LEVEL II SCOUR ANALYSIS FOR BRIDGE 40 (ANDOVT00110040) on STATE ROUTE 11, crossing LYMAN BROOK, ANDOVER, VERMONT

U.S. Geological Survey
Open-File Report 97-594

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

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By MICHAEL A. IVANOFF & RONDA L. BURNS

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Pembroke, New Hampshire

1997

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 40 (ANDOVT00110040) ON STATE ROUTE 11, CROSSING LYMAN BROOK, ANDOVER, VERMONT

By **Michael A. Ivanoff and Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ANDOVT00110040 on State Route 11 crossing Lyman Brook, Andover, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in south-central Vermont. The 4.18-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture while the immediate banks have dense woody vegetation.

In the study area, Lyman Brook has an incised, straight channel with a slope of approximately 0.03 ft/ft, an average channel top width of 42 ft and an average bank height of 8 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 86.0 mm (0.282 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 9, 1996, indicated that the reach was stable.

The State Route 11 crossing of Lyman Brook is a 28-ft-long, two-lane bridge consisting of one 27-foot concrete tee-beam span (Vermont Agency of Transportation, written communication, March 29, 1995). The opening length of the structure parallel to the bridge face is 24.8 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 0 degrees to the opening while the opening-skew-to-roadway is 30 degrees.

The scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream right wingwall and the downstream ends of the downstream left and right wingwalls. There was also a stone wall along the top of the left bank from 36 to 76 feet upstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 0.7 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge which was more than the 100-year discharge. Left abutment scour ranged from 1.2 to 7.5 ft. The worst-case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 5.2 to 6.7 ft. The worst-case right abutment scour occurred at the 100-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.

Andover, VT. Quadrangle, 1:24,000, 1971

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 ANDOVT00110040 ***Stream*** Lyman Brook

County Windsor ***Road*** VT 11 ***District*** 2

Description of Bridge

Bridge length 28 ***ft*** ***Bridge width*** 34 ***ft*** ***Max span length*** 27 ***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*** 09/09/96

Description of stone fill Type-2, around the upstream end of the upstream right wingwall and around the downstream ends of the left and right downstream wingwalls.

There was also a stone wall along the top of the left bank from 36 to 76 feet upstream.

Brief description of piers/abutments Abutments and wingwalls are concrete.

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

Is bridge located on a bend in channel? No ***If so, describe (mild, moderate, severe)*** -

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	09/09/96	0	0
Level II	09/09/96	0	0

Potential for debris Low. There are some tree roots exposed and trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) A point bar was located along right bank upstream and along the left bank through the bridge opening as of 09/09/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a narrow flood plain on the left.

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

Date of inspection 09/09/96

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

DS right: Confluence with the Middle Branch Williams River.

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

US right: Steep channel bank to a moderately sloping overbank.

Description of the Channel

Average top width 42 *ft* ***Average depth*** 8 *ft*

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

Straight and stable with semi-alluvial channel boundaries and a narrow flood plain on the left.

09/09/96

Vegetative co Trees and brush on the immediate bank with pasture on the flood plain.

DS left: Brush and grass.

DS right: Trees and brush on the immediate bank with pasture on the flood plain.

US left: Trees and brush on the immediate bank with pasture on the overbank.

US right: Yes

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

The assessment of 09/09/96 noted a point bar along the right bank upstream and along the left bank through the bridge.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 4.18 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

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

Is there a lake/p No

-

Calculated Discharges

Q100 1,050 ***ft***^{3}***/s*** ***Q500*** 1,450 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(4.2/3.9)exp 0.7] with bridge number 26 in Andover. Bridge number 26 crosses Lyman Brook upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 26 is 3.9 square miles. These values are within a range defined by several empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans Subtract 53.0 ft from the USGS arbitrary survey datum to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM13 is a chiseled X on top of the upstream end of the right abutment (elev. 420.39 ft, arbitrary survey datum). RM14 is a chiseled X on top of the downstream end of the left abutment (elev. 419.97 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	-25	2	Modelled Exit section (Templated from EXTEM)
EXTEM	-5	1	Exit section as surveyed (Used as a template)
FULLV	0	2	Downstream Full-valley section (Templated from EXTEM)
DSBRG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	51	2	Modelled Approach section (Templated from APTEM)
APTEM	64	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.065, and overbank "n" values ranged from 0.025 to 0.055.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0278 ft/ft which was calculated from the surveyed thalweg points downstream of the bridge. Lyman Brook enters the Middle Branch of the Williams River just downstream of the bridge. The surveyed exit section (EXTEM) was moved along the exit channel slope (0.0278 ft/ft) to establish the modelled exit section (EXITX). Normal depth was assumed at the templated exit section (EXITX) based on the assumption that Lyman Brook will rise prior to or with the Middle Branch of the Williams River.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.021 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the 100-year and incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 420.4 ***ft***
Average low steel elevation 417.5 ***ft***

100-year discharge 1,050 ***ft³/s***
Water-surface elevation in bridge opening 414.0 ***ft***
Road overtopping? No ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 90 ***ft²***
Average velocity in bridge opening 11.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.4 ***ft/s***

Water-surface elevation at Approach section with bridge 416.6
Water-surface elevation at Approach section without bridge 414.9
Amount of backwater caused by bridge 1.7 ***ft***

500-year discharge 1,450 ***ft³/s***
Water-surface elevation in bridge opening 417.5 ***ft***
Road overtopping? Yes ***Discharge over road*** 163 ***ft³/s***
Area of flow in bridge opening 164 ***ft²***
Average velocity in bridge opening 8.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.2 ***ft/s***

Water-surface elevation at Approach section with bridge 419.0
Water-surface elevation at Approach section without bridge 417.1
Amount of backwater caused by bridge 1.9 ***ft***

Incipient overtopping discharge 1,200 ***ft³/s***
Water-surface elevation in bridge opening 414.4 ***ft***
Area of flow in bridge opening 98 ***ft²***
Average velocity in bridge opening 12.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.1 ***ft/s***

Water-surface elevation at Approach section with bridge 417.5
Water-surface elevation at Approach section without bridge 415.3
Amount of backwater caused by bridge 2.2 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year and incipient-overtopping discharges were computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Additional estimates of contraction scour also were computed by use of Laursen's clear-water scour equation (Richardson and others, 1995, p. 32, equation 20) and the results are presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting alternative estimates for the depth of flow in the bridge at the downstream face in the Chang equation and Laursen's clear-water equation. Contraction scour results with respect to these substitutions also are provided in Appendix F.

