LEVEL II SCOUR ANALYSIS FOR BRIDGE 137 (FERRUS00070137) on U.S. ROUTE 7, crossing LITTLE OTTER CREEK, FERRISBURG, VERMONT

U.S. Geological Survey
Open-File Report 97-189

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

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By Erick M. Boehmler and Ronda L. Burns

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1997

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

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information
write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

Copies of this report may be
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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 137 (FERRUS00070137) ON U.S. ROUTE 7, CROSSING LITTLE OTTER CREEK, FERRISBURG, VERMONT

***By* Erick M. Boehmler 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 FERRUS00070137 on U.S. Route 7 crossing Little Otter Creek, Ferrisburg, 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 Champlain section of the St. Lawrence Valley physiographic province in northwestern Vermont. The 56.7-mi^2 drainage area is in a predominantly rural and forested basin with some pasture on the valley bottom. In the vicinity of the study site, the surface cover consists of pasture upstream of the bridge. Downstream of the bridge the surface cover consists of trees, shrubs, and grass.

In the study area, Little Otter Creek has a meandering channel with a slope of approximately 0.007 ft/ft, an average channel top width of 86 ft and an average channel depth of 3 ft. The predominant channel bed materials are cobbles and gravel with a median grain size (D_{50}) of 54.9 mm (0.180 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 1, 1996, indicated that the reach was laterally unstable.

The U.S. Route 7 crossing of Little Otter Creek is a 157-ft-long, two-lane bridge consisting of three steel-beam spans (Vermont Agency of Transportation, written communication, December 12, 1995). The bridge is supported by vertical, concrete abutment walls with spill-through embankments in front of each abutment wall and two solid concrete piers. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is zero degrees.

The scour protection measures at the site consist of type-3 stone fill (less than 48 inches diameter) on the banks upstream and downstream of the bridge and the lower half of the spill-through embankment slopes on each abutment. Type-1 stone fill (less than 12 inches diameter) protects the upper half of the spill-through embankments and each roadway embankment. Additional details describing conditions at the site are included in the Level II Summary and Appendices D
and E.

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

Contraction scour for all modelled flows ranged from 1.8 to 2.3 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 10.4 to 14.9 ft. The worst-case abutment scour occurred at the 500-year discharge. There are two piers for which computed pier scour ranged from 7.5 to 13.4 ft. The left and right piers in this report are presented as pier 1 and pier 2 respectively. The worst-case pier scour occurred at pier 1 for 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.

Monkton, VT. Quadrangle, 1:24,000, 1963
Photorevised 1972, Contour interval, 10 feet.

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 FERRUS00070137 ***Stream*** Little Otter Creek

County Addison ***Road*** U.S. 7 ***District*** 5

Description of Bridge

Bridge length 157 ***ft*** ***Bridge width*** 35.0 ***ft*** ***Max span length*** 57 ***ft***

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

Abutment type Spill-through ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 7/1/96

Description of stone fill Type-3 on the lower half of each spill-through embankment and Type-1 on the upper half. Type-3 stone fill protection is present on the banks upstream and downstream of the bridge.

Brief description of piers/abutments Abutments and piers are concrete. There are spill-through embankments in front of each abutment wall.

Is bridge skewed to flood flow according to Yes ***survey?*** Y ***Angle*** 15

The valley is straight but the channel meanders across the valley bottom. The spill-through embankment on the left abutment blocks the left side of the channel.

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	7/1/96	0	0
Level II	7/1/96	0	0

Potential for debris Low. Although the banks are unstable, there are few trees on the banks upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None evident on 7/1/96.

Description of the Geomorphic Setting

General topography The channel is located in a low relief valley setting with narrow overbanks and moderately sloping valley walls on both sides.

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

Date of inspection 7/1/96

DS left: Slightly sloping channel bank to a narrow overbank.

DS right: Slightly sloping channel bank to a narrow overbank.

US left: Slightly sloping channel bank to valley wall.

US right: Slightly sloping channel bank to a narrow overbank.

Description of the Channel

Average top width 86 ***ft*** ***Average depth*** 3 ***ft***

Predominant bed material Gravel / Cobbles ***Bank material*** Silt & Clay

Meandering and laterally unstable with alluvial channel boundaries.

7/1/96

Vegetative co

DS left: Trees with some shrubs and brush.

DS right: Trees with some shrubs and brush.

US left: Grass with a few trees.

US right: Grass.

Do banks appear stable? No ***If not, describe location and type of instability and date of observation.***

On 7/1/96 there was a cut-bank noted on the upstream right bank. A block of bank material has slumped down and away from the bank.

Describe any obstructions in channel and date of observation.

None evident on 7/1/96

Hydrology

Drainage area 56.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
St. Lawrence Valley / Champlain	100

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

Is there a USGS gage on the stream of interest? Yes

USGS gage description Little Otter Creek at Ferrisburg, VT

USGS gage number 04282650

Gage drainage area 57.1 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 4,420 ***ft³/s*** ***Q500*** 5,450 ***ft³/s***

The gage just below this site has less than 7 years of record. Hence, the record was not considered in the selection of the 100- and 500-year discharges for this analysis. The discharges are based on discharge frequency curves computed by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957a&b; and Talbot, 1887). The median of the 100- and 500-year discharges from each empirical discharge frequency curve were selected for the hydraulic analysis at this site.

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 321.4 feet from the USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a one half inch bolt on top of the stream gage orifice pier (elev. 470.76 ft, arbitrary survey datum). RM2 is a brass tablet engraved "VT Hwy Dept. 1959" on top of the concrete curb at the upstream left corner of the bridge deck (elev. 500.54 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	-152	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	18	1	Road Grade section
APPRO	102	2	Modelled Approach section (Templated from APTEM)
APTEM	189	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 0.040 to 0.044, and overbank "n" values were 0.040.

The starting water surface at the exit section (EXITX) for each flow modeled was estimated by use of the rating curve for the gage, extrapolated to the 500-year discharge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.00397 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 the 500-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles, it was determined that the water surface profile passes through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.2 *ft*
Average low steel elevation 497.3 *ft*

100-year discharge 4,420 *ft^3/s*
Water-surface elevation in bridge opening 474.8 *ft*
Road overtopping? No *Discharge over road* -- *ft^3/s*
Area of flow in bridge opening 349 *ft^2*
Average velocity in bridge opening 12.7 *ft/s*
Maximum WSPRO tube velocity at bridge 14.8 *ft/s*

Water-surface elevation at Approach section with bridge 478.8
Water-surface elevation at Approach section without bridge 476.6
Amount of backwater caused by bridge 2.2 *ft*

500-year discharge 5,450 *ft^3/s*
Water-surface elevation in bridge opening 475.7 *ft*
Road overtopping? No *Discharge over road* -- *ft^3/s*
Area of flow in bridge opening 407 *ft^2*
Average velocity in bridge opening 13.4 *ft/s*
Maximum WSPRO tube velocity at bridge 15.9 */s*

Water-surface elevation at Approach section with bridge 480.1
Water-surface elevation at Approach section without bridge 477.3
Amount of backwater caused by bridge 2.8

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. There is no armoring potential.

