in Stowe, VT
T2        STOWTH00160039
*
Q            1190.0   1700.0
WS           492.11   493.08
*
CV   CULVT   0  11  50  486.01  486.02
CG           327  128  251
*
EX
ER
```

APPENDIX B:

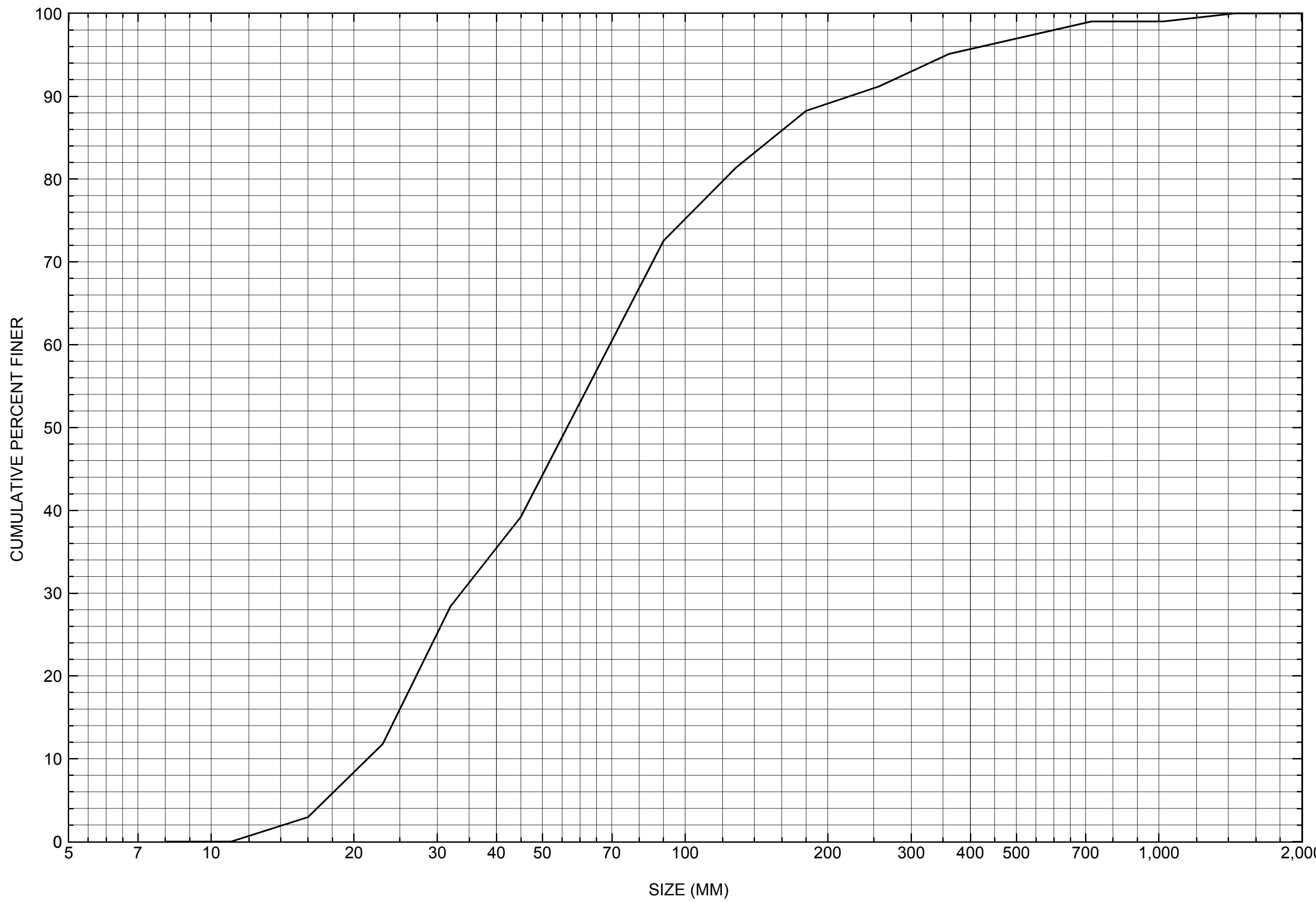
WSPRO OUTPUT FILE

