LEVEL II SCOUR ANALYSIS FOR BRIDGE 28 (MNTGTH00190028) on TOWN HIGHWAY 19, crossing WADE BROOK, MONTGOMERY, VERMONT

U.S. Geological Survey
Open-File Report 96-562

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

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By Erick M. Boehmler and Robert E. Hammond

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Pembroke, New Hampshire

1996

U.S. DEPARTMENT OF THE INTERIOR
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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 28 (MNTGTH00190028) ON TOWN HIGHWAY 19, CROSSING WADE BROOK, MONTGOMERY, VERMONT

By Erick M. Boehmler 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 MNTGTH00190028 on town highway 19 crossing Wade Brook, Montgomery, 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). A Level I study is included in Appendix E of this report. A Level I study 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 can be found in Appendix D.

The site is in the Green Mountain physiographic province of north-central Vermont in the town of Montgomery. The 6.51-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the banks have dense woody vegetation coverage.

In the study area, Wade Brook has an incised, sinuous channel with a slope of approximately 0.0253 ft/ft, an average channel top width of 58 ft and an average channel depth of 4 ft. The predominant channel bed material is gravel and cobbles (D_{50} is 81.8 mm or 0.269 ft). The geomorphic assessment at the time of the Level I and Level II site visit on November 9, 1994, indicated that the reach was stable.

The town highway 19 crossing of Wade Brook is a 24-ft-wide corrugated steel, multi-plate pipe-arch (Vermont Agency of Transportation, written communication, August 3, 1994). The culvert is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 30 degrees to the opening while the opening-skew-to-roadway is 26 degrees.

There was no localized scour evident during the Level I assessment. The scour protection measures at the site were type-2 stone fill (less than 36 inches diameter) on all of the roadway embankments, the upstream left bank, and each wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.5 to 1.0 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.6 to 16.1 ft. The worst-case abutment scour also occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number MNTGTH00190028 ***Stream*** Wade Brook

County Franklin ***Road*** TH 19 ***District*** 08

Description of Bridge

Bridge length 24 ***ft*** ***Bridge width*** -- ***ft*** ***Max span length*** 23 ***ft***

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

Abutment type Vertical ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 11/9/94

Description of stone fill Type-2 on all roadway approach embankments, the upstream left bank and each wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. The concrete abutments support a corrugated metal, multi-plate-arch pipe culvert.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 30

There is a mild 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	11/9/94	0	0
Level II	11/9/94	0	0

Potential for debris Low due to generally stable banks.

Describe any features near or at the bridge that may affect flow (include observation date) None evident on 11/9/94.

Description of the Geomorphic Setting

General topography The channel is located within a narrow, incised, upland, moderate relief valley setting with moderately sloping valley walls on each side.

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

Date of inspection 11/9/94

DS left: Steep channel bank to valley wall.

DS right: Narrow, irregular flood plain to valley wall.

US left: Steep channel bank to narrow flood plain and valley wall.

US right: Moderately sloped channel bank to valley wall.

Description of the Channel

Average top width 58 *ft* ***Average depth*** 4 *ft*

Predominant bed material Cobbles ***Bank material*** Gravel to boulders

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

Vegetative co 11/9/94

DS left: Trees

DS right: Trees and brush.

US left: Trees and brush.

US right: Trees

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

-

Describe any obstructions in channel and date of observation.

None evident on 11/9/94.

Hydrology

Drainage area 6.51 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province	***Percent of drainage area***
Green Mountain	100

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

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

USGS gage description -

USGS gage number -

Gage drainage area - ***mi²***

Is there a lake/ No -

Calculated Discharges

Q100 1,250 ***ft³/s*** ***Q500*** 1,590 ***ft³/s***

The 100- and 500-year discharges are based on discharge frequency curves computed by use of several empirical equations (FHWA, 1983; Johnson and Laraway, unpublished draft, 1972; Johnson and Tasker, 1974; Potter, 1957a&b; and Talbot, 1887) and taken from the VTAOT database (written communication, May 1995) The median values shown above were selected and used for the hydraulic analyses.

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

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

Datum tie between USGS survey and VTAOT plans Add 501.0 feet to USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum.
RM1 is the center point of a "X" punched in top of a wooden guard rail post on the downstream left end of the guard rail (elev. 500.39 ft, arbitrary survey datum). RM2 is a brass plate imprinted VTAOT survey mark, on top of the DS end of the right abutment (elev. 490.59 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-33	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
APPRO	120	2	Modelled 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. 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, Jr. 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 0.060, and the overbank "n" value applied was 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 0.0253 ft/ft which was estimated from surveyed channel thalweg points at the EXITX section and downstream about 145 feet of the EXITX section.

The original approach section was surveyed at 130 feet upstream of the culvert outlet. This section was placed at 120 feet upstream of the outlet and each surveyed point was lowered manually based on the approach channel slope of 0.005 ft/ft to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also 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 culvert entrance is projecting 20.3 feet upstream from the roadway embankment. The CAP computes the appropriate discharge coefficient based on the techniques documented in Bodhaine (1968).

Bridge Hydraulics Summary

Average bridge embankment elevation 499.8 *ft*
Average low steel elevation 491.4 *ft*

100-year discharge 1,250 *ft*^{3}*/s*
Water-surface elevation in bridge opening 483.4 *ft*
Road overtopping? N *Discharge over road* -- *ft*^{3}*/s*
Area of flow in bridge opening 98.1 *ft*^{2}
Average velocity in bridge opening 12.7 *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge 488.5 *ft*
Water-surface elevation at Approach section without bridge 484.2 *ft*
Amount of backwater caused by bridge 4.3 *ft*

500-year discharge 1,590 *ft*^{3}*/s*
Water-surface elevation in bridge opening 484.2 *ft*
Road overtopping? N *Discharge over road* -- *ft*^{3}*/s*
Area of flow in bridge opening 115 *ft*^{2}
Average velocity in bridge opening 13.8 *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge 490.3 *ft*
Water-surface elevation at Approach section without bridge 484.8 *ft*
Amount of backwater caused by bridge 5.5 *ft*

Incipient overtopping discharge -- *ft*^{3}*/s*
Water-surface elevation in bridge opening -- *ft*
Area of flow in bridge opening -- *ft*^{2}
Average velocity in bridge opening -- *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) for the 100- and 500-year discharges. For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. Streambed armoring depths computed indicate that armoring will not limit the depth of contraction scour.

