LEVEL II SCOUR ANALYSIS FOR BRIDGE 24 (MANCUS00070024) on U.S. ROUTE 7, crossing LYE BROOK, MANCHESTER, VERMONT

U.S. Geological Survey
Open-File Report 97-390

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

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By SCOTT A. OLSON

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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 24 (MANCUS00070024) ON U.S. ROUTE 7, CROSSING LYE BROOK, MANCHESTER, VERMONT

By **Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MANCUS00070024 on U.S. Route 7 crossing Lye Brook, Manchester, 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 Taconic section of the New England physiographic province in southwestern Vermont. The 8.13-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the primary surface cover consists of brush and trees.

In the study area, Lye Brook has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 66 ft and an average bank height of 11 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 90.0 mm (0.295 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 6, 1996, indicated that the reach was stable. Although, the immediate reach is considered stable, upstream of the bridge the Lye Brook valley is very steep (0.05 ft/ft). Extreme events in a valley this steep may quickly reveal the instability of the channel. In the Flood Insurance Study for the Town of Manchester (Federal Emergency Management Agency, January, 1985), Lye Brook's overbanks were described as "boulder strewn" after the August 1976 flood.

The U.S. Route 7 crossing of Lye Brook is a 28-ft-long, two-lane bridge consisting of one 25-foot concrete span (Vermont Agency of Transportation, written communication, September 28, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 45 degrees to the opening while the opening-skew-to-roadway is 55 degrees.

At the time of construction, the downstream channel was relocated (written communication, Dan Landry, VTAOT, January 2, 1997). A levee on the downstream right bank was also constructed and is protected by type-4 stone-fill (less than 60 inches diameter) extending from the bridge to more than 300 feet downstream. Type-2 stone fill (less than 36 inches diameter) covers the downstream right bank from the bridge to more than 300 feet downstream. Type-2 stone-fill also extends from the bridge to 220 feet upstream on both upstream banks. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is analyzed since it has the potential of being the worst-case scour scenario. 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 1.0 to 1.6 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour computations for the left abutment ranged from 14.5 to 16.1 ft. with the worst-case occurring at the 100-year discharge. Abutment scour computations for the right abutment ranged from 6.9 to 10.4 ft. with the worst-case occurring 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.

Manchester, VT. Quadrangle, 1:24,000, 1968

NORTH

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

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

LEVEL II SUMMARY

Structure Number MANCUS00070024 ***Stream*** Lye Brook

County Bennington ***Road*** US7 ***District*** 1

Description of Bridge

Bridge length 28 ***ft*** ***Bridge width*** 44.8 ***ft*** ***Max span length*** 25 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/6/96

Description of stone fill Type-2, along the upstream banks and the downstream right bank. Type-4 along the downstream right bank/levee.

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

Y 45

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

There is a moderate channel bend in the downstream reach. This downstream channel reach was relocated when the bridge was constructed.

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	8/6/96	0	0
Level II	8/6/96	0	0

Potential for debris Moderate. Upstream banks are heavily forested.

Describe any features near or at the bridge that may affect flow (include observation date) August 6, 1996. There is a man-made levee along the downstream right bank.

Description of the Geomorphic Setting

General topography Upstream the channel is in a very steep, narrow, mountainous valley.
Downstream the channel enters a delta.

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

Date of inspection 8/6/96

DS left: Steep channel bank to moderately sloped highway embankment.

DS right: Man-made levee covered by type-4 stone-fill.

US left: Steep channel bank to high terrace.

US right: Steep channel bank to steeply sloped overbank.

Description of the Channel

Average top width 66 *ft* ***Average depth*** 11 *ft*

Predominant bed material Cobbles ***Bank material*** Boulder (fill)

Sinuous, but stable
with semi-alluvial channel boundaries. The downstream channel has been redirected.

8/6/96

Vegetative co Trees and brush with some field grasses.

DS left: Trees and brush with some field grasses.

DS right: Trees and brush with some field grasses.

US left: Trees and brush with some field grasses.

US right:

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

None. August 6, 1996.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 8.13 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p [illegible] No

Calculated Discharges

Q100 1,620 ***ft³/s*** ***Q500*** 2,670 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(8.13/9.5)exp 0.75] with flood frequency estimates at the mouth of Lye Brook in the Flood Insurance Study for the Town of Manchester (Federal Emergency Management Agency, 1985). The discharges compared well with results of several empirical methods for determining flood frequency estimates (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 Not available.

Description of reference marks used to determine USGS datum. RM1 is a standard brass disk set in top of the upstream end of the left abutment (elev. 500.21 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 498.50 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	-53	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	22	1	Road Grade section
APPRO	95	2	Modelled Approach section (Templated from APTEM)
APTEM	126	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 0.050.

Critical depth at the exit section (EXITX) was assumed as the starting water surface. Normal depth at the exit section was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990) and was determined to be supercritical but within 0.4 feet of critical depth. The slope used for the computation was 0.030 ft/ft determined from surveyed thalweg points downstream of the structure.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.015 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.

For all flows, the bridge was also modelled as a culvert so that results could be compared with those obtained using bridge routines. Results of the culvert routines indicate that normal depths are 0.8 to 1.0 feet above critical depths within the constriction. It is assumed that convergence to normal depth is possible in the structure. However, the downstream water surfaces (FULLV) for all modelled flows are below the critical water surfaces in the bridge. Thus, near the downstream face of the bridge the water surface must pass through critical depth and the defaults to critical depth are allowed. This is true for the 500-year water-surface profile as well, although it is unsubmerged orifice flow. Values found in the Bridge Hydraulics Summary on page 12 and used in the scour computations reflect the critical water surface in the bridge section.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.3 *ft*
Average low steel elevation 498.7 *ft*

100-year discharge 1,620 *ft^3/s*
Water-surface elevation in bridge opening 492.5 *ft*
Road overtopping? Y *Discharge over road* 6 *ft^3/s*
Area of flow in bridge opening 120 *ft^2*
Average velocity in bridge opening 13.4 *ft/s*
Maximum WSPRO tube velocity at bridge 16.7 *ft/s*

Water-surface elevation at Approach section with bridge 497.5 *ft*
Water-surface elevation at Approach section without bridge 492.2 *ft*
Amount of backwater caused by bridge 5.3 *ft*

500-year discharge 2,670 *ft^3/s*
Water-surface elevation in bridge opening 493.5 *ft*
Road overtopping? Y *Discharge over road* 584 *ft^3/s*
Area of flow in bridge opening 142 *ft^2*
Average velocity in bridge opening 14.5 *ft/s*
Maximum WSPRO tube velocity at bridge 18.4 *ft/s*

Water-surface elevation at Approach section with bridge 500.3 *ft*
Water-surface elevation at Approach section without bridge 493.7 *ft*
Amount of backwater caused by bridge 6.6 *ft*

Incipient overtopping discharge 1,510 *ft^3/s*
Water-surface elevation in bridge opening 492.3 *ft*
Area of flow in bridge opening 115 *ft^2*
Average velocity in bridge opening 13.1 *ft/s*
Maximum WSPRO tube velocity at bridge 16.3 *ft/s*