```
 U.S. Geological Survey WSPRO Input File stow039.wsp
 Hydraulic analysis for structure STOWTH00160039   Date: 15-AUG-97
 Arch Culvert 39 on Town Highway 16 over Moss Glen Brook Stowe, VT  MAI
    *** RUN DATE & TIME: 11-06-97  15:22


 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = APPRO;  SRD =      75.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      101      5656     33     34                          995
           2      294     21780     42     45                         4412
  495.37          395     27436     76     79  1.04    -37     38     5037


 VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = APPRO;  SRD =      75.

       WSEL     LEW     REW    AREA        K        Q    VEL
     495.37   -37.9    37.7   395.1   27436.    1190.   3.01

X STA.       -37.9      -21.3      -14.5       -9.2       -5.0       -1.3
  A(I)            33.3       23.7       21.7       19.9       21.6
  V(I)            1.78       2.52       2.74       2.98       2.76

X STA.        -1.3        1.1        3.1        5.0        6.8        8.4
  A(I)            18.2       16.4       16.4       15.8       15.2
  V(I)            3.27       3.63       3.63       3.77       3.91

X STA.         8.4       10.2       11.9       13.7       15.6       17.5
  A(I)            15.7       15.6       16.1       16.7       16.6
  V(I)            3.78       3.82       3.70       3.57       3.58

X STA.        17.5       19.6       21.7       24.3       27.4       37.7
  A(I)            17.6       18.1       19.9       22.3       34.3
  V(I)            3.39       3.28       2.99       2.67       1.73


 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = APPRO;  SRD =      75.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      202     14616     45     46                         2415
           2      411     35530     46     50                         6956
  498.01          612     50145     91     96  1.02    -49     42     8913


 VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = APPRO;  SRD =      75.

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.01   -49.7    41.6   612.4   50145.    1700.   2.78

X STA.       -49.7      -27.8      -21.3      -16.1      -11.5       -7.5
  A(I)            53.6       36.2       31.5       29.9       28.4
  V(I)            1.59       2.35       2.70       2.85       2.99

X STA.        -7.5       -3.8       -0.5        1.9        4.2        6.4
  A(I)            27.6       30.6       25.5       25.0       24.5
  V(I)            3.08       2.78       3.34       3.40       3.47

X STA.         6.4        8.4       10.5       12.6       14.8       17.1
  A(I)            24.2       24.2       24.2       25.7       25.6
  V(I)            3.51       3.51       3.51       3.30       3.32

X STA.        17.1       19.5       22.1       25.1       28.8       41.6
  A(I)            27.1       28.1       31.0       35.2       54.1
  V(I)            3.14       3.02       2.74       2.41       1.57
```

```
        U.S. Geological Survey WSPRO Input File stow039.wsp
        Hydraulic analysis for structure STOWTH00160039   Date: 15-AUG-97
        Arch Culvert 39 on Town Highway 16 over Moss Glen Brook Stowe, VT  MAI
           *** RUN DATE & TIME: 11-06-97  15:22

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

EXITX:XS   ******     -8      151  0.96 *****  492.67  490.76    1190  491.70
       -21 ******     32     9613  1.00 ***** *******    0.72    7.87

FULLV:XS       22    -15      159  0.88  0.32  492.99 *******    1190  492.11
         0     22     32    10282  1.01  0.00    0.01    0.73    7.50

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.42

APPRO:XS       75    -30      250  0.38  0.71  493.69 *******    1190  493.32
        75     75     35    14636  1.08  0.00    0.00    0.44    4.75



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

EXITX:XS   ******    -54      206  1.18 *****  493.75  491.78    1700  492.57
       -21 ******     33    13735  1.12 ***** *******    1.00    8.25

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.88     493.07     492.02

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   492.07     508.39    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   492.07     508.39     492.02

FULLV:XS       22    -58      230  0.97  0.30  494.04  492.02    1700  493.08
         0     22     34    15486  1.14  0.00   -0.01    0.88    7.38

