LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (WFAITH00030007) on TOWN HIGHWAY 3, crossing ALGERINE BROOK, WEST FAIRLEE, VERMONT

Open-File Report 98-405

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (WFAITH00030007) on TOWN HIGHWAY 3, crossing ALGERINE BROOK, WEST FAIRLEE, VERMONT

By MICHAEL A. IVANOFF AND ERICK M. BOEHMLER

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Pembroke, New Hampshire

1998

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
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Box 25286
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	Max	maximum
D_{50}	median diameter of bed material	MC	main channel
DS	downstream	RAB	right abutment
elev.	elevation	RABUT	face of right abutment
f/p	flood plain	RB	right bank
ft^2	square feet	ROB	right overbank
ft/ft	feet per foot	RWW	right wingwall
FEMA	Federal Emergency Management Agency	TH	town highway
FHWA	Federal Highway Administration	UB	under bridge
JCT	junction	US	upstream
LAB	left abutment	USGS	United States Geological Survey
LABUT	face of left abutment	VTAOT	Vermont Agency of Transportation
LB	left bank	WSPRO	water-surface profile model
LOB	left overbank	yr	year

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 7 (WFAITH00030007) ON TOWN HIGHWAY 3, CROSSING ALGERINE BROOK, WEST FAIRLEE, VERMONT

By **Michael A. Ivanoff 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 WFAITH00030007 on Town Highway 3 crossing Algerine Brook, West Fairlee, 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 (FHWA, 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 central Vermont. The 7.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, Algerine Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 31 ft and an average bank height of 3 ft. The channel bed material ranges from cobble to boulder with a median grain size (D_{50}) of 101 mm (0.332 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 8, 1995, indicated that the reach was stable.

The Town Highway 3 crossing of Algerine Brook is a 25-ft-long galvanized plate arch culvert with an opening span width of 25 ft (Vermont Agency of Transportation, written communication, March 9, 1995). The opening length of the structure parallel to the bridge face is 23.4 ft. The culvert is supported by vertical, concrete abutments with “laid-up” stone wingwalls upstream. The channel is skewed approximately 30 degrees to the opening. The opening skew-to-roadway value from the VTAOT database is 30 degrees while zero degrees was computed from surveyed points.

The scour counter measures at the site include type-2 stone fill (less than 36 inches diameter) along the downstream right bank, type-3 stone fill (less than 48 inches diameter) along the upstream right bank, and “laid-up” stone walls along the left and right downstream road embankments. 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 Davis, 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 1.0 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.6 to 14.9 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 Davis, 1995, p. 46). 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.

Vershire, VT. Quadrangle, 1:24,000, 1981
Photoinspected 1983

NORTH

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

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

LEVEL II SUMMARY

Structure Number WFAITH00030007 ***Stream*** Algerine Brook

County Orange ***Road*** TH 3 ***District*** 4

Description of Bridge

Bridge length 25.0 ***ft*** ***Bridge width*** -- ***ft*** ***Max span length*** 25.0 ***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*** 9/8/95

Description of stone fill None.

Abutments are concrete. The upstream wingwalls are "laid-up" stone.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 30

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	9/8/95	0	0
Level II	9/8/95	0	0

Potential for debris Moderate. There are some trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 9/8/95.

Description of the Geomorphic Setting

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

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

Date of inspection 9/8/95

DS left: Steep channel to a narrow overbank.

DS right: Steep valley wall.

US left: Steep valley wall.

US right: Moderately sloped channel bank to a narrow overbank.

Description of the Channel

Average top width 31 ***ft*** ***Average depth*** 3 ***ft***

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

Sinuous but stable with non-alluvial channel boundaries.

9/8/95

Vegetative co Trees and brush.

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, 9/8/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 7.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,610 ***ft³/s*** ***Q500*** 2,250 ***ft³/s***

The 100- and 500-year discharges are based on a method documented by the Federal Highway Administration (FHWA, 1983). The discharge values are within a range defined by several other empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; 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 X in bedrock on the US left bank, 70 ft perpendicular to the culvert centerline between two jeep trails (elev. 495.98 ft, arbitrary survey datum). RM2 is a nail 4.5 ft above the ground in a telephone pole (18-6-295), 120 ft along the DS side of the right bank of TH 3, 15 ft from the edge of the pavement (elev. 510.94 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO and CAP Analysis

[1]Cross-section	Section Reference Distance (SRD) in feet	[2]Cross-section development	Comments
EXITX	-21	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
CLVRT	0	1	Culvert outlet section
APPRO	109	1	Approach section

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

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's one-dimensional, step-backwater computer program, WSPRO (Shearman and others, 1986, and Shearman, 1990) and the U.S. Geological Survey's Culvert Analysis Program (CAP, Fulford, 1995). 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. Although flow approaches this site at an angle greater than the opening-skew-to-roadway, flow was assumed to align with the abutments in the culvert. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.075.

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 0.0218 ft/ft, which was estimated from surveyed points downstream of the bridge.

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

The unconstricted channel was modeled for each discharge by use of WSPRO. Then the water surface elevation computed at the FULLV section for each discharge under the unconstricted channel condition was applied as the starting water surface elevation for the culvert hydraulic analysis by use of the CAP. The CAP computes the appropriate discharge coefficient based on the techniques documented in Bodhaine (1968).