Water-surface elevation at Approach section with bridge 497.1 *ft*
Water-surface elevation at Approach section without bridge 492.0 *ft*
Amount of backwater caused by bridge 5.1 *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 Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). Since, flow was in contact with the upstream low chord in the 500-year model, the results of the Chang and Umbrell pressure flow scour equations (Richardson and others, 1995, pp. 144-146) were also found for this discharge. The results of both the Chang and the Umbrell equation were 0.0 ft of scour. Both the 100-year and the incipient roadway-overtopping discharges, which were free surface flows, had scour results from the Laursen equation of at least 1.0 ft of scour. The fact that scour for a larger discharge is less than scour for a smaller discharge is not logical for the conditions at this site. The cause of the discrepancy is due to the significant drop in water-surface, 7.7 ft, from the upstream to downstream sides of the bridge during the 500-year event and the fact that the hydraulic properties at the upstream face of the bridge are applied to the pressure flow equations and hydraulic properties of the downstream face are applied to the Laursen equation. The discrepancy was resolved by estimating the hydraulic properties at the downstream bridge face for the 500-year discharge (critical depth) and applying these to the Laursen equation. This gave results which were consistent with the 100-year and incipient roadway-overtopping discharge--more flow through the bridge, more scour.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.1	1.6	1.0
Depth to armoring	33.3	45.0	30.1
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	16.1	14.5	15.8
Right abutment	7.3	10.4	6.9
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	2.3	2.8	2.2
Right abutment	2.3	2.8	2.2
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

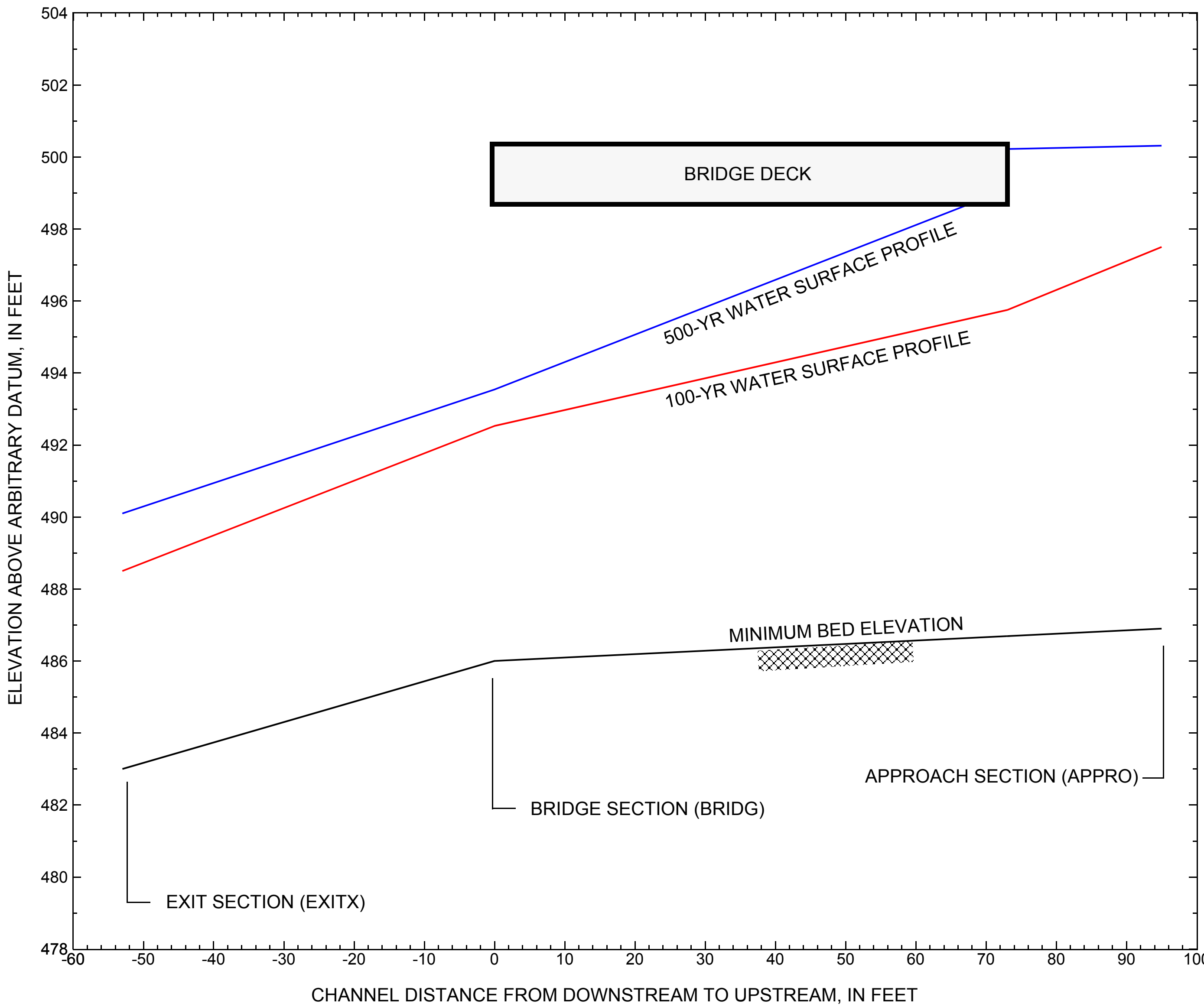

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure MANCUS00070024 on U.S. Route 7, crossing Lye Brook, Manchester, Vermont.