APPRO:XS       75    -33      314  0.48  0.70  494.74 *******    1700  494.26
        75     75     36    19936  1.06  0.00   -0.01    0.46    5.41


        Culvert bridge # 39 on Moss Glen Brook in Stowe, VT
        STOWTH00160039
           *** RUN DATE & TIME: 11-21-97  07:55
    CULVERT SUMMARY:

        ISHAPE      RISE      SPAN    BOTRAD    TOPRAD    CORNER
             3    128.00    251.00    434.38    125.59     18.00

         IEQNO       CKE        CN    CVALPH    CVLENG    CVSLPE
            12      0.50     0.035      1.16     50.00    0.0002

         TWDEP      QBBL      HWIC      HWOC    OTFULL
          6.10   1190.00      8.33      9.36     -2.36

         DSUBC     ASUBC     DSUBN     ASUBN
          5.38     97.53     10.67    165.76

         VELOT      AOUT     VELIN       AIN       HWE
         10.79    110.33      9.43    126.15    495.37
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure STOWTH00160039, in Stowe, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **STOWTH00160039**

General Location Descriptive

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

Date *(MM/DD/YY)* **10** / **13** / **95**

Highway District Number *(I - 2; nn)* **06**

County *(FIPS county code; I - 3; nnn)* **015**

Town *(FIPS place code; I - 4; nnnnn)* **70525**

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

Waterway *(I - 6)* **MOSS GLEN BROOK**

Road Name *(I - 7)*: **MOSS GLEN FALLS RD**

Route Number **C3016**

Vicinity *(I - 9)* **0.55 MI TO JCT W CL2 TH2**

Topographic Map **Stowe**

Hydrologic Unit Code: **02010005**

Latitude *(I - 16; nnnn.n)* **44291**

Longitude *(i - 17; nnnnn.n)* **72375**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10080800390808**

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

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

Year built *(I - 27; YYYY)* **1982**

Structure length *(I - 49; nnnnnn)* **000022**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000100**

Deck Width *(I - 52; nn.n)* **000**

Year of ADT *(I - 30; YY)* **93**

Channel & Protection *(I - 61; n)* **5**

Opening skew to Roadway *(I - 34; nn)* **05**

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

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

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

Structure type *(I - 43; nnn)* **319**

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*) **-**

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

Waterway of full opening (*nnn.n* ft^2) **135**

Comments:

According to the structural inspection report dated 6/7/95, the structure is a corrugated galvanized plate pipe arch. The roadway over it is gravel surfaced with a sharp corner onto the RABUT side. The channel is scoured down to the bottom of the footing at the inlet on the LABUT side. The embankments are eroded US, with boulders showing. Small and minor gravel bars are noted. Debris is mostly minor at present. Stone fill is good at the arch ends, but partially slid into channel at the inlet on the right side, blocking 1/3 of flow. The free poured concrete footing exposed near the outlet end on the right side is spalled with section loss plus a voided area at the very end. **(Continued, page 32)**

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **4.57**

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} **560** Q_{25} **820**

Q_{50} **990** Q_{100} **1190** Q_{500} -

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

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

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

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

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

Describe any significant site conditions upstream or downstream that may influence the stream's stage: **A report dated 12/29/82 mentions a rather large beaver dam just US of the site that has apparently caused a complete shift in the course of the stream, adding to the unstableness of the channel bed.**

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*)	-	**5.5**	**6.7**	**7.8**	**9**
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

There are small areas of erosion at the inlet end of the arch. There is 4-5 ft of cover over the pipe. The pipe has a slight reverse camber.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **4.75** mi^2

Lake/pond/swamp area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **820** ft

Headwater elevation **2500** ft

Main channel length **4.23** mi

10% channel length elevation **950** ft

85% channel length elevation **2400** ft

Main channel slope *(S)* **457.05** 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:

NO BENCKMARK INFORMATION

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 DRILL BORING INFORMATION

Comments:

-

Cross-sectional Data

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

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

Comments: **NO CROSS SECTIONAL INFORMATION**

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

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 10/21/96
Computerized by: RB Date: 10/22/96
Reviewd by: MAL Date: 9/9/97

Structure Number STOWTH00160039

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND Date *(MM/DD/YY)* 07 / 10 / 1996

2. Highway District Number 06 Mile marker 00000
County LAMOILLE (015) Town STOWE (70525)
Waterway *(I - 6)* MOSS GLEN BROOK Road Name MOSS GLEN FALLS RD
Route Number TH 16 Hydrologic Unit Code: 02010003

3. Descriptive comments:
Located 0.55 miles from the junction with CL2 TH2.

B. Bridge Deck Observations

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

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

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

7. Bridge length 22 *(feet)* Span length 21 *(feet)* Bridge width 50.5 *(feet)*

Road approach to bridge:

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

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

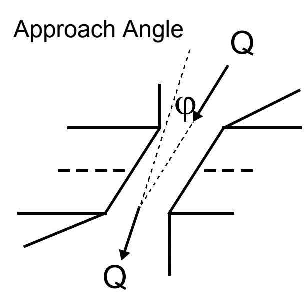
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

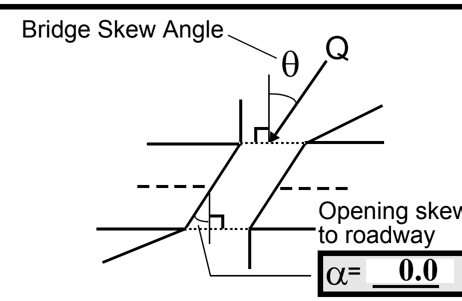
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	-
RBUS	1	2	1	2
RBDS	2	2	1	2
LBDS	2	1	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 0





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 5 feet US *(US, UB, DS)* to 10 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 8 feet DS *(US, UB, DS)* to 50 feet DS

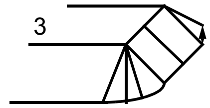
*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: **1b**

1a- Vertical abutments with wingwalls

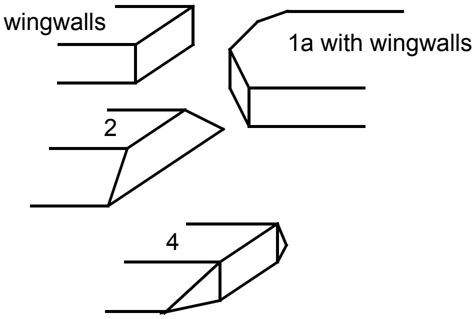
1b- Vertical abutments without wingwalls

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



3- Spill through abutments

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



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

4. The DS left bank is a lawn and the DS right bank is intersected by Moss Glenn Falls Road.
5. The upstream water surface is a series of small pools and riffles.
6. This is a multi-plate pipe arch set in concrete footings.
8. The road slopes gradually from the culvert in both directions.
15. The flow is straight from the approach cross section through the culvert to the exit section, but it bends just US and just DS of this straight section.
17. At high flows, water will impact both sides of the culvert opening. Also, a moderately severe third impact zone exists on the right bank from 120 ft US to 90 ft US.

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
24.5	**3.0**			**11.0**	**3**	**2**	**5**	**5**	**1**	**2**

23. Bank width **30.0** 24. Channel width **25.0** 25. Thalweg depth **56.0** 29. Bed Material **342**

30 .Bank protection type: LB **3** RB **3** 31. Bank protection condition: LB **1** 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.):

27. Both banks consist of large placed boulders and concrete blocks.
28. On the right bank, there is some mass wasting but it is not threatening to the road or culvert.
29. The sand in the bed fills the voids between the larger materials.
30. The left and right bank protection extends from the US bridge face to 100 ft US.
31. On the right bank some of the protection is eroded and slumping.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 12 35. Mid-bar width: 10

36. Point bar extent: 35 feet US (US, UB) to UB feet 50 (US, UB, DS) positioned 10 %LB to 0 %RB

37. Material: 324

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

This point bar extends into the culvert.