Abutment scour at each discharge modeled 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	0.5	1.0	--
Depth to armoring	32.8	40.0	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	8.6	11.0	--
Right abutment	14.2	16.1	--
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	2.6	--
Right abutment	2.2	2.6	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

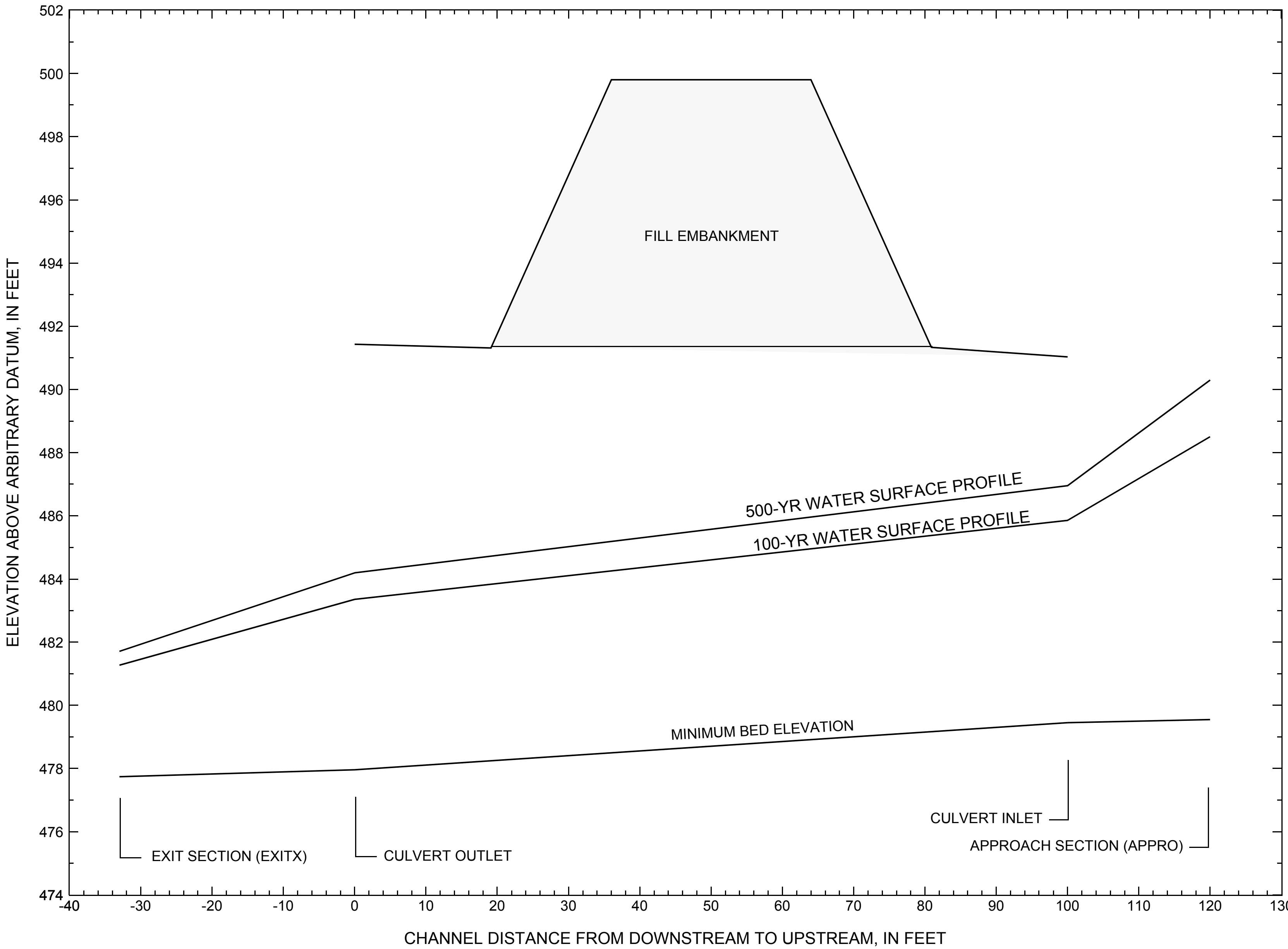

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure MNTGTH00190028 on town highway 19, crossing Wade Brook, Montgomery, Vermont.