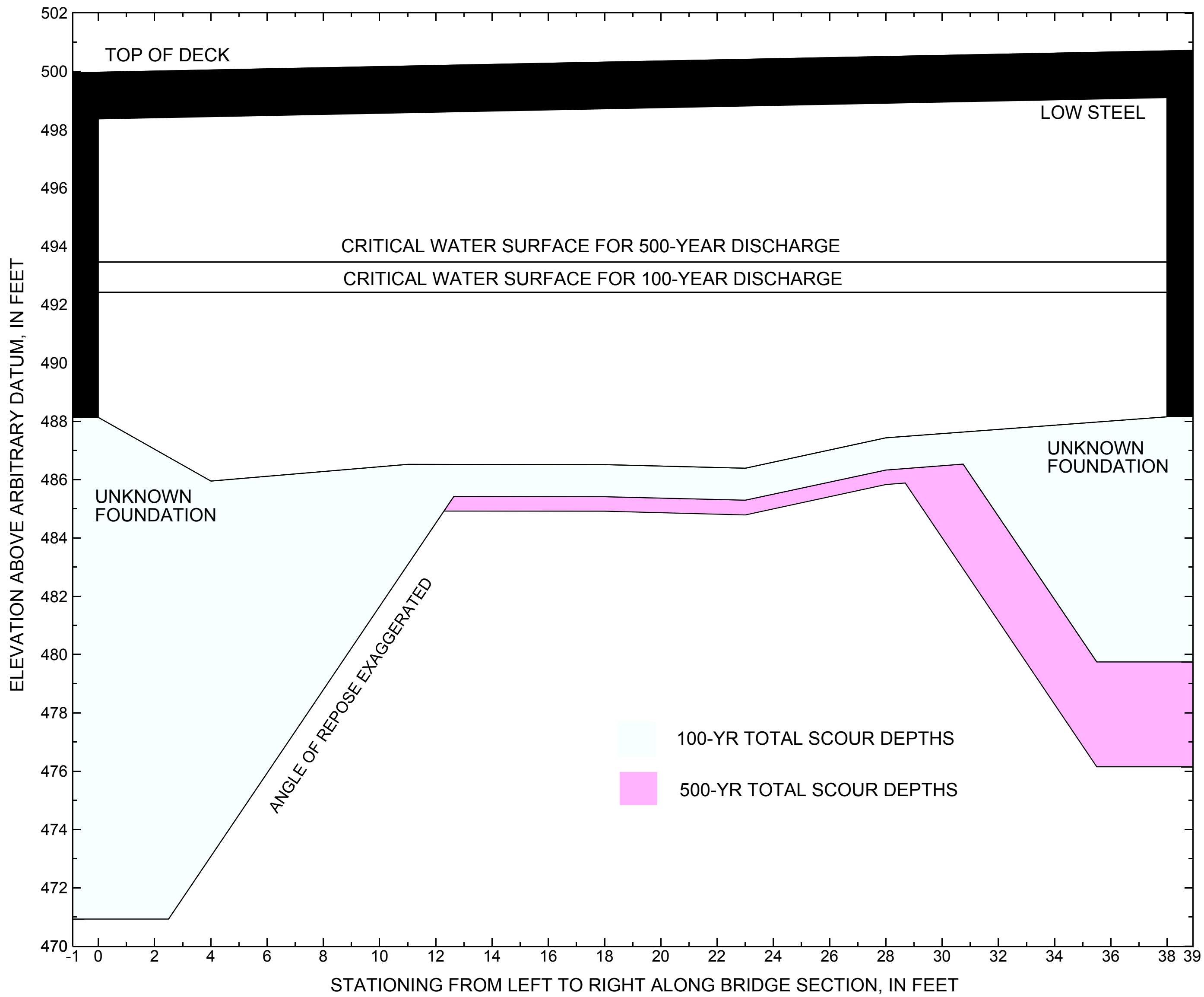

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure MANCUS00070024 on U.S. Route 7, crossing Lye Brook, Manchester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure MANCUS00070024 on U.S. Route 7, crossing Lye Brook, Manchester, 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 1,620 cubic-feet per second											
Left abutment	0.0	--	498.4	--	488.1	1.1	16.1	--	17.2	470.9	--
Right abutment	38.0	--	499.1	--	488.2	1.1	7.3	--	8.4	479.8	--

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 MANCUS00070024 on U.S. Route 7, crossing Lye Brook, Manchester, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,670 cubic-feet per second											
Left abutment	0.0	--	498.4	--	488.1	1.6	14.5	--	16.1	472.0	--
Right abutment	38.0	--	499.1	--	488.2	1.6	10.4	--	12.0	476.2	--

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

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U.S. Geological Survey, 1968, Manchester, 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             HYDRAULIC ANALYSIS
T2             MANCHESTER BRIDGE #024 OVER LYE BROOK
T3             USGS  PEMBROKE,NH          12/24/96
*
J3             6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q              1620 2670 1510
SK             0.030 0.030 0.030
*
XS   EXITX     -53
*            -159., 494.63     -95., 494.14     -70., 497.04     -26., 497.32
GR            -26., 497.32     -21., 496.52     -12., 491.61       0., 484.21
GR              2., 483.82       8., 483.49      11., 483.02      15., 483.67
GR             20., 484.37      30., 486.36      43., 494.79      54., 498.61
N              0.028        0.050
SA                    -21
*
XS   FULLV     0 * * * 0.024
*
BR   BRIDG     0 498.74 55
GR              0., 497.37       1., 488.13       4., 485.95      11., 486.52
GR             18., 486.51      23., 486.39      28., 487.43      38., 488.15
GR             38., 498.39      34., 499.10       5., 498.37       0., 497.37
N              0.045
CD             4 73 2 500.8 43
*
XR   RDWAY     22
GR           -144., 503.27    -105., 501.18     -49., 497.02     -41., 499.12
GR            -28., 499.37      -2., 499.76      -2., 500.62       0., 500.69
GR             38., 501.73      41., 501.80      41., 500.90     109., 503.24
GR            193., 505.60
*
XT   APTEM     126
GR            -33., 504.77     -29., 501.69     -16., 496.61       0., 488.55
GR              3., 488.20       6., 487.57      13., 487.38      16., 487.67
GR             19., 488.30      29., 489.61      41., 496.65      48., 497.72
GR             48., 499.45      54., 500.46      79., 504.27
*
AS   APPRO     95 * * * 0.015
GT
N              0.050
*
HP 1 BRIDG     492.53 1 492.53
HP 2 BRIDG     492.53 * * 1614
HP 2 RDWAY     497.45 * * 6
HP 1 APPRO     497.45 1 497.45
HP 2 APPRO     497.45 * * 1620
*
HP 1 BRIDG     493.54 1 493.54
HP 2 BRIDG     493.54 * * 2062
HP 1 BRIDG     499.10 1 499.10
HP 2 BRIDG     499.10 * * 2062
HP 2 RDWAY     499.96 * * 584
HP 1 APPRO     500.31 1 500.31
HP 2 APPRO     500.31 * * 2670
*
HP 1 BRIDG     492.29 1 492.29
```

```
HP 2 BRIDG    492.29 * * 1510
HP 1 APPRO    497.09 1 497.09
HP 2 APPRO    497.09 * * 1510
*
EX
ER
```

The following is the input file for the culvert routines. The results of the culvert routines were compared to the bridge routine results.

```
T1             HYDRAULIC ANALYSIS / WSPRO CULVERT ROUTINES
T2             MANCHESTER BRIDGE #024 OVER LYE BROOK
T3             USGS  PEMBROKE,NH          1/22/97
*
Q              1614 2062 1510
WS             489.93 491.40 489.76
*
CV   BRIDG   0 10.9 73 485.1 486.5 1
CG           111 147 262
CC           * * * 0.045
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
          HYDRAULIC ANALYSIS
          MANCHESTER BRIDGE #024 OVER LYE BROOK
          USGS  PEMBROKE,NH          12/24/96

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#    AREA       K  TOPW   WETP  ALPH    LEW    REW     QCR
            1     120.   9754.   21.    31.                      1613.
  492.53          120.   9754.   21.    31.  1.00     1.    38.  1613.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
       WSEL     LEW     REW    AREA        K        Q    VEL
     492.53     0.5    38.0   120.2    9754.    1614.  13.43
X STA.        0.5        4.4        6.2        7.8        9.4       10.9
  A(I)           11.6        6.7        5.9        5.5        5.2
  V(I)           6.95      12.05      13.79      14.64      15.61

X STA.       10.9       12.3       13.8       15.2       16.6       18.0
  A(I)            5.1        4.9        4.9        4.9        4.9
  V(I)          15.84      16.53      16.40      16.59      16.58

X STA.       18.0       19.4       20.8       22.2       23.6       25.2
  A(I)            4.8        4.9        4.9        5.0        5.3
  V(I)          16.71      16.61      16.33      16.12      15.27

X STA.       25.2       27.0       29.0       31.1       33.7       38.0
  A(I)            5.7        5.8        6.1        7.1       11.2
  V(I)          14.28      13.89      13.19      11.42       7.22

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      22.
       WSEL     LEW     REW    AREA        K        Q    VEL
     497.45   -54.8   -47.4     1.6      30.       6.   3.76
X STA.      -54.8      -52.7      -52.0      -51.6      -51.2      -50.9
  A(I)            0.2        0.1        0.1        0.1        0.1
  V(I)           1.80       2.60       2.95       3.42       3.63