Bridge Hydraulics Summary

Average bridge embankment elevation 499.0 *ft*
Average low steel elevation 495.3 *ft*

100-year discharge 1,610 *ft³/s*
Water-surface elevation in bridge opening 488.6 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 134 *ft²*
Average velocity in bridge opening 12.0 *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge 493.6
Water-surface elevation at Approach section without bridge 490.6
Amount of backwater caused by bridge 3.0 *ft*

500-year discharge 2,250 *ft³/s*
Water-surface elevation in bridge opening 489.4 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 149 *ft²*
Average velocity in bridge opening 15.1 *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 491.5
Amount of backwater caused by bridge 6.5 *ft*

Incipient overtopping discharge -- *ft³/s*
Water-surface elevation in bridge opening -- *ft*
Area of flow in bridge opening -- *ft²*
Average velocity in bridge opening -- *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100- and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 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	1.0	--
Depth to armoring	10.6	37.2	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour	11.3	14.9	--
Left abutment	6.6	11.2	--
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:	2.5	2.9	--
Left abutment	2.5	2.9	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

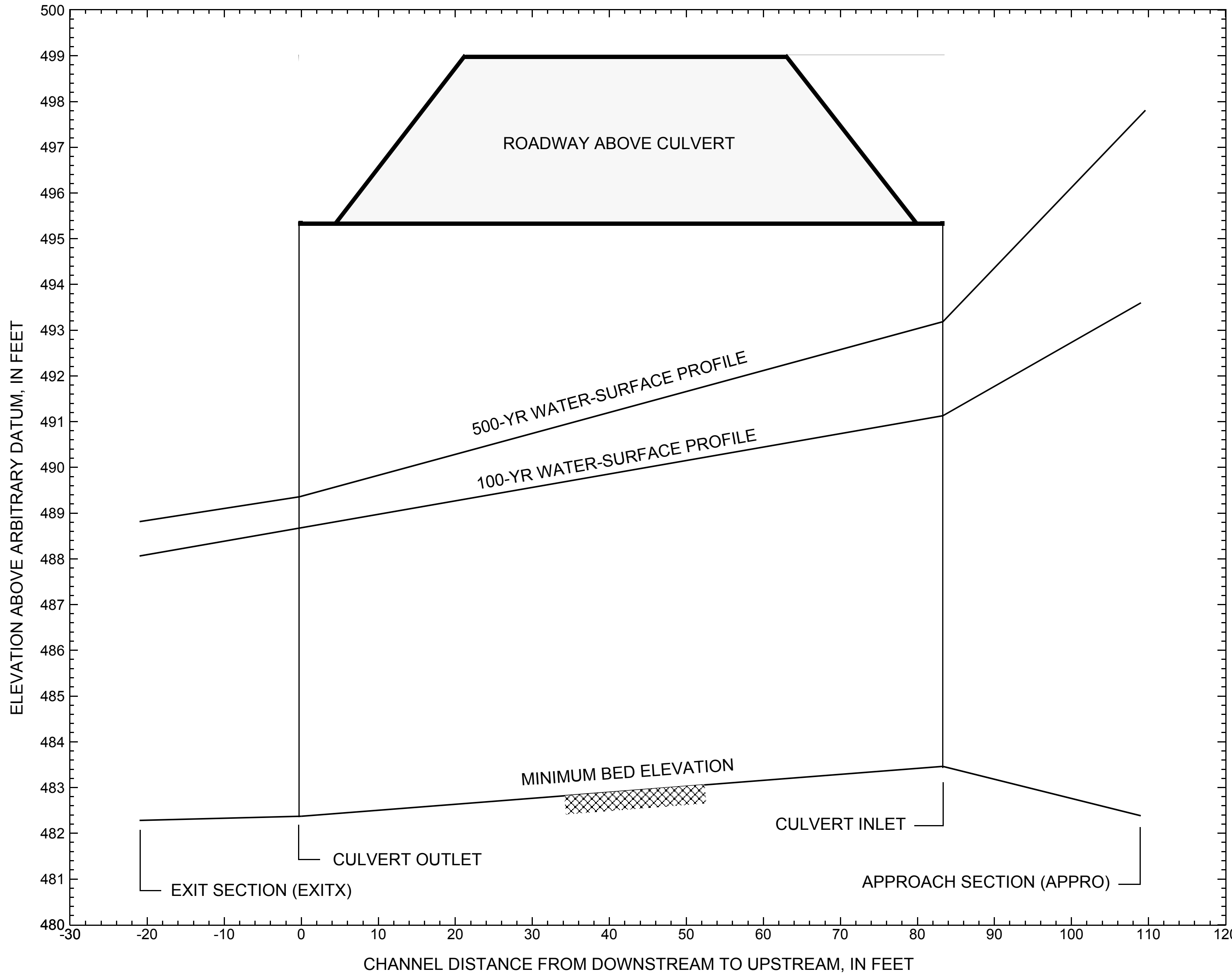

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WFAITH00030007 on Town Highway 3, crossing Algerine Brook, West Fairlee, Vermont.