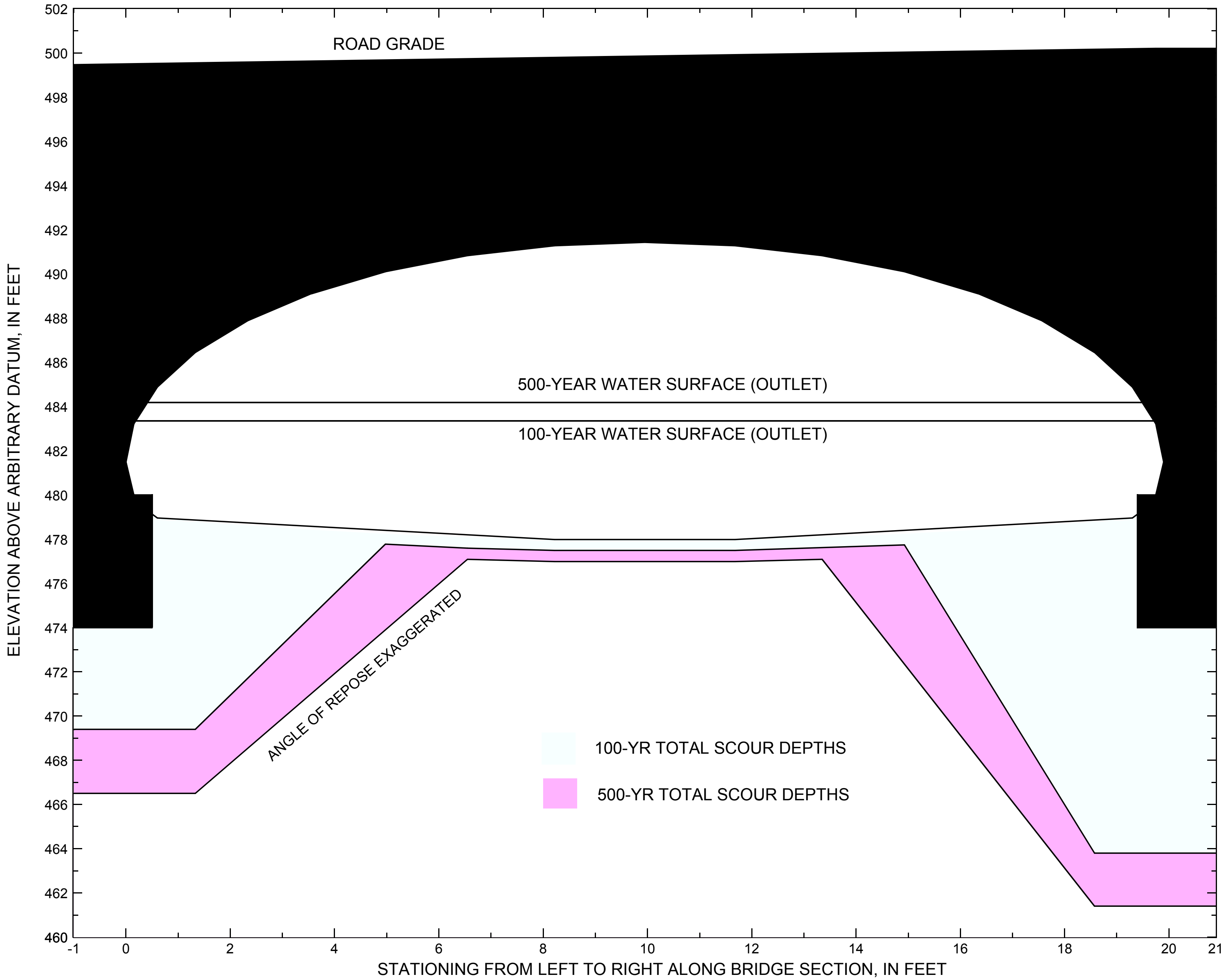

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure MNTGTH00190028 on town highway 19, crossing Wade Brook, Montgomery, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MNTGTH00190028 on Town Highway 19, crossing Wade Brook, Montgomery, 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 1,250 cubic-feet per second											
Left abutment	0.0	--	--	474.0	478.5	0.5	8.6	--	9.1	469.4	-5
Right abutment	19.9	--	--	474.0	478.5	0.5	14.2	--	14.7	463.8	-10

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 MNTGTH00190028 on Town Highway 19, crossing Wade Brook, Montgomery, 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 1,590 cubic-feet per second											
Left abutment	0.0	--	--	474.0	478.5	1.0	11.0	--	12.0	466.5	-8
Right abutment	19.9	--	--	474.0	478.5	1.0	16.1	--	17.1	461.4	-13

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

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U.S. Geological Survey, 1986, Hazens Notch, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, aerial photography, 1980; contour interval, 6 meters, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File mntg028.wsp
T2        Hydraulic analysis for structure MNTGTH00190028   Date: 13-MAR-96
T3        Town Highway 19 Culvert Crossing Wade Brook, Montgomery, VT        EMB
Q           1250.0   1590.0
SK          0.0253   0.0253
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -33           0.
GR          -38.4, 496.76    -22.9, 490.74    -12.5, 483.48     -8.8, 479.16
GR           -6.4, 478.51      0.0, 478.75      5.8, 477.95     11.8, 477.75
GR           19.2, 478.82     25.6, 477.74     33.5, 478.63     35.8, 479.14
GR           55.1, 483.58     79.5, 484.68     89.5, 488.19     98.5, 488.39
GR          104.4, 490.25    151.3, 490.67    173.8, 500.16
*
N           0.050
*
XS   FULLV      0   *  *  *  0.0092
*
XS   APPRO    120
GR         -125.1, 497.54    -44.8, 494.07    -29.3, 486.03     -7.3, 485.14
GR            4.8, 481.05      8.4, 480.50     14.1, 479.88     20.6, 479.55
GR           24.3, 479.78     28.1, 479.65     34.2, 481.15     40.8, 483.89
GR           53.7, 485.87     73.8, 504.68
*
N           0.075       0.060
SA                -7.3
*
HP 1 APPRO 488.50 1 488.50
HP 2 APPRO 488.50 * * 1250
*
HP 1 APPRO 490.29 1 490.29
HP 2 APPRO 490.29 * * 1590
EX
ER
*****************************************************************************************
*           CAP INPUT FILE
*****************************************************************************************
*       U.S. Geological Survey CAP Input File mntg028.cap
*       Hydraulic analysis for structure MNTGTH00190028   Date: 13-MAR-96
*       Town Highway 19 Culvert Crossing Wade Brook, Montgomery, VT       EMB
*
CV   CLVRT  0  9.95  100.  477.96  479.45  1
CG          321  161.6   238.8  527.6  119.4  2.0
*C1         0.92
*C3         * * * 1, 0.90
*C5         0.75,0.40,1.4,0.46,2.0,0.50,3.0,0.53,5.0
*CX         482.32,482.85
*CQ         1250.0,1590.0
*CN         0.040
*CF         5
*PD         0.,27.,0.5
XS   APPRO    120
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
          *** RUN DATE & TIME: 03-14-96  15:45
  T1        U.S. Geological Survey WSPRO Input File mntg028.wsp
  T2        Hydraulic analysis for structure MNTGTH00190028   Date: 13-MAR-96
  T3        Town Highway 19 Culvert Crossing Wade Brook, Montgomery, VT        EMB
  Q           1250.0   1590.0
  SK          0.0253   0.0253
  *
    CROSS-SECTION PROPERTIES:  ISEQ =  2;  SECID = APPRO;  SRD =     120.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       70      2601     27     27                          643
             2      403     33271     64     66                         5747
   488.50           473     35872     91     94  1.12    -33     57     5805

    VELOCITY DISTRIBUTION:  ISEQ =  2;  SECID = APPRO;  SRD =     120.