X STA.      -50.9      -50.7      -50.4      -50.2      -50.0      -49.9
  A(I)            0.1        0.1        0.1        0.1        0.1
  V(I)           3.91       4.19       4.33       4.51       4.62

X STA.      -49.9      -49.7      -49.5      -49.4      -49.2      -49.1
  A(I)            0.1        0.1        0.1        0.1        0.1
  V(I)           4.82       4.97       4.96       5.05       5.00

X STA.      -49.1      -48.9      -48.8      -48.6      -48.3      -47.4
  A(I)            0.1        0.1        0.1        0.1        0.1
  V(I)           4.97       4.79       4.35       3.78       2.51

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      95.
    WSEL  SA#    AREA       K  TOPW   WETP  ALPH    LEW    REW     QCR
            1     432.  42599.   67.    72.                      6218.
  497.45          432.  42599.   67.    72.  1.00   -19.    48.  6218.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      95.
       WSEL     LEW     REW    AREA        K        Q    VEL
     497.45   -19.3    48.0   432.4   42599.    1620.   3.75
X STA.      -19.3       -6.3       -2.7       -0.1        2.0        3.9
  A(I)           38.6       25.7       22.1       20.0       18.6
  V(I)           2.10       3.16       3.66       4.04       4.35

X STA.        3.9        5.7        7.3        9.0       10.6       12.2
  A(I)           17.6       17.4       17.0       17.1       16.6
  V(I)           4.59       4.64       4.78       4.74       4.87

X STA.       12.2       13.8       15.4       17.2       19.0       21.0
  A(I)           17.1       16.9       17.9       17.8       19.0
  V(I)           4.74       4.80       4.52       4.56       4.27

X STA.       21.0       23.1       25.5       28.1       31.5       48.0
  A(I)           19.2       21.3       22.4       26.4       43.6
  V(I)           4.21       3.80       3.61       3.07       1.86
```

```
          HYDRAULIC ANALYSIS
          MANCHESTER BRIDGE #024 OVER LYE BROOK
          USGS  PEMBROKE,NH          12/24/96

  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#    AREA       K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     142.  12343.    22.    33.                      2067.
  493.54         142.  12343.    22.    33.  1.00     0.    38.  2067.

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
       WSEL     LEW     REW    AREA        K        Q    VEL
     493.54     0.4    38.0   142.0   12343.    2062.  14.53
X STA.        0.4         4.4         6.4         8.0         9.6        11.1
 A(I)            14.0         8.3         6.8         6.6         6.0
 V(I)            7.34       12.42       15.16       15.64       17.15

X STA.       11.1        12.6        14.0        15.4        16.8        18.2
 A(I)             6.1         5.7         5.7         5.7         5.7
 V(I)           17.00       18.18       18.03       18.24       18.23

X STA.       18.2        19.6        21.0        22.4        23.8        25.4
 A(I)             5.6         5.6         5.7         5.9         6.2
 V(I)           18.40       18.31       18.01       17.47       16.76

X STA.       25.4        27.1        29.1        31.2        33.7        38.0
 A(I)             6.3         6.9         7.3         8.2        13.8
 V(I)           16.30       15.04       14.17       12.54        7.49

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      22.
       WSEL     LEW     REW    AREA        K        Q    VEL
     499.96   -88.6    -2.0    92.9    5485.     584.   6.29
X STA.      -88.6       -73.8       -69.5       -66.4       -64.0       -61.9
 A(I)             8.1         5.4         4.8         4.2         3.9
 V(I)            3.60        5.42        6.13        6.92        7.44

X STA.      -61.9       -60.1       -58.4       -56.9       -55.5       -54.2
 A(I)             3.8         3.6         3.4         3.4         3.3
 V(I)            7.76        8.12        8.57        8.61        8.80

X STA.      -54.2       -52.9       -51.7       -50.5       -49.4       -48.1
 A(I)             3.3         3.3         3.3         3.4         3.5
 V(I)            8.86        8.83        8.92        8.67        8.28

X STA.      -48.1       -46.6       -44.5       -40.0       -30.6        -2.0
 A(I)             3.8         4.2         5.5         6.9        11.8
 V(I)            7.68        6.88        5.35        4.25        2.47

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      95.
   WSEL  SA#    AREA       K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     641.  70917.    83.    90.                     10118.
  500.31         641.  70917.    83.    90.  1.00   -27.    56.  10118.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      95.
       WSEL     LEW     REW    AREA        K        Q    VEL
     500.31   -26.7    56.1   640.7   70917.    2670.   4.17
X STA.      -26.7        -9.7        -5.2        -2.1         0.5         2.7
 A(I)            58.7        37.6        32.5        30.3        27.3
 V(I)            2.27        3.55        4.11        4.41        4.90

X STA.        2.7         4.7         6.6         8.5        10.3        12.2
 A(I)            25.6        25.4        24.8        24.6        24.7
 V(I)            5.22        5.25        5.38        5.42        5.40

X STA.       12.2        14.0        15.9        17.9        20.0        22.2
 A(I)            24.2        25.4        25.3        26.8        26.7
 V(I)            5.52        5.25        5.29        4.99        4.99

X STA.       22.2        24.7        27.3        30.4        35.0        56.1
 A(I)            28.9        30.7        33.7        41.7        65.8
 V(I)            4.61        4.35        3.96        3.20        2.03
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           HYDRAULIC ANALYSIS
           MANCHESTER BRIDGE #024 OVER LYE BROOK
           USGS  PEMBROKE,NH          12/24/96
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     115.    9161.    21.    31.                        1511.
  492.29          115.    9161.    21.    31.  1.00     1.    38.   1511.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      492.29     0.5    38.0   115.1    9161.    1510.  13.12
X STA.         0.5         4.4         6.2         7.8         9.3        10.8
  A(I)            11.1         6.4         5.4         5.2         5.1
  V(I)             6.80       11.76       13.87       14.61       14.79

X STA.        10.8        12.3        13.7        15.1        16.5        17.9
  A(I)             4.8         4.9         4.7         4.6         4.6
  V(I)            15.74       15.55       16.08       16.26       16.26

X STA.        17.9        19.3        20.7        22.1        23.6        25.2
  A(I)             4.6         4.7         4.7         4.9         5.1
  V(I)            16.32       16.22       15.94       15.40       14.83

X STA.        25.2        26.9        28.9        31.1        33.7        38.0
  A(I)             5.3         5.7         5.8         6.7        10.6
  V(I)            14.24       13.28       12.93       11.21        7.11


   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      95.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     408.   39573.    65.    70.                        5795.
  497.09          408.   39573.    65.    70.  1.00   -18.    47.   5795.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      95.
        WSEL     LEW     REW    AREA        K        Q    VEL
      497.09   -18.4    46.9   408.4   39573.    1510.   3.70
X STA.       -18.4        -5.9        -2.3         0.1         2.1         4.0
  A(I)            36.6        24.4        20.6        18.5        17.7
  V(I)             2.06        3.09        3.67        4.07        4.27

X STA.         4.0         5.8         7.4         9.0        10.6        12.2
  A(I)            17.1        16.5        16.1        15.9        16.0
  V(I)             4.41        4.57        4.70        4.74        4.72