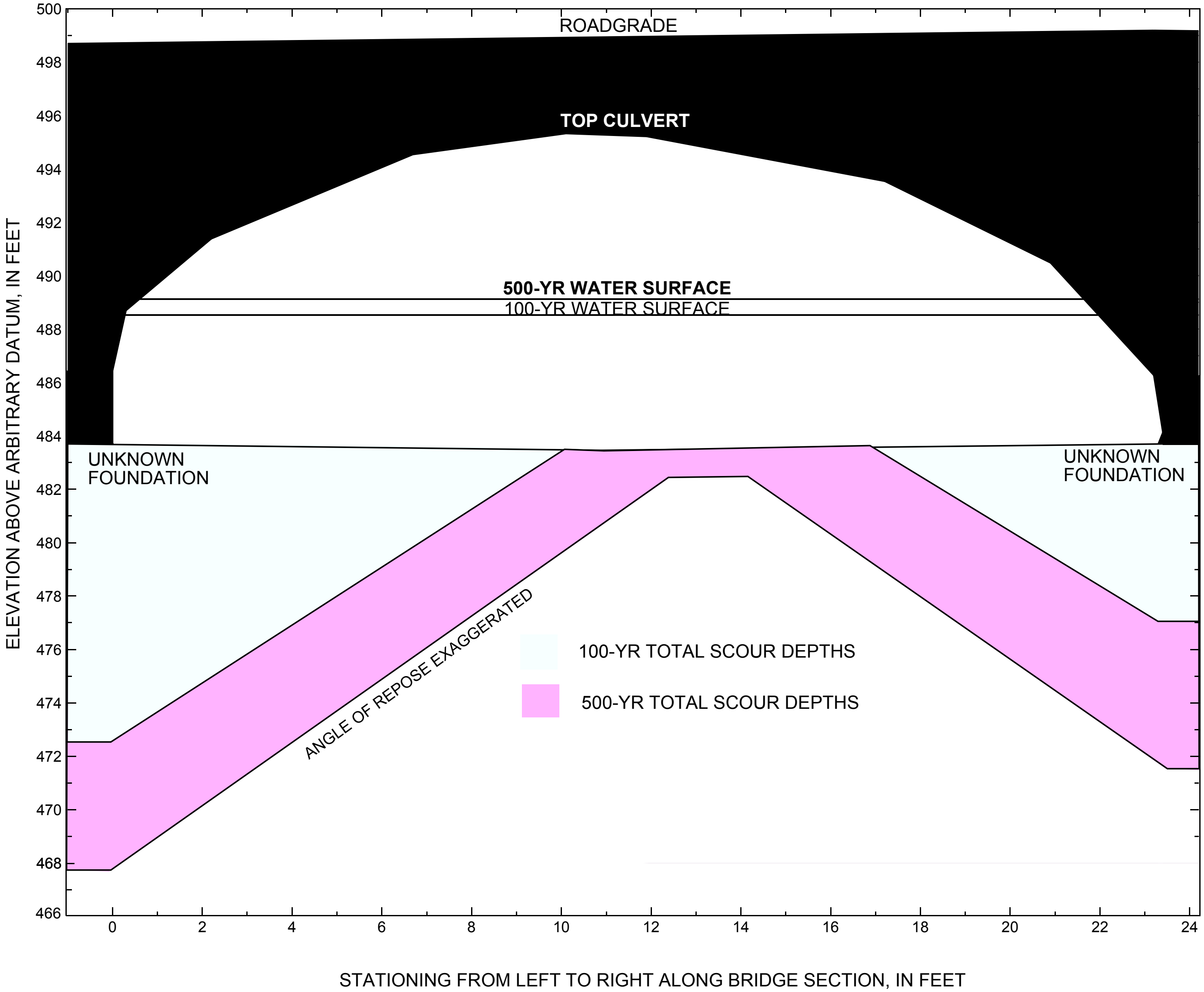

Figure 8. Scour elevations for the 100- and 500-yr discharges at structure WFAITH00030007 on Town Highway 3, crossing Algerine Brook, West Fairlee, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-yr discharge at structure WFAITH00030007 on Town Highway 3, crossing Algerine Brook, West Fairlee, 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 1,610 cubic-feet per second											
Left abutment	0.0	--	495.3	--	483.7	0.0	11.3	--	11.3	472.4	--
Right abutment	23.4	--	495.3	--	483.7	0.0	6.6	--	6.6	477.1	--

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-yr discharge at structure WFAITH00030007 on Town Highway 3, crossing Algerine Brook, West Fairlee, 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 2,250 cubic-feet per second											
Left abutment	0.0	--	495.3	--	483.7	1.0	14.9	--	15.9	467.8	--
Right abutment	23.4	--	495.3	--	483.7	1.0	11.2	--	12.2	471.5	--

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File wfai007.wsp
T2        Hydraulic analysis for structure WFAITH00030007   Date: 03-NOV-97
T3        Bridge 7 on Town Highway 3 over Algerine Brook West Fairlee, VT by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1610.0   2250.0
SK          0.0218   0.0218
*
XS   EXITX    -21
*          -111.1, 498.11    -89.7, 493.93    -75.7, 491.85    -61.9, 493.84
GR          -33.9, 494.82    -29.4, 494.16    -16.4, 488.11      0.0, 487.26
GR            7.9, 483.02     13.0, 482.68     15.9, 482.45     20.4, 482.28
GR           23.6, 482.28     27.2, 482.66     34.1, 484.32     50.2, 486.66
GR           93.4, 507.22
*
N           0.060
*
XS   FULLV      0  * * *   0.0112
*
XS   APPRO    109           0.
GR         -109.0, 519.03    -51.2, 499.13    -31.7, 497.84    -15.5, 490.08
GR           -3.6, 487.81      0.0, 484.30      3.7, 483.74      8.4, 483.31
GR           11.5, 482.38     16.6, 483.45     18.6, 484.29     20.9, 484.85
GR           25.0, 486.80     36.1, 492.84     63.5, 495.45     80.5, 500.18
GR          135.9, 501.96    188.7, 525.05
*
N           0.075
*
HP 1 APPRO   493.68 1 493.68
HP 2 APPRO   493.68 * * 1610
*
HP 1 APPRO   497.96 1 497.96
HP 2 APPRO   497.96 * * 2250
*
EX
ER
CV   CLVRT  0 23.4   83. 482.37 483.46 1
CG          411 137.9 285.6
*C1         0.92
*C3         * * * 1, 0.90
*C5         0.75,0.44,1.4,0.46,1.5,0.51,2.0,0.54,2.5
*CF         5, 500.0
*           10.1, 495.33      6.7, 494.54      2.2, 491.38      0.3, 488.69
*            0.0, 486.44      2.3, 483.70      5.5, 483.67      8.1, 483.60
*           10.9, 483.46     17.1, 483.64     23.3, 483.70     23.4, 484.12
*           23.2, 486.27     20.9, 490.48     17.2, 493.54     11.9, 495.22
*           10.1, 495.33
*CS         12.7, 493.86     11.1, 493.77      6.0, 492.26      2.3, 489.26
*CS          0.0, 484.95      0.4, 484.92      0.5, 483.09      5.2, 482.47
*CS          8.6, 482.68     15.1, 482.37     20.4, 482.77     23.0, 483.12
*CS         23.8, 485.16     23.2, 485.27     21.4, 490.33     16.8, 493.27
*CS         12.7, 493.86
*CX         488.62   489.39
*CQ         1610.0   2250.0
*CN         0.050
*PD         0.,23.,1.0
XS   APPRO    109
GR         -109.0, 519.03    -51.2, 499.13    -31.7, 497.84    -15.5, 490.08
GR           -3.6, 487.81      0.0, 484.30      3.7, 483.74      8.4, 483.31
GR           11.5, 482.38     16.6, 483.45     18.6, 484.29     20.9, 484.85
GR           25.0, 486.80     36.1, 492.84     63.5, 495.45     80.5, 500.18
GR          135.9, 501.96    188.7, 525.05
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
CAP -USGS culvert analysis program VER 97-01                          page  0