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: 50 42. Cut bank extent: 0 feet US (US, UB) to 100 feet US (US, UB, DS)

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

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

This cut bank is a high water cut that is eroded with some slumping. Another very minor low water cut is on the left bank from 20 ft to 30 ft US.

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

Some minor scour holes are behind boulders in the channel. The maximum scour depth is 1.5 ft.

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
26.5		1.0		2	7	7	0

58. Bank width (BF) - 59. Channel width - 60. Thalweg depth 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.):

324

63. The stream bed grades from gravel and sand at the US face to gravel and cobble at the DS face. Sand fills the voids between the larger particles and is more extensive at the US right corner of the bridge where the US point bar ends.

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

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

1

There is a lot of debris on the large concrete blocks along the left bank US. There is also some small debris buried in the point bar inside the culvert.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**2**	**2**	**0.4**	**0.9**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**2**	**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.):

0

1.6

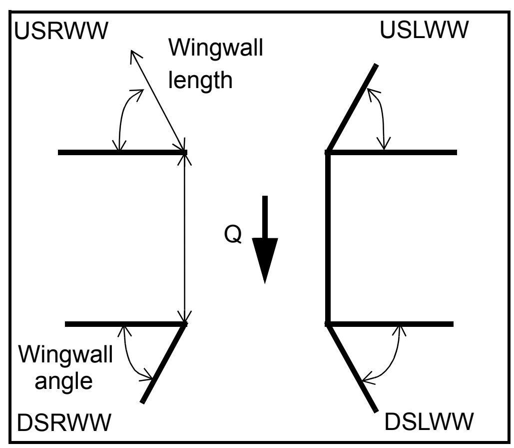
1

74. The US end of the left abutment footing is exposed. The DS end of the right abutment footing is exposed. The spread base of the footing is undermined 0.4 ft horizontally. Also, the DS end of the right abutment footing has broken off and is missing.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**20.5**	
USRWW:	**N**		**-**		**-**	**0.5**	
DSLWW:	**-**		**-**		**N**	**50.0**	
DSRWW:	**-**		**-**		**-**	**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	**-**	**-**	**N**	**-**	**-**	**-**	**1**	**1**
Condition	**N**	**-**	**-**	**-**	**-**	**-**	**4**	**4**
Extent	**-**	**-**	**-**	**-**	**-**	**3**	**3**	**-**

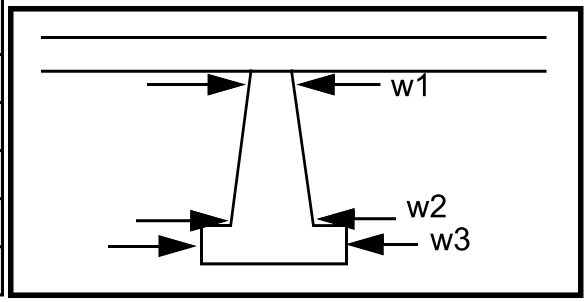
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? 82. (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)	The	and DS		-	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	left	ends		-	1- Solid pier, 2- column, 3- bent
88. Material	and	of		-	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	right	the		-	1- Round; 2- Square; 3- Pointed
90. Inclined?	abut	abut		-	Y- yes; N- no
91. Attack ∠ (BF)	ment	ment	N	-	
92. Pushed	pro-	s.	-	-	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	tec-		-	-	
95. Cross-members	tion		-	-	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	is at		-	-	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	the		-	-	
98. Exposure depth	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	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-	-	-	-	-	-	-	-	-	-

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

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

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

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

101. Is a drop structure present? ____ *(Y or N, if N type ctrl-n ds)* 102. Distance: **23.5** feet

103. Drop: **5.0** feet 104. Structure material: ____ *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

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

1
1
5
5

106. Point/Side bar present? 1 (Y or N. if N type ctrl-n pb) Mid-bar distance: 1 Mid-bar width: 432

Point bar extent: 3 feet 3 (US, UB, DS) to 1 feet 2 (US, UB, DS) positioned Th %LB to e %RB

Material: rig

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

ht and left bank protection extends from the DS bridge face to 100 ft DS. On the right bank the protection is eroded and is slumping near the end of the culvert.