         WSEL     LEW     REW    AREA        K        Q    VEL
       488.50   -34.1    56.5   473.0   35872.    1250.   2.64

X STA.       -34.1      -13.3       -3.3        1.3        4.4        7.1
  A(I)            50.5       35.7       25.1       21.3       20.1
  V(I)            1.24       1.75       2.49       2.94       3.11

X STA.         7.1        9.5       11.7       13.9       15.9       18.0
  A(I)            19.0       18.7       18.3       17.8       18.0
  V(I)            3.28       3.35       3.42       3.51       3.47

X STA.        18.0       20.0       22.0       24.2       26.3       28.5
  A(I)            18.0       18.1       18.7       18.8       19.6
  V(I)            3.48       3.46       3.35       3.33       3.19

X STA.        28.5       31.0       33.8       37.5       43.6       56.5
  A(I)            20.6       22.2       24.6       29.8       38.2
  V(I)            3.04       2.82       2.54       2.10       1.64

    CROSS-SECTION PROPERTIES:  ISEQ =  2;  SECID = APPRO;  SRD =     120.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      121      5925     30     31                         1374
             2      519     49417     66     69                         8275
   490.29           640     55343     96    100  1.12    -37     58     8874

    VELOCITY DISTRIBUTION:  ISEQ =  2;  SECID = APPRO;  SRD =     120.

         WSEL     LEW     REW    AREA        K        Q    VEL
       490.29   -37.5    58.4   640.0   55343.    1590.   2.48

X STA.       -37.5      -19.1       -8.5       -2.3        1.7        4.9
  A(I)            63.2       51.5       36.6       30.0       27.8
  V(I)            1.26       1.54       2.17       2.65       2.86

X STA.         4.9        7.7       10.3       12.7       15.1       17.4
  A(I)            26.3       25.4       24.8       24.2       24.6
  V(I)            3.02       3.13       3.21       3.28       3.24

X STA.        17.4       19.7       22.0       24.3       26.7       29.2
  A(I)            24.5       24.6       24.6       25.4       26.4
  V(I)            3.25       3.23       3.23       3.13       3.02

X STA.        29.2       32.0       35.2       39.6       45.8       58.4
  A(I)            28.1       29.7       33.8       38.2       50.4
  V(I)            2.83       2.68       2.35       2.08       1.58

+++ BEGINNING PROFILE CALCULATIONS --   2

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

EXITX:XS   ******    -10      143  1.19 *****  482.46  481.20    1250  481.27
       -32 ******     45     7852  1.00 ***** *******    0.96    8.73

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.48

FULLV:XS       33    -10      186  0.70  0.57  483.02 *******    1250  482.32
         0     33     48    11592  1.00  0.00    0.00    0.67    6.72
```

```
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.84     484.22     483.79

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   481.82     504.68    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   481.82     504.68     483.79

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

APPRO:XS      120     -4      148  1.10  2.09  485.32  483.79    1250  484.22
       120    120     43     7721  1.00  0.20    0.00    0.84    8.43

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -33.   -11.    45.   1250.    7852.     143.    8.73  481.27
   FULLV:XS       0.   -11.    48.   1250.   11592.     186.    6.72  482.32
   APPRO:XS     120.    -5.    43.   1250.    7721.     148.    8.43  484.22

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    481.20    0.96  477.74  500.16************  1.19  482.46  481.27
   FULLV:XS  ********    0.67  478.04  500.46  0.57  0.00  0.70  483.02  482.32
   APPRO:XS    483.79    0.84  479.55  504.68  2.09  0.20  1.10  485.32  484.22

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

EXITX:XS   ******    -10      168  1.39 *****  483.10  481.68    1590  481.71
       -32 ******     47     9991  1.00 ***** *******    0.98    9.45

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

FULLV:XS       33    -11      218  0.83  0.57  483.67 *******    1590  482.85
         0     33     51    14616  1.00  0.00    0.00    0.69    7.29

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.87     484.79     484.41

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   482.35     504.68    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   482.35     504.68     484.41

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.66

APPRO:XS      120     -5      177  1.26  2.15  486.04  484.41    1590  484.79
       120    120     47     9637  1.00  0.22    0.00    0.87    8.99


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -33.   -11.    47.   1590.    9991.     168.    9.45  481.71
   FULLV:XS       0.   -12.    51.   1590.   14616.     218.    7.29  482.85
   APPRO:XS     120.    -6.    47.   1590.    9637.     177.    8.99  484.79

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    481.68    0.98  477.74  500.16************  1.39  483.10  481.71
   FULLV:XS  ********    0.69  478.04  500.46  0.57  0.00  0.83  483.67  482.85
   APPRO:XS    484.41    0.87  479.55  504.68  2.15  0.22  1.26  486.04  484.79
  ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

```
CAP -USGS culvert analysis program VER 94-10


               CULVERT SECTION PROPERTIES - ID: CLVRT

                            KR      KW    Ktheta     n       Inlet
                           1.00    1.00    1.00    0.040        1
            Pipe arch radii:   527.6(bottom) 119.4(top)   2.0(corner)

                    <<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         0.40     1.40
                       0.00     0.00         0.46     2.00
                       0.00     0.00         0.50     3.00
                       0.00     0.00         0.53     5.00
```

Barrel depth (ft)	Area (sq.ft)	Conveyance (cfs)	Top width (ft)	Wetted perimeter (ft)
0.00	0.0	0.0	0.00	0.0
0.45	2.8	38.7	12.53	12.5
0.90	9.7	239.8	17.68	17.8
1.35	18.3	635.1	19.42	20.4
1.80	27.1	1183.5	19.60	21.3
2.24	35.9	1842.7	19.74	22.2
2.69	44.8	2593.8	19.83	23.1
3.14	53.7	3422.2	19.89	24.0
3.59	62.6	4315.6	19.90	24.9
4.04	71.6	5263.2	19.87	25.8
4.49	80.5	6255.0	19.80	26.7
4.94	89.3	7282.1	19.70	27.6
5.39	98.1	8335.5	19.55	28.5
5.84	106.9	9406.9	19.35	29.4
6.28	115.5	10488.0	19.11	30.3
6.73	124.0	11570.6	18.83	31.3
7.18	132.4	12646.3	18.50	32.2
7.63	140.6	13706.8	18.12	33.2
8.08	148.7	14743.6	17.68	34.2
8.53	156.5	15747.6	17.19	35.2
8.98	164.1	16709.7	16.63	36.3
9.43	171.4	17619.8	16.01	37.4
9.88	178.4	18467.1	15.31	38.5
10.32	185.1	19239.8	14.51	39.7
10.77	191.5	19924.1	13.62	41.0
11.22	197.3	20503.6	12.59	42.4
11.67	202.7	20957.7	11.40	43.9
12.12	207.6	21257.6	10.00	45.5
12.57	211.7	21357.1	8.26	47.5
13.02	214.9	21158.6	5.91	50.0
13.47	216.7	19894.2	0.01	56.0