CV   CLVRT  0 23.4   83. 482.37 483.46 1
CG          411 137.9 285.6
*C1         0.92
*C3         * * * 1, 0.90
     KR <1, default of 1 used
     KW <1, default of 1 used
*C5         0.75,0.44,1.4,0.46,1.5,0.51,2.0,0.54,2.5
*CF         5, 500.0
*           10.1, 495.33      6.7, 494.54      2.2, 491.38      0.3, 488.69
*            0.0, 486.44      2.3, 483.70      5.5, 483.67      8.1, 483.60
*           10.9, 483.46     17.1, 483.64     23.3, 483.70     23.4, 484.12
*           23.2, 486.27     20.9, 490.48     17.2, 493.54     11.9, 495.22
*           10.1, 495.33
*CS         12.7, 493.86     11.1, 493.77      6.0, 492.26      2.3, 489.26
*CS          0.0, 484.95      0.4, 484.92      0.5, 483.09      5.2, 482.47
*CS          8.6, 482.68     15.1, 482.37     20.4, 482.77     23.0, 483.12
*CS         23.8, 485.16     23.2, 485.27     21.4, 490.33     16.8, 493.27
*CS         12.7, 493.86
*CX         488.62   489.39
*CQ         1610.0   2250.0
*CN         0.050
*PD         0.,23.,1.0
XS   APPRO    109
GR         -109.0, 519.03    -51.2, 499.13    -31.7, 497.84    -15.5, 490.08
GR           -3.6, 487.81      0.0, 484.30      3.7, 483.74      8.4, 483.31
GR           11.5, 482.38     16.6, 483.45     18.6, 484.29     20.9, 484.85
GR           25.0, 486.80     36.1, 492.84     63.5, 495.45     80.5, 500.18
GR          135.9, 501.96    188.7, 525.05
N           0.075

CAP -USGS culvert analysis program VER 97-01                          page  1

Hydraulic analysis for the culvert structure WFAITH00030007
               CULVERT SECTION PROPERTIES - ID: CLVRT

                    Culvert section type: 6.3,07X,F7.2)
               (r or w)/D  KR or KW  Ktheta  Kproj    n      Inlet
                  0.00      1.00   1.00   0.90   0.050       1

                    <<User supplied discharge coefficients>>
                      CB12 = 0.92          C46 = 0.75
                      For type123 flow     For type 5 flow
                         C    (h1-z)/D        C    (h1-z)/D
                       0.00     0.00        0.44     1.40
                       0.00     0.00        0.46     1.50
                       0.00     0.00        0.51     2.00
                       0.00     0.00        0.54     2.50
```

Barrel depth (ft)	Area (sq.ft)	Conveyance (cfs)	Top width (ft)	Wetted perimeter (ft)
0.00	0.0	0.0	0.00	0.0
0.38	3.4	33.8	17.12	17.2
0.77	11.0	204.0	22.51	22.7
1.15	19.7	522.7	22.68	23.5
1.53	28.4	941.6	22.85	24.2
1.91	37.2	1443.7	23.02	25.0
2.30	46.1	2017.8	23.19	25.8
2.68	55.0	2634.0	23.70	27.0
3.06	63.9	3276.2	22.88	28.4
3.45	72.6	3974.2	22.54	29.2
3.83	81.2	4696.2	22.20	30.0
4.21	89.6	5436.5	21.86	30.9
4.60	97.9	6190.1	21.52	31.7
4.98	106.1	6952.9	21.18	32.6
5.36	114.2	7721.2	20.84	33.4
5.74	122.1	8492.0	20.50	34.2
6.13	129.9	9262.7	20.16	35.1
6.51	137.5	10030.8	19.82	35.9
6.89	145.1	10794.0	19.47	36.8
7.28	152.4	11509.1	18.87	37.8
7.66	159.5	12200.2	18.26	38.8
8.04	166.4	12851.2	17.55	39.9
8.43	172.9	13406.7	16.48	41.2
8.81	179.0	13909.5	15.40	42.5
9.19	184.7	14359.3	14.33	43.8
9.57	190.0	14755.9	13.26	45.1
9.96	194.8	15070.4	12.04	46.6
10.34	199.1	15178.2	10.15	48.7
10.72	202.6	15202.6	8.26	50.7
11.11	205.3	14931.8	5.25	53.8
11.49	206.5	14158.6	0.00	59.2

```
^LCAP -USGS culvert analysis program VER 97-01                          page  2

Hydraulic analysis for the culvert structure WFAITH00030007
                          APPROACH SECTION PROPERTIES - ID: APPRO

        Water                                 Top                Critical
       Surface      Area      Conveyance     width    Alpha     discharge
       el.(ft)*    (sq.ft)       (cfs)        (ft)                 (cfs)
        482.38        0.0            0.0        0.0     1.00            0.0
        483.34        3.7           43.6        8.0     1.00           14.4
        484.30       17.1          314.2       18.6     1.00           92.6
        485.26       37.1          991.7       22.7     1.00          268.9
        486.21       60.3         2029.5       25.7     1.00          524.0
        487.17       86.4         3407.6       28.6     1.00          851.5
        488.13      115.4         5027.2       32.7     1.00         1229.0
        489.09      150.0         6891.8       39.5     1.00         1658.0
        490.05      191.1         9310.7       46.3     1.00         2202.9
        491.01      237.3        12641.3       50.2     1.00         2929.7
        491.96      287.2        16522.2       53.9     1.00         3761.5
        492.92      340.7        20810.7       58.4     1.00         4670.4
        493.88      402.5        24392.0       70.5     1.00         5458.4
        494.84      475.8        29146.6       82.5     1.00         6482.5
        495.80      560.2        35624.8       92.2     1.00         7836.4
        496.76      651.1        44054.4       97.6     1.00         9542.5
        497.71      747.3        53449.6      103.1     1.00        11418.7
        498.67      853.2        60710.4      119.4     1.00        12944.8
        499.63      974.7        71304.0      131.2     1.00        15075.7
        500.59     1105.6        81171.5      148.7     1.00        17110.8
        501.55     1263.7        89286.8      181.3     1.00        18934.7
        502.51     1448.8       105791.8      198.1     1.00        22229.8
        503.46     1641.1       128008.0      203.1     1.00        26468.8
        504.42     1838.1       152083.3      208.1     1.00        30999.1
        505.38     2039.9       177997.1      213.1     1.00        35815.3