Abutment scour for the right abutment 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 at the left abutment was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

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	0.0	0.7
Depth to armoring	23.6	N/A	26.9
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	1.2	7.5	3.6
Right abutment	6.7	5.2	6.2
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.8	1.9	2.0
Right abutment	1.8	1.9	2.0
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

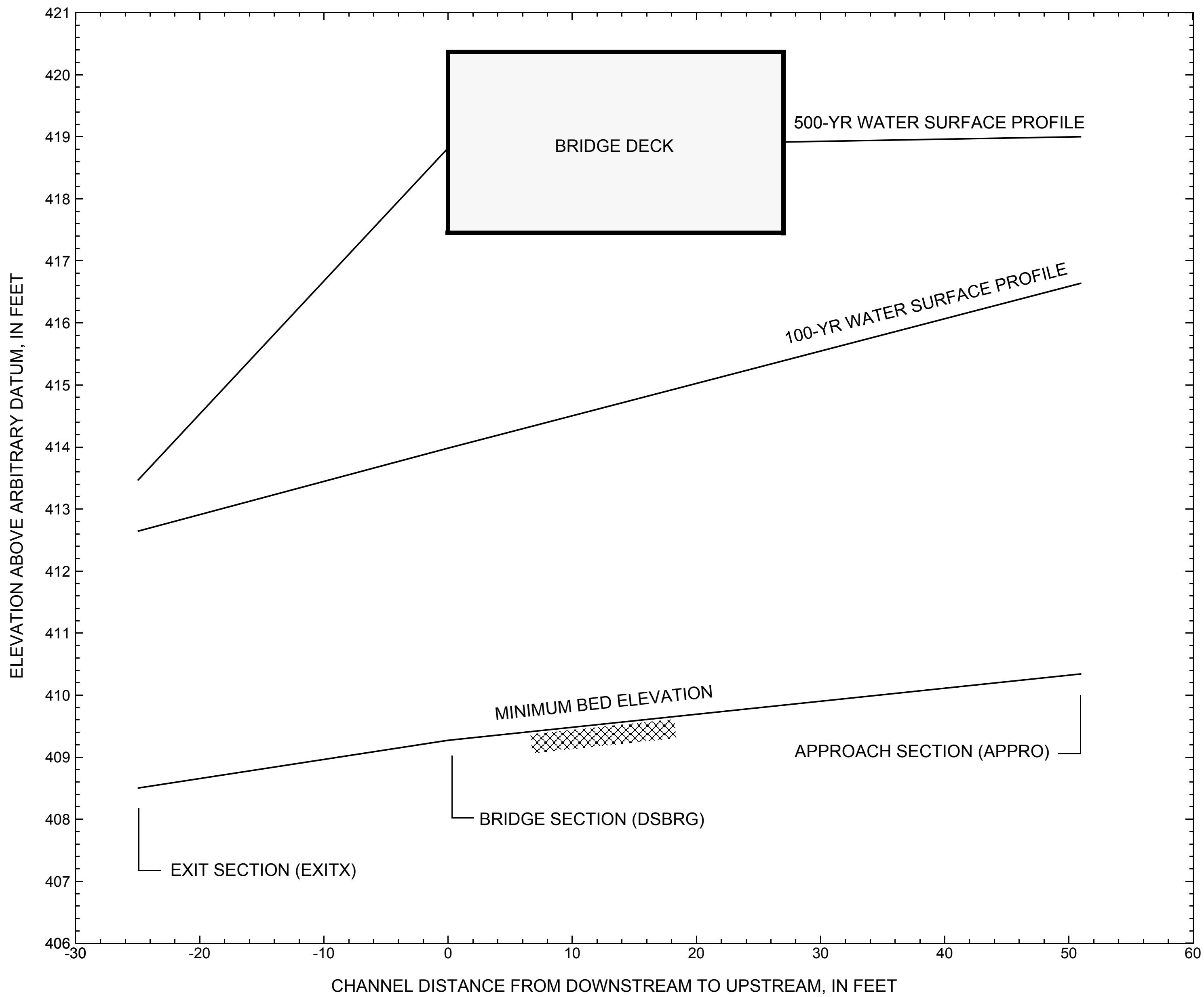

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ANDOVT00110040 on State Route 11, crossing Lyman Brook, Andover, Vermont.

