LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (CRAFTH00040004) on TOWN HIGHWAY 4, crossing WHITNEY BROOK, CRAFTSBURY, VERMONT

U.S. Geological Survey
Open-File Report 96-402

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (CRAFTH00040004) on TOWN HIGHWAY 4, crossing WHITNEY BROOK, CRAFTSBURY, VERMONT

By Erick M. Boehmler and Robert E. Hammond

U.S. Geological Survey
Open-File Report 96-402

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

Pembroke, New Hampshire

1996

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

Copies of this report may be purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Federal Center
Denver, CO 80225

CONTENTS

Introduction and Summary of Results 1
Level II summary 7
Description of Bridge 7
Description of the Geomorphic Setting 8
Description of the Channel 8
Hydrology 9
Calculated Discharges 9
Description of the Water-Surface Profile Model (WSPRO) Analysis 10
Cross-Sections Used in WSPRO Analysis 10
Data and Assumptions Used in WSPRO Model 11
Bridge Hydraulics Summary 12
Scour Analysis Summary 13
Special Conditions or Assumptions Made in Scour Analysis 13
Scour Results 14
Riprap Sizing 14
References 18

Appendixes:
A. WSPRO input file 19
B. WSPRO output file 21
C. Bed-material particle-size distribution 26
D. Historical data form 28
E. Level I data form 34
F. Scour computations 44

FIGURES

1. Map showing location of study area on USGS 1:24,000 scale map 3
2. Map showing location of study area on Vermont Agency of Transportation town highway map 4
3. Structure CRAFTH00040004 viewed from upstream (June 7, 1995) 5
4. Downstream channel viewed from structure CRAFTH00040004 (June 7, 1995). 5
5. Upstream channel viewed from structure CRAFTH00040004 (June 7, 1995). 6
6. Structure CRAFTH00040004 viewed from downstream (June 7, 1995). 6
7. Water-surface profiles for the 100- and 500-year discharges at structure CRAFTH00040004 on Town Highway 4, crossing Whitney Brook, Craftsbury, Vermont. 15
8. Scour elevations for the 100- and 500-year discharges at structure CRAFTH00040004 on Town Highway 4, crossing Whitney Brook, Craftsbury, Vermont. 16

TABLES

1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CRAFTH00040004 on Town Highway 4, crossing Whitney Brook, Craftsbury, Vermont 17
2. Remaining footing/pile depth at abutments for the 500-year discharge at structure CRAFTH00040004 on Town Highway 4, crossing Whitney Brook, Craftsbury, Vermont 17

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 4 (CRAFTH00040004) ON TOWN HIGHWAY 4, CROSSING WHITNEY BROOK, CRAFTSBURY, VERMONT

By Erick M. Boehmler and Robert E. Hammond

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CRAFTH00040004 on town highway 4 crossing Whitney Brook, Craftsbury, 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 New England Upland secton of the New England physiographic province of north-central Vermont in the town of Craftsbury. The 13.3-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the banks have dense woody vegetation coverage.

In the study area, Whitney Brook has an incised, sinuous channel with a slope of approximately 0.014 ft/ft, an average channel top width of 40 ft and an average channel depth of 3 ft. The observed predominant channel bed material is cobble and boulder while results from the pebble count provided a D_{50} of 78.5 mm or 0.258 ft. The geomorphic assessment at the time of the Level I and Level II site visit on June 7, 1995 indicated that the reach was stable.

The town highway 4 crossing of Whitney Brook is a 41-ft-long, one-lane bridge consisting of one 39-foot span steel-beam and concrete superstructure (Vermont Agency of Transportation, written commun., August 3, 1994). The bridge is supported by slightly sloping, mortared stone block abutments with wingwalls. The channel is skewed approximately 20 degrees to the opening while the opening-skew-to-roadway is 20 degrees.

A scour hole 2 ft deeper than the mean thalweg depth was observed along the upstream right wingwall and right abutment during the Level I assessment. There were no scour protection measures evident at the site. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock riprap 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 degradation; 2) contraction scour (due to accelerated flow caused by 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 computed scour results follow.

Contraction scour for all modelled flows ranged from 0.7 to 1.7 feet. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 10.7 to 15.3 feet. The worst-case abutment scour also occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number CRAFTH00040004 ***Stream*** Whitney Brook

County Windsor ***Road*** TH 4 ***District*** 09

Description of Bridge

Bridge length 41 ***ft*** ***Bridge width*** 20.2 ***ft*** ***Max span length*** 39 ***ft***

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

Abutment type Steeply sloping ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 6/7/94

Description of stone fill None.

Abutments and wingwalls are mortared stone blocks.

There is a two feet deep scour hole in front of the upstream right wingwall and right abutment.

Y

Is bridge skewed to flood flow according to Gener ***survey?*** ***Angle*** 20 N

ally, the channel is straight upstream but approaches the bridge opening at approximately 20 degrees.

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***
	6/7/95	0	0
Level I	6/7/95	--	--
Level II			

Potential for debris Low. The channel is incised and straight with stable banks. The cut-banks noted were minor.

Describe any features near or at the bridge that may affect flow (include observation date) The right abutment is in the channel flow path upstream resulting in a significant scour hole as of 6/7/95.

Description of the Geomorphic Setting

General topography The channel is located within a 100 foot-wide, narrow, irregular flood plain with steep valley walls on both sides.

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

Date of inspection 6/7/95

DS left: Narrow flood plain to steep valley wall

DS right: Narrow flood plain to steep valley wall

US left: Narrow, irregular flood plain to steep valley wall

US right: Steep valley wall

Description of the Channel

Average top width 40 ft ***Average depth*** 3 ft

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

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

Vegetative co 6/7/95

DS left: Forest

DS right: Forest

US left: Forest

US right: Forest

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

Describe any obstructions in channel and date of observation. The assessment of 6/7/95 noted flow is influenced by the right abutment, which partially blocks the channel upstream.

Hydrology

Drainage area 13.3 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description

USGS gage number

Gage drainage area ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 2,150 ***ft³/s*** ***Q500*** 2,950 ***ft³/s***

The 100-year discharge is based on estimates derived from several empirical equations (Potter, 1957b; Johnson and Tasker, 1974; Benson, 1962; Talbot, 1887; and FHWA, 1983). Flood frequency curves based on the empirical equations were extrapolated to obtain the 500-year discharge.

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the concrete curb at the left US end of the guard rail (elev. 510.00 ft, arbitrary datum). RM2 is a chiseled X on top of the concrete curb at the right DS end of the guard rail (elev. 511.89 ft., arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-42	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
APPRO	55	2	Modelled Approach section (Templated from APTEM)
APTEM	61	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 analysis 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 0.075, and overbank "n" values ranged from 0.075 to 0.085.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the User's manual for WSPRO (Shearman, 1990). The slope used was 0.014 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0155 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 the 500-year discharge. Analyzing both the supercritical and subcritical profile, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satifactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 510.7 *ft*
Average low steel elevation 507.4 *ft*

100-year discharge 2,150 *ft³/s*
Water-surface elevation in bridge opening 502.2 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 180 *ft²*
Average velocity in bridge opening 12.0 *ft/s*
Maximum WSPRO tube velocity at bridge 14.0 *ft/s*

Water-surface elevation at Approach section with bridge 504.7
Water-surface elevation at Approach section without bridge 504.0
Amount of backwater caused by bridge 0.7 *ft*

500-year discharge 2,950 *ft³/s*
Water-surface elevation in bridge opening 503.0 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 208 *ft²*
Average velocity in bridge opening 14.2 *ft/s*
Maximum WSPRO tube velocity at bridge 16.6 *ft/s*

Water-surface elevation at Approach section with bridge 506.6
Water-surface elevation at Approach section without bridge 504.8
Amount of backwater caused by bridge 1.8

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

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

Abutment scour at the 100- and 500-year discharges was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.7	1.7	--
Depth to armoring	16.5	49.2	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
Abutment scour			
Left abutment	11.5	15.3	--
Right abutment	10.7	12.5	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.2	2.6	--
Right abutment	2.2	2.6	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

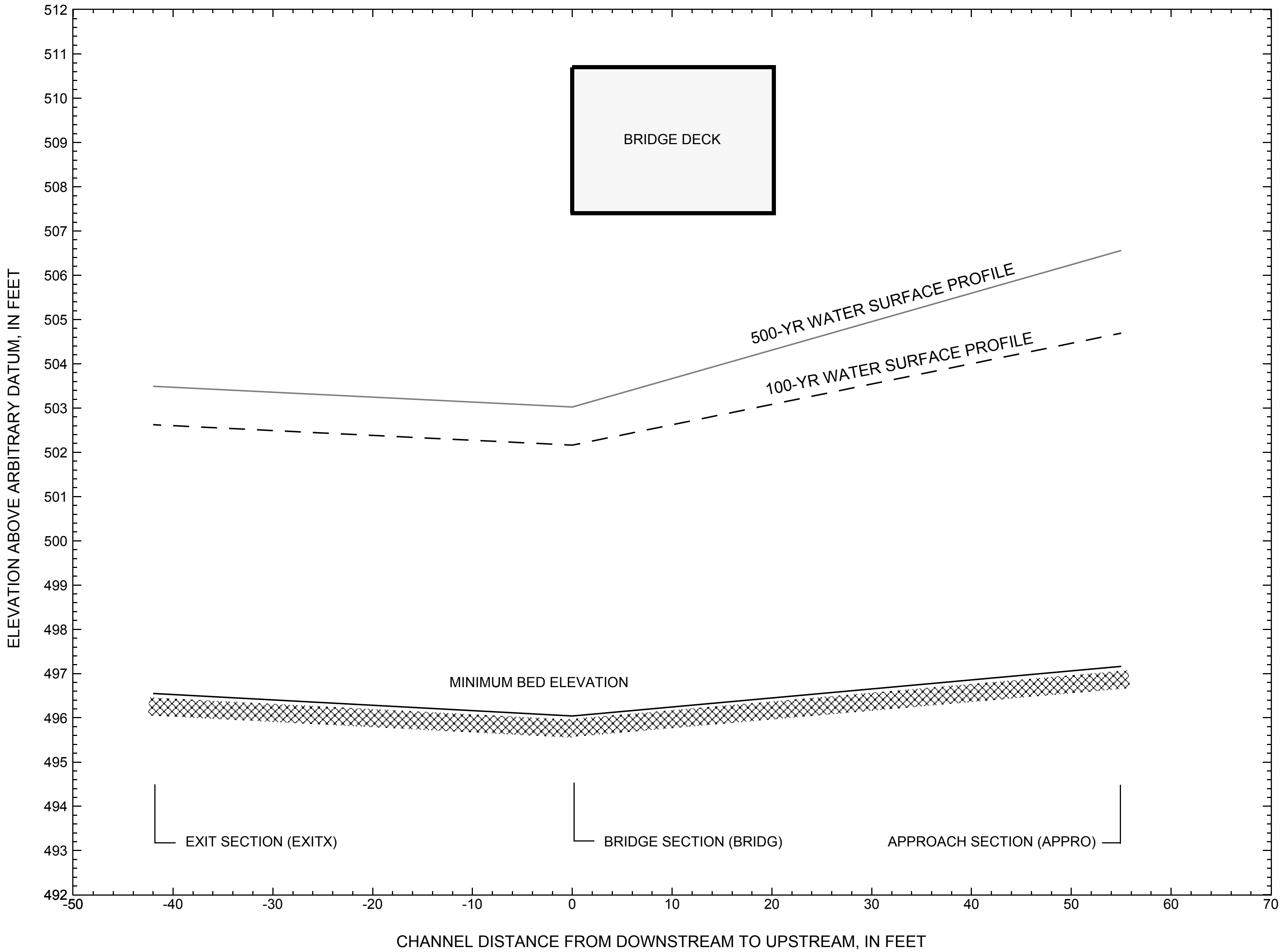


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CRAFTH00040004 on town highway 4, crossing Whitney Brook, Craftsbury, Vermont.

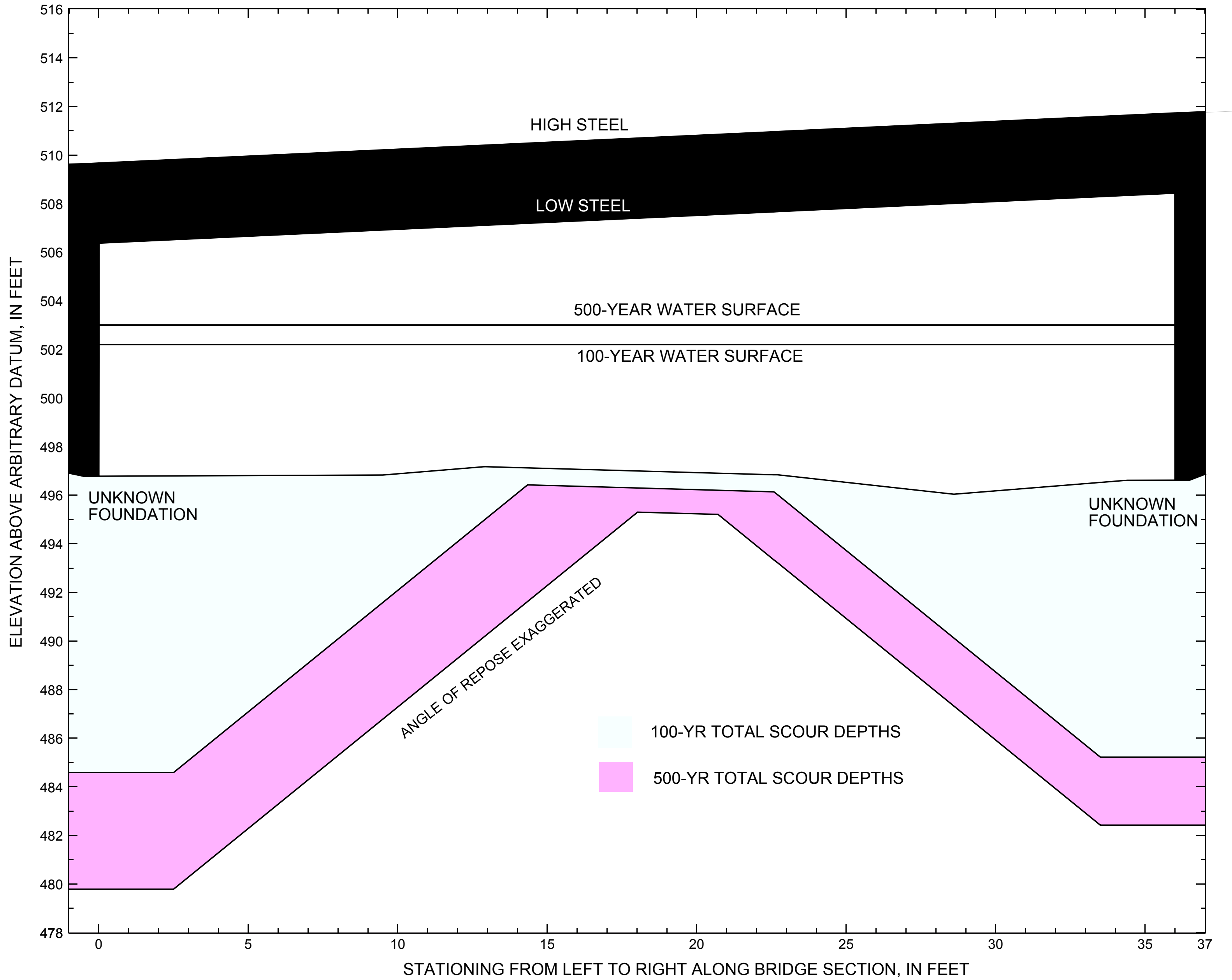


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CRAFTH00040004 on town highway 4, crossing Whitney Brook, Craftsbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CRAFTH00040004 on Town Highway 4, crossing Whitney Brook, Craftsbury, 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 2,150 cubic-feet per second											
Left abutment	0.0	--	506.4	--	496.8	0.7	11.5	--	12.2	484.6	--
Right abutment	36.0	--	508.4	--	496.6	0.7	10.7	--	11.4	485.2	--

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 CRAFTH00040004 on Town Highway 4, crossing Whitney Brook, Craftsbury, 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 2,950 cubic-feet per second											
Left abutment	0.0	--	506.4	--	496.8	1.7	15.3	--	17.0	479.8	--
Right abutment	36.0	--	508.4	--	496.6	1.7	12.5	--	14.2	482.4	--

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M.A., 1962, Factors Influencing the Occurrence of floods in a Humid Region of Diverse Terrain, U.S. Geological Survey Water-supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1986, Craftsbury, Vermont 7.5 Minute Series quadrangle map, provisional edition: U.S. Geological Survey Topographic Maps, Aerial photographs, 1980; Contour interval, 6 meters; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File craf004.wsp
T2        Hydraulic analysis for structure CRAFTH00040004   Date: 01-MAR-96
T3        Town Highway 4 Bridge Crossing Whitney Brook, Craftsbury, VT       EMB
Q           2150.0   2950.0
SK          0.0140   0.0140
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -42
GR          -30.6, 506.00    -28.6, 499.94    -18.4, 499.54    -15.3, 498.49
GR           -2.1, 498.20      0.0, 496.81      4.6, 496.99     16.3, 496.55
GR           19.2, 496.67     21.3, 497.10     26.5, 499.01     46.7, 499.94
GR           57.5, 500.48     70.2, 505.36
*
N           0.070         0.075
SA                 26.5
*
XS   FULLV      0  * * *   0.0140
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    507.38      20.0
GR            0.0, 506.38      0.5, 496.78      9.5, 496.83     12.9, 497.17
GR           22.7, 496.84     28.6, 496.04     34.4, 496.61     35.4, 496.62
GR           36.0, 508.37      0.0, 506.38
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      27.7 * *     45.5      9.5
N           0.040
*
*           Removed roadway points due to roadway not overtopped by modeled
*           discharges above.
*
XT   APTEM     61
GR          -55.0, 508.59    -50.1, 505.88    -43.6, 502.28    -22.8, 502.67
GR           -4.7, 501.86      0.0, 498.08      3.0, 497.36     11.3, 497.25
GR           20.8, 497.55     26.1, 497.70     29.9, 498.02     41.4, 499.07
GR           46.8, 503.97     52.8, 509.19
*
*            Added: -55.0, 508.59 based on field experience and topo. map.
AS   APPRO     55  *  *  *  0.0155
GT
N            0.085       0.075
SA                -4.7
*
HP 1 BRIDG   502.16 1 502.16
HP 2 BRIDG   502.16 * * 2150
HP 1 APPRO   504.69 1 504.69
HP 2 APPRO   504.69 * * 2150
*
HP 1 BRIDG   503.02 1 503.02
HP 2 BRIDG   503.02 * * 2950
HP 1 APPRO   506.56 1 506.56
HP 2 APPRO   506.56 * * 2950
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V042094           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

           *** RUN DATE & TIME: 03-20-96  15:40

   T1        U.S. Geological Survey WSPRO Input File craf004.wsp
   T2        Hydraulic analysis for structure CRAFTH00040004   Date: 01-MAR-96
   T3        Town Highway 4 Bridge Crossing Whitney Brook, Craftsbury, VT       EMB
   Q           2150.0   2950.0
 *** Q-DATA FOR SEC-ID, ISEQ =           1
   SK          0.0140   0.0140
   *

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      179     17100     33     44                         2362
    502.16           179     17100     33     44  1.00      0     36     2362
1
     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

          WSEL     LEW     REW    AREA         K        Q    VEL
        502.16     0.2    35.7   179.4   17100.    2150.  11.98

 X STA.         0.2        3.4        5.4        7.1        8.8       10.4
   A(I)            15.5        9.7        9.0        8.3        8.2
   V(I)            6.95      11.07      11.93      13.02      13.07

 X STA.        10.4       12.1       13.9       15.5       17.2       18.9
   A(I)             8.3        8.1        7.9        7.9        8.0
   V(I)           13.00      13.20      13.55      13.56      13.42

 X STA.        18.9       20.4       22.0       23.6       25.1       26.5
   A(I)             7.8        7.9        7.8        7.7        7.7
   V(I)           13.82      13.68      13.81      13.98      13.94

 X STA.        26.5       27.9       29.3       30.8       32.6       35.7
   A(I)             7.9        8.2        8.4        9.7       15.5
   V(I)           13.66      13.14      12.80      11.11       6.93
1
     CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = APPRO;  SRD =      55.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1       99      2988     43     44                          851
              2      330     21359     52     56                         4698
    504.69           429     24347     96    100  1.18    -47     48     4751
1
     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = APPRO;  SRD =      55.

          WSEL     LEW     REW    AREA         K        Q    VEL
        504.69   -48.1    47.7   429.2   24347.    2150.   5.01

 X STA.       -48.1      -27.3      -10.7       -1.2        1.8        4.2
   A(I)            43.9       38.6       32.1       20.1       17.3
   V(I)            2.45       2.78       3.35       5.36       6.20

 X STA.         4.2        6.4        8.6       10.9       13.0       15.3
   A(I)            16.7       16.5       16.7       16.2       16.6
   V(I)            6.43       6.53       6.45       6.63       6.49

 X STA.        15.3       17.5       19.8       22.2       24.6       27.1
   A(I)            16.7       16.6       17.2       17.2       17.6
   V(I)            6.43       6.49       6.26       6.25       6.10

 X STA.        27.1       29.6       32.5       35.6       39.1       47.7
   A(I)            17.8       18.8       19.8       21.5       31.3
   V(I)            6.03       5.72       5.44       4.99       3.43
1
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      208     21341     33     46                         2947
    503.02           208     21341     33     46  1.00      0     36     2947
1
```

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        503.02     0.2    35.7   208.1   21341.    2950.  14.18

 X STA.         0.2        3.5        5.5        7.2        8.9       10.5
   A(I)            18.5       11.4       10.2        9.9        9.3
   V(I)            7.96      12.90      14.40      14.88      15.91

 X STA.        10.5       12.2       13.9       15.5       17.1       18.7
   A(I)             9.4        9.3        9.0        9.1        8.9
   V(I)           15.76      15.93      16.38      16.17      16.53

 X STA.        18.7       20.2       21.8       23.3       24.8       26.3
   A(I)             8.9        9.0        8.9        8.9        9.0
   V(I)           16.48      16.34      16.55      16.51      16.38

 X STA.        26.3       27.7       29.1       30.7       32.5       35.7
   A(I)             9.0        9.3       10.0       11.6       18.4
   V(I)           16.44      15.83      14.80      12.77       8.01
1
     CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = APPRO;  SRD =      55.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      184      7876     47     48                         2063
              2      430     32132     55     59                         6850
    506.56           614     40009    101    107  1.14    -50     50     8024
1
     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = APPRO;  SRD =      55.

          WSEL     LEW     REW    AREA        K        Q    VEL
        506.56   -51.5    49.9   613.6   40009.    2950.   4.81

 X STA.       -51.5      -34.8      -23.9      -13.2       -4.1        0.5
   A(I)            54.9       44.7       44.8       42.0       32.6
   V(I)            2.68       3.30       3.29       3.51       4.52

 X STA.         0.5        3.2        5.7        8.3       10.7       13.2
   A(I)            24.6       23.6       23.4       23.2       23.2
   V(I)            5.99       6.24       6.30       6.35       6.35

 X STA.        13.2       15.7       18.3       20.9       23.6       26.4
   A(I)            23.5       23.3       24.2       24.3       25.0
   V(I)            6.26       6.32       6.09       6.07       5.91

 X STA.        26.4       29.3       32.3       35.8       39.6       49.9
   A(I)            25.4       26.2       28.4       30.2       45.9
   V(I)            5.80       5.63       5.20       4.88       3.21
1
   EX
 +++ BEGINNING PROFILE CALCULATIONS --   2

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

 EXITX:XS   ******    -28      352  0.62 *****  503.25  501.42    2150  502.62
        -41 ******     63    18166  1.08 ***** *******    0.57    6.10

 FULLV:FV       42    -28      353  0.62  0.59  503.84 *******    2150  503.22
          0     42     63    18249  1.08  0.00    0.01    0.57    6.08
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS       55    -46      359  0.66  0.73  504.61 *******    2150  503.95
         55     55     47    19190  1.18  0.02    0.02    0.59    5.99
         <<<<<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       42      0      180  2.23  0.62  504.39  501.83    2150  502.16
          0     42     36    17112  1.00  0.52    0.00    0.91   11.98

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  1.000 ******  507.38 ****** ****** ******
```

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

 APPRO:AS       27    -47      429  0.46  0.32  505.15  502.00    2150  504.69
         55     29     48    24347  1.18  0.44    0.01    0.45    5.01

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.620  0.248   18274.    -2.    33.   504.48

                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -42.   -29.    63.   2150.   18166.     352.    6.10  502.62
    FULLV:FV       0.   -29.    63.   2150.   18249.     353.    6.08  503.22
    BRIDG:BR       0.     0.    36.   2150.   17112.     180.   11.98  502.16
    APPRO:AS      55.   -48.    48.   2150.   24347.     429.    5.01  504.69

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS      -2.    33.   18274.
1
  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    501.42    0.57  496.55  506.00************  0.62  503.25  502.62
    FULLV:FV  ********    0.57  497.14  506.59  0.59  0.00  0.62  503.84  503.22
    BRIDG:BR    501.83    0.91  496.04  508.37  0.62  0.52  2.23  504.39  502.16
    APPRO:AS    502.00    0.45  497.16  509.10  0.32  0.44  0.46  505.15  504.69
1
  XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
        SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

 EXITX:XS   ******    -29      434  0.77 *****  504.26  502.07    2950  503.49
        -41 ******     65    24928  1.07 ***** *******    0.58    6.79

 FULLV:FV       42    -29      435  0.76  0.59  504.86 *******    2950  504.09
          0     42     65    25025  1.07  0.00    0.01    0.58    6.77
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS       55    -47      442  0.81  0.76  505.64 *******    2950  504.82
         55     55     48    25332  1.17  0.03    0.00    0.60    6.67
          <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

  ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID “BRIDG”     Q,CRWS =    2950.     503.02

             <<<<<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       42      0      208  3.13 *****  506.14  503.02    2950  503.02
          0     42     36    21327  1.00 ***** *******    1.00   14.18

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  1.000 ******  507.38 ****** ****** ******

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

 APPRO:AS       27    -51      614  0.41  0.30  506.97  503.31    2950  506.56
         55     29     50    40054  1.14  0.53    0.00    0.37    4.80

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.629  0.335   26638.    -3.    32.   506.42

                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -42.   -30.    65.   2950.   24928.     434.    6.79  503.49
    FULLV:FV       0.   -30.    65.   2950.   25025.     435.    6.77  504.09
    BRIDG:BR       0.     0.    36.   2950.   21327.     208.   14.18  503.02
    APPRO:AS      55.   -52.    50.   2950.   40054.     614.    4.80  506.56
```

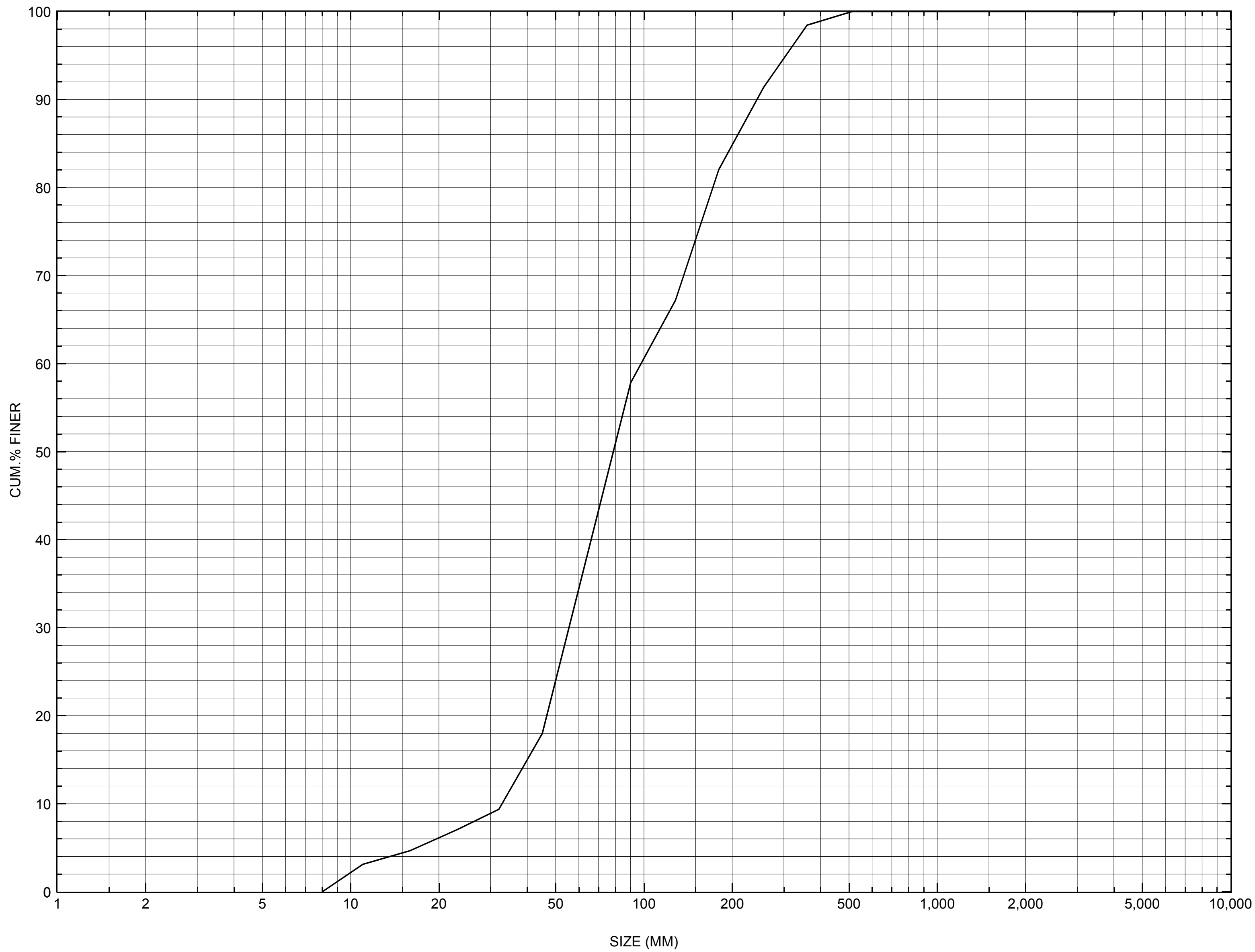
```
     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS      -3.    32.   26638.
1
  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    502.07    0.58  496.55  506.00************  0.77  504.26  503.49
    FULLV:FV  ********    0.58  497.14  506.59  0.59  0.00  0.76  504.86  504.09
    BRIDG:BR    503.02    1.00  496.04  508.37************  3.13  506.14  503.02
    APPRO:AS    503.31    0.37  497.16  509.10  0.30  0.53  0.41  506.97  506.56
   ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one pebble count transect at the approach cross-section for structure CRAFTH00040004, in Craftsbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CRAFTH00040004

General Location Descriptive

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

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

Highway District Number *(I - 2; nn)* 09

County *(FIPS county code; I - 3; nnn)* 019

Town *(FIPS place code; I - 4; nnnnn)* 16300

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

Waterway *(I - 6)* WHITNEY BROOK

Road Name *(I - 7):* -

Route Number TH004

Vicinity *(I - 9)* 0.9 MI TO JCT W CL3 TH32

Topographic Map Craftsbury

Hydrologic Unit Code: 01110000

Latitude *(I - 16; nnnn.n)* 44396

Longitude *(i - 17; nnnnn.n)* 72212

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10100600041006

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

Maximum span length *(I - 48; nnnn)* 0039

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

Structure length *(I - 49; nnnnnn)* 000041

Average daily traffic, ADT *(I - 29; nnnnnn)* 000140

Deck Width *(I - 52; nn.n)* 202

Year of ADT *(I - 30; YY)* 91

Channel & Protection *(I - 61; n)* 4

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 012.0

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

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

Comments:

Structural inspection report of 7/20/93 indicates distinct vertical cracking in the left abutment with some settlement. A scour hole 3 feet deep is noted as located at the upstream end of the right abutment. Embankment erosion is noted as minor. Channel makes a moderate bend into the bridge. Stone fill is noted as needed on the right abutment. No point bars were noted. Debris was indicated as minor.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: **Coarse gravel and stone with some boulders.**

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)* : **LIGHT** Debris *(Heavy, Moderate, Light)*: **LIGHT**

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

Are there other structures nearby? (*Yes, No, Unknown*): 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 (*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:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 13.26 mi^2 Lake and pond area 0.22 mi^2

Watershed storage *(ST)* 1.7 %

Bridge site elevation 1014 ft Headwater elevation 1988 ft

Main channel length 6.87 mi

10% channel length elevation 1011 ft 85% channel length elevation 1604 ft

Main channel slope *(S)* 115 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? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: - / -

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

-

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **MI** Date: **10/27/95**
Computerized by: **MI** Date: **10/27/95**
Reviewed by: **EMB** Date: **3/20/96**

Structure Number **CRAFTH00040004**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. Hammond** Date *(MM/DD/YY)* **06** / **07** / 19**95**

2. Highway District Number **09** Mile marker **0**

County **Orleans (019)** Town **Craftsbury (16300)**

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

Route Number **TH 4** Hydrologic Unit Code: **01110000**

3. Descriptive comments:

The bridge is located 0.9 miles to junction with town highway 32.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **6** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

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

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

7. Bridge length **41.0** *(feet)* Span length **39.0** *(feet)* Bridge width **20.2** *(feet)*

Road approach to bridge:

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

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

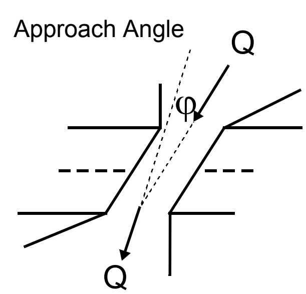
10. Embankment slope (*run / rise in feet / foot*):
US left **0.0:1** US right **0.0:1**

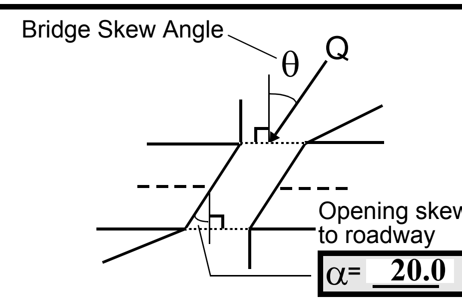
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	0	-	0	-
RBUS	0	-	2	1
RBDS	2	1	0	-
LBDS	2	1	0	-

*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: **20**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **29** feet **US** *(US, UB, DS)* to **0** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **3**
Range? **0** feet **DS** *(US, UB, DS)* to **40** feet **DS**

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

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

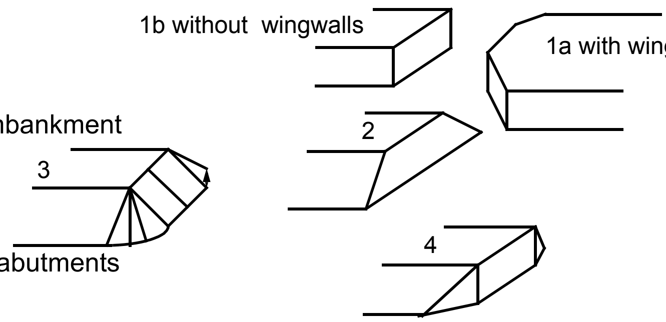
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. Measurements agreed with the historical values.

17. The upstream right wingwall to abutment protrudes into the channel directing flow to the DS left wingwall face.

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
41.5	4.0			5.0	4	4	45	45	1	1

23. Bank width **40.0**   24. Channel width **40.0**   25. Thalweg depth **51.5**   29. Bed Material **45**

30 .Bank protection type: LB **0** RB **0**   31. 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*

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

29. Cobble and boulder riffle.

A slight bend in the US channel concentrates high flow to the right bank side in approach to the bridge. Medium flows remain at center of the channel. No apparent bars or scour conditions.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **35** 35. Mid-bar width: **8**

36. Point bar extent: **60** feet **US** (US, UB) to **0** feet **US** (US, UB, DS) positioned **70** %LB to **100** %RB

37. Material: **4**

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

Side bar below a pile of rocks on the right bank extending to the US right wingwall.

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

41. Mid-bank distance: **50** 42. Cut bank extent: **80** feet **US** (US, UB) to **0** feet **US** (US, UB, DS)

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

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

Tree roots exposed. Erosion is slight with exposed roots protecting the bank.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **-10**

47. Scour dimensions: Length **30** Width **10** Depth : **2** Position **60** %LB to **100** %RB

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

Most of the scour is along the US right wingwall to the DS end of the right abutment.

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
41.5		**1.0**		**2**	**7**	**7**	**0**

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

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

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

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

34

63. Bed material is gravel in the scour and flow path under the bridge with few boulders.

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

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

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

70. Debris and Ice Comments:

1

Debris at head of an island just DS of the 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		10	90	2	0	0	0	90.0
RABUT	2	0	90			2	2	34.0

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.):

2

2

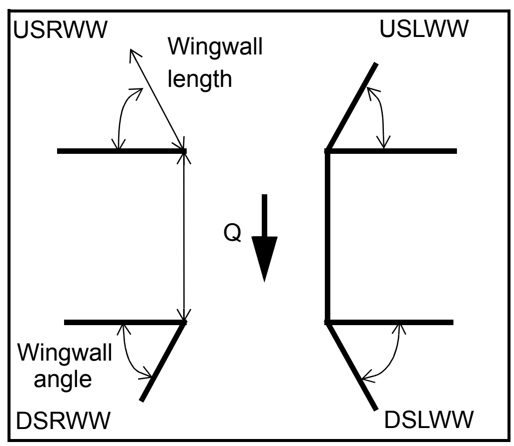
2

77. The abutments consist of cut stone with mortar.
The footing along the right abutment is concrete.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						34.0	
USRWW:	Y		2		0	1.5	
DSLWW:	0		-		Y	21.5	
DSRWW:	2		2		2	21.0	

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

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

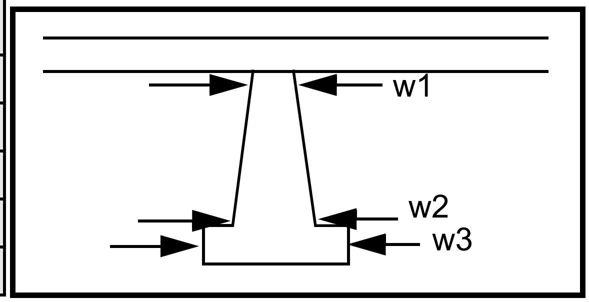
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
0
-
-

Piers:

84. Are there piers? **80.** *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**6.0**		**65.0**	**25.0**	**18.0**
Pier 2				**35.0**	**12.5**	**55.0**
Pier 3		**-**	**-**	**10.5**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**the**		**-**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**US**	**cor-**		**-**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**right**	**ner**		**-**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**wing**	**junc-**		**-**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wall**	**tion**		**-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**is**	**with**		**-**	
92. Pushed	**expo**	**the**		**-**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**sed**	**abut**		**-**	
95. Cross-members	**for**	**ment**	**N**	**-**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**10**	**.**	**-**	**-**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**feet**		**-**	**-**	
98. Exposure depth	**from**		**-**	**-**	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

NO PIERS

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

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

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

2

106. Point/Side bar present? 4 (Y or N. if N type ctrl-n pb) Mid-bar distance: 43 Mid-bar width: 43

Point bar extent: 3 feet 0 (US, UB, DS) to 534 feet 0 (US, UB, DS) positioned 0 %LB to - %RB

Material: -

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

The left bank erosion is severe where flow hits the head of an island with some flow deflected parallel to the DS left wingwall, forming another stream channel.

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 ____ (US, UB, DS)

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

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

N

Is channel scour present? - (Y or if N type ctrl-n cs) Mid-scour distance: NO

Scour dimensions: Length DRO Width P Depth: STR Positioned UC %LB to TU %RB

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

RE

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

Confluence 1: Distance Y Enters on 0 (LB or RB) Type 10 (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance 10 Enters on US (LB or RB) Type 30 (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

DS

0

F. Geomorphic Channel Assessment

107. Stage of reach evolution 30

__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)*:

34

Side bar due to deflected flow path parallel to the bar mostly along the left abutment under the bridge; see sketch.

Y
LB
40
0
DS
65
DS
3

109. G. Plan View Sketch

\- T

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:	CRAFTH00040004	Town:	CRAFTSBURY
Road Number:	TH 4	County:	ORLEANS
Stream:	WHITNEY BROOK		

Initials EMB Date: 3/20/96 Checked: Date:

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	2150	2950	0
Main Channel Area, ft2	330	430	0
Left overbank area, ft2	99	184	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	52.4	54.6	0
Top width L overbank, ft	43.4	46.8	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.258	0.258	0
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	6.3	7.9	ERR
y1, average depth, LOB, ft	2.3	3.9	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	24347	40009	0
Conveyance, main channel	21359	32132	0
Conveyance, LOB	2988	7876	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0	0.002499	ERR
Qm, discharge, MC, cfs	1886.14	2369.202	ERR
Ql, discharge, LOB, cfs	263.86	580.7243	ERR
Qr, discharge, ROB, cfs	0	0	ERR
Vm, mean velocity MC, ft/s	5.7	5.5	ERR
Vl, mean velocity, LOB, ft/s	2.7	3.2	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.7	10.1	N/A
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	N/A	N/A

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	N/A
Left Overbank	1	1	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)
```

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	330	430	0
Main channel width, ft	52.4	54.6	0
y1, main channel depth, ft	6.29771	7.875458	ERR

Bridge Section	Q100	Q500	Qother
(Q) total discharge, cfs	2150	2950	0
(Q) discharge thru bridge, cfs	2150	2950	
Main channel conveyance	17100	21341	
Total conveyance	17100	21341	
Q2, bridge MC discharge,cfs	2150	2950	ERR
Main channel area, ft2	179	208	0
Main channel width (skewed), ft	33.1	33.1	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.1	33.1	0
y_bridge (avg. depth at br.), ft	5.41994	6.287009	ERR
Dm, median (1.25*D50), ft	0.3225	0.3225	0
y2, depth in contraction,ft	6.119053	8.024935	ERR
ys, scour depth (y2-ybridge), ft	0.70	1.74	N/A
ys, scour depth (y2-y1), ft	-0.18	0.15	N/A

ARMORING			
D90	0.797	0.797	
D95	1	1	
Critical grain size,Dc, ft	0.741656	0.971433	ERR
Decimal-percent coarser than Dc	0.119	0.0559	
Depth to armoring,ft	16.47225	49.21987	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	2150	2950	0	2150	2950	0
a’, abut.length blocking flow, ft	48.4	51.8	0	12.2	14.4	0
Ae, area of blocked flow ft2	125	217.9	0	53.1	78.1	0
Qe, discharge blocked abut.,cfs	378	732.7	0	216.7	305.5	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	3.024	3.362552	ERR	4.080979	3.911652	ERR
ya, depth of f/p flow, ft	2.58	4.21	ERR	4.35	5.42	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	110	110	0	70	70	0
K2	1.02643	1.02643	0	0.967857	0.967857	0
Fr, froude number f/p flow	0.33	0.29	ERR	0.34	0.30	ERR
ys, scour depth, ft	11.46	15.30	N/A	10.73	12.50	N/A

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	0.91	1		0.91	1	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.4	6.3		5.4	6.3	
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0
Fr>0.8 (vertical abut.)	2.20	2.63	ERR	2.20	2.63	ERR