LEVEL II SCOUR ANALYSIS FOR BRIDGE 12 (SUNDFLR0030012) on FOREST LAND ROAD 3 (FAS 114), crossing ROARING BRANCH BROOK, SUNDERLAND, VERMONT

U.S. Geological Survey
Open-File Report 97-185

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

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By ROBERT H. FLYNN AND LAURA MEDALIE

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Pembroke, New Hampshire

1997

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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	VT AOT	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 12 (SUNDFLR0030012) ON FOREST LAND ROAD 3 (FAS 114), CROSSING ROARING BRANCH BROOK, SUNDERLAND, VERMONT

By ROBERT H. FLYNN AND LAURA MEDALIE

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SUNDFLR0030012 on Forest Land Road (FLR) 3 (FAS 114) crossing Roaring Branch Brook, Sunderland, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in southwestern Vermont. The 4.93-mi² drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is dense forest along the left bank and primarily shrubs and trees along the right bank, both upstream and downstream of the bridge.

In the study area, Roaring Branch Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 33 ft and an average bank height of 4 ft. The channel bed material ranges from cobble to bedrock with a median grain size (D_{50}) of 139 mm (0.457 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 30, 1996, indicated that the reach was stable.

Forest Land Road 3 (FAS 114) crossing of Roaring Branch Brook is a 37-ft-long, two-lane bridge consisting of one 35-foot steel-beam span (Vermont Agency of Transportation, written communication, December 14, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 30 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

The scour protection measures at the site included type-3 stone fill (less than 48 inches diameter) along the left and right abutments, along the upstream left and downstream right wing walls and along the downstream right bank. Type-4 (less than 60 inches diameter) stone fill was found along the upstream right and downstream left wingwalls and along the downstream left bank. Type-2 (less than 36 inches diameter) stone fill scour protection was found along the upstream left and right banks. 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 was calculated to be 0.0 ft. Abutment scour ranged from 4.3 to 10.4 ft. The worst-case abutment scour occurred at the 500-year discharge along the right abutment. 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.

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

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 SUNDFLR0030012 **Stream** Roaring Branch Brook
County Bennington **Road** FLR 3 **District** 1

Description of Bridge

Bridge length 37 **ft** **Bridge width** 27.3 **ft** **Max span length** 35 **ft**
Alignment of bridge to road (on curve or straight) Straight left and curved right
Abutment type Vertical, concrete **Embankment type** Sloping
Stone fill on abutment? Yes **Date of inspection** 7/30/96
Description of stone fill Type-3, along the entire base length of the upstream left and downstream right wingwalls and the left and right abutments . Type-4, along the upstream right and downstream left wingwalls.

Abutments and wingwalls are concrete.

Is bridge skewed to flood flow according to Y **' survey?** 30 **Angle**
There is a mild channel bend in the upstream reach and a moderate channel bend in the downstream reach at the confluence with Branch Pond Brook (85 ft downstream).

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	<u>7/30/96</u>	<u>0</u>	<u>0</u>
Level II	<u>Moderate. The banks are stable but, vegetation is abundant.</u>		

Potential for debris

A 10 ft wide side bar along the entire base length of the right abutment diverts flow left for flows less than one-third of bridge height. 7/30/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley setting with little to no flood plain and steep valley walls on both sides.

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

Date of inspection 7/30/96

DS left: Moderately sloped channel bank and overbank

DS right: Moderately sloped channel bank and overbank

US left: Moderately sloped channel bank and overbank to steep valley wall

US right: Moderately sloped channel bank and overbank to steep valley wall

Description of the Channel

Average top width	<u>33</u>	Average depth	<u>4</u>
	<u>Cobbles</u>		<u>Cobbles/Boulders</u>

Predominant bed material	Bank material
	<u>Sinuuous but stable</u>

with semi-alluvial to non-alluvial channel boundaries.

7/30/96

Vegetative cover Trees and brush

DS left: Trees and brush

DS right: Trees

US left: Brush with a few trees.

US right: Y

Do banks appear stable? Yes, no serious erosion and type of instability was

date of observation.