CAP -USGS culvert analysis program VER 94-10

APPROACH SECTION PROPERTIES - ID: APPRO

Water Surface el.(ft)*	Area (sq.ft)	Conveyance (cfs)	Top width (ft)	Alpha	Critical discharge (cfs)
479.55	0.0	0.0	0.0	1.00	0.0
493.05	916.2	92571.8	104.2	1.12	15414.7
499.80	1977.0	228802.9	193.7	1.31	35840.6
503.17	2636.7	339189.8	197.3	1.23	54698.0
504.86	2971.2	401713.7	198.9	1.20	65162.9
505.71	3139.0	435236.8	198.9	1.19	70761.1
506.13	3222.9	452352.0	198.9	1.18	73617.3
506.34	3264.9	460996.1	198.9	1.18	75059.5
506.44	3285.8	465339.5	198.9	1.18	75784.1
506.50	3296.3	467516.4	198.9	1.18	76147.2
506.52	3301.6	468606.3	198.9	1.18	76329.0
506.54	3304.2	469151.6	198.9	1.18	76420.0
506.54	3305.5	469424.2	198.9	1.18	76465.5
506.55	3306.2	469560.6	198.9	1.18	76488.2
506.55	3306.5	469628.8	198.9	1.18	76499.6
506.55	3306.6	469662.9	198.9	1.18	76505.3
506.55	3306.7	469680.5	198.9	1.18	76508.3
506.55	3306.8	469689.3	198.9	1.18	76509.7
506.55	3306.8	469693.2	198.9	1.18	76510.4
506.55	3306.8	469695.8	198.9	1.18	76510.8
506.55	3306.8	469696.9	198.9	1.18	76511.0
506.55	3306.8	469696.9	198.9	1.18	76511.0
506.55	3306.8	469696.9	198.9	1.18	76511.0
506.55	3306.8	469696.9	198.9	1.18	76511.0
506.55	3306.8	469696.9	198.9	1.18	76511.0

*elevation referenced to common vertical datum

CAP -USGS culvert analysis program VER 94-10

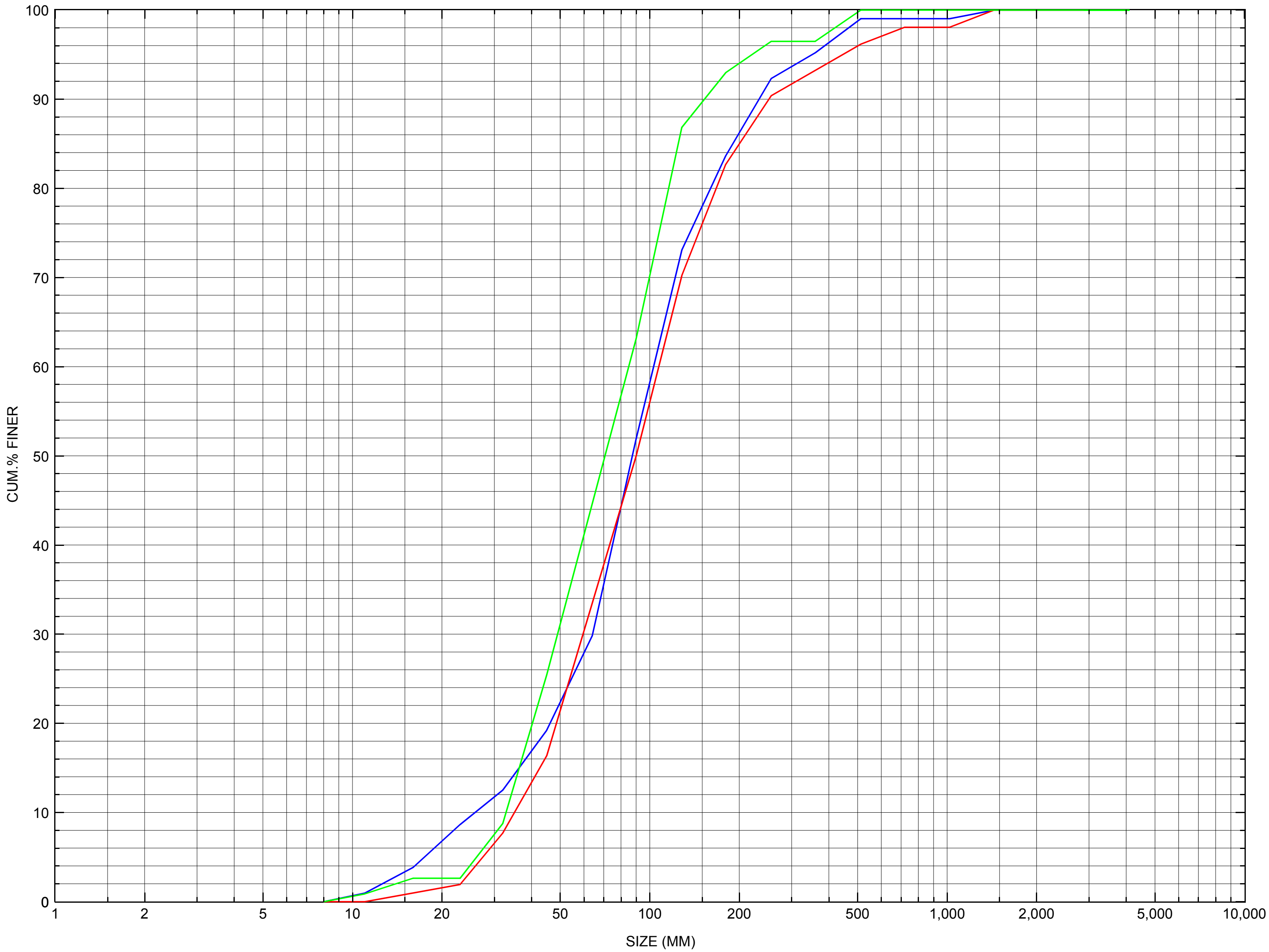
CULVERT				APPROACH SECTION	
I.D. CLVRT		Mannings n	0.040	I.D. APPRO	
Height	13.47 ft	Width	19.9ft	Station	120.0 ft
Station	0.0 ft	Length	100.0 ft	Minimum el.	479.55ft
Inlet el.	479.45ft	Outlet el.	477.96ft		