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

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

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

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

N

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

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

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

RE

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

Confluence 1: Distance Y Enters on 0 (LB or RB) Type 11 (*1- perennial; 2- ephemeral)*

Confluence 2: Distance 19 Enters on UB (LB or RB) Type 20 (*1- perennial; 2- ephemeral)*

Confluence comments (eg. confluence name):

DS

0

F. Geomorphic Channel Assessment

107. Stage of reach evolution 50

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)*:

342

-

Y

LB

20

10

DS

40

DS

1

109. **G. Plan View Sketch**

T

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: STOWTH00160039 Town: Stowe
Road Number: TH 16 County: Lamoille
Stream: Moss Glen Brook

Initials MAI Date: 08/21/97 Checked: RLB

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	1190	1700	0
Main Channel Area, ft2	294	411	0
Left overbank area, ft2	101	202	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	42	46	0
Top width L overbank, ft	33	45	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.1854	0.1854	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.8	8.9	ERR
y1, average depth, LOB, ft	6.1	4.5	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	27436	50145	0
Conveyance, main channel	21780	35530	0
Conveyance, LOB	5656	14616	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	944.7	1349.5	ERR
Ql, discharge, LOB, cfs	245.3	350.5	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	3.2	3.3	ERR
Vl, mean velocity, LOB, ft/s	2.4	1.7	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.3	9.3	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	1190	1700	0
(Q) discharge thru bridge, cfs	1190	1700	0
Main channel conveyance	7050	8540	0
Total conveyance	7050	8540	0
Q2, bridge MC discharge,cfs	1190	1700	ERR
Main channel area, ft2	110	126	0
Main channel width (normal), ft	20.6	20.6	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	20.6	20.6	0
y_bridge (avg. depth at br.), ft	6.10	7.07	ERR
Dm, median (1.25*D50), ft	0.23175	0.23175	0
y2, depth in contraction,ft	6.08	8.26	ERR
ys, scour depth (y2-ybridge), ft	**-0.02**	**1.19**	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	1190	1700	0
Main channel area (DS), ft2	110.33	126.41	0
Depth in Culvert, ft	6.1	7.1	0.0
D90, ft	0.7295	0.7295	0.0000
D95, ft	1.1711	1.1711	0.0000
Dc, critical grain size, ft	0.5483	0.8006	ERR
Pc, Decimal percent coarser than Dc	0.133	0.092	0.000
Depth to armoring, ft	**10.76**	**23.65**	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	1190	1700	0	1190	1700	0
a’, abut.length blocking flow, ft	37.9	49.7	0	17.1	21	0
Ae, area of blocked flow ft2	130.06	243.11	0	85.98	136.51	0
Qe, discharge blocked abut.,cfs	329.73	612.71	0	209.67	304.04	0

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

Ve, (Qe/Ae), ft/s	2.54	2.52	ERR	2.44	2.23	ERR
ya, depth of f/p flow, ft	3.43	4.89	ERR	5.03	6.50	ERR

--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)

K1	1	1	1	1	1	1

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.241	0.201	ERR	0.192	0.154	ERR
ys, scour depth, ft	**12.62**	**16.19**	N/A	**12.08**	**14.30**	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)	37.9	49.7	0	17.1	21	0
y1 (depth f/p flow, ft)	3.43	4.89	ERR	5.03	6.50	ERR
a’/y1	11.04	10.16	ERR	3.40	3.23	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.24	0.20	N/A	0.19	0.15	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	Other Q	Q100	Q500	Other Q
V, max Velocity in culvert, ft/s	10.79	13.45	0	10.79	13.45	0
Fr, Froude Number (V/(32.2y)^1/2)	0.77	0.89	ERR	0.77	0.89	ERR
y, depth of flow in bridge, ft	6.10	7.07	0.00	6.10	7.07	0.00

Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**2.24**	ERR	N/A	**2.24**	ERR	N/A
Fr>0.8 (vertical abut.)	ERR	**2.86**	ERR	ERR	**2.86**	ERR