Abutment scour at the left abutment for each modeled discharge 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 right abutment for each modeled discharge 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.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, scour depths were applied for the entire spill-through embankment below the elevation at the toe of each embankment, as shown in
figure 8. At the toe of the left abutment spill-through embankment, the maximum scour depth between pier 1 and the left abutment was shown in figure 8. However, the computed scour depth at pier 1 did not result in an elevation below the bottom of the footing.

Pier scour was computed by use of an equation developed at Colorado State University (Richardson and others, 1995, p. 36, equation 21) for all discharges modeled. Variables for the pier scour equation include pier length, pier width, average depth and maximum velocity (for the froude number) immediately upstream of the bridge, and four correction factors for pier shape, flow attack angle, streambed-form, and streambed armoring.

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	1.8	2.3	--
Depth to armoring	N/A	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour	14.2	14.9	--
Left abutment	10.4	12.6	--
Right abutment			
Pier scour	7.5	7.9	--
Pier 1	12.7	13.4	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	2.3	2.6	--
Left abutment	2.3	2.6	--
Right abutment	2.4	2.6	--
Piers:	2.4	2.6	--
Pier 1	--	--	--
Pier 2			

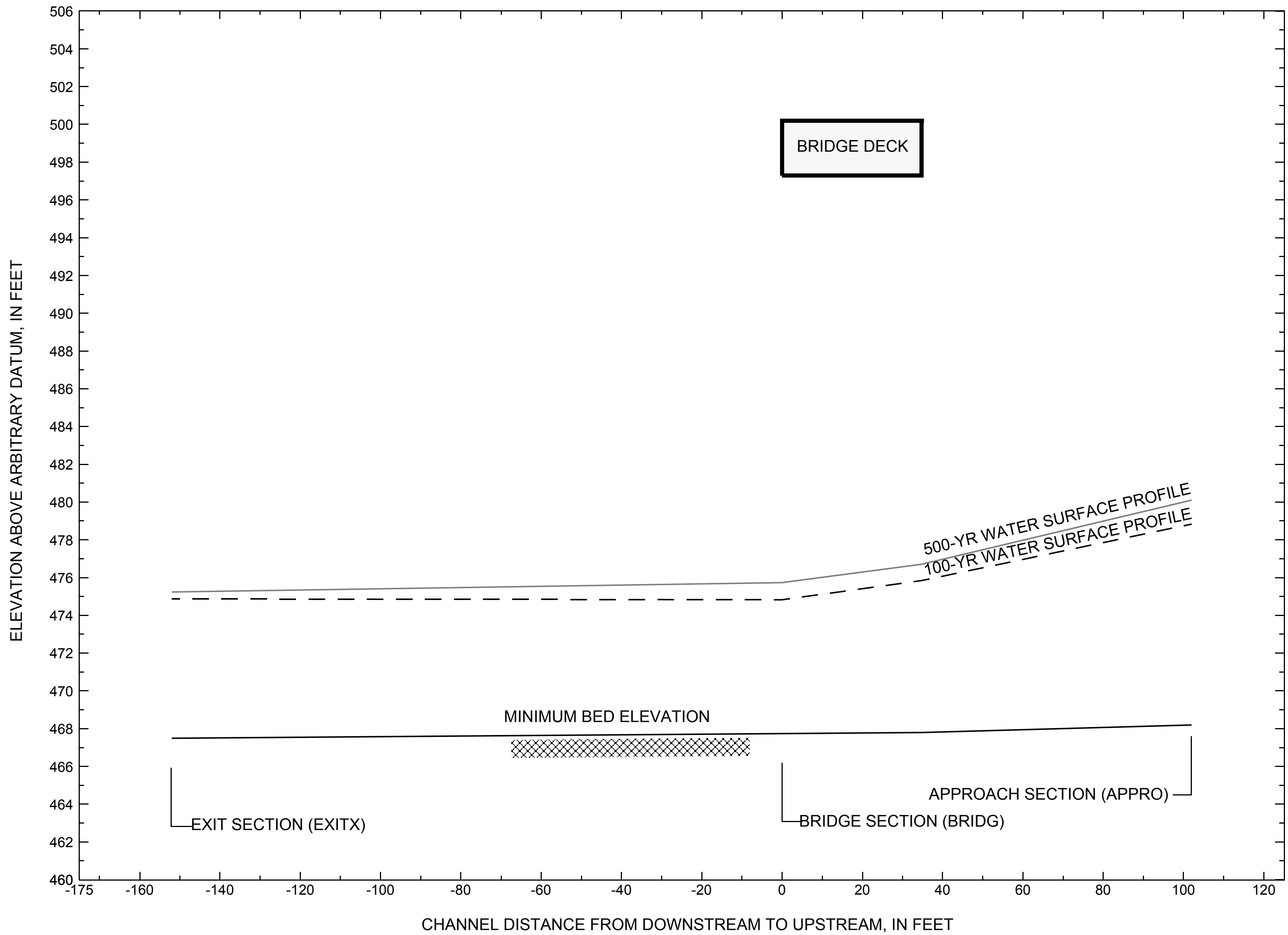

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure FERRUS00070137 on U.S. Route 7, crossing Little Otter Creek, Ferrisburg, Vermont.

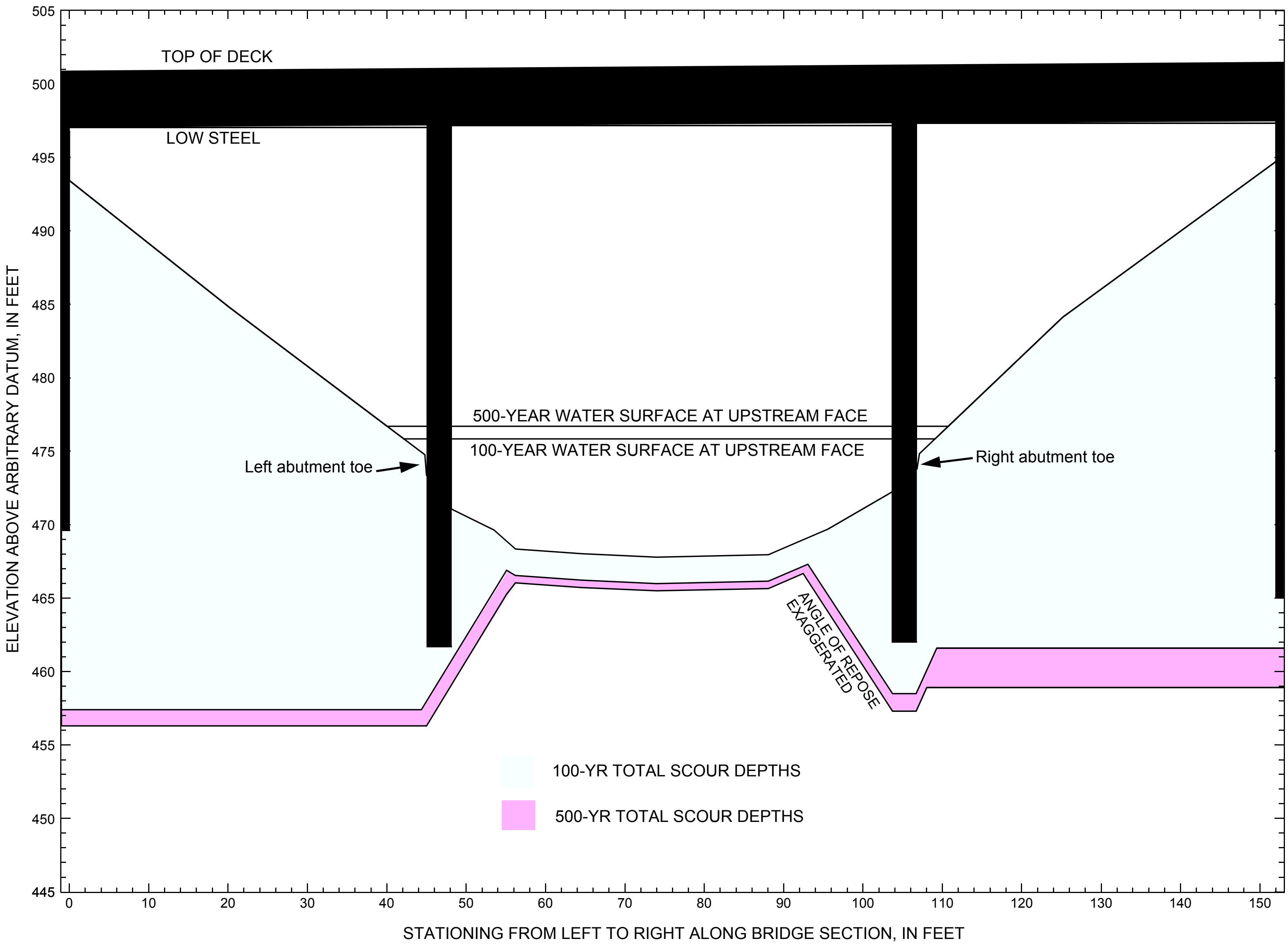

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure FERRUS00070137 on U.S. Route 7, crossing Little Otter Creek, Ferrisburg, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure FERRUS00070137 on U.S. Route 7, crossing Little Otter Creek, Ferrisburg, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT Bridge seat elevation (feet)	Surveyed Bridge seat 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 4,420 cubic-feet per second											
Left abutment	0.0	175.4	496.7	469.6	493.4	--	--	--	--	--	-12.2
Left abutment toe	45.1	--	--	--	473.4	1.8	14.2	--	16.0	457.4	--
Pier 1	46.6	175.5	--	461.7	472.2	1.8	--	7.5	9.3	462.9	1.2
Pier 2	105.2	175.7	--	461.9	473.0	1.8	--	12.7	14.5	458.5	-3.5
Right abutment toe	106.7	--	--	--	473.8	1.8	10.4	--	12.2	461.6	--
Right abutment	152.0	175.9	497.2	465.1	494.7	--	--	--	--	--	-3.5

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 FERRUS00070137 on U.S. Route 7, crossing Little Otter Creek, Ferrisburg, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT Bridge seat elevation (feet)	Surveyed Bridge seat 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 5,450 cubic-feet per second											
Left abutment	0.0	175.4	496.7	469.6	493.4	--	--	--	--	--	-13.4
Left abutment toe	45.1	--	--	--	473.4	2.3	14.9	--	17.2	456.2	--
Pier 1	46.6	175.5	--	461.7	472.2	2.3	--	7.9	10.2	462.0	0.3
Pier 2	105.2	175.7	--	461.9	473.0	2.3	--	13.4	15.7	457.3	-4.7
Right abutment toe	106.7	--	--	--	473.8	2.3	12.6	--	14.9	458.9	--
Right abutment	152.0	175.9	497.2	465.1	494.7	--	--	--	--	--	-6.2

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, 1980, Westport, New York-Vermont 7.5 x 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1974, Contour interval, 5 meters, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ferr137.wsp
T2        Hydraulic analysis for structure FERRUS00070137   Date: 20-NOV-96
T3        U.S. Route 7 Crossing Little Otter Creek, Ferrisburg, VT           EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4420.0   5450.0
WS          474.86   475.23
*           SK         0.0067   0.0067
*
XS   EXITX   -152
GR          -85.2, 486.79    -55.4, 484.44      0.0, 478.31     20.7, 474.23
GR           45.1, 471.52     57.2, 469.45     68.1, 468.67     77.2, 468.11
GR           84.0, 467.49     93.8, 467.85    104.7, 469.59    126.5, 471.28
GR          208.6, 478.34    381.4, 491.02
*
N           0.040        0.040        0.040
SA                 45.1        104.7
*
XS   FULLV      0  * * *   0.0020
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.25       0.0
GR            0.0, 497.05      0.0, 493.44     20.2, 484.78     44.8, 474.76
GR           45.1, 473.36     48.1, 471.04     53.5, 469.63     56.2, 468.34
GR           64.6, 468.02     74.0, 467.79     88.1, 467.95     95.6, 469.70
GR          103.6, 472.21    106.7, 473.80    107.1, 474.82    125.2, 484.14
GR          152.0, 494.71    152.0, 497.45      0.0, 497.05
*
*          Note: EMBSS was not surveyed; used design slope from plans...
*
PW 0      471.04, 3.0  472.21, 3.0  472.21, 6.0  497.17, 6.0  497.17, 3.0
PW 0      497.78, 3.0
*         Two piers are located at stations 46.6 and 105.2
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD           3      35.2     2.0     501.2
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     18      34.8     1
GR         -575.2, 503.86   -398.5, 501.61     -9.1, 500.86     -9.1, 501.64
GR            0.0, 501.62    152.7, 502.12    161.6, 502.05    161.7, 501.46
GR          387.8, 502.35    638.4, 503.17
*
*
XT   APTEM    189
GR          -52.2, 500.44      0.0, 476.85     17.4, 469.33     54.4, 468.54
GR           68.1, 468.75     79.1, 468.81     86.5, 469.77    111.2, 471.08
GR          161.0, 473.63    326.1, 475.52    390.5, 493.53
*
AS   APPRO    102 *  *  *  0.00397
GT
BP          0.0
N           0.044        0.040
SA                111.2
*
HP 1 BRIDG 474.82 1 474.82
HP 2 BRIDG 474.82 * * 4420
HP 2 BRIDG 475.84 * * 4420
HP 1 APPRO 478.83 1 478.83
HP 2 APPRO 478.83 * * 4420
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ferr137.wsp
        Hydraulic analysis for structure FERRUS00070137   Date: 20-NOV-96
        U.S. Route 7 Crossing Little Otter Creek, Ferrisburg, VT           EMB
           *** RUN DATE & TIME: 01-17-97  07:25