no.	Discharge (cfs)	Flow type	Water Surface Elevations (feet) appr.	inlet	outlet	exit	Critical Dc	Error code@
1	1250.0	2	488.50	485.85	483.35	482.32	5.4	0
2	1250.0	2	488.50	485.85	483.35	482.85	5.4	0
3	1590.0	2	490.29	486.95	484.19	482.32	6.2	0
4	1590.0	2	490.29	486.95	484.19	482.85	6.2	0

		Fall (ft)		Losses (ft)			Appr. Section			Control Section	
no.	C	entry	eff.	entry	(1-2)	(2-3)	VH	alph	F	energy	F
1	0.85	5.15	3.47	0.95	0.22	1.74	0.27	1.08	0.34	485.87	1.00
2	0.85	5.15	3.47	0.95	0.22	1.74	0.27	1.08	0.34	485.87	1.00
3	0.83	6.10	4.35	1.35	0.15	1.82	0.22	1.09	0.27	487.19	1.00
4	0.83	6.10	4.35	1.35	0.15	1.82	0.22	1.09	0.27	487.19	1.00

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure MNTGTH00190028, in Montgomery, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MNTGTH00190028

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 03 / 94

Highway District Number *(I - 2; nn)* 08

County *(FIPS county code; I - 3; nnn)* 011

Town *(FIPS place code; I - 4; nnnnn)* 45850

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

Waterway *(I - 6)* Wade Brook

Road Name *(I - 7):* -

Route Number TH019

Vicinity *(I - 9)* 0.6 MI TO JCT VT 58

Topographic Map Hazens.Notch

Hydrologic Unit Code: 02010007

Latitude *(I - 16; nnnn.n)* 44519

Longitude *(i - 17; nnnnn.n)* 72331

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10061000280610

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

Maximum span length *(I - 48; nnnn)* 0023

Year built *(I - 27; YYYY)* 1988

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000040

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

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

Channel & Protection *(I - 61; n)* 7

Opening skew to Roadway *(I - 34; nn)* 26

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)* 0000

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

Clear span (*nnn.n ft*) 023.0

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

Vertical clearance from streambed (*nnn.n ft*) 015.0

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

Waterway of full opening (*nnn.n ft*^{2}) 345.0

Comments:

Structural inspection report of 8/28/92 indicates channel scour is minor. Structure is a corrugated galvanized plate pipe arch. The embankments are noted in good condition. A small point bar is noted at the upstream end of the left abutment. Debris collection at the bridge is minor. Stone fill is noted as in good condition around the arch ends.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area (*mi²*): **6.3**

Terrain character: **Mountainous, forested**

Stream character & type: -

Streambed material: -

Discharge Data (*cfs*): $Q_{2.33}$ - Q_{10} **925** Q_{25} **1250**

Q_{50} **1550** Q_{100} **1850** 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*): **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*)	-	**990.3**	**992.3**	**994.0**	**995.7**
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} (ft^3/ *sec*): -

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

Upstream distance (*miles*): - Town: **Montgomery** Year Built: **1927**

Highway No. : **TH02** Structure No. : **4** Structure Type: **Concrete slab**

Clear span (*ft*): **20.0** Clear Height (*ft*): **5.0** Full Waterway (ft^2): **100.0**

Downstream distance (*miles*): - Town: Montgomery Year Built: 1930

Highway No. : VT118 Structure No. : 15 Structure Type: WF I-BEAM

Clear span (*ft*): 50.0 Clear Height (*ft*): 11.0 Full Waterway (ft^2): 550.0

Comments:

Plans called for the placement of "fish habitat stones". Boulders were to be submerged two thirds of their diameter into the stream bed.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 6.51 mi^2 Lake and pond area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 1058 ft Headwater elevation 3196 ft

Main channel length 3.21 mi

10% channel length elevation 1112 ft 85% channel length elevation 2441 ft

Main channel slope *(S)* 551.39 ft / mi

Watershed Precipitation Data

Average site precipitation ____ in Average headwater precipitation ____ in

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

Average seasonal snowfall *(Sn)* ____ ft

Bridge Plan Data

Are plans available? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **05** / **1988**

Project Number **TH 3622** Minimum channel bed elevation: **979.0**

Low superstructure elevation: USLAB **981.0*** DSLAB ________ USRAB ________ DSRAB ________

Benchmark location description:

BM#1, 10 inch spruce, elevation 1000.00, 100 feet west on TH 19 travelling from left bank then 15 feet off the left hand side of the road. BM#2, 10 inch maple elevation 1021.31, 130 feet east on TH 19 to Westfield travelling from right bank then 10 feet off the left hand side of the road.