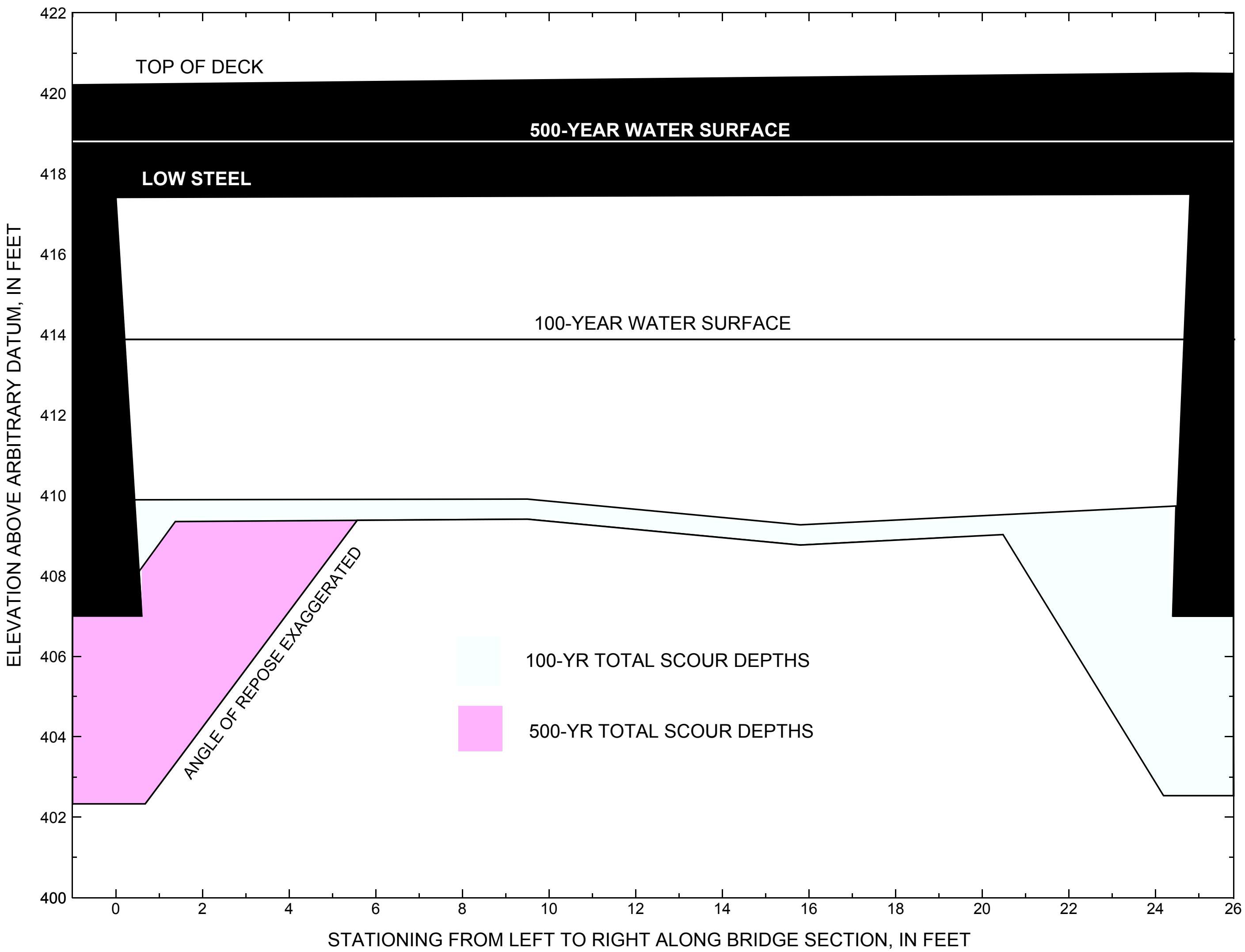

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ANDOVT00110040 on State Route 11, crossing Lyman Brook, Andover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ANDOVT00110040 on State Route 11, crossing Lyman Brook, Andover, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,050 cubic-feet per second											
Left abutment	0.0	367.0	417.4	407.0	409.8	0.5	1.2	--	1.7	408.1	1.1
Right abutment	24.8	367.0	417.5	407.0	409.7	0.5	6.7	--	7.2	402.5	-4.5

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 ANDOVT00110040 on State Route 11, crossing Lyman Brook, Andover, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 1,450 cubic-feet per second											
Left abutment	0.0	367.0	417.4	407.0	409.8	0.0	7.5	--	7.5	402.3	-4.7
Right abutment	24.8	367.0	417.5	407.0	409.7	0.0	5.2	--	5.2	404.5	-2.5

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

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U.S. Geological Survey, 1971, Andover, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ando040.wsp
T2        Hydraulic analysis for structure ANDOVT00110040   Date: 07-APR-97
T3        Bridge # 40 on State Route 11 over Lyman Brook by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1050.0   1450.0   1200.0
SK          0.0278   0.0278   0.0278
*
XT   EXTEM     -5
GR         -300.9, 412.44   -179.4, 412.01      0.0, 418.72      8.6, 409.29
GR           17.4, 409.31     27.9, 409.06     37.8, 409.96     50.3, 419.25
GR          343.5, 426.16    597.1, 436.10
*
XS   EXITX     -25 * * * 0.0278
GT          * 0.0
N           0.035        0.065        0.025
SA                   0.0         50.3
*
XS   FULLV      0  * * *   0.0267
*
*              SRD     LSEL    XSSKEW
BR   DSBRG     0    417.45      30.0
GR            0.0, 417.41      0.6, 409.84      9.5, 409.91     15.8, 409.27
GR           24.4, 409.74     24.8, 417.49      0.0, 417.41
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      36.7 * *     61.6      4.9
N           0.045
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     13      34.0     1
* GR           -228.1, 416.88   -226.6, 415.34   -203.1, 414.35   -173.8, 415.36
GR         -140.0, 424.7    -135.4, 417.56      0.0, 420.22     27.6, 420.50
GR          345.5, 427.73    498.7, 434.58
*
XT   APTEM     64
GR         -207.2, 424.68   -183.5, 416.16    -18.6, 418.04     -7.4, 419.12
GR            0.0, 415.77      1.1, 411.94      3.5, 411.11      6.7, 410.61
GR            9.1, 410.61     19.6, 411.43     25.5, 413.54     26.5, 417.02
GR           32.8, 418.73    149.3, 421.10    211.7, 422.48    232.1, 424.28
GR          303.8, 426.12    327.0, 428.16
*
AS   APPRO     51 * * * 0.021
GT
N           0.055        0.065        0.045
SA                   0.0         32.8
*
HP 1 DSBRG   413.98 1 413.98
HP 2 DSBRG   413.98 * * 1050
HP 1 APPRO   416.64 1 416.64
HP 2 APPRO   416.64 * * 1050
*
HP 1 DSBRG   417.45 1 417.45
HP 2 DSBRG   417.45 * * 1302
HP 1 DSBRG   414.18 1 414.18
HP 2 RDWAY   418.82 * * 163
HP 1 APPRO   419.00 1 419.00
HP 2 APPRO   419.00 * * 1450
*
HP 1 DSBRG   414.38 1 414.38
HP 2 DSBRG   414.38 * * 1200
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ando040.wsp
        Hydraulic analysis for structure ANDOVT00110040   Date: 07-APR-97
        Bridge # 40 on State Route 11 over Lyman Brook by MAI
           *** RUN DATE & TIME: 04-24-97  15:00

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       90      6321     21     29                         1054
   413.98            90      6321     21     29  1.00      0     25     1054


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       413.98     0.3    24.6    89.9    6321.    1050.  11.68

X STA.         0.3         2.7         4.1         5.4         6.6         7.8
  A(I)             8.2         4.9         4.5         4.3         4.2
  V(I)            6.40       10.68       11.66       12.24       12.64

X STA.         7.8         8.9        10.0        11.1        12.1        13.1
  A(I)             4.0         4.0         3.9         3.8         3.8
  V(I)           13.16       13.23       13.30       13.85       13.95

X STA.        13.1        14.1        15.0        15.9        16.9        17.8
  A(I)             3.8         3.6         3.7         3.8         3.8
  V(I)           13.85       14.44       14.04       13.81       13.70

X STA.        17.8        18.8        19.9        21.0        22.3        24.6
  A(I)             3.9         4.1         4.4         4.9         8.3
  V(I)           13.56       12.74       11.94       10.71        6.33


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       27       386     71     71                           95
             2      140      8545     26     32                         1835
   416.64           168      8931     97    104  1.25   -185     26     1117


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

         WSEL     LEW     REW    AREA        K        Q    VEL
       416.64  -185.6    26.5   167.5    8931.    1050.   6.27

X STA.      -185.6         1.2         3.0         4.3         5.5         6.5
  A(I)            31.1         9.6         7.6         6.8         6.5
  V(I)            1.69        5.50        6.87        7.68        8.10

X STA.         6.5         7.5         8.5         9.5        10.4        11.4
  A(I)             6.3         6.2         6.1         6.1         6.1
  V(I)            8.36        8.52        8.66        8.54        8.65

X STA.        11.4        12.5        13.5        14.6        15.7        16.8
  A(I)             6.3         6.2         6.4         6.4         6.7
  V(I)            8.36        8.48        8.20        8.24        7.88

X STA.        16.8        18.0        19.3        20.8        22.6        26.5
  A(I)             6.7         7.2         7.8         8.7        13.0
  V(I)            7.85        7.31        6.77        6.05        4.05
```

```
        U.S. Geological Survey WSPRO Input File ando040.wsp
        Hydraulic analysis for structure ANDOVT00110040   Date: 07-APR-97
        Bridge # 40 on State Route 11 over Lyman Brook by MAI
           *** RUN DATE & TIME: 04-24-97  15:00
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = DSBRG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     164.   12486.    11.    47.                         3623.
   417.45          164.   12486.    11.    47.  1.00     0.    25.   3623.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       417.45     0.0    24.8   163.5   12486.    1302.   7.96

 X STA.         0.0        2.8        4.4        5.8        7.2        8.5
   A(I)             16.5       10.4        9.2        8.9        8.9
   V(I)             3.95       6.25       7.08       7.29       7.34

 X STA.         8.5        9.9       11.1       12.4       13.3       14.1
   A(I)              8.6        8.4        8.2        6.3        6.0
   V(I)             7.60       7.73       7.90      10.34      10.88

 X STA.        14.1       15.0       15.8       16.7       17.5       18.3
   A(I)              5.9        5.9        5.8        5.9        6.0
   V(I)            11.08      10.96      11.20      11.09      10.94

 X STA.        18.3       19.2       20.2       21.2       22.4       24.8
   A(I)              6.2        6.5        7.0        8.4       14.6
   V(I)            10.48      10.01       9.32       7.79       4.46

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      94.    6761.    21.    29.                         1128.
   414.18           94.    6761.    21.    29.  1.00     0.    25.   1128.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

         WSEL     LEW     REW    AREA        K        Q    VEL
       418.82  -136.2   -71.3    40.9    1271.     163.   3.98

 X STA.      -136.2     -134.3     -133.1     -132.0     -130.8     -129.6
   A(I)              1.8        1.5        1.4        1.4        1.5
   V(I)             4.44       5.57       5.93       5.77       5.61

 X STA.      -129.6     -128.3     -126.9     -125.4     -123.8     -122.1
   A(I)              1.5        1.5        1.6        1.7        1.7
   V(I)             5.51       5.31       5.11       4.93       4.78

 X STA.      -122.1     -120.3     -118.4     -116.2     -113.8     -111.1
   A(I)              1.8        1.8        2.0        2.1        2.2
   V(I)             4.56       4.45       4.13       3.93       3.77

 X STA.      -111.1     -108.0     -104.3      -99.7      -93.1      -71.3
   A(I)              2.3        2.6        2.7        3.2        4.7
   V(I)             3.51       3.15       2.96       2.51       1.74

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     393.   17083.   192.   193.                         3190.
             2     212.   14969.    33.    39.                         3054.
             3       7.     101.    27.    27.                           21.
   419.00          612.   32153.   252.   259.  1.21  -192.    59.   4931.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.
         WSEL     LEW     REW    AREA        K        Q    VEL
       419.00  -192.2    59.5   612.1   32153.    1450.   2.37

 X STA.      -192.2     -176.5     -166.3     -155.8     -144.7     -132.4
   A(I)             35.0       30.2       30.0       30.4       32.1
   V(I)             2.07       2.40       2.42       2.38       2.26

 X STA.      -132.4     -118.6     -103.1      -84.7      -62.4      -31.9
   A(I)             33.7       35.6       38.4       41.4       47.6
   V(I)             2.15       2.04       1.89       1.75       1.52

 X STA.       -31.9        2.4        4.9        7.0        9.1       11.3
   A(I)             54.6       19.9       18.5       18.1       18.8
   V(I)             1.33       3.65       3.92       4.02       3.85

 X STA.        11.3       13.5       15.9       18.6       21.8       59.5
   A(I)             18.7       20.0       21.0       24.7       43.6
   V(I)             3.89       3.63       3.46       2.94       1.66
```

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      U.S. Geological Survey WSPRO Input File ando040.wsp
      Hydraulic analysis for structure ANDOVT00110040   Date: 07-APR-97
      Bridge # 40 on State Route 11 over Lyman Brook by MAI
         *** RUN DATE & TIME: 04-24-97  15:00

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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1      98.    7209.    21.    30.                       1204.
 414.38           98.    7209.    21.    30.  1.00     0.    25.   1204.


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

       WSEL     LEW     REW    AREA        K        Q    VEL
     414.38     0.2    24.6    98.4    7209.    1200.  12.20

X STA.        0.2        2.7        4.2        5.4        6.6        7.8
  A(I)            9.1        5.5        4.9        4.7        4.5
  V(I)           6.58      10.87      12.27      12.88      13.30

X STA.        7.8        8.9       10.0       11.0       12.1       13.1
  A(I)            4.3        4.3        4.2        4.1        4.1
  V(I)          13.84      13.92      14.36      14.48      14.62

X STA.       13.1       14.0       14.9       15.9       16.8       17.8
  A(I)            4.0        4.1        4.0        4.1        4.2
  V(I)          15.06      14.77      14.84      14.57      14.44

X STA.       17.8       18.8       19.8       21.0       22.3       24.6
  A(I)            4.3        4.5        4.8        5.5        9.1
  V(I)          13.90      13.35      12.50      10.84       6.61


  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     127.    3015.   153.   154.                        654.
           2     165.   10535.    29.    36.                       2222.
 417.53          292.   13550.   183.   189.  1.53  -188.    29.   1695.


  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

       WSEL     LEW     REW    AREA        K        Q    VEL
     417.53  -188.1    29.4   291.8   13550.    1200.   4.11

X STA.     -188.1     -172.7     -158.8     -141.2     -114.2        2.3
  A(I)           20.9       19.9       22.3       27.1       48.1
  V(I)           2.88       3.01       2.69       2.21       1.25

X STA.        2.3        3.9        5.3        6.5        7.7        8.9
  A(I)           10.5        9.3        8.9        8.6        8.6
  V(I)           5.72       6.47       6.75       6.95       6.95

X STA.        8.9       10.1       11.4       12.6       13.9       15.3
  A(I)            8.6        8.8        8.6        9.1        9.3
  V(I)           6.96       6.84       6.96       6.56       6.47

X STA.       15.3       16.7       18.3       20.0       22.2       29.4
  A(I)            9.6       10.0       11.1       12.7       19.7
  V(I)           6.28       5.98       5.41       4.72       3.04
```

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        U.S. Geological Survey WSPRO Input File ando040.wsp
        Hydraulic analysis for structure ANDOVT00110040   Date: 07-APR-97
        Bridge # 40 on State Route 11 over Lyman Brook by MAI
           *** RUN DATE & TIME: 04-24-97  15:00

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

EXITX:XS   ******     5.     127.  1.06 *****  413.71  412.11   1050.  412.64
      -25. ******    42.    6295.  1.00 ***** *******    0.79    8.27

FULLV:FV      25.     5.     129.  1.03  0.68  414.39 *******   1050.  413.36
        0.    25.    42.    6426.  1.00  0.00    0.00    0.77    8.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     1.05     414.82     414.94

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   412.86     427.89    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   412.86     427.89     414.94

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   414.94     427.89     414.94

APPRO:AS      51.     0.      96.  1.86 *****  416.80  414.94   1050.  414.94
       51.    51.    26.    4764.  1.00 ***** *******    1.00   10.94
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "DSBRG"     Q,CRWS =    1050.     413.98

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

DSBRG:BR      25.     0.      90.  2.12 *****  416.10  413.98   1050.  413.98
        0.    25.    25.    6323.  1.00 ***** *******    1.00   11.68

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  417.45 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      14.  -186.     167.  0.77  0.28  417.40  414.94   1050.  416.64
       51.    15.    26.    8917.  1.25  1.01   -0.01    0.94    6.28

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.060  0.039    8610.    -1.    23.   416.40

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -25.     5.    42.   1050.    6295.     127.    8.27  412.64
   FULLV:FV       0.     5.    42.   1050.    6426.     129.    8.15  413.36
   DSBRG:BR       0.     0.    25.   1050.    6323.      90.   11.68  413.98
   RDWAY:RG      13.**************      0.******************    1.00********
   APPRO:AS      51.  -186.    26.   1050.    8917.     167.    6.28  416.64

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    23.    8610.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    412.11    0.79  408.50  435.54************  1.06  413.71  412.64
   FULLV:FV  ********    0.77  409.17  436.21  0.68  0.00  1.03  414.39  413.36
   DSBRG:BR    413.98    1.00  409.27  417.49************  2.12  416.10  413.98
   RDWAY:RG  ****************  417.56  434.58**********************************
   APPRO:AS    414.94    0.94  410.34  427.89  0.28  1.01  0.77  417.40  416.64
```

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        U.S. Geological Survey WSPRO Input File ando040.wsp
        Hydraulic analysis for structure ANDOVT00110040   Date: 07-APR-97
        Bridge # 40 on State Route 11 over Lyman Brook by MAI
           *** RUN DATE & TIME: 04-24-97  15:00

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

EXITX:XS   ******     4.     158.  1.31 *****  414.77  412.86   1450.  413.46
      -25. ******    43.    8695.  1.00 ***** *******    0.80    9.18

FULLV:FV      25.     4.     160.  1.28  0.68  415.45 *******   1450.  414.18
        0.    25.    43.    8865.  1.00  0.00    0.01    0.79    9.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.12     415.53     417.08

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   413.68     427.89    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   413.68     427.89     417.08

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   417.08     427.89     417.08

APPRO:AS      51.  -187.     220.  0.97 *****  418.05  417.08   1450.  417.08
       51.    51.    28.   10830.  1.44 ***** *******    1.11    6.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   418.74       0.00     415.00     417.56

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   421.11         0.      1450.

 ===280 REJECTED FLOW CLASS 4 SOLUTION.

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

DSBRG:BR      25.     0.     164.  0.99 *****  418.44  414.64   1302.  417.45
        0. ******    25.   12486.  1.00 ***** *******    0.55    7.96

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.451 ******  417.45 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    17.  0.03  0.11  419.07    0.01    163.  418.82

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    163.    65.  -136.   -71.   1.3   0.6   4.3   4.0   0.9   3.0
   RT:      0.    73.    13.    86.   1.5   0.8   5.9   8.1   1.7   3.1

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

APPRO:AS      14.  -192.     612.  0.11  0.11  419.10  417.08   1450.  419.00
       51.    25.    59.   32139.  1.21  0.00    0.01    0.29    2.37

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS      -25.     4.    43.   1450.    8695.     158.    9.18  413.46
   FULLV:FV        0.     4.    43.   1450.    8865.     160.    9.06  414.18
   DSBRG:BR        0.     0.    25.   1302.   12486.     164.    7.96  417.45
   RDWAY:RG       13.*******   163.    163.*********       0.    1.00  418.82
   APPRO:AS       51.  -192.    59.   1450.   32139.     612.    2.37  419.00

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     412.86    0.80  408.50  435.54************  1.31  414.77  413.46
   FULLV:FV   ********    0.79  409.17  436.21  0.68  0.00  1.28  415.45  414.18
   DSBRG:BR     414.64    0.55  409.27  417.49************  0.99  418.44  417.45
   RDWAY:RG ****************  417.56  434.58  0.03******  0.11  419.07  418.82
   APPRO:AS     417.08    0.29  410.34  427.89  0.11  0.00  0.11  419.10  419.00
```

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       U.S. Geological Survey WSPRO Input File ando040.wsp
       Hydraulic analysis for structure ANDOVT00110040   Date: 07-APR-97
       Bridge # 40 on State Route 11 over Lyman Brook by MAI
          *** RUN DATE & TIME: 04-24-97  15:00

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

EXITX:XS   ******     5.     139.  1.16 *****  414.12  412.39   1200.  412.96
      -25. ******    43.    7194.  1.00 ***** *******    0.79    8.64

FULLV:FV      25.     5.     141.  1.13  0.68  414.81 *******   1200.  413.68
        0.    25.    43.    7341.  1.00  0.00    0.00    0.78    8.52
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.08     415.10     415.31

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   413.18     427.89    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   413.18     427.89     415.31

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   415.31     427.89     415.31

APPRO:AS      51.     0.     105.  2.02 *****  417.32  415.31   1200.  415.31
       51.    51.    26.    5474.  1.00 ***** *******    1.00   11.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "DSBRG"     Q,CRWS =    1200.     414.38

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

DSBRG:BR      25.     0.      98.  2.31 *****  416.70  414.38   1200.  414.38
        0.    25.    25.    7214.  1.00 ***** *******    1.00   12.20

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  417.45 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      14.  -188.     291.  0.40  0.21  417.93  415.31   1200.  417.53
       51.    15.    29.   13531.  1.53  1.02   -0.01    0.71    4.12

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.066  0.184   11115.    -1.    23.   417.40

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -25.     5.    43.   1200.    7194.     139.    8.64  412.96
   FULLV:FV       0.     5.    43.   1200.    7341.     141.    8.52  413.68
   DSBRG:BR       0.     0.    25.   1200.    7214.      98.   12.20  414.38
   RDWAY:RG      13.**************      0.******************    1.00********
   APPRO:AS      51.  -188.    29.   1200.   13531.     291.    4.12  417.53

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    23.   11115.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    412.39    0.79  408.50  435.54************  1.16  414.12  412.96
   FULLV:FV  ********    0.78  409.17  436.21  0.68  0.00  1.13  414.81  413.68
   DSBRG:BR    414.38    1.00  409.27  417.49************  2.31  416.70  414.38
   RDWAY:RG  ****************  417.56  434.58**********************************
   APPRO:AS    415.31    0.71  410.34  427.89  0.21  1.02  0.40  417.93  417.53
```
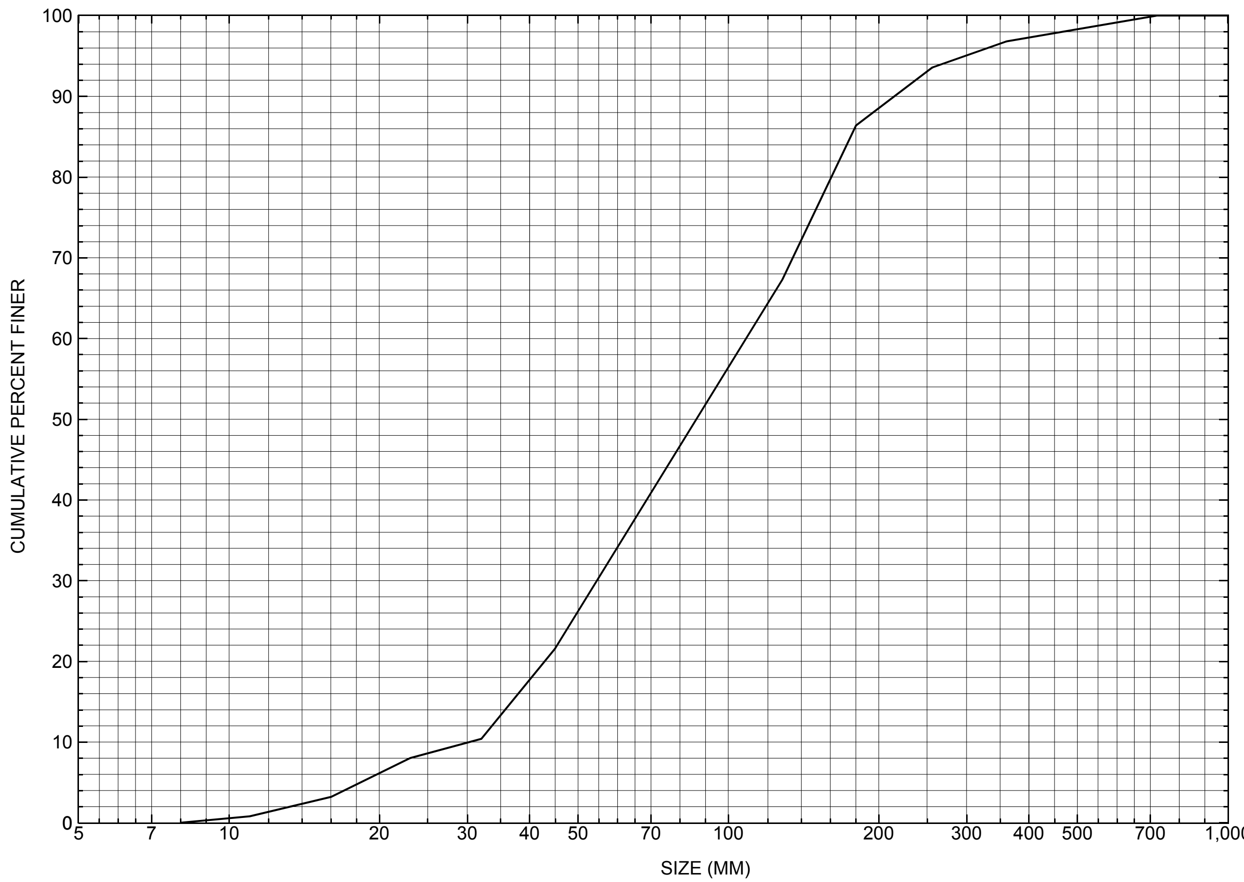

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ANDOVT00110040, in Andover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ANDOVT00110040

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 29 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 01300

Mile marker *(I - 11; nnn.nnn)* 001830

Waterway *(I - 6)* LYMAN BROOK

Road Name *(I - 7):* -

Route Number VT 11

Vicinity *(I - 9)* 3.1 MI E JCT VT 121

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43154

Longitude *(i - 17; nnnnn.n)* 72431

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001600401401

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

Maximum span length *(I - 48; nnnn)* 0027

Year built *(I - 27; YYYY)* 1929

Structure length *(I - 49; nnnnnn)* 000028

Average daily traffic, ADT *(I - 29; nnnnnn)* 002736

Deck Width *(I - 52; nn.n)* 340

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

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

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

Waterway adequacy *(I - 71; n)* 5

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

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

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 1972

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*) 7.0

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

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

Comments:

Structural inspection report of 11/10/93 indicates a concrete T-beam bridge with an asphalt surface and approaches. Some minor reinforcement is exposed in the spalled area near right abutment. Both concrete abutment stems have minor to moderate staining at the downstream end. The left abutment has a couple of vertical hairline shrinkage cracks with very minor staining. The wingwalls have some newer concrete along the tops; overall, they are in good condition. The footings are not in view. The waterway takes a moderate turn through the structure, then flows into the Middle Branch of the Williams River just downstream. The streambed consists of stone and boulders, with some gravel deposits.

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: -

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)* 4.18 mi^2 Lake/pond/swamp area 0 mi^2
Watershed storage *(ST)* 0 %
Bridge site elevation 1163 ft Headwater elevation 2346 ft
Main channel length 4.29 mi
10% channel length elevation 1220 ft 85% channel length elevation 1670 ft
Main channel slope *(S)* 139.92 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)*: 01 / 1971

Project Number FA 100 C Minimum channel bed elevation: 360.0

Low superstructure elevation: USLAB - DSLAB - USRAB 367.0 DSRAB -

Benchmark location description:
NO BENCHMARK INFORMATION.

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: 354.0

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:
Plans note: "bottom of footings foundation: boulders"

Comments:
The bridge was widened on the original abutments and wingwalls and now covers part of the wingwalls on the up and downstream sides. There are no elevations on the widening plans but they mention using the bridge seat elevation of the original structure. The bridge is just upstream from the confluence with the Middle Branch of the Williams River. Other elevation points: 1) the top streamward edge of the concrete at the upstream end of upstream left wingwall, elevation 367.5; and 2) the point at the same location described above, but on the downstream right wingwall, elevation 364.0.

Cross-sectional Data

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

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

Comments: NO CROSS SECTION INFORMATION

-

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

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

Comments: NO CROSS SECTION INFORMATION

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **10/1/96**

Computerized by: **EW** Date: **10/2/96**

Reviewd by: **MAL** Date: **05/22/97**

Structure Number **ANDOVT00110040**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R**. **BURNS** Date *(MM/DD/YY)* **09** / **09** / 19**96**

2. Highway District Number **02**

Mile marker **001830**

County **WINDSOR (027)**

Town **ANDOVER (01300)**

Waterway *(I - 6)* **LYMAN BROOK**

Road Name **-**

Route Number **VT 11**

Hydrologic Unit Code: **01080107**

3. Descriptive comments:

Located 3.1 miles east of junction with VT 121, 0.05 miles west of Middletown road, and 0.1 miles east of Andover bridge 39.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **4** LBDS **4** RBDS **4** Overall **4**

*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

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

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

7. Bridge length **28** *(feet)* Span length **27** *(feet)* Bridge width **34** *(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	-
RBUS	0	-	2	1
RBDS	0	-	2	1
LBDS	0	-	0	-

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

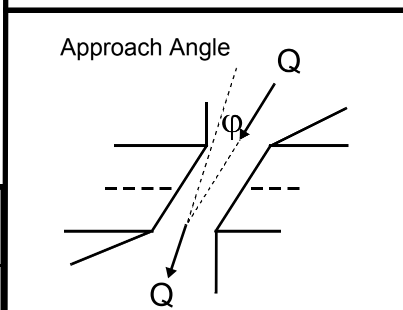
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

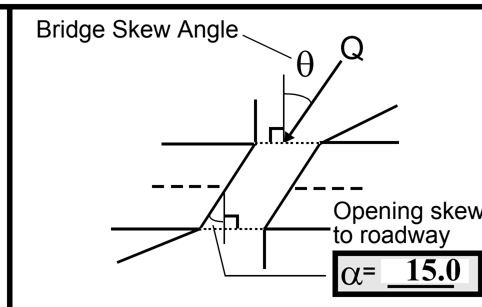
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

Channel approach to bridge (BF):

15. Angle of approach: **20** 16. Bridge skew: **0**





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

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

Range? **0** feet **US** *(US, UB, DS)* to **15** feet **DS**

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

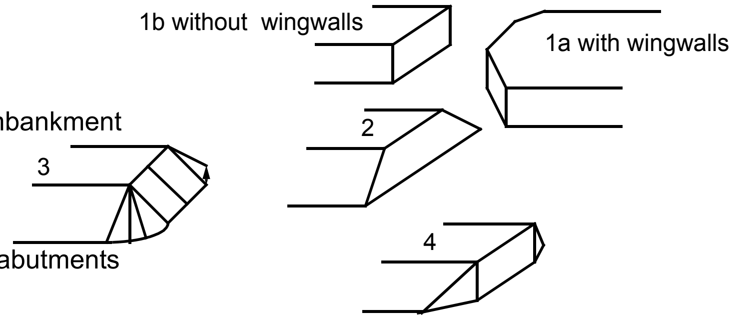
Where? ____ *(LB, RB)* Severity ____

Range? ____ feet ____ *(US, UB, DS)* to ____ feet ____

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

18. 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.)

#4: There are trees on the immediate US left and right banks. There is a lawn, gravel parking lot, and Rowell's Inn on the US left bank. There is a gravel driveway, a house and a lawn on the US right bank. Downstream, the banks are grass covered at the confluence of the Middle Branch Williams River.

#7: Measured bridge length = 29 feet; bridge span = 27 feet; and bridge width = 35 feet.

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
30.0	**7.0**			**5.0**	**3**	**3**	**543**	**543**	**1**	**1**

23. Bank width **40.0** 24. Channel width **35.0** 25. Thalweg depth **32.8** 29. Bed Material **543**

30 .Bank protection type: LB **5** RB **2** 31. Bank protection condition: LB **1** RB **1**

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

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

#30: The left bank protection is a short stone wall on the top of the bank from 76 feet upstream to 36 feet upstream. On the right bank, there is also type 2 protection from 22 feet upstream to the end of the USRWW. Also from 58 feet upstream to 32 feet upstream, there are rocks piled on top of the USRB.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **27** 35. Mid-bar width: **12**

36. Point bar extent: **64** feet **US** (US, UB) to **12** feet **US** (US, UB, DS) positioned **60** %LB to **100** %RB

37. Material: **543**

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

There is some grass growing at the US and DS ends. The DS half of the bar is composed of large boulders. The US half of the bar is composed of cobbles. Another point bar extends from 21 ft US to 14 ft DS. The mid-bar distance is at the US bridge face where it is 16 ft wide, and there are two large boulders. The material is comprised of gravel, sand, cobble, and boulder with vines, shrubs and grass growing on top on the DS end.

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

41. Mid-bank distance: **33** 42. Cut bank extent: **48** feet **US** (US, UB) to **21** 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.):

Some tree roots are exposed on the RB.

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

PVC pipes empty into the stream at 64 feet upstream and 13 feet upstream.

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
24.5		0.5		2	7	7	-

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

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

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

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

543

A point bar exists along the left abutment.

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

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

69. Is there evidence of ice build-up? 1___ *(Y or N)* Ice Blockage Potential N____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		-	90	2	0	-	-	90.0
RABUT	1	10	90			2	0	24.0

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.):

-

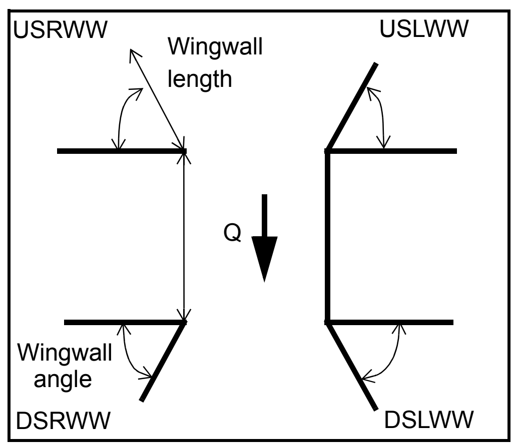
-

1

Most of the flow is along the right abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						24.0	
USRWW:	Y		1		0	-	
DSLWW:	-		-		Y	23.5	
DSRWW:	1		0		-	30.5	



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	Y	-	-	1	-	-
Condition	Y	-	1	-	-	2	-	-
Extent	1	-	0	0	2	0	0	-

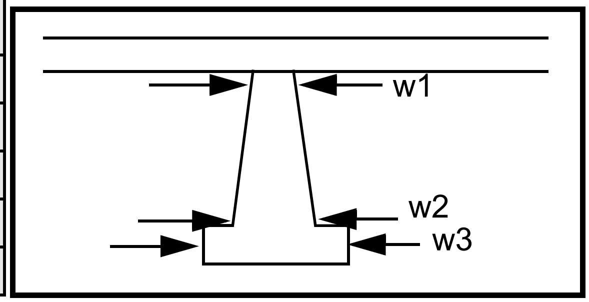
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? _____ *(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				**85.0**	**12.5**	**40.0**
Pier 2				**11.0**	**55.0**	**16.5**
Pier 3		**4.0**	**-**	**95.0**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	**NO**	**PIE**	**RS**		

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.):

1
1
543
543
0
0
543
2
2
1
1
Bank protection on the DSRB goes from the end of DSRWW to 15 feet downstream. On the DSLB, protection also starts at the downstream end of the DSLWW to 10 feet downstream.

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

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

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

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

Point bar extent: ______ feet ____ *(US, UB, DS)* to **N** feet **-** *(US, UB, DS)* positioned **NO** %LB to **DR** %RB

Material: **OP**

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

STRUCTURE

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

Cut bank extent: **15** feet **12** *(US, UB, DS)* to **0** feet **DS** *(US, UB, DS)*

Bank damage: **15** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
50
100
543

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

Scour dimensions: Length **bar** Width **is on** Depth: **the** Positioned **left** %LB to **ban** %RB

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

k of the Middle Branch Williams River.

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

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

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

Confluence comments (eg. confluence name):

NO CUT BANKS

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)*:

N
-
-
-
-
-
-
NO CHANNEL SCOUR

Y

109. G. Plan View Sketch

- 1

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: ANDOVT00110040   Town: Andover
Road Number: VT 11   County: Windsor
Stream: Lyman Brook

Initials MAI   Date: 04/24/97 Checked: RLB

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1050	1450	1200
Main Channel Area, ft2	141	212	165
Left overbank area, ft2	28	393	127
Right overbank area, ft2	0	7	0
Top width main channel, ft	26	33	29
Top width L overbank, ft	72	192	153
Top width R overbank, ft	0	27	0
D50 of channel, ft	0.282	0.282	0.282
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.4	6.4	5.7
y1, average depth, LOB, ft	0.4	2.0	0.8
y1, average depth, ROB, ft	ERR	0.3	ERR
Total conveyance, approach	8970	32153	13550
Conveyance, main channel	8570	14969	10535
Conveyance, LOB	400	17083	3015
Conveyance, ROB	0	101	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1003.2	675.1	933.0
Ql, discharge, LOB, cfs	46.8	770.4	267.0
Qr, discharge, ROB, cfs	0.0	4.6	0.0
Vm, mean velocity MC, ft/s	7.1	3.2	5.7
Vl, mean velocity, LOB, ft/s	1.7	2.0	2.1
Vr, mean velocity, ROB, ft/s	ERR	0.7	ERR
Vc-m, crit. velocity, MC, ft/s	9.7	10.0	9.8
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	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1050	1450	1200
(Q) discharge thru bridge, cfs	1050	1302	1200
Main channel conveyance	6278	12486	7209
Total conveyance	6278	12486	7209
Q2, bridge MC discharge,cfs	1050	1302	1200
Main channel area, ft2	90	164	98
Main channel width (normal), ft	21.0	21.5	21.1
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21	21.5	21.1
y_bridge (avg. depth at br.), ft	4.26	7.60	4.66
Dm, median (1.25*D50), ft	0.3525	0.3525	0.3525
y2, depth in contraction,ft	4.77	5.62	5.32
ys, scour depth (y2-ybridge), ft	0.51	-1.99	0.66

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1050	1450	1200
Q, thru bridge MC, cfs	1050	1302	1200
Vc, critical velocity, ft/s	9.74	10.02	9.82
Va, velocity MC approach, ft/s	7.11	3.18	5.65
Main channel width (normal), ft	21.0	21.5	21.1
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.0	21.5	21.1
qbr, unit discharge, ft2/s	50.0	60.6	56.9
Area of full opening, ft2	89.5	163.5	98.4
Hb, depth of full opening, ft	4.26	7.60	4.66
Fr, Froude number, bridge MC	0	0.55	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	94	N/A
**Hb, depth at downstream face, ft	N/A	4.37	N/A
**Fr, Froude number at DS face	ERR	1.17	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A

Elevation of Low Steel, ft	0	417.45	0
Elevation of Bed, ft	-4.26	409.85	-4.66
Elevation of Approach, ft	0	419	0
Friction loss, approach, ft	0	0.11	0
Elevation of WS immediately US, ft	0.00	418.89	0.00
ya, depth immediately US, ft	4.26	9.04	4.66
Mean elevation of deck, ft	0	420.36	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.96	1.00
**Cc, for downstream face (<=1.0)	ERR	0.79	ERR
Ys, scour w/Chang equation, ft	N/A	-1.29	N/A
Ys, scour w/Umbrell equation, ft	N/A	-2.61	N/A

**=for UNsubmerged orifice flow only.

**Ys, scour w/Chang equation, ft	N/A	3.28	N/A
**Ys, scour w/Umbrell equation, ft	ERR	0.62	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	4.77	5.62	5.32
WSEL at downstream face, ft	--	414.18	--
Depth at downstream face, ft	ERR	4.33	ERR
Ys, depth of scour (Laursen), ft	N/A	1.28	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	1050	1302	1200
Main channel area (DS), ft2	89.5	94	98.4
Main channel width (normal), ft	21.0	21.5	21.1
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	21.0	21.5	21.1
D90, ft	0.7043	0.7043	0.7043
D95, ft	0.9750	0.9750	0.9750
Dc, critical grain size, ft	0.7498	1.0328	0.7773
Pc, Decimal percent coarser than Dc	0.087	0.045	0.080
Depth to armoring, ft	23.55	N/A	26.89

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	1050	1450	1200	1050	1450	1200
a', abut.length blocking flow, ft	187.6	193.8	190	3.5	36.4	6.4
Ae, area of blocked flow ft2	36	366.7	138.1	11.7	42.1	17.5
Qe, discharge blocked abut.,cfs	77.4	--	299.8	47.1	70	53.3

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

Ve, (Qe/Ae), ft/s	2.15	1.95	2.17	4.03	1.66	3.05
ya, depth of f/p flow, ft	0.19	1.89	0.73	3.34	1.16	2.73
--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)						
theta	120	120	120	60	60	60
K2	1.04	1.04	1.04	0.95	0.95	0.95
Fr, froude number f/p flow	0.865	0.237	0.449	0.388	0.272	0.325
ys, scour depth, ft	6.75	13.01	10.16	6.72	5.23	6.24

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)	187.6	193.8	190	3.5	36.4	6.4
y1 (depth f/p flow, ft)	0.19	1.89	0.73	3.34	1.16	2.73
a'/y1	977.60	102.42	261.40	1.05	31.47	2.34
Skew correction (p. 49, fig. 16)	1.07	1.07	1.07	0.90	0.90	0.90
Froude no. f/p flow	0.86	0.24	0.45	0.39	0.27	0.32
Ys w/ corr. factor K1/0.55:						
vertical	1.42	9.13	4.33	ERR	4.93	ERR
vertical w/ ww's	1.16	7.49	3.55	ERR	4.04	ERR
spill-through	0.78	5.02	2.38	ERR	2.71	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	1.17	1	1	1.17	1
y, depth of flow in bridge, ft	4.26	4.37	4.66	4.26	4.37	4.66
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	1.78	1.91	1.95	1.78	1.91	1.95