The assessment of

7/30/96 noted boulders (less than 48 inches diameter) along the entire base length of the left
Describe any obstructions in channel and date of observation.
and right abutments.

Hydrology

Drainage area 4.93 **mi²**

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	Percent of drainage area
<u>New England/Green Mountain</u>	<u>100</u>

Is drainage area considered rural or urban? Rural **Describe any significant urbanization:** None. July 30, 1996

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

USGS gage description --

USGS gage number --

Gage drainage area -- **mi²** No

Is there a lake/p -----

Calculated Discharges	
<u>960</u>	<u>1,630</u>
Q100	Q500
ft³/s	ft³/s

The 100- and 500-year discharges are based on the FHWA discharge frequency curve, which is the median of the discharge frequency curves developed from empirical relationships (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887) and extended to 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 Add 3.5 ft to the USGS arbitrary survey datum to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 499.10 ft, arbitrary survey datum). RM2 is a VTAOT brass tablet (1966, SAB-6543) on top of the upstream end of the left abutment (elev. 499.26 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

¹ <i>Cross-section</i>	<i>Section Reference Distance (SRD) in feet</i>	² <i>Cross-section development</i>	<i>Comments</i>
EXITX	-34	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	63	1	Modelled Approach section (as surveyed)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.060, and overbank "n" values ranged from 0.060 to 0.070.

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 0.009 ft/ft, which was estimated from surveyed points at and downstream of the bridge.

The approach section (APPRO) was surveyed one bridge length upstream of the upstream bridge face as recommended by Shearman and others (1986). This method also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.5 *ft*
Average low steel elevation 496.5 *ft*

100-year discharge 960 *ft³/s*
Water-surface elevation in bridge opening 495.1 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 141 *ft²*
Average velocity in bridge opening 6.8 *ft/s*
Maximum WSPRO tube velocity at bridge 8.3 *ft/s*

Water-surface elevation at Approach section with bridge 495.7
Water-surface elevation at Approach section without bridge 495.8
Amount of backwater caused by bridge 0.0 *ft*

500-year discharge 1,630 *ft³/s*
Water-surface elevation in bridge opening 496.5 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 185 *ft²*
Average velocity in bridge opening 8.8 *ft/s*
Maximum WSPRO tube velocity at bridge 10.5 *ft/s*

Water-surface elevation at Approach section with bridge 498.8
Water-surface elevation at Approach section without bridge 496.7
Amount of backwater caused by bridge 2.1 *ft*

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-year discharge. The 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996 and Richardson and others, 1995, p. 145-146) and thus, was applied to compute the contraction scour for the 500-year discharge. The result of Laursen's clear-water contraction scour equation for the 500-year event was also computed and can be found in appendix F. In this case, use of either equation for the 100- and 500-year models resulted in a computed contraction scour depth of 0.0 ft.

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

Scour Results

<i>Contraction scour:</i>	<i>100-yr discharge</i>	<i>500-yr discharge</i>	<i>Incipient overtopping discharge</i>
	<i>(Scour depths in feet)</i>		
<i>Main channel</i>			
<i>Live-bed scour</i>	--	--	--
	0.0		0.8
<i>Clear-water scour</i>	2.2	--	--
<i>Depth to armoring</i>	--	--	--
<i>Left overbank</i>	--	--	4.3
<i>Right overbank</i>			
<i>Local scour:</i>			
<i>Abutment scour</i>	7.3	--	5.4
<i>Left abutment</i>	10.4	--	--
<i>Right abutment</i>			
<i>Pier scour</i>	--	--	--
<i>Pier 1</i>	--	--	--
<i>Pier 2</i>	--	--	0.9
<i>Pier 3</i>			

Riprap Sizing

	<i>100-yr discharge</i>	<i>500-yr discharge</i>	<i>Incipient overtopping discharge</i>
	<i>(D₅₀ in feet)</i>		
<i>Abutments:</i>	1.6	--	0.9
<i>Left abutment</i>	1.6	--	--
<i>Right abutment</i>	--	--	--
<i>Piers:</i>	--	--	--
<i>Pier 1</i>	--	--	--
<i>Pier 2</i>

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure SUNDFLR0030012 on Forest Land Road 3 (Forest Land Road 03) (FAS 114), crossing Roaring Branch Brook, Sunderland, Vermont.