       *elevation referenced to common vertical datum
^LCAP -USGS culvert analysis program VER 97-01                          page  3

Hydraulic analysis for the culvert structure WFAITH00030007
                     CULVERT                                     APPROACH SECTION
 I.D. CLVRT                 Mannings n     0.050        I.D. APPRO
 Height       11.49 ft         Width       23.8ft       Station       109.0 ft
 Station        0.0 ft        Length      83.0 ft       Minimum el.   482.38ft
 Inlet el.    483.46ft      Outlet el.   482.37ft

         Discharge  Flow      Water Surface Elevations (feet) Critical  Error
   no.     (cfs)    type      appr.   inlet   outlet  exit      Dc       code@
    1       1610.0   3        493.68  491.20  488.62  488.62      5.6    0
    2       1610.0   3        493.45  491.28  489.39  489.39      5.6    0
    3       2250.0  25        498.07  494.95********  488.62      6.9   11
    4       2250.0  35        497.96  494.95********  489.39      6.9   11

             Fall (ft)     Losses (ft)       Appr. Section  Control Section
  no.   C   entry  eff.  entry(1-2) (2-3)     VH  alph    F    energy    F
   1   0.84  5.06  3.26  0.97  0.23  1.83    0.27 1.00  0.31   490.92  0.83
   2   0.85  4.06  2.55  0.70  0.24  1.56    0.29 1.00  0.32   491.24  0.70
   3   0.44 ***** ***** ***** ***** *****    0.13 1.00  0.19 ******** *****
   4   0.44 ***** ***** ***** ***** *****    0.13 1.00  0.19 ******** *****
________________________________________________________________________________
Abrevs. used: appr.-approach  C-discharge coefficient  eff.-effective
VH-velocity head  alph-velocity coefficient  n-Manning's roughness coef.
energy-specific energy  F-Froude number  entry,(1-2),(2-3)-part of reach
```

```
      U.S. Geological Survey WSPRO Input File wfai007.wsp
      Hydraulic analysis for structure WFAITH00030007   Date: 03-NOV-97
      Bridge 7 on Town Highway 3 over Algerine Brook West Fairlee, VT by MAI
         *** RUN DATE & TIME: 03-13-98  14:14

  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = APPRO;  SRD =     109.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     389.   23547.    68.    73.                        5274.
 493.68          389.   23547.    68.    73.  1.00   -23.    45.   5274.


  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = APPRO;  SRD =     109.

       WSEL     LEW     REW    AREA        K        Q    VEL
     493.68   -23.0    44.9   388.6   23547.    1610.   4.14

X STA.       -23.0       -7.5       -3.9       -1.0        0.7        2.2
  A(I)            48.7       19.4       20.3       15.5       14.6
  V(I)            1.65       4.14       3.96       5.19       5.50

X STA.         2.2        3.7        5.1        6.5        8.0        9.4
  A(I)            14.3       14.2       14.5       14.6       14.8
  V(I)            5.64       5.65       5.54       5.53       5.42

X STA.         9.4       10.7       12.0       13.2       14.5       15.8
  A(I)            14.4       14.0       13.9       13.8       14.1
  V(I)            5.57       5.75       5.77       5.82       5.72

X STA.        15.8       17.2       18.7       20.2       21.9       44.9
  A(I)            13.7       14.8       14.0       15.0       69.8
  V(I)            5.88       5.44       5.75       5.38       1.15


  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = APPRO;  SRD =     109.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     773.   55524.   106.   112.                       11843.
 497.96          773.   55524.   106.   112.  1.00   -34.    73.  11843.


  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = APPRO;  SRD =     109.

       WSEL     LEW     REW    AREA        K        Q    VEL
     497.96   -33.5    72.5   773.0   55524.    2250.   2.91

X STA.       -33.5      -12.7       -8.9       -5.5       -2.3        0.3
  A(I)            88.0       33.0       32.6       32.9       32.9
  V(I)            1.28       3.41       3.46       3.42       3.42

X STA.         0.3        2.3        4.4        6.3        8.3       10.2
  A(I)            27.9       28.9       28.3       29.2       28.2
  V(I)            4.03       3.90       3.97       3.85       3.99

X STA.        10.2       11.9       13.6       15.4       17.2       19.2
  A(I)            25.5       26.9       26.7       26.2       27.1
  V(I)            4.42       4.18       4.22       4.29       4.15

X STA.        19.2       21.3       23.5       26.3       29.8       72.5
  A(I)            27.4       28.4       30.9       33.4      158.7
  V(I)            4.10       3.97       3.65       3.37       0.71
```