X STA.        12.2        13.7        15.4        17.0        18.8        20.8
  A(I)            15.9        16.2        16.4        17.3        17.9
  V(I)             4.75        4.66        4.61        4.37        4.23

X STA.        20.8        22.9        25.2        27.8        31.0        46.9
  A(I)            18.6        19.6        21.7        24.6        40.8
  V(I)             4.06        3.84        3.48        3.07        1.85
```

WSPRO OUTPUT FILE (continued)

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          HYDRAULIC ANALYSIS
          MANCHESTER BRIDGE #024 OVER LYE BROOK
          USGS  PEMBROKE,NH           12/24/96

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                           WSI,CRWS =   488.34     488.56

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

EXITX:XS   ******    -7.     149.  1.84 *****  490.40  488.56   1620.  488.56
      -53. ******    33.   10205.  1.00 ***** *******    1.00   10.88

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.95     489.96     489.83
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   488.06     499.88    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   488.06     499.88     489.83

FULLV:FV      53.    -7.     153.  1.74  1.28  491.67  489.83   1620.  489.93
        0.    53.    34.   10624.  1.00  0.00   -0.01    0.96   10.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.97     492.19     492.10
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   489.43     504.30    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   489.43     504.30     492.10

APPRO:AS      95.    -8.     155.  1.70  2.21  493.90  492.10   1620.  492.20
       95.    95.    34.   10624.  1.00  0.00    0.02    0.96   10.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   497.46       0.00     492.55     497.02
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1614.     492.53

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

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

BRIDG:BR      53.     1.     120.  2.80 *****  495.33  492.53   1614.  492.53
        0.    53.    38.    9762.  1.00 ***** *******    1.00   13.42

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   4.  1.000 ******  498.74 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      22.    22.  0.03  0.22  497.63    0.00      6.  497.45

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      6.     7.   -55.   -47.   0.4   0.2   2.9   3.6   0.4   3.0
   RT:      0. ****** ****** ****** ***** ***** ***** ***** ***** *****

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

APPRO:AS      22.   -19.     433.  0.22  0.16  497.67  492.10   1620.  497.45
       95.    25.    48.   42622.  1.00  2.18    0.00    0.26    3.74

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      0.123  0.000   44450.     -4.     34. ********

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -53.     -7.    33.   1620.   10205.     149.   10.88  488.56
   FULLV:FV       0.     -7.    34.   1620.   10624.     153.   10.58  489.93
   BRIDG:BR       0.      1.    38.   1614.    9762.     120.   13.42  492.53
   RDWAY:RG      22.*******     6.      6.*********       0.    1.00  497.45
   APPRO:AS      95.    -19.    48.   1620.   42622.     433.    3.74  497.45

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    488.56    1.00  483.02  498.61************  1.84  490.40  488.56
   FULLV:FV    489.83    0.96  484.29  499.88  1.28  0.00  1.74  491.67  489.93
   BRIDG:BR    492.53    1.00  485.95  499.10************  2.80  495.33  492.53
   RDWAY:RG  ****************  497.02  505.60  0.03******  0.22  497.63  497.45
   APPRO:AS    492.10    0.26  486.92  504.30  0.16  2.18  0.22  497.67  497.45
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           HYDRAULIC ANALYSIS
           MANCHESTER BRIDGE #024 OVER LYE BROOK
           USGS  PEMBROKE,NH          12/24/96
          *** RUN DATE & TIME: 01-21-97  12:46

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                          WSI,CRWS =   489.72     490.13

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

EXITX:XS   ******   -10.     216.  2.37 *****  492.50  490.13   2670.  490.13
      -53. ******    36.   17436.  1.00 ***** *******    1.00   12.35

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.01     491.36     491.40
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   489.63     499.88    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   489.63     499.88     491.40
 ===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 "FULLV"
                  WSBEG,WSEND,CRWS =   491.40     499.88     491.40

FULLV:FV      53.   -10.     216.  2.37 *****  493.77  491.40   2670.  491.40
        0.    53.    36.   17436.  1.00 ***** *******    1.00   12.35
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.97     493.74     493.63
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   490.90     504.30    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   490.90     504.30     493.63

APPRO:AS      95.   -11.     223.  2.22  2.17  495.94  493.63   2670.  493.72
       95.    95.    37.   17869.  1.00  0.00    0.00    0.98   11.95
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   500.70       0.00     494.77     497.02
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =  494.12     499.52     499.69     498.74
 ===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

BRIDG:BR      53.     0.     252.  1.04 *****  500.14  493.54   2062.  499.10
        0. ******    38.   20814.  1.00 ***** *******    0.56    8.17

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.453 ******  498.74 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG       22.    22.  0.03  0.27  500.54    -0.01    584.  499.96

            Q   WLEN    LEW     REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    584.    87.   -89.    -2.   2.9   1.1   6.1   6.3   1.7   3.2
   RT:      0.     1.    41.    42.   0.0   0.0   4.0 221.2   0.8   3.0

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

APPRO:AS      22.   -27.     640.  0.27  0.09  500.58  493.63   2670.  500.31
       95.    24.    56.   70866.  1.00  2.14   -0.01    0.26    4.17

   FIRST USER DEFINED TABLE.
     XSID:CODE     SRD    LEW    REW       Q        K      AREA     VEL    WSEL
    EXITX:XS      -53.   -10.    36.   2670.   17436.     216.   12.35  490.13
    FULLV:FV        0.   -10.    36.   2670.   17436.     216.   12.35  491.40