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure SUNDFLR0030012 on Forest Land Road 3 (FAS 114), crossing Roaring Branch Brook, Sunderland, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SUNDFLR0030012 on Forest Land Road 3 (FAS 114), crossing Roaring Branch Brook, Sunderland, Vermont.

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

Description	Station ¹	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum 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 960 cubic-feet per second											
Left abutment	0.0	499.8	496.3	488.8	492.9	0.0	4.3	--	4.3	488.6	-0.2
Right abutment	33.1	499.8	496.3	489.0	492.4	0.0	5.4	--	5.4	487.0	-2.0

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 SUNDFLR0030012 on Forest Land Road 3 (FAS 114), crossing Roaring Branch Brook, Sunderland, Vermont.

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

Description	Station ¹	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum 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 1,630 cubic-feet per second											
Left abutment	0.0	499.8	496.3	488.8	492.9	0.0	7.3	--	7.3	485.6	-3.2
Right abutment	33.1	499.8	496.3	489.0	492.4	0.0	10.4	--	10.4	482.0	-7.0

1. Measured along the face of the most constricting side of the bridge.

2. Arbitrary datum for this study.

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```

T1      U.S. Geological Survey WSPRO Input File sund012.wsp
T2      Hydraulic analysis for structure SUNDFLR0030012   Date: 08-JAN-97
T3      FLR 3 (FAS 114) over the Roaring Branch Brook, Sunderland, VT   RHF
*
J3      6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q      960.0    1630.0
SK      0.009    0.009
*
XS      EXITX      -34
GR      -154.5, 507.77    -138.2, 502.59    -84.9, 500.45    -60.9, 494.33
GR      0.0, 493.37      7.1, 489.85      8.3, 489.08      10.6, 488.90
GR      14.4, 489.24      17.2, 489.95      22.0, 490.51      29.6, 493.38
GR      41.4, 494.91      70.7, 495.95      124.8, 498.16      168.6, 498.61
GR      469.8, 513.33
*
N      0.070      0.055      0.060
SA      0.0      29.6
*
XS      FULLV      0 * * * 0.0105
*
*      SRD      LSEL      XSSKEW
BR      BRIDG      0      496.49      15.0
GR      0.0, 496.52      0.1, 492.92      7.4, 490.20      8.6, 489.21
GR      12.6, 489.22      15.7, 489.88      19.9, 490.31      22.2, 490.51
GR      26.6, 490.95      32.9, 492.37      33.1, 496.46      0.0, 496.52
*
*      BRTYPE  BRWDTH
CD      1      30.7
N      0.045
*
*      SRD      EMBWID  IPAVE
XR      RDWAY      15      27.3      2
GR      -90.4, 504.85      -39.9, 499.81      0.0, 499.46      34.4, 499.46
GR      71.9, 499.45      138.1, 499.52      206.0, 501.18      298.4, 504.25
GR      453.5, 514.96
*
AS      APPRO      63 * * * 0.0086
GR      -43.0, 514.67      -26.3, 499.68      -7.8, 498.83      0.0, 496.63
GR      6.3, 491.83      10.6, 491.17      12.1, 490.37      15.7, 489.63
GR      18.7, 489.77      23.3, 490.46      24.6, 491.22      29.9, 491.89