```
        U.S. Geological Survey WSPRO Input File wfai007.wsp
        Hydraulic analysis for structure WFAITH00030007   Date: 03-NOV-97
        Bridge 7 on Town Highway 3 over Algerine Brook West Fairlee, VT by MAI
           *** RUN DATE & TIME: 02-10-98  16:38
```

100-year discharge

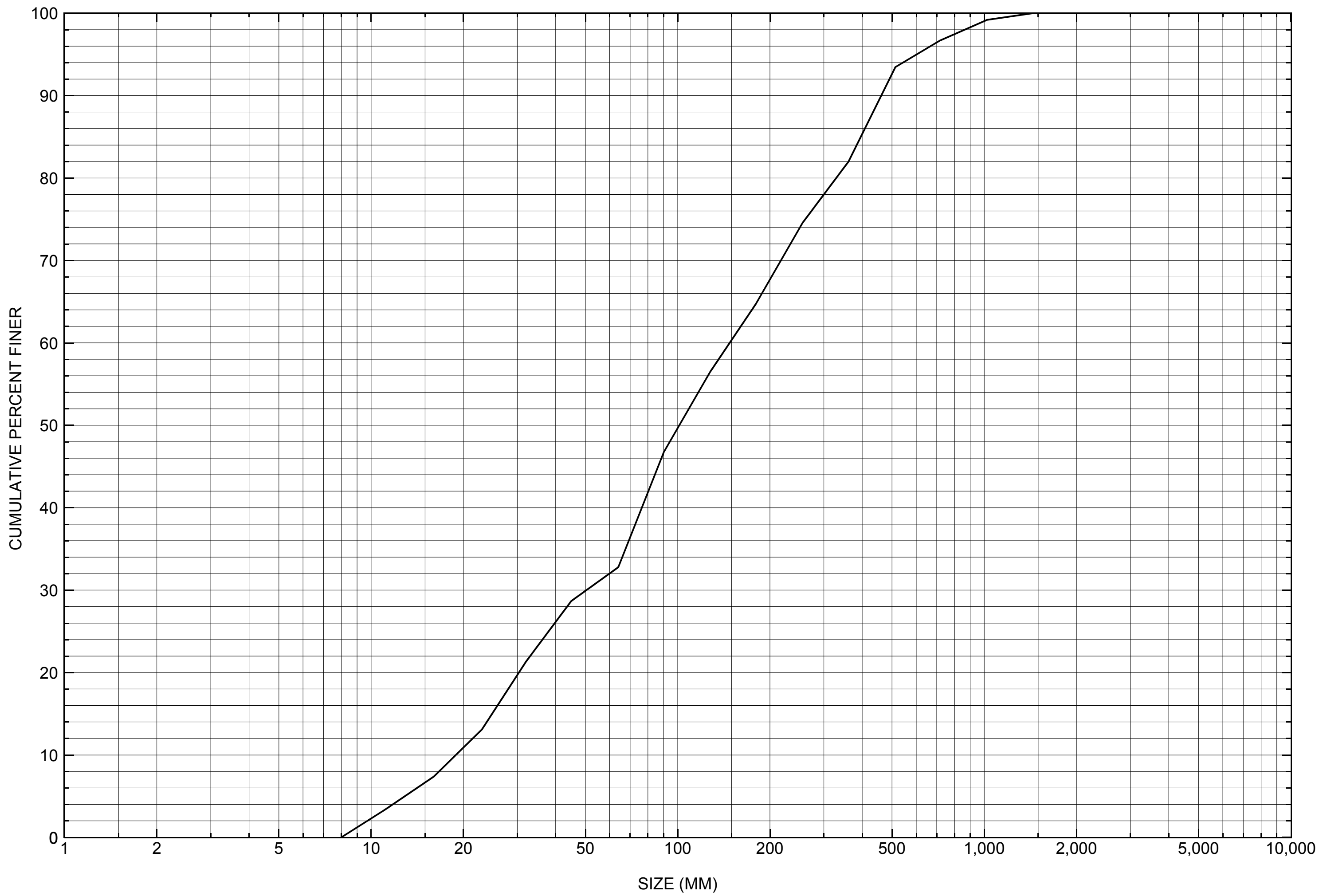
```
  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

 EXITX:XS   ******   -15.     211.  0.90 *****  488.97  487.22   1610.  488.06
       -21. ******    53.   10900.  1.00 ***** *******    0.77    7.63

 FULLV:XS      21.   -17.     234.  0.74  0.40  489.36 *******   1610.  488.62
         0.    21.    54.   12629.  1.00  0.00    0.00    0.67    6.89

 APPRO:XS     109.   -17.     216.  0.86  2.02  491.44 *******   1610.  490.58
       109.   109.    32.   11082.  1.00  0.06    0.00    0.62    7.45
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -21.   -15.    53.   1610.   10900.     211.    7.63  488.06
    FULLV:XS       0.   -17.    54.   1610.   12629.     234.    6.89  488.62
    APPRO:XS     109.   -17.    32.   1610.   11082.     216.    7.45  490.58

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
    EXITX:XS    487.22    0.77  482.28  507.22************  0.90  488.97  488.06
    FULLV:XS  ********    0.67  482.52  507.46  0.40  0.00  0.74  489.36  488.62
    APPRO:XS  ********    0.62  482.38  525.05  2.02  0.06  0.86  491.44  490.58
```

500-year discharge

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

 EXITX:XS   ******   -18.     264.  1.13 *****  489.94  488.24   2250.  488.81
       -21. ******    55.   15229.  1.00 ***** *******    0.79    8.51

 FULLV:XS      21.   -19.     290.  0.94  0.40  490.33 *******   2250.  489.39
         0.    21.    55.   17487.  1.00  0.00   -0.01    0.69    7.77

 APPRO:XS     109.   -18.     262.  1.15  2.18  492.63 *******   2250.  491.48
       109.   109.    34.   14492.  1.00  0.11    0.02    0.68    8.60

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -21.   -18.    55.   2250.   15229.     264.    8.51  488.81
    FULLV:XS       0.   -19.    55.   2250.   17487.     290.    7.77  489.39
    APPRO:XS     109.   -18.    34.   2250.   14492.     262.    8.60  491.48

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
    EXITX:XS    488.24    0.79  482.28  507.22************  1.13  489.94  488.81
    FULLV:XS  ********    0.69  482.52  507.46  0.40  0.00  0.94  490.33  489.39
    APPRO:XS  ********    0.68  482.38  525.05  2.18  0.11  1.15  492.63  491.48
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WFAITH00030007, in West Fairlee, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WFAITH00030007

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. Boehmler

Date *(MM/DD/YY)* 03 / 09 / 95

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 79975

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

Waterway *(I - 6)* Algerine (Coppermine) Brook

Road Name *(I - 7)*: -

Route Number TH003

Vicinity *(I - 9)* 0.85 miles to jct with VT 113

Topographic Map Vershire

Hydrologic Unit Code: 01080103

Latitude *(I - 16; nnnn.n)* 43547

Longitude *(i - 17; nnnnn.n)* 72167

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10091600070916

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

Maximum span length *(I - 48; nnnn)* 0025

Year built *(I - 27; YYYY)* 1958

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000350

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

Year of ADT *(I - 30; YY)* 90

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

Opening skew to Roadway *(I - 34; nn)* 30

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

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

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

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

Year Reconstructed *(I - 106)* 1992

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 12.0

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

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

Comments:

The structural inspection report of 5/27/94 indicates the structure is a multi-plate arch crossing. This arch culvert was built in 1992 and no problems were reported. The streambed is noted as stone and gravel, except upstream of the culvert opening where some bedrock outcrops are present in the channel.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: Stone and gravel.

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 7.74 mi^2 Lake/pond/swamp area 0.02 mi^2

Watershed storage *(ST)* 0.3 %

Bridge site elevation 890 ft Headwater elevation 2080 ft

Main channel length 3.75 mi

10% channel length elevation 930 ft 85% channel length elevation 1580 ft

Main channel slope *(S)* 231.11 ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 09 / 1958

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK 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 FOUNDATION MATERIAL INFORMATION.

Comments:

The plans that are available are those for the original structure. No plans exist for the current multi-plate arch structure.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **2/22/96**

Computerized by: **RB** Date: **2/22/96**

Reviewd by: **MAI** Date: **11/18/97**

Structure Number **WFAITH00030007**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E**. **Boehmler** Date *(MM/DD/YY)* **9** / **8** / 19**95**

2. Highway District Number **4** Mile marker **0**

County **Orange (017)** Town **West Fairlee (79975)**

Waterway *(I - 6)* **Algerine (Coppermine) Brook** Road Name **Beanville Road**

Route Number **TH 3** Hydrologic Unit Code: **01080103**

3. Descriptive comments:

The site is located 0.85 miles from State Route 113.

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 **2** 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 **25.0** *(feet)* Span length **25.0** *(feet)* Bridge width **--** *(feet)*

Road approach to bridge:

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

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

10. Embankment slope (*run / rise in feet / foot*):

US left **--** US right **--**

	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	0	-	2	1
RBDS	5	1	0	0
LBDS	5	1	0	0

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

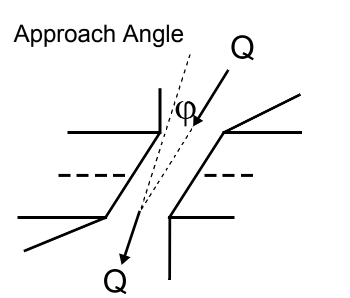
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

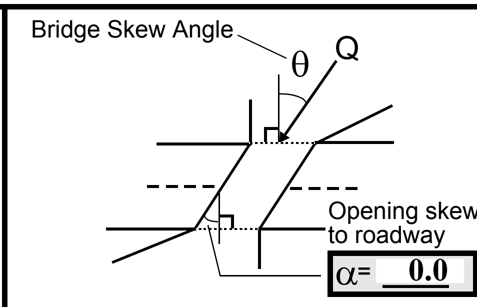
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **30**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*

Where? **LB** *(LB, RB)* Severity **3**

Range? **85** feet **US** *(US, UB, DS)* to **65** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*

Where? **RB** *(LB, RB)* Severity **1**

Range? **130** feet **DS** *(US, UB, DS)* to **195** feet **DS**

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

18. Bridge Type: **1a/1b**

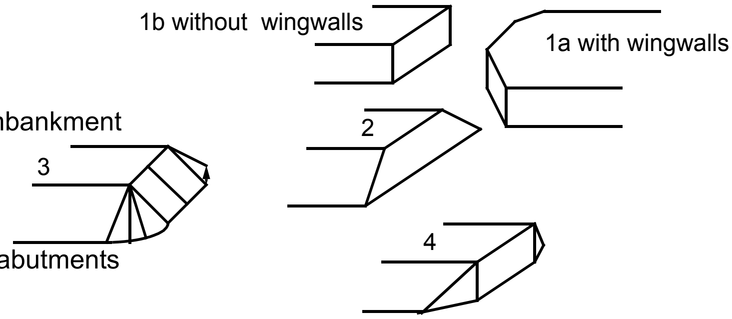
1a- Vertical abutments with wingwalls

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.)

The structure is a multiplate arch culvert with wingwalls at the US end and no wingwalls DS. The culvert opening measured 25 feet wide at the base of the plates where they meet the concrete footings. The surface cover is all forest except for small grass plots near the culvert orifices at each end. The roadway width or crest for weir flow, is 20.2 feet. While the left bank impact is severe due to a 90 degree bend right in the channel, the left bank is bedrock.

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
25.0	**3.5**			**2.5**	**4**	**3**	**6**	**45**	**1**	**0**

23. Bank width **45.0** 24. Channel width **20.0** 25. Thalweg depth **28.5** 29. Bed Material **564**

30 .Bank protection type: LB **0** RB **3** 31. Bank protection condition: LB **-** RB **1**

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

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

The channel US extends straight US from the culvert entrance then makes a 90 degree bend centered on 80 ft US of the culvert. The 90 degree bend follows the joint geometry and configuration of the bedrock on the left bank US. The bedrock extends around the bend to 98 ft US and ends about 4 ft US of the culvert entrance. It also forms part of the bed material mainly on the left bank side of the channel. The bedrock only visibly crosses the channel in the area of 25 ft US to 50 ft US. There is a higher than usual silt clay fraction to the material particularly on the right bank and right bank side of the channel. The right bank is protected from 15 ft US at the end of the stone wingwall and 35 ft US.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **48** 35. Mid-bar width: **5.5**

36. Point bar extent: **62** feet **US** *(US, UB)* to **35** feet **US** *(US, UB, DS)* positioned **90** %LB to **100** %RB

37. Material: **35**

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

A small unvegetated side bar composed primarily of fine to medium gravel, some silt, clay, and sand deposited on top of boulders and bedrock.

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

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

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

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

NO CUT BANKS

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 small pools have developed in the bedrock between 60 ft US and 40 ft US, and between 35 ft US and 40 ft US which are slightly deeper than the thalweg depths elsewhere, at most 0.5 to 0.8 ft deeper. Bedrock has formed 2 small water falls US at 35 ft US and 60 ft US with a pool below each but no abnormal erosion.

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
18.5		2.0		2	7	7	-

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

451

-

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

70. Debris and Ice Comments:

2

Debris and ice are likely to build up at the 90 degree bend US, the bedrock in the channel, and on the left bank. The banks are stable for the most part, but with forest all around on each bank US, the potential for debris generation in the channel is moderate.

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	2	90.0
RABUT	1	-	90			2	2	23.0

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

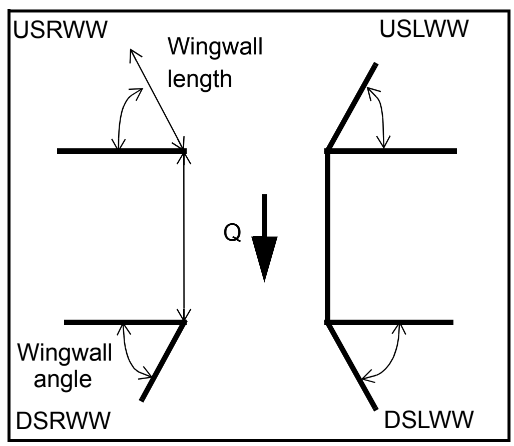
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
2
1

The abutments are concrete at the base then the corrugated metal is sealed into the concrete on each side. The concrete portion, footing, is exposed on both sides for their entire length.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						23.0	
USRWW:	Y		2		0	0.5	
DSLWW:	0		0		Y	83.5	
DSRWW:	2		0		0	83.5	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	0	-	N	-	-	-	-	-
Condition	N	-	-	-	-	-	-	-
Extent	-	-	-	0	0	0	0	-

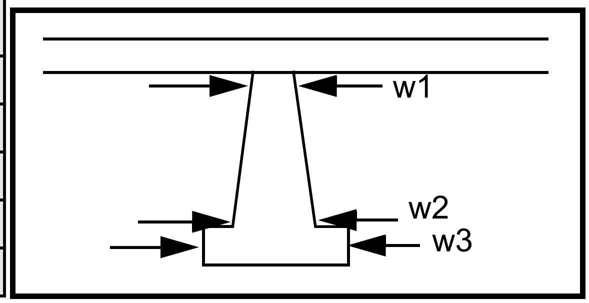
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		6.0		20.0	70.0	13.5
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

1
3

101. Is a drop structure present? 7 *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

103. Drop: - feet 104. Structure material: 514 *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
0
1
451
0
2
-

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

Point bar extent: chan feet nel (US, UB, DS) to is feet str (US, UB, DS) positioned aig %LB to ht %RB

Material: fro

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

m the culvert exit. The channel is lined on the left bank side by a stone fill ridge which makes up the left bank in a sort of crude stone wall fashion. This ridge is about 5 ft high and extends beyond 300 ft DS. It is 5-6 ft high on the channel side and drops 4-5 ft down on the bankward side. On the right bank side, the bank appears to be stream material dug out and piled up. The gaps between the boulder protection is mainly silt, clay and sand

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

Cut bank extent: s, feet shr (US, UB, DS) to ubs, feet an (US, UB, DS)

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

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

brush growing in it. This protection is present from 0 ft DS to 150 ft DS. The bank material description by numbers above is reflecting the right bank material beyond 150 ft DS on the right bank.

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

Scour dimensions: Length ____ Width ____ Depth: ____ Positioned ____ %LB to N %RB

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

-

NO DROP STRUCTURE

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

Confluence 1: Distance ____ Enters on N (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 -

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 POINT BARS

N

-

-

-

-

-

-

109. G. Plan View Sketch

- -

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number:	WFAITH00030007	Town:	West Fairlee
Road Number:	TH 3	County:	Orange
Stream:	Algerine (Coppermine) Brook		

Initials MAI Date: 11/13/97 Checked: ECW

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1610	2250	0
Main Channel Area, ft2	384	756	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	67	104	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.3321	0.3321	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.7	7.3	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	23264	54346	0
Conveyance, main channel	23264	54346	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	1610.0	2250.0	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	4.2	3.0	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	10.4	10.8	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 Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1610	2250	0
(Q) discharge thru bridge, cfs	1610	2250	0
Main channel conveyance	9900	11390	0
Total conveyance	9900	11390	0
Q2, bridge MC discharge,cfs	1610	2250	ERR
Main channel area, ft2	134	149	0
Main channel width (normal), ft	23.4	23.4	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	23.4	23.4	0
y_bridge (avg. depth at br.), ft	6.25	7.02	0.00
Dm, median (1.25*D50), ft	0.415125	0.415125	0
y2, depth in contraction,ft	5.98	7.97	ERR
ys, scour depth (y2-ybridge), ft	**-0.27**	**0.95**	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	1610	2250	N/A
Main channel area (DS), ft2	134	149	0
Main channel width (normal), ft	23.4	23.4	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	23.4	23.4	0.0
D90, ft	1.5110	1.5110	1.5110
D95, ft	1.9750	1.9750	1.9750
Dc, critical grain size, ft	0.9897	1.4805	ERR
Pc, Decimal percent coarser than Dc	0.219	0.107	0.000
Depth to armoring, ft	**10.61**	**37.18**	ERR

Abutment Scour

Froehlich’s Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a’/Y1)^0.43*Fr1^0.61+1

(Richardson and Davis, 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	1610	2250	0	1610	2250	0

a', abut.length blocking flow, ft	23	33.5	0	21.5	49.1	0
Ae, area of blocked flow ft2	97.52	215.6	0	65.25	224.29	0
Qe, discharge blocked abut.,cfs	288.85	549.52	0	75.25	342.61	0

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

Ve, (Qe/Ae), ft/s	2.96	2.55	ERR	1.15	1.53	ERR
ya, depth of f/p flow, ft	4.24	6.44	ERR	3.03	4.57	ERR

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

K1	0.82	0.82	0.82	0.82	0.82	0.82

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

^L 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	0.253	0.177	ERR	0.117	0.126	ERR
ys, scour depth, ft	**11.31**	**14.91**	N/A	**6.57**	**11.24**	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)	23	33.5	0	21.5	49.1	0
y1 (depth f/p flow, ft)	4.24	6.44	ERR	3.03	4.57	ERR
a'/y1	5.42	5.21	ERR	7.08	10.75	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.25	0.18	N/A	0.12	0.13	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 Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.85	1	0	0.85	1	0
y, depth of flow in bridge, ft	6.25	7.02	0.00	6.25	7.02	0.00

Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	**2.50**	**2.94**	ERR	**2.50**	**2.94**	ERR