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      349     39164     62     67                         4673
   474.82           349     39164     62     67  1.00     45    107     4673

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       474.82    44.7   107.1   348.6   39164.    4420.  12.68

X STA.        44.7        52.6        56.1        58.7        61.1        63.5
  A(I)            27.6        19.7        16.9        16.4        16.1
  V(I)            8.00       11.23       13.10       13.52       13.74

X STA.        63.5        65.8        68.0        70.2        72.3        74.5
  A(I)            15.1        15.4        15.0        15.0        15.1
  V(I)           14.63       14.34       14.71       14.77       14.67

X STA.        74.5        76.6        78.7        80.9        83.1        85.4
  A(I)            15.0        14.9        15.0        15.5        15.6
  V(I)           14.77       14.82       14.70       14.26       14.14

X STA.        85.4        87.7        90.2        93.3        97.2       107.1
  A(I)            16.0        16.4        18.6        20.2        29.1
  V(I)           13.78       13.51       11.90       10.93        7.58

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       475.84    42.1   109.1   414.5   49850.    4420.  10.66

X STA.        42.1        52.2        55.8        58.6        61.1        63.6
  A(I)            34.8        23.5        20.6        19.3        19.0
  V(I)            6.34        9.40       10.73       11.43       11.63

X STA.        63.6        65.9        68.2        70.4        72.6        74.8
  A(I)            18.2        18.1        17.6        17.5        17.6
  V(I)           12.17       12.23       12.56       12.62       12.55

X STA.        74.8        76.9        79.1        81.3        83.6        85.9
  A(I)            17.5        17.5        17.6        17.8        18.7
  V(I)           12.60       12.64       12.53       12.41       11.82

X STA.        85.9        88.3        90.9        94.1        98.1       109.1
  A(I)            18.3        20.0        21.8        23.9        35.2
  V(I)           12.06       11.06       10.16        9.24        6.28

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     102.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     1039    149517    116    119                        17610
             2     1123    120916    228    229                        14145
   478.83          2162    270433    344    347  1.06     -4    339    29808

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     102.

         WSEL     LEW     REW    AREA        K        Q    VEL
       478.83    -5.1   339.2  2161.7  270433.    4420.   2.04

X STA.        -5.1        20.1        29.7        38.6        47.1        55.2
  A(I)           138.5        95.7        91.3        88.4        85.8
  V(I)            1.60        2.31        2.42        2.50        2.58

X STA.        55.2        63.5        71.5        79.7        88.8        99.1
  A(I)            86.8        84.3        84.9        88.3        92.8
  V(I)            2.55        2.62        2.60        2.50        2.38

X STA.        99.1       110.4       122.9       137.7       155.3       177.2
  A(I)            95.8        97.5       105.2       110.4       121.2
  V(I)            2.31        2.27        2.10        2.00        1.82

X STA.       177.2       201.2       227.2       256.7       289.5       339.2
  A(I)           124.9       128.4       136.5       139.5       165.5
  V(I)            1.77        1.72        1.62        1.58        1.34
```

WSPRO OUTPUT FILE (continued)

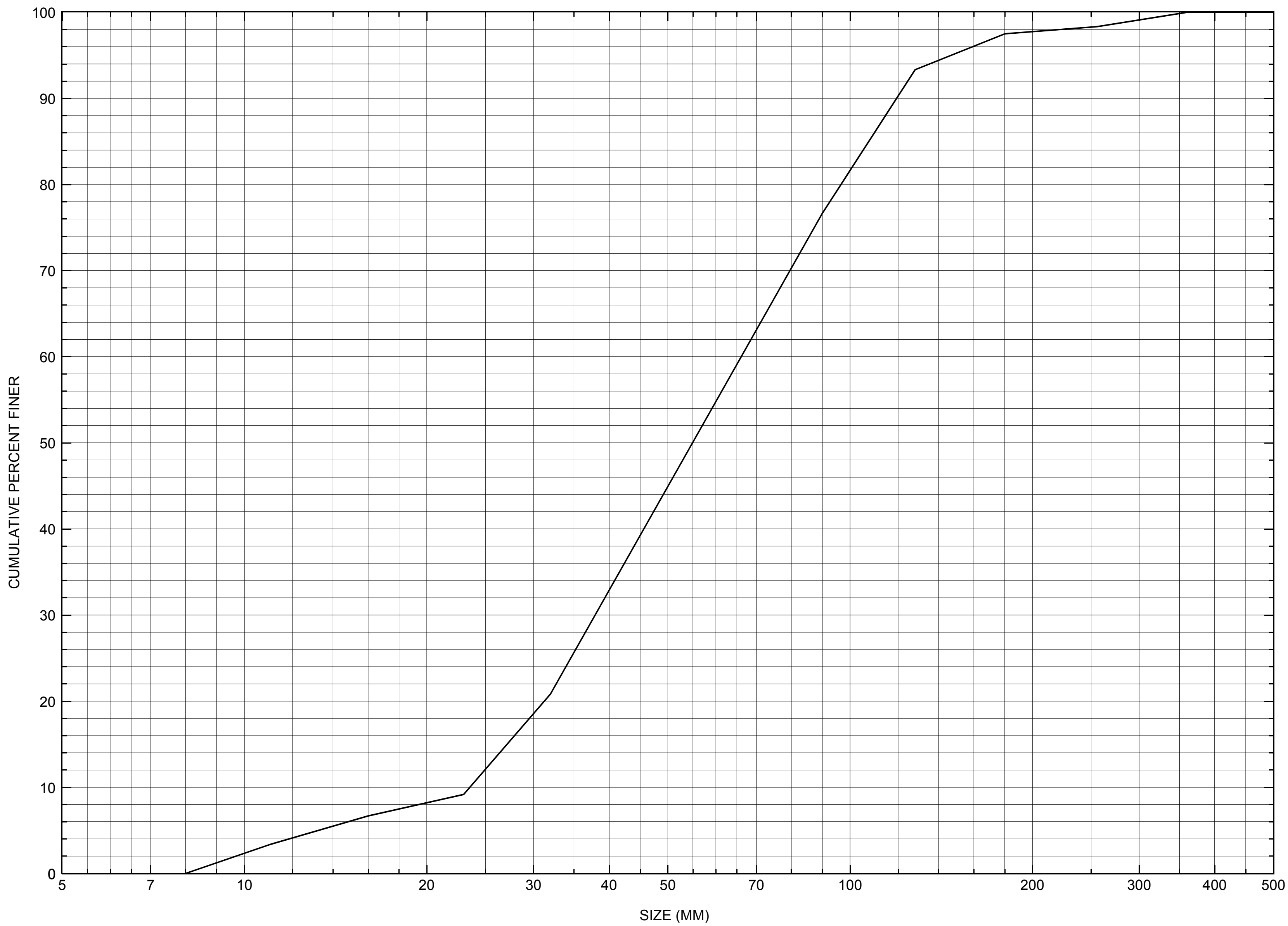
```
         U.S. Geological Survey WSPRO Input File ferr137.wsp
         Hydraulic analysis for structure FERRUS00070137   Date: 20-NOV-96
         U.S. Route 7 Crossing Little Otter Creek, Ferrisburg, VT           EMB
            *** RUN DATE & TIME: 01-17-97  07:25

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      407     48630     66     71                          5720
    475.73           407     48630     66     71  1.00     42    109      5720

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        475.73    42.4   108.9   407.2   48630.    5450.  13.38

 X STA.        42.4       52.3       55.9       58.6       61.1       63.6
   A(I)            34.0       23.1       20.2       19.0       18.7
   V(I)            8.00      11.80      13.46      14.35      14.60

 X STA.        63.6       65.8       68.1       70.3       72.5       74.7
   A(I)            17.5       17.8       17.4       17.3       17.4
   V(I)           15.57      15.28      15.69      15.77      15.67

 X STA.        74.7       76.9       79.1       81.3       83.6       85.9
   A(I)            17.2       17.2       17.3       17.8       18.0
   V(I)           15.82      15.87      15.74      15.27      15.13

 X STA.        85.9       88.2       90.8       94.0       98.1      108.9
   A(I)            18.5       19.2       21.4       24.1       34.1
   V(I)           14.74      14.21      12.74      11.31       7.99

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        476.70    40.0   110.8   473.7   59965.    5450.  11.50

 X STA.        40.0       51.8       55.6       58.3       60.9       63.4
   A(I)            41.3       27.5       23.4       22.0       21.6
   V(I)            6.59       9.92      11.66      12.40      12.64

 X STA.        63.4       65.8       68.2       70.4       72.7       74.9
   A(I)            20.6       20.5       19.9       19.8       19.9
   V(I)           13.23      13.31      13.67      13.75      13.67

 X STA.        74.9       77.1       79.4       81.6       84.0       86.3
   A(I)            19.9       19.8       20.0       20.6       20.3
   V(I)           13.73      13.77      13.64      13.23      13.43

 X STA.        86.3       88.8       91.5       94.7       99.0      110.8
   A(I)            21.8       22.5       24.0       28.6       39.9
   V(I)           12.52      12.10      11.35       9.53       6.83

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     102.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1     1188    183915    119    122                         21292
              2     1415    175415    233    233                         19818
    480.10          2604    359330    352    355  1.04     -7    344     39470

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     102.

          WSEL     LEW     REW    AREA        K        Q    VEL
        480.10    -8.0   343.7  2603.7  359330.    5450.   2.09

 X STA.        -8.0       19.9       30.6       40.3       49.6       58.5
   A(I)           170.5      120.5      111.4      108.5      105.8
   V(I)            1.60       2.26       2.45       2.51       2.58

 X STA.        58.5       67.4       76.3       85.8       96.4      108.1
   A(I)           105.0      104.0      107.0      111.2      115.2
   V(I)            2.60       2.62       2.55       2.45       2.37

 X STA.       108.1      120.9      134.9      151.4      171.1      193.0
   A(I)           117.2      119.1      128.2      136.0      143.9
   V(I)            2.32       2.29       2.13       2.00       1.89

 X STA.       193.0      215.7      240.6      267.3      296.8      343.7
   A(I)           143.4      150.2      153.8      160.1      192.7
   V(I)            1.90       1.81       1.77       1.70       1.41
```

```
        U.S. Geological Survey WSPRO Input File ferr137.wsp
        Hydraulic analysis for structure FERRUS00070137   Date: 20-NOV-96
        U.S. Route 7 Crossing Little Otter Creek, Ferrisburg, VT           EMB
           *** RUN DATE & TIME: 01-17-97  07:25

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

EXITX:XS   ******     18      581  1.08 *****  475.94  473.96    4420  474.86
      -151 ******    168    59381  1.20 ***** *******    0.75    7.61

FULLV:FV      152     14      683  0.78  0.68  476.60 *******    4420  475.82
         0    152    176    73711  1.20  0.00   -0.02    0.61    6.47
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.95

APPRO:AS      102      0     1412  0.18  0.19  476.79 *******    4420  476.61
       102    102    331   143650  1.17  0.00    0.00    0.29    3.13
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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      152     45      349  2.92  1.28  477.74  474.74    4420  474.82
         0    152    107    39161  1.17  0.52    0.00    1.02   12.68

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.925  0.055  497.25 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      18.        <<<<<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       67     -4     2162  0.07  0.14  478.90  473.04    4420  478.83
       102     78    339   270567  1.06  1.02    0.01    0.15    2.04

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.798  0.656   92777.    50.   113.   478.81

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -152.    18.   168.   4420.   59381.     581.    7.61  474.86
   FULLV:FV       0.    14.   176.   4420.   73711.     683.    6.47  475.82
   BRIDG:BR       0.    45.   107.   4420.   39161.     349.   12.68  474.82
   RDWAY:RG      18.**************      0.*****************    1.00********
   APPRO:AS     102.    -5.   339.   4420.  270567.    2162.    2.04  478.83

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      50.   113.   92777.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    473.96    0.75  467.49  491.02************  1.08  475.94  474.86
   FULLV:FV  ********    0.61  467.79  491.32  0.68  0.00  0.78  476.60  475.82
   BRIDG:BR    474.74    1.02  467.79  497.45  1.28  0.52  2.92  477.74  474.82
   RDWAY:RG  ****************  500.86  503.86********************************
   APPRO:AS    473.04    0.15  468.19  500.09  0.14  1.02  0.07  478.90  478.83
```

```
       U.S. Geological Survey WSPRO Input File ferr137.wsp
       Hydraulic analysis for structure FERRUS00070137   Date: 20-NOV-96
       U.S. Route 7 Crossing Little Otter Creek, Ferrisburg, VT          EMB
          *** RUN DATE & TIME: 01-17-97  07:25

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

EXITX:XS   ******     16      638  1.37 *****  476.60  474.60    5450  475.23
      -151 ******    172    67254  1.20 ***** *******    0.82    8.55

FULLV:FV      152     11      785  0.90  0.76  477.34 *******    5450  476.43
         0    152    183    88795  1.21  0.00   -0.01    0.63    6.94
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           “APPRO”     KRATIO =  2.04

APPRO:AS      102     -1     1653  0.19  0.19  477.52 *******    5450  477.33
       102    102    334   180743  1.12  0.00    0.00    0.28    3.30
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID “BRIDG”     Q,CRWS =    5450.     475.73

            <<<<<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      152     42      407  3.34 *****  479.07  475.73    5450  475.73
         0    152    109    48613  1.20 ***** *******    1.04   13.39

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.914  0.060  497.25 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG      18.        <<<<<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       67     -7     2605  0.07  0.13  480.17  473.30    5450  480.10
       102     79    344   359564  1.04  0.97    0.00    0.14    2.09

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.793  0.673  117700.    54.   121.   480.09

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -152.    16.   172.   5450.   67254.     638.    8.55  475.23
   FULLV:FV      0.    11.   183.   5450.   88795.     785.    6.94  476.43
   BRIDG:BR      0.    42.   109.   5450.   48613.     407.   13.39  475.73
   RDWAY:RG     18.**************      0.*****************    1.00********
   APPRO:AS    102.    -8.   344.   5450.  359564.    2605.    2.09  480.10

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      54.   121.  117700.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    474.60    0.82  467.49  491.02************  1.37  476.60  475.23
   FULLV:FV  ********    0.63  467.79  491.32  0.76  0.00  0.90  477.34  476.43
   BRIDG:BR    475.73    1.04  467.79  497.45************  3.34  479.07  475.73
   RDWAY:RG ****************  500.86  503.86**********************************
   APPRO:AS    473.30    0.14  468.19  500.09  0.13  0.97  0.07  480.17  480.10
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure FERRUS00070137, in Ferrisburg, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number FERRUS00070137

General Location Descriptive

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

Date *(MM/DD/YY)* 12 / 12 / 95

Highway District Number *(I - 2; nn)* 05

County *(FIPS county code; I - 3; nnn)* 001

Town *(FIPS place code; I - 4; nnnnn)* 26275

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

Waterway *(I - 6)* LITTLE OTTER CREEK

Road Name *(I - 7)*: -

Route Number -

Vicinity *(I - 9)* 1.1 MI TO JCT W VT 22A

Topographic Map MONKTON

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 44115

Longitude *(i - 17; nnnnn.n)* 73146

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001901370105

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

Maximum span length *(I - 48; nnnn)* 0057

Year built *(I - 27; YYYY)* 1959

Structure length *(I - 49; nnnnnn)* 000157

Average daily traffic, ADT *(I - 29; nnnnnn)* 010900

Deck Width *(I - 52; nn.n)* 350

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

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

Opening skew to Roadway *(I - 34; nn)* 00

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

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

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

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 0

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

Clear span (*nnn.n ft*) -

Number of spans *(I - 45; nnn)* 003

Vertical clearance from streambed (*nnn.n ft*) 0310

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

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

Comments:

According to the structural inspection report dated 9/28/93, the structure is a 3-span, rolled beam bridge. The stem of the right abutment has some minor cracking. Neither pier is located in the channel. The slopes in the pier area are protected with stone fill. The curtain wall at the left abutment is in good condition, except for some minor scaling. The channel takes a moderate turn into and out of the structure.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **54.844**

Terrain character: **Rolling to mountainous**

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*): **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:

Ordinary high water elev. = 152.0 feet; extreme high water elev. = 160.0 feet (according to Dickens Formula); low water elev. = 148.0. Velocity of stream at high water stage is 8.3 fps at the estimated discharge of 6800 cfs. The full-opening area = 3000 sq. ft. and the area below ordinary high water = 282 sq. ft. Character of scour, drift, ice, all normal.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **56.73** mi^2

Lake and pond area **1.59** mi^2

Watershed storage *(ST)* **2.8** %

Bridge site elevation **150** ft

Headwater elevation **900** ft

Main channel length **18.66** mi

10% channel length elevation **155** ft

85% channel length elevation **395** ft

Main channel slope *(S)* **17.15** 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)*: 4 / 1958

Project Number DF019-4(4) Minimum channel bed elevation: 146

Low superstructure elevation: USLAB 174.26 DSLAB 175.36 USRAB 174.77 DSRAB 175.86

Benchmark location description:

No benchmarks noted on plans.

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

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

If 1: Footing Thickness ______ Footing bottom elevation: ______

If 2: Pile Type: 2 (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: 20*

If 3: Footing bottom elevation: ______

Is boring information available? Y *If no, type ctrl-n bi* Number of borings taken: 6

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

Briefly describe material at foundation bottom elevation or around piles:

There were 8 drill borings documented on the plans. The bottom of the concrete left abutment footing is set in clay with piles driven through the clay into fine sand and gravel. Both pier footings are set in clay. The bottom of the concrete right abutment footing was set above the existing ground surface with piles driven into topsoil, clay and gravel, and clay hardpan.

Comments:

Plan sheet 30 indicates that there are spreadfootings at the piers and steel piles at the abutments. The footing thickness at the piers is 3 feet. The bottom elevation at the left pier is 140.35 feet while that at the right pier is 140.55 feet. The bottom of the left abutment concrete wall is shown at elevation 168.26 below which steel piles were driven to 20 feet on average. The bottom of the right abutment concrete wall is shown at elevation 168.77 below which steel piles were driven to 25 feet on average. Pier 1 upstream and downstream beam seat elevations were 174.36 feet and 175.46 feet, respectively. Pier 2 upstream and downstream beam seat elevations were 174.55 feet and 175.65 feet, respectively.

The low superstructure elevations shown above are the bridge seat elevations from the bridge plans.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTIONAL INFORMATION**

Station		-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low 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: **10/9/96**
Computerized by: **EW** Date: **10/11/96**
Reviewd by: **EMB** Date: **12/19/96**

Structure Number **FERRUS00070137**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. BURNS** Date *(MM/DD/YY)* **07** / **01** / 19**96**

2. Highway District Number **05** Mile marker **000000**

County **Addison (001)** Town **Ferrisburg (26275)**

Waterway *(I - 6)* **Little Otter Creek** Road Name **-**

Route Number **US 7** Hydrologic Unit Code: **02010002**

3. Descriptive comments:

Located about 1.1 miles from the junction of VT 22A with U.S. Route 7.
The structure is a three span, rolled steel beam bridge with spill-through embankment slopes in front of each abutment wall.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **4** LBDS **5** RBDS **6** 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 **1** UB **1** DS **1** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **157** *(feet)* Span length **57** *(feet)* Bridge width **35.0** *(feet)*

Road approach to bridge:

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

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

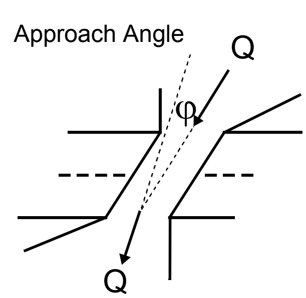
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

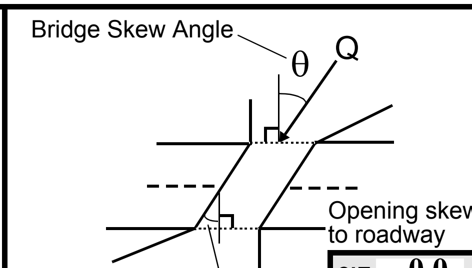
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	1	2	1
RBUS	1	1	0	-
RBDS	1	1	0	-
LBDS	1	1	0	-

*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: **15** 16. Bridge skew: **15**





α= **0.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **80** feet **US** *(US, UB, DS)* to **70** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **160** feet **US** *(US, UB, DS)* to **150** feet **US**

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

18. Bridge Type: **1b**

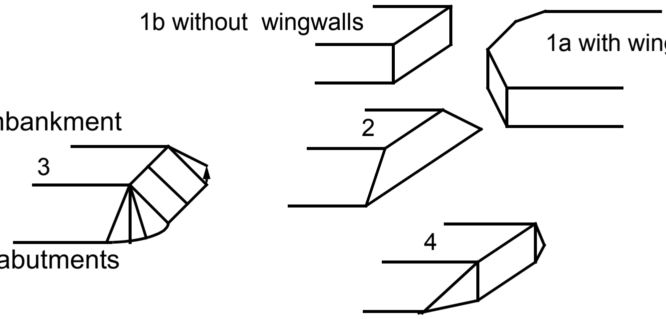
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

On the upstream left bank, there is forest at about 300 feet upstream. The immediate bank is grass covered with a strip of trees and more pasture within two bridge lengths. The downstream right bank is forest except for a grass covered section between 100 feet and 150 feet downstream. The downstream left bank has a variety of trees, shrubs and grass coverage.

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
154.0	7.5			1.5	1	1	104	104	1	2

23. Bank width **25.0** 24. Channel width **5.0** 25. Thalweg depth **111.5** 29. Bed Material **431**

30 .Bank protection type: LB **3** RB **3** 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.):

Right bank protection extends from the upstream bridge face to 35 feet upstream.
Left bank protection extends from 0 feet upstream to 70 feet upstream.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 80 35. Mid-bar width: 15

36. Point bar extent: 150 feet US (US, UB) to 50 feet US (US, UB, DS) positioned 70 %LB to 100 %RB

37. Material: 10

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

Point bar is vegetated with tall grass and is mostly under 2 inches of water.

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

41. Mid-bank distance: 230 42. Cut bank extent: 300 feet US (US, UB) to 215 feet US (US, UB, DS)

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

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

A 10 ft. wide section of the bank has slid down.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 0

47. Scour dimensions: Length 25 Width 10 Depth : 1.25 Position 10 %LB to 50 %RB

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

The water depth is 3.25; average thalweg is 2 feet.
The scour hole extends from 20 feet upstream to 5 feet under bridge, measured from upstream bridge face.

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
69.0		1.0		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.):

451
The channel is currently flowing between the two piers. On both sides of the pier is type 3 stone fill. At about 20 feet up the slope towards the abutment, it changes to type 1 stone fill for another 20 feet, where it reaches the concrete abutment. About 6 feet of the type 3 stone fill is on the streamward side of both piers.

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

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

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

70. Debris and Ice Comments:

2

Capture efficiency and ice blockage potential are moderate because of piers.

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		-	45	1	2	0	0.5	90.0
RABUT	1	10	45			1	0	152.0

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.):

-

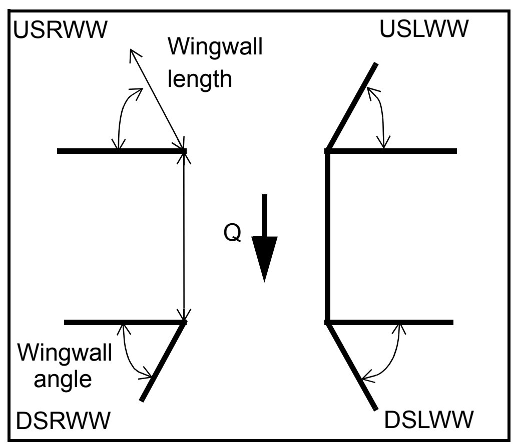
-

1

#74: The left abutment footing is not completely covered with stone fill like the right side.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						42.0	
USRWW:	N		-		-	-	
DSLWW:	-		-		N	35.0	
DSRWW:	-		-		-	35.5	



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	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	1	1	-

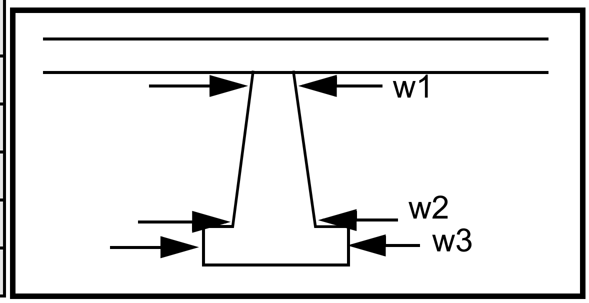
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	3.0	3.0	-	497.17	471.04
Pier 3	-	3.0	3.0	-	497.78	472.21
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	: The	ment	slope	the	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	pro-	is	, the	right	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	tec-	type	pro-	and	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	tion	1.	tec-	left	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	imm	Then	tion	bank	*Y- yes; N- no*
91. Attack ∠ (BF)	edi-	20	is	s.	
92. Pushed	ately	feet	type		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	in	dow	3 to		
95. Cross-members	front	n a	the		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	of	45	piers		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	the	degr	on		
98. Exposure depth	abut	ee	both		

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

Y
MCL
1
2
3
N
0

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
-	-			-	-	-	0	0	-	-

Bank width (BF) **-** Channel width (Amb) **21.5** Thalweg depth (Amb) **22.0** Bed Material **MC**

Bank protection type (Qmax): LB **R** RB **1** Bank protection condition: LB **2** RB **3**

*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.):
N
10
RB
-
0
0
-
-
-
-
-
-
-
-
-

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 __-__ feet __-__ *(US, UB, DS)* positioned __-__ %LB to __-__ %RB

Material: __Pie__

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

rs are protected on all sides by type 3 protection.

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

Cut bank extent: _____ feet ____ *(US, UB, DS)* to _____ feet __1__ *(US, UB, DS)*

Bank damage: __3__ *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

10
10
1
1

Is channel scour present? __451__ *(Y or if N type ctrl-n cs)* Mid-scour distance: __3__

Scour dimensions: Length __3__ Width __1__ Depth: __1__ Positioned __Rig__ %LB to __ht__ %RB

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

bank and left bank protection extends from downstream bridge face to 68 feet downstream.

Bank erosion is occurring downstream of the protection in the form of scallops along the bank.

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 _____

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 DROP STRUCTURE

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: FERRUS00070137 Town: Ferrisburg
Road Number: U.S. 7 County: Addison
Stream: Little Otter Creek

Initials EMB Date: 12/19/96 Checked SAO

I. 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	4420	5450	0
Main Channel Area, ft2	1039	1188	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	1123	1415	0
Top width main channel, ft	116	119	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	228	233	0
D50 of channel, ft	0.1802	0.1802	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.0	10.0	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	4.9	6.1	ERR
Total conveyance, approach	270433	359330	0
Conveyance, main channel	149517	183915	0
Conveyance, LOB	0	0	0
Conveyance, ROB	120916	175415	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	2443.7	2789.5	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	1976.3	2660.5	ERR
Vm, mean velocity MC, ft/s	2.4	2.3	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	1.8	1.9	ERR
Vc-m, crit. velocity, MC, ft/s	9.1	9.3	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Main Channel	0	0	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	1039	1188	0
Main channel width, ft	116	119	0
y1, main channel depth, ft	8.96	9.98	ERR
Bridge Section			
(Q) total discharge, cfs	4420	5450	0
(Q) discharge thru bridge, cfs	4420	5450	0
Main channel conveyance	39164	48630	0
Total conveyance	39164	48630	0
Q2, bridge MC discharge,cfs	4420	5450	ERR
Main channel area, ft2	349	407	0
Main channel width (skewed), ft	62.2	63.2	0.0
Cum. width of piers in MC, ft	6.0	6.0	0.0
W, adjusted width, ft	56.2	57.2	0
y_bridge (avg. depth at br.), ft	6.20	7.12	ERR
Dm, median (1.25*D50), ft	0.22525	0.22525	0
y2, depth in contraction,ft	7.99	9.42	ERR
ys, scour depth (y2-ybridge), ft	1.78	2.30	N/A
ARMORING			
D90	0.3914	0.3914	0
D95	0.4813	0.4813	0
Critical grain size,Dc, ft	0.6082	0.6426	ERR
Decimal-percent coarser than Dc	0.0243	0.023	0
Depth to armoring,ft	73.26	81.88	ERR

Abutment Scour

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

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	4420	5450	0	4420	5450	0
a', abut.length blocking flow, ft	49.9	50.3	0	231.1	234.8	0
Ae, area of blocked flow ft2	390	425.7	0	1148.6	1437.3	0
Qe, discharge blocked abut.,cfs	824.2	876.1	0	2034	2708	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.11	2.06	ERR	1.77	1.88	ERR
ya, depth of f/p flow, ft	7.82	8.46	ERR	4.97	6.12	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.133	0.125	ERR	0.140	0.134	ERR
ys, scour depth, ft	14.15	14.85	N/A	14.72	16.89	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	49.9	50.3	0	231.1	234.8	0
y1 (depth f/p flow, ft)	7.82	8.46	ERR	4.97	6.12	ERR
a'/y1	6.38	5.94	ERR	46.50	38.36	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.13	0.12	N/A	0.14	0.13	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	18.89	22.95	ERR
vertical w/ ww's	ERR	ERR	ERR	15.49	18.82	ERR
spill-through	ERR	ERR	ERR	10.39	12.62	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	1	1	0	1	1	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	6.20	7.12	0.00	6.20	7.12	0.00

Median Stone Diameter for riprap at: left abutment | right abutment, ft

Fr<=0.8 (spillthrough abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (spillthrough abut.)	2.29	2.63	ERR	2.29	2.63	ERR

Pier Scour(both live-bed and clear water scour)

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)
V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	46.6	46.6	0
Area of WSPRO flow tube, ft2	17.5	19.8	0
Skewed width of flow tube, ft	2.2	2.3	0
y1, pier approach depth, ft	7.95	8.61	ERR
y1 in meters	2.424	2.624	N/A
V1, pier approach velocity, ft/s	12.6	13.8	0
a, pier width, ft	3	3	0
L, pier length, ft	21.3	21.3	0
Fr1, Froude number at pier	0.787	0.829	ERR
Pier attack angle, degrees	0	0	0

K1, shape factor	0.9	0.9	0
K2, attack factor	1.00	1.00	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.1802	0.1802	0
D50, m	0.054922	0.054922	0
D90, ft	0.3914	0.3914	0
D90, m	0.119293	0.119293	0
Vc50,critical velocity(D50),m/s	2.727	2.763	N/A
Vc90,critical velocity(D90),m/s	3.532	3.579	N/A
Vi,incipient velocity,m/s	1.515	1.536	ERR
Vr, velocity ratio	1.153	1.307	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth (K4 not applied)ft	7.54	7.92	ERR

Pier 2	Q100	Q500	Qother
Pier stationing, ft	105.2	105.2	0
Area of WSPRO flow tube, ft2	17.5	19.8	0
Skewed width of flow tube, ft	2.2	2.3	0
y1, pier approach depth, ft	7.95	8.61	ERR
y1 in meters	2.424	2.624	N/A
V1, pier approach velocity, ft/s	12.6	13.8	0
a, pier width, ft	3	3	0
L, pier length, ft	21.6	21.6	0
Fr1, Froude number at pier	0.787	0.829	ERR
Pier attack angle, degrees	10	10	0
K1, shape factor	0.9	0.9	0
K2, attack factor	1.69	1.69	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.1802	0.1802	0
D50, m	0.054922	0.054922	0
D90, ft	0.3914	0.3914	0
D90, m	0.119293	0.119293	0
Vc50,critical velocity(D50),m/s	2.727	2.763	N/A
Vc90,critical velocity(D90),m/s	3.532	3.579	N/A
Vi,incipient velocity,m/s	1.515	1.536	ERR
Vr, velocity ratio	1.153	1.307	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth, (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth, (K4 not applied)ft	12.72	13.37	ERR

D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	0
V, char. aver. velocity, ft/s	12.7	13.4	0
D50, median stone diameter, ft	2.36	2.63	0.00

Pier 2			
K, pier shape coeff.	1.5	1.5	0
V, char. aver. velocity, ft/s	12.7	13.4	0
D50, median stone diameter, ft	2.36	2.63	0.00