GR      35.2, 495.57      78.2, 497.62      124.3, 499.02      270.4, 504.40
GR      398.2, 512.90
*
N      0.070      0.060      0.060
SA      0.0      35.2
*
HP 1 BRIDG 495.11 1 495.11
HP 2 BRIDG 495.11 * * 960
HP 1 APPRO 495.74 1 495.74
HP 2 APPRO 495.74 * * 960
*
HP 1 BRIDG 496.52 1 496.52
HP 2 BRIDG 496.52 * * 1634
HP 1 APPRO 498.76 1 498.76
HP 2 APPRO 498.76 * * 1630
*
EX
ER

```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

1

WSPRO FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V090192 MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS

U.S. Geological Survey WSPRO Input File sund012.wsp
Hydraulic analysis for structure SUNDFLR0030012 Date: 08-JAN-97
FLR 3 (FAS 114) over the Roaring Branch Brook, Sunderland, VT RHF
*** RUN DATE & TIME: 01-27-97 09:19

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	141.	11281.	32.	38.				1689.
495.11		141.	11281.	32.	38.	1.00	0.	33.	1689.

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

WSEL	LEW	REW	AREA	K	Q	VEL
495.11	0.0	33.0	141.4	11281.	960.	6.79

X STA.	0.0	4.2	6.2	7.8	9.0	10.1
A(I)	11.9	7.9	7.5	6.6	6.1	
V(I)	4.04	6.05	6.44	7.22	7.93	

X STA.	10.1	11.1	12.2	13.2	14.3	15.4
A(I)	5.9	5.8	5.8	5.8	5.9	
V(I)	8.20	8.22	8.26	8.32	8.15	

X STA.	15.4	16.6	17.8	19.1	20.5	21.9
A(I)	6.0	6.2	6.1	6.4	6.5	
V(I)	8.04	7.74	7.82	7.49	7.41	

X STA.	21.9	23.4	25.1	26.9	29.1	33.0
A(I)	6.6	6.9	7.3	8.4	11.8	
V(I)	7.23	6.95	6.56	5.73	4.07	

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD = 63.

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	2	140.	8380.	34.	37.				1604.
	3	0.	1.	4.	4.				1.
495.74		140.	8382.	38.	41.	1.00	1.	39.	1528.

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD = 63.

WSEL	LEW	REW	AREA	K	Q	VEL
495.74	1.2	38.8	139.9	8382.	960.	6.86

X STA.	1.2	6.8	8.8	10.4	11.9	13.0
A(I)	12.2	8.0	7.2	7.1	6.4	
V(I)	3.95	5.99	6.66	6.79	7.55	

X STA.	13.0	14.1	15.1	16.0	16.9	17.9
A(I)	6.0	5.8	5.7	5.6	5.6	
V(I)	8.02	8.28	8.47	8.56	8.62	

X STA.	17.9	18.8	19.7	20.8	21.8	23.0
A(I)	5.7	5.6	5.9	5.9	6.2	
V(I)	8.47	8.62	8.16	8.15	7.79	

X STA.	23.0	24.3	25.8	27.5	29.5	38.8
A(I)	6.6	7.0	7.2	8.1	12.4	
V(I)	7.26	6.88	6.63	5.94	3.88	

WSPRO OUTPUT FILE (continued)

U.S. Geological Survey WSPRO Input File sund012.wsp
Hydraulic analysis for structure SUNDFLR0030012 Date: 08-JAN-97
FLR 3 (FAS 114) over the Roaring Branch Brook, Sunderland, VT RHF

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

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	185.	11480.	0.	73.				0.
496.52		185.	11480.	0.	73.	1.00	0.	33.	0.

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

WSEL	LEW	REW	AREA	K	Q	VEL
496.52	0.0	33.1	185.4	11480.	1634.	8.81

X STA.	0.0	3.6	5.6	7.3	8.6	9.8
A(I)	14.4	10.5	9.3	9.1	8.1	
V(I)	5.66	7.81	8.75	9.00	10.03	

X STA.	9.8	10.9	12.0	13.2	14.3	15.5
A(I)	7.9	7.9	7.8	7.8	8.0	
V(I)	10.38	10.41	10.43	10.46	10.19	

X STA.	15.5	16.8	18.1	19.5	20.9	22.4
A(I)	8.1	8.2	8.3	8.5	8.6	
V(I)	10.03	9.93	9.84	9.57	9.49	