    BRIDG:BR        0.     0.    38.   2062.   20814.     252.    8.17  499.10
    RDWAY:RG       22.*******   584.    584.*********       0.    1.00  499.96
    APPRO:AS       95.   -27.    56.   2670.   70866.     640.    4.17  500.31

 SECOND USER DEFINED TABLE.
     XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS     490.13    1.00  483.02  498.61************  2.37  492.50  490.13
    FULLV:FV     491.40    1.00  484.29  499.88************  2.37  493.77  491.40
    BRIDG:BR     493.54    0.56  485.95  499.10************  1.04  500.14  499.10
    RDWAY:RG   ****************  497.02  505.60  0.03******  0.27  500.54  499.96
    APPRO:AS     493.63    0.26  486.92  504.30  0.09  2.14  0.27  500.58  500.31
```

```
          HYDRAULIC ANALYSIS
          MANCHESTER BRIDGE #024 OVER LYE BROOK
          USGS  PEMBROKE,NH          12/24/96

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                          WSI,CRWS =   488.17     488.37

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

EXITX:XS   ******    -7.     141.  1.77 *****  490.14  488.37   1510.  488.37
      -53. ******    33.    9469.  1.00 ***** *******    1.00   10.68

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.94     489.81     489.64
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   487.87     499.88    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   487.87     499.88     489.64

FULLV:FV      53.    -7.     146.  1.66  1.28  491.42  489.64   1510.  489.76
        0.    53.    33.    9933.  1.00  0.00   -0.01    0.96   10.33
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.97     492.00     491.93
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   489.26     504.30    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   489.26     504.30     491.93

APPRO:AS      95.    -8.     147.  1.65  2.23  493.65  491.93   1510.  492.00
       95.    95.    34.    9796.  1.00  0.00    0.01    0.97   10.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
         WS1,WSSD,WS3,RGMIN =   497.09       0.00     492.29     497.02
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                 SECID "BRIDG"     Q,CRWS =    1510.     492.29

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

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

BRIDG:BR      53.     1.     115.  2.67 *****  494.97  492.29   1510.  492.29
        0.    53.    38.    9171.  1.00 ***** *******    1.00   13.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   4.  1.000 ******  498.74 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      22.        <<<<<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      22.   -18.     409.  0.21  0.16  497.31  491.93   1510.  497.09
       95.    25.    47.   39597.  1.00  2.18    0.00    0.26    3.70

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.107  0.000   41562.    -4.    34. ********

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW        Q         K     AREA     VEL    WSEL
   EXITX:XS     -53.    -7.    33.   1510.    9469.     141.   10.68  488.37
   FULLV:FV       0.    -7.    33.   1510.    9933.     146.   10.33  489.76
   BRIDG:BR       0.     1.    38.   1510.    9171.     115.   13.11  492.29
   RDWAY:RG      22.**************       0.        0.       0.    1.00********
   APPRO:AS      95.   -18.    47.   1510.   39597.     409.    3.70  497.09

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    488.37    1.00  483.02  498.61************  1.77  490.14  488.37
   FULLV:FV    489.64    0.96  484.29  499.88  1.28  0.00  1.66  491.42  489.76
   BRIDG:BR    492.29    1.00  485.95  499.10************  2.67  494.97  492.29
   RDWAY:RG  ****************  497.02  505.60  0.03******  0.21  497.26********
   APPRO:AS    491.93    0.26  486.92  504.30  0.16  2.18  0.21  497.31  497.09
```

```
        HYDRAULIC ANALYSIS / WSPRO CULVERT ROUTINES
        MANCHESTER BRIDGE #024 OVER LYE BROOK
        USGS  PEMBROKE,NH         1/22/97

CULVERT SUMMARY:

    ISHAPE      RISE      SPAN    BOTRAD    TOPRAD    CORNER
         1    147.00    262.00      0.00      0.00      0.00

     IEQNO       CKE        CN    CVALPH    CVLENG    CVSLPE
         1      0.40     0.045      1.00     73.00    0.0192

     TWDEP      QBBL      HWIC      HWOC    OTFULL
      4.83   1614.00      9.84     10.70     -4.36

     DSUBC     ASUBC     DSUBN     ASUBN
      5.54    120.87      6.38    139.40

     VELOT      AOUT     VELIN       AIN       HWE
     13.35    120.87     11.58    139.40    495.80



CULVERT SUMMARY:

    ISHAPE      RISE      SPAN    BOTRAD    TOPRAD    CORNER
         1    147.00    262.00      0.00      0.00      0.00

     IEQNO       CKE        CN    CVALPH    CVLENG    CVSLPE
         1      0.40     0.045      1.00     73.00    0.0192

     TWDEP      QBBL      HWIC      HWOC    OTFULL
      6.30   2062.00     11.37     12.35     -3.62

     DSUBC     ASUBC     DSUBN     ASUBN
      6.52    142.32      7.60    165.89

     VELOT      AOUT     VELIN       AIN       HWE
     14.49    142.32     12.61    163.57    497.45



CULVERT SUMMARY:

    ISHAPE      RISE      SPAN    BOTRAD    TOPRAD    CORNER
         1    147.00    262.00      0.00      0.00      0.00

     IEQNO       CKE        CN    CVALPH    CVLENG    CVSLPE
         1      0.40     0.045      1.00     73.00    0.0192

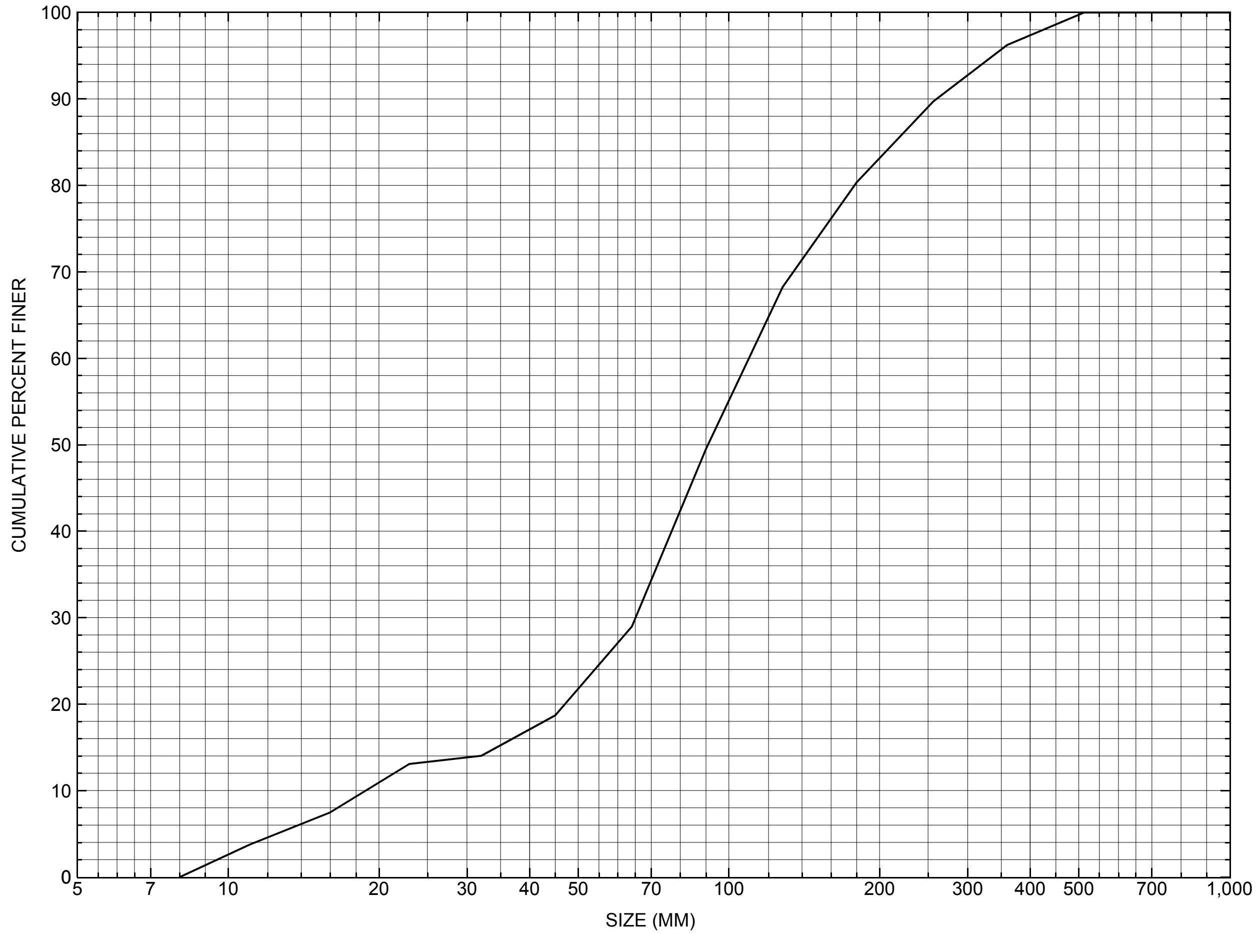
     TWDEP      QBBL      HWIC      HWOC    OTFULL
      4.66   1510.00      9.47     10.29     -4.53

     DSUBC     ASUBC     DSUBN     ASUBN
      5.30    115.62      6.09    133.03

     VELOT      AOUT     VELIN       AIN       HWE
     13.06    115.62     11.45    131.88    495.39
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure MANCUS00070024, in Manchester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MANCUS00070024

General Location Descriptive

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

Date *(MM/DD/YY)* 09 / 28 / 95

Highway District Number *(I - 2; nn)* 01

County *(FIPS county code; I - 3; nnn)* 003

Town *(FIPS place code; I - 4; nnnnn)* 42850

Mile marker *(I - 11; nnn.nnn)* 003250

Waterway *(I - 6)* LYE BROOK

Road Name *(I - 7):* -

Route Number US7

Vicinity *(I - 9)* 1.4 MI S EXIT 4

Topographic Map Manchester

Hydrologic Unit Code: 2020003

Latitude *(I - 16; nnnn.n)* 43095

Longitude *(i - 17; nnnnn.n)* 73025

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001900240206

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

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

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

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 003750

Deck Width *(I - 52; nn.n)* 448

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 107

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 24.5

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

Vertical clearance from streambed (*nnn.n ft*) 10

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

Waterway of full opening (*nnn.n* ft^2) 245

Comments:

According to structural inspection report dated 8/24/93, structure is a concrete rigid frame. Wings at the inlet and outlet are in good condition. The channel is straight entering the stone fill on the channel banks for a considerable distance US and DS. Currently, flow in the channel is over the entire width of the channel. There are concrete curbs with granite facings on each side of the structure. These curbs are in good condition with the exception of some minor map cracking. Overall, this structure is in good condition. Footings not exposed. Minor cracks on wings noted. No channel scour noted.

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area (mi^2): 7.65

Terrain character: steep, mountainous, unstable

Stream character & type: -

Streambed material: boulders and gravel

Discharge Data (*cfs*): $Q_{2.33}$ 820 Q_{10} 1000 Q_{25} 1250
Q_{50} 1400 Q_{100} 1520 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*) : moderate Debris (*Heavy, Moderate, Light*): heavy

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): 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*)	728.6	729.4	730.2	730.8	731.3
Velocity (*ft / sec*)	-	-	-	12.0	-

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

Hydraulic info from plans. Additional info: Estimated scour depth is 2.5 ft. Velocity of stream at design stage is 12 fps. Design discharge at Q50 is 1400 cfs. Ordinary high water elev at new structure is 725.1 ft. Design high water elev is 730.8 ft. Vertical clearance above design stage is 1.5 ft. Allowable water surface elevation is 732 ft (+/-) limited by top of frame at inlet.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **8.132** mi^2

Lake and pond area **0.15** mi^2

Watershed storage *(ST)* **1.67** %

Bridge site elevation **780** ft

Headwater elevation **2941** ft

Main channel length **6.749** mi

10% channel length elevation **940** ft

85% channel length elevation **2580** ft

Main channel slope *(S)* **323.99** 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)*: - / -

Project Number **FLH-F019-112** Minimum channel bed elevation: -

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

Benchmark location description:

No Benchmark Information Available

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

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

If 1: Footing Thickness 2 Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

No Drill Boring Information Available

Comments:

-

Cross-sectional Data

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

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

Comments: -

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:

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: 9/27/96
Computerized by: EW Date: 9/27/96
Reviewd by: SAO Date: 2/24/97

Structure Number MANCUS00070024

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 08 / 06 / 1996

2. Highway District Number 01 Mile marker 003250

County BENNINGTON 03 Town MANCHESTER 42850

Waterway *(I - 6)* LYE BROOK Road Name US 7

Route Number US 7 Hydrologic Unit Code: 02020003

3. Descriptive comments:

LOCATED 1.4 MILES SOUTH OF EXIT 4. THE CHANNEL APPEARS TO HAVE BEEN CONSTRUCTED.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 5 LBDS 5 RBDS 6 Overall 5

*(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 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 25 *(feet)* Bridge width 44.8 *(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	-	2	1
RBUS	0	-	0	-
RBDS	0	-	2	1
LBDS	2	1	0	-

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

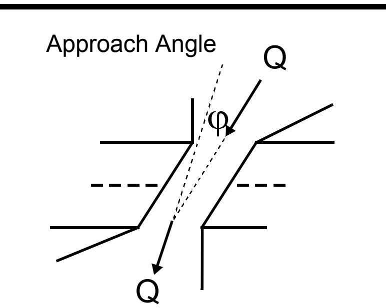
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

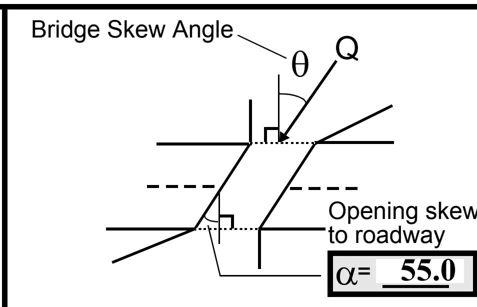
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 45





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

Where? RB *(LB, RB)* Severity 2

Range? 70 feet DS *(US, UB, DS)* to 120 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: 4

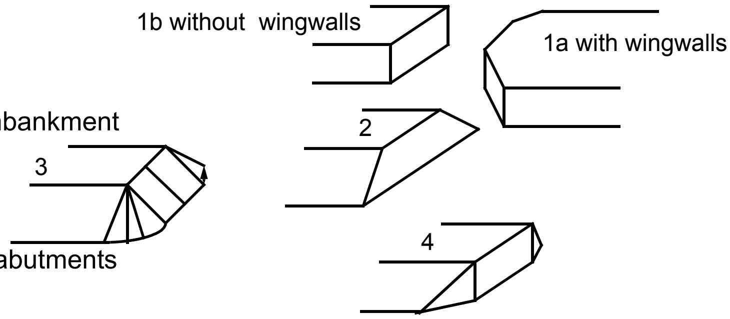
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#4: At 110 feet upstream on the left bank, the surface cover is forest.
At 220 feet upstream on the right bank, the surface cover is forest.

#7: Measured bridge length = 27.4 feet (measured perpendicularly); span length = 25.4 feet, perpendicular to abutment; deck width parallel to abutments = 48 feet, and deck width perpendicular to curb = 40.5 feet.

#11: LBDS road embankment protection is the same as the bank protection.

#17: Maximum impact at 120 feet downstream.

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
58.5	8.0			8.5	1	1	5437	547	0	0

23. Bank width 25.0 24. Channel width 20 25. Thalweg depth 57.5 29. Bed Material 54

30 .Bank protection type: LB 2 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.):

#26: Left bank vegetation cover changes to type 3 beyond 110 feet upstream. Right bank surface cover changes to type 3 beyond 220 feet upstream.

#27: Bank material on both sides is the stone protection.

#30: LB protection extends from bridge face to 110 feet upstream. RB protection extends from 20 feet upstream (end of wingwall) to 220 feet upstream.

Boulders are positioned across the channel at 83 feet upstream, creating a 1.5 feet drop. Another 1.5 feet drop exists at 94 feet upstream.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 86 35. Mid-bar width: 17

36. Point bar extent: *45 feet US (US, UB) to 120 feet US (US, UB, DS) positioned 50 %LB to 80 %RB

37. Material: 54

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

*** Measured from the downstream end of the USRWW, the bar extends to 20 feet upstream.**

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

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
19.5		1.0		2	7	7	-

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

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