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

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **975.0**

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

If 3: Footing bottom elevation: **-**

Is boring information available? **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:

***Typical elevation of the junction of the concrete abutments with the steel arch; as stated on the plans. Other elevation point is the top of the downstream right wingwall at 985.5. Built over old bridge site. Hydraulic data available on page 1; is the same as that quoted in hydraulics report given above.**

Cross-sectional Data

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

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

Comments: **Upstream bridge cross section at stationing of 9+ 50, 50 feet from the center of the roadway and arch. The channel base line (0) runs along the left bank 20 feet behind the left abutment parallel to the channel and arch. *Top of the concrete at the junction with the steel arch.**

Station	20	21	24	27	31	35	38				
Feature	LCL*	BLB	footing		TD		foo-	41	42		
Low cord elevation	981.0		t977				tingt97	BRB	LCR*		
Bed elevation		980.4	b975	979.8	979.7	979.9	7		981.0		
Low cord to bed length							b975	980.0			

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

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

Comments: **VTAOT**
Downstream bridge cross section at stationing of 10 +30, 30 feet from the center of the road-

Station	way	con-	with	LCL*	BLB	footing	TD	footing	BRB	LCR*	
Feature	and	crete	the	981.0		t977		t977		981.0	
Low cord elevation	arch.	at the	steel		980.1	b975	979.5	b975	980.0		
Bed elevation	*Top	junc-	arch.								
Low cord to bed length	of the	tion	20	21	24	31	38	41	42		

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: MAI Date: 2/8/95

Computerized by: MAI Date: 2/8/95

Reviewd by: EMB Date: 5/20/96

Structure Number MNTGTH00190028

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND Date *(MM/DD/YY)* 11 / 09 / 1994

2. Highway District Number 08 Mile marker 0

County Franklin (011) Town Montgomery (45850)

Waterway *(I - 6)* Wade Brook Road Name -

Route Number TH019 Hydrologic Unit Code: 02010007

3. Descriptive comments:

Located 0.6 miles from the junction of VT 58 and TH 19. This junction is 2.5 mi. east from the junction of VT 58 and VT118 in Montgomery Center. Bridge project number on the plaque "TH - 3622, 1989".

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 24 *(feet)* Span length 23 *(feet)* Bridge width 101 *(feet)*

Road approach to bridge:

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

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

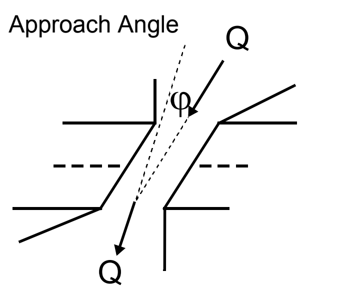
10. Embankment slope (*run / rise in feet / foot*):
US left 2.2:1 US right 1.7:1

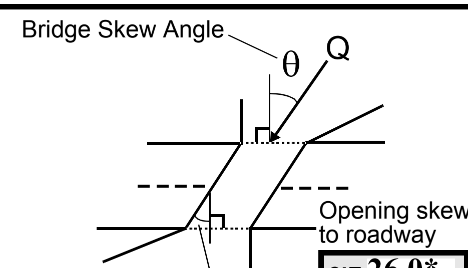
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	0
RBUS	2	1	0	0
RBDS	2	1	0	0
LBDS	2	1	0	0

*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: 5 16. Bridge skew: 30





α= 26.0*

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 110 feet US *(US, UB, DS)* to 0 feet US

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

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

18. Level II Bridge Type: **1a**

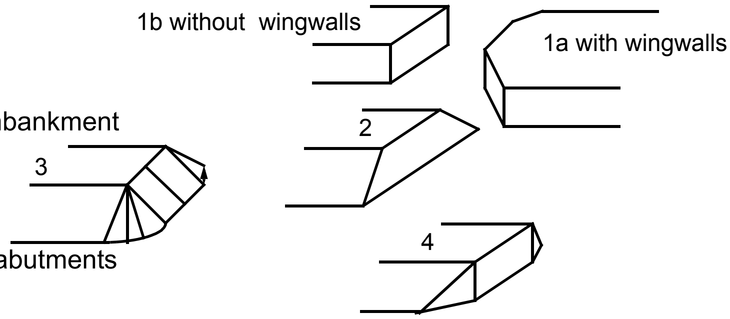
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

Measured culvert opening maximum length: 24, between wingwall tops: 23, and roadway width: 28
Culvert does not have a 'deck'. Road surface is about 9 ft. above low chord.
The opening skew to roadway value is the value from the historical data for this structure. The actual skew is zero, as the width measured across the opening is the roughly the same through the culvert. The skew from the historical form is the acute angle of the culvert from normal to the roadway embankment.

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
30.5	4.0			3.0	4	4	3	4	2	0

23. Bank width **20.0** 24. Channel width **25.0** 25. Thalweg depth **48.0** 29. Bed Material **4**

30 .Bank protection type: LB **2** RB **0** 31. Bank protection condition: LB **1** 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*

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

The channel changes direction such that the right bank is impacted. However a cut bank is on the left bank, possibly due to disturbance from the major tributary upstream entering on the right bank that forces flow towards the left bank. There is native cobble/ boulder size material exposed on the right bank. The left bank has a larger gravel component than the right bank. The bed material is mostly cobbles with gravel and a few boulders. Protection on left bank extends 30 ft. upstream from culvert. Beyond 30 feet upstream only native material is evident on the bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **55** 35. Mid-bar width: **10**

36. Point bar extent: **70** feet **US** *(US, UB)* to **35** feet **US** *(US, UB, DS)* positioned **0** %LB to **50** %RB

37. Material: **2345**

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

Lots of sand and gravel between and behind boulders. One large boulder deflects flow towards the right bank and may be contributing to the point bar development on the inside of the channel bed; see sketch.

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

41. Mid-bank distance: **100** 42. Cut bank extent: **150** feet **US** *(US, UB)* to **70** feet **US** *(US, UB, DS)*

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

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

Cut bank is about two feet high. Only the lower end of the general bank is cut. Lots of roots to limit additional erosion.

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
29.5		**1.5**		**2**	**7**	**7**	**0**

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

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

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

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

4

There is 0.5 foot of exposed footing at the base of the metal culvert. The culvert metal consists of several sections bolted together. Native stream bed consists of cobbles and gravel with some boulders. The concrete footing protrudes into the channel 0.7 ft. on both sides of the channel.

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 1____ (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

No debris accumulation near the bridge, the upstream section is laterally stable and has few cut banks, and consists of cobble and boulder sized material. Moderate channel gradient and the span is 47% of the upstream bank width.

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	0.5	90.0
RABUT	3	0	90			2	2	22.0

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

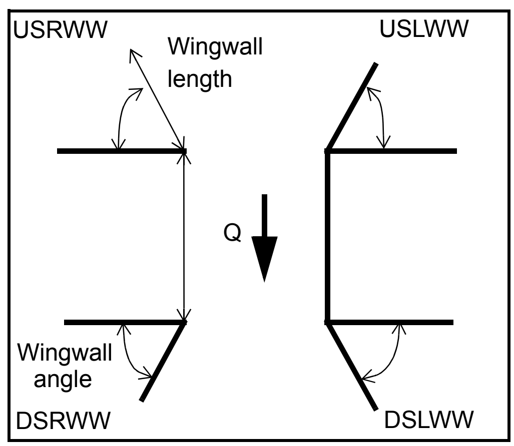
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
0.5
3
Exposed footing appears to be designed as placed above the streambed. No scour evident.
The footings are concrete and the walls are metal.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						20.0	
USRWW:	Y		1		0	1.5	
DSLWW:	-		-		Y	101.0	
DSRWW:	1		0		-	101.0	

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



82. Bank / Bridge Protection:

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

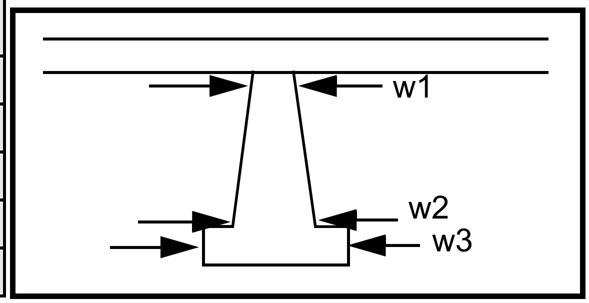
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **Ro** *(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**	**6.0**	**45.0**	**45.0**	**45.0**
Pier 2	**6.0**	**6.0**	-	**45.0**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

NO PIERS

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

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

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

106. Point/Side bar present? 4 (Y or N. if N type ctrl-n pb) Mid-bar distance: 4 Mid-bar width: 4

Point bar extent: 4 feet 1 (US, UB, DS) to 1 feet 4 (US, UB, DS) positioned 0 %LB to 0 %RB

Material: -

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

-

Bank erosion consists of cuts along both banks into the soil that covers the cobble/ boulder matrix.
Road embankment protection extends to the end of the wingwalls and into the channel for a short distance.
Most of the banks have larger native material in front of sand and gravel material. The bed material is mostly

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

Cut bank extent: with feet gra (US, UB, DS) to vel feet an (US, UB, DS)

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

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

few boulders.

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

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

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

N
-
NO DROP STRUCTURE

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

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

Confluence 2: Distance Y Enters on 135 (LB or RB) Type 10 (*1*- perennial; *2*- ephemeral)

Confluence comments (eg. confluence name):

100
DS

F. Geomorphic Channel Assessment

107. Stage of reach evolution 200

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)*:

DS

60

80

534

Two large boulders with one near the head and tail of the bar influence the formation of this bar. Mid channel bar.

Y

LB

50

20

DS

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: MNTGTH00190028 Town: Montgomery
Road Number: TH 19 County: Franklin
Stream: Wade Brook

Initials EMB Date: 5/2/96 Checked:

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	1250	1590	0
Main Channel Area, ft2	403	519	0
Left overbank area, ft2	70	121	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	63.8	65.7	0
Top width L overbank, ft	26.8	30.2	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.269	0.269	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	6.3	7.9	ERR
y1, average depth, LOB, ft	2.6	4.0	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	35872	55343	0
Conveyance, main channel	33271	49417	0
Conveyance, LOB	2601	5925	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0018	ERR
Qm, discharge, MC, cfs	1159.4	1419.7	ERR
Ql, discharge, LOB, cfs	90.6	170.2	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	2.9	2.7	ERR
Vl, mean velocity, LOB, ft/s	1.3	1.4	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.8	10.2	N/A
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	N/A	N/A

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

Main Channel	0	0	N/A
Left Overbank			
Right Overbank			

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)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	403	519	0
Main channel width, ft	63.8	65.7	0
y1, main channel depth, ft	6.32	7.90	ERR

Bridge Section			
(Q) total discharge, cfs	1250	1590	0
(Q) discharge thru bridge, cfs	1250	1590	
Main channel conveyance	9530	11881	
Total conveyance	9530	11881	
Q2, bridge MC discharge,cfs	1250	1590	ERR
Main channel area, ft2	98	115	0
Main channel width (skewed), ft	19.9	19.9	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.9	19.9	0
y_bridge (avg. depth at br.), ft	5.39	6.23	ERR
Dm, median (1.25*D50), ft	0.33625	0.33625	0
y2, depth in contraction,ft	5.88	7.22	ERR
ys, scour depth (y2-ybridge), ft	0.49	0.99	N/A
ys, scour depth (y2-y1), ft	-0.44	-0.68	N/A

ARMORING			
D90	0.708	0.708	
D95	1.17	1.17	
Critical grain size,Dc, ft	0.8295	0.9104	ERR
Decimal-percent coarser than Dc	0.0706	0.0639	
Depth to armoring,ft	32.76	40.01	ERR

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1250	1590	0	1250	1590	0
a', abut.length blocking flow, ft	34.1	37.5	0	36.6	38.5	0
Ae, area of blocked flow ft2	104.21	168.55	0	211.5	279.06	0
Qe, discharge blocked abut.,cfs	169.84	284.21	0	565.63	708.59	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	1.63	1.69	ERR	2.67	2.54	ERR
ya, depth of f/p flow, ft	3.06	4.49	ERR	5.78	7.25	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	116	116	0	64	64	0
K2	1.03	1.03	0.00	0.96	0.96	0.00
Fr, froude number f/p flow	0.164	0.140	ERR	0.196	0.166	ERR
ys, scour depth, ft	8.57	10.99	N/A	14.20	16.11	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)	34.1	37.5	0	36.6	38.5	0
y1 (depth f/p flow, ft)	3.06	4.49	ERR	5.78	7.25	ERR
a'/y1	11.16	8.34	ERR	6.33	5.31	ERR
Skew correction (p. 49, fig. 16)						
Froude no. f/p flow	0.16	0.14	N/A	0.20	0.17	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	1		1	1	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.39	6.23		5.39	6.23	
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0
Fr>0.8 (vertical abut.)	2.25	2.61	ERR	2.25	2.61	ERR