X STA.	22.4	24.0	25.7	27.5	29.7	33.1
A(I)	9.0	9.2	9.4	10.8	14.3	
V(I)	9.06	8.91	8.69	7.54	5.71	

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD = 63.

WSEL	SA#	AREA	K	TOPW	WETP	ALPH	LEW	REW	QCR
	1	8.	174.	8.	8.				47.
	2	245.	20909.	35.	39.				3676.
	3	114.	3593.	81.	81.				775.
498.76		368.	24676.	123.	127.	1.40	-8.	116.	3047.

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD = 63.

WSEL	LEW	REW	AREA	K	Q	VEL
498.76	-7.6	115.7	367.9	24676.	1630.	4.43

X STA.	-7.6	5.0	7.5	9.5	11.4	13.0
A(I)	28.2	16.8	14.8	14.2	13.6	
V(I)	2.89	4.84	5.51	5.73	5.98	

X STA.	13.0	14.5	15.9	17.2	18.6	19.9
A(I)	12.7	12.4	12.1	12.3	12.1	
V(I)	6.43	6.56	6.75	6.63	6.72	

X STA.	19.9	21.3	22.8	24.5	26.3	28.3
A(I)	12.3	12.8	13.6	13.4	14.1	
V(I)	6.63	6.39	5.98	6.08	5.77	

X STA.	28.3	30.5	34.4	44.4	58.1	115.7
A(I)	15.4	19.9	29.9	33.3	54.0	
V(I)	5.29	4.10	2.73	2.45	1.51	

WSPRO OUTPUT FILE (continued)

WSPRO FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V090192 MODEL FOR WATER-SURFACE PROFILE COMPUTATIONS

U.S. Geological Survey WSPRO Input File sund012.wsp
Hydraulic analysis for structure SUNDFLR0030012 Date: 08-JAN-97
FLR 3 (FAS 114) over the Roaring Branch Brook, Sunderland, VT RHF

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
EXITX:XS	*****	-63.	198.	0.56	*****	495.46	494.40	960.	494.90
-34.	*****	41.	10111.	1.54	*****	*****	0.77	4.84	
FULLV:FV	34.	-63.	194.	0.59	0.31	495.80	*****	960.	495.21
0.	34.	41.	9854.	1.54	0.01	0.01	0.79	4.95	
<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>									
APPRO:AS	63.	1.	144.	0.70	0.68	496.54	*****	960.	495.84
63.	63.	41.	8702.	1.01	0.06	0.01	0.62	6.68	
<<<<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	34.	0.	141.	0.72	0.36	495.82	493.70	960.	495.11
0.	34.	33.	11267.	1.00	0.00	-0.01	0.57	6.80	
TYPE PPCD FLOW C P/A LSEL BLEN XLAB XRAB									
1. **** 1. 1.000 ***** 496.49 ***** ***** *****									
XSID:CODE	SRD	FLEN	HF	VHD	EGL	ERR	Q	WSEL	
RDWAY:RG	15.		<<<<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	32.	1.	140.	0.74	0.43	496.48	494.39	960.	495.74
63.	34.	39.	8382.	1.00	0.22	0.00	0.63	6.86	
M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL				
0.171	0.000	8582.	3.	36.	495.27				

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

U.S. Geological Survey WSPRO Input File sund012.wsp
Hydraulic analysis for structure SUNDFLR0030012 Date: 08-JAN-97
FLR 3 (FAS 114) over the Roaring Branch Brook, Sunderland, VT RHF
*** RUN DATE & TIME: 01-27-97 09:19

FIRST USER DEFINED TABLE.

XSID:CODE	SRD	LEW	REW	Q	K	AREA	VEL	WSEL
EXITX:XS	-34.	-63.	41.	960.	10111.	198.	4.84	494.90
FULLV:FV	0.	-63.	41.	960.	9854.	194.	4.95	495.21
BRIDG:BR	0.	0.	33.	960.	11267.	141.	6.80	495.11
RDWAY:RG	15.	*****			0.	*****		
APPRO:AS	63.	1.	39.	960.	8382.	140.	6.86	495.74
XSID:CODE	XLKQ	XRKQ	KQ					
APPRO:AS	3.	36.	8582.					

U.S. Geological Survey WSPRO Input File sund012.wsp
Hydraulic analysis for structure SUNDFLR0030012 Date: 08-JAN-97
FLR 3 (FAS 114) over the Roaring Branch Brook, Sunderland, VT RHF