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

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

453

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

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

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

70. Debris and Ice Comments:

1

#67: Many trees exist along banks upstream of bridge.

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	0	-	-	90.0
RABUT	1	0	90			2	0	21.5

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

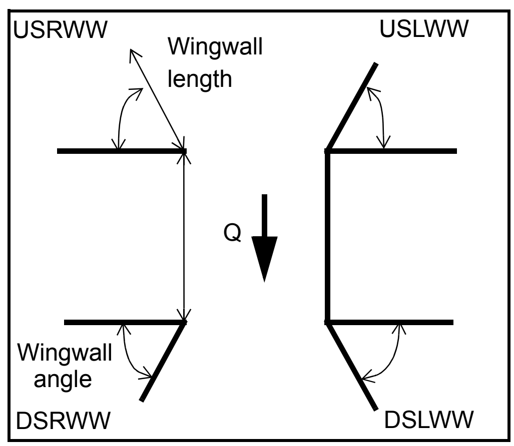
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

-
-
1

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						21.5	
USRWW:	Y		1		0	0.5	
DSLWW:	-		-		Y	73.0	
DSRWW:	1		0		-	73.0	

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	-	1	4	-	-
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

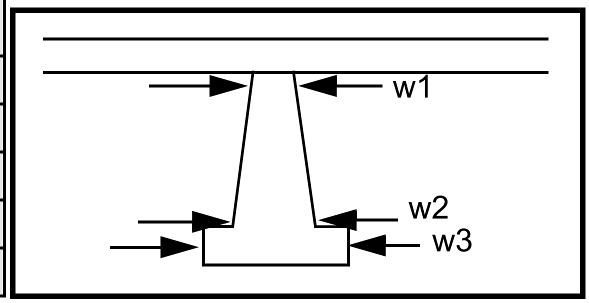
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
2
1
3
3
1
1

Piers:

84. Are there piers? **#82** *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**70.0**	**12.0**	**15.0**
Pier 2				**37.5**	**15.0**	**31.0**
Pier 3			**-**	**75.0**	**14.0**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



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

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: _____

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

Is a cut-bank present? **1** (Y or if N type ctrl-n cb) Where? **1** (LB or RB) Mid-bank distance: **573**

Cut bank extent: **573** feet **0** (US, UB, DS) to **0** feet **45** (US, UB, DS)

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

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

4

1

1

LB protection extends from 12 feet downstream to over 300 feet downstream.

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

Scour dimensions: Length **tec-** Width **tion** Depth: **exte** Positioned **nds** %LB to **fro** %RB

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

m downstream bridge face to over 300 feet downstream.

Bank material both sides is boulder-sized protection.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution **N**

1- Constructed
2- Stable
3- Aggraded
4- Degraded
5- Laterally unstable
6- Vertically and laterally unstable

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

-

NO DROP STRUCTURE

Many small boulder “dams” with the largest at 116 feet downstream and 175 feet downstream. Each boulder dam creates a 1 to 1.25 feet drop in water level.

N

-

-

-

-

-

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: MANCUS00070024 Town: MANCHESTER
Road Number: US7 County: BENNINGTON
Stream: LYE BROOK

Initials SAO Date: 1/21/97 Checked: RF

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	1620	2670	1510
Main Channel Area, ft2	432	641	408
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	67	83	65
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.295	0.295	0.295
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.4	7.7	6.3
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	42599	70917	39573
Conveyance, main channel	42599	70917	39573
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1620.0	2670.0	1510.0
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	3.8	4.2	3.7
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	10.2	10.5	10.1
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	1620	2670	1510
(Q) discharge thru bridge, cfs	1614	2062	1510
Main channel conveyance	3904	7044	3577
Total conveyance	3904	7044	3577
Q2, bridge MC discharge,cfs	1614	2062	1510
Main channel area, ft2	120	142	115
Main channel width (normal), ft	21.5	21.5	21.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.5	21.5	21.5
y_bridge (avg. depth at br.), ft	5.58	6.60	5.35
Dm, median (1.25*D50), ft	0.36875	0.36875	0.36875
y2, depth in contraction,ft	6.67	8.22	6.30
ys, scour depth (y2-ybridge), ft	1.09	1.62	0.95

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	1620	2670	1510
Q, thru bridge MC, cfs	1614	2062	1510
Vc, critical velocity, ft/s	10.18	10.49	10.14
Va, velocity MC approach, ft/s	3.75	4.17	3.70
Main channel width (normal), ft	21.5	21.5	21.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.5	21.5	21.5
qbr, unit discharge, ft2/s	75.1	95.9	70.2
Area of full opening, ft2	120.0	252.0	115.0
Hb, depth of full opening, ft	5.58	11.72	5.35
Fr, Froude number, bridge MC	0	0.56	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	142	N/A
**Hb, depth at downstream face, ft	N/A	6.60	N/A
**Fr, Froude number at DS face	ERR	1.00	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A

Elevation of Low Steel, ft	0	498.74	0
Elevation of Bed, ft	-5.58	487.02	-5.35
Elevation of Approach, ft	0	500.31	0
Friction loss, approach, ft	0	0.09	0
Elevation of WS immediately US, ft	0.00	500.22	0.00
ya, depth immediately US, ft	5.58	13.20	5.35
Mean elevation of deck, ft	0	501.21	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.97	1.00
**Cc, for downstream face (<=1.0)	ERR	0.79	ERR
Ys, scour w/Chang equation, ft	N/A	-2.31	N/A
Ys, scour w/Umbrell equation, ft	N/A	-3.39	N/A
**=for UNsubmerged orifice flow only.			
**Ys, scour w/Chang equation, ft	N/A	4.97	N/A
**Ys, scour w/Umbrell equation, ft	N/A	1.73	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	1614	2062	1510
Main channel area (DS), ft2	120	142	115
Main channel width (normal), ft	21.5	21.5	21.5
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	21.5	21.5	21.5
D90, ft	0.8481	0.8481	0.8481
D95, ft	1.1030	1.1030	1.1030
Dc, critical grain size, ft	0.9481	1.0251	0.9214
Pc, Decimal percent coarser than Dc	0.079	0.064	0.084
Depth to armoring, ft	33.25	44.98	30.06

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	1620	2670	1510	1620	2670	1510
a', abut.length blocking flow, ft	27.4	34.8	26.5	18.1	26.2	17
Ae, area of blocked flow ft2	166	164	158	56	113	49.3
Qe, discharge blocked abut.,cfs	--	--	562	119	289	101
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.60	4.05	3.56	2.13	2.56	2.05
ya, depth of f/p flow, ft	6.06	4.71	5.96	3.09	4.31	2.90

--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	145	145	145	35	35	35
K2	1.06	1.06	1.06	0.88	0.88	0.88
Fr, froude number f/p flow	0.256	0.262	0.257	0.213	0.217	0.212
ys, scour depth, ft	16.06	14.45	15.75	7.33	10.39	6.87

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 (DS)	1	1	1	1	1	1
y, depth of flow in bridge (DS), ft	5.58	6.60	5.35	5.58	6.60	5.35
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.)	2.33	2.76	2.24	2.33	2.76	2.24