*** RUN DATE & TIME: 01-27-97 09:19

SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
EXITX:XS	494.40	0.77	488.90	513.33	*****			0.56	495.46
FULLV:FV	*****	0.79	489.26	513.69	0.31	0.01	0.59	495.80	495.21
BRIDG:BR	493.70	0.57	489.21	496.52	0.36	0.00	0.72	495.82	495.11
RDWAY:RG	*****		499.45	514.96	*****				
APPRO:AS	494.39	0.63	489.63	514.67	0.43	0.22	0.74	496.48	495.74

WSPRO OUTPUT FILE (continued)

U.S. Geological Survey WSPRO Input File sund012.wsp
Hydraulic analysis for structure SUNDFLR0030012 Date: 08-JAN-97
FLR 3 (FAS 114) over the Roaring Branch Brook, Sunderland, VT RHF

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
EXITX:XS	*****	-67.	318.	0.65	*****	496.54	495.32	1630.	495.89
-34.	*****	69.	17171.	1.60	*****	*****	0.75	5.13	

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
FULLV:FV	34.	-67.	312.	0.68	0.31	496.88	*****	1630.	496.20
0.	34.	68.	16781.	1.60	0.01	0.01	0.77	5.23	

<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

===125 FR# EXCEEDS FNTEST AT SECID "APPRO": TRIALS CONTINUED.
FNTEST,FR#,WSEL,CRWS = 0.80 0.91 496.73 495.83

===110 WSEL NOT FOUND AT SECID "APPRO": REDUCED DELTAY.
WSLIM1,WSLIM2,DELTAY = 495.70 514.67 0.50

===115 WSEL NOT FOUND AT SECID "APPRO": USED WSMIN = CRWS.
WSLIM1,WSLIM2,CRWS = 495.70 514.67 495.83

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
APPRO:AS	63.	0.	188.	1.29	0.83	498.02	495.83	1630.	496.73
63.	63.	59.	12007.	1.10	0.30	0.00	0.91	8.68	

<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
WS3,WSIU,WS1,LSL = 495.62 496.74 497.20 496.49

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

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

XSID:CODE	SRDL	LEW	AREA	VHD	HF	EGL	CRWS	Q	WSEL
SRD	FLEN	REW	K	ALPH	HO	ERR	FR#	VEL	
BRIDG:BR	34.	0.	185.	1.21	*****	497.73	495.02	1634.	496.52
0.	*****	33.	11480.	1.00	*****	*****	0.66	8.81	

TYPE	PCPD	FLOW	C	P/A	LSEL	BLEN	XLAB	XRAB
1.	****	2.	0.482	*****	496.49	*****	*****	*****

XSID:CODE	SRDL	FLEN	HF	VHD	EGL	ERR	Q	WSEL
RDWAY:RG	15.							

<<<<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	32.	-8.	368.	0.43	0.31	499.19	495.83	1630.	498.76
63.	33.	116.	24696.	1.40	0.46	0.00	0.53	4.43	

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
*****	*****	*****	*****	*****	498.61

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

U.S. Geological Survey WSPRO Input File sund012.wsp
Hydraulic analysis for structure SUNDFLR0030012 Date: 08-JAN-97
FLR 3 (FAS 114) over the Roaring Branch Brook, Sunderland, VT RHF
*** RUN DATE & TIME: 01-27-97 09:19

FIRST USER DEFINED TABLE.

XSID:CODE	SRDL	LEW	REW	Q	K	AREA	VEL	WSEL
EXITX:XS	-34.	-67.	69.	1630.	17171.	318.	5.13	495.89
FULLV:FV	0.	-67.	68.	1630.	16781.	312.	5.23	496.20
BRIDG:BR	0.	0.	33.	1634.	11480.	185.	8.81	496.52
RDWAY:RG	15.	*****	*****	0.	*****	*****	2.00	*****
APPRO:AS	63.	-8.	116.	1630.	24696.	368.	4.43	498.76

XSID:CODE	XLKQ	XRKQ	KQ
APPRO:AS	*****	*****	*****

U.S. Geological Survey WSPRO Input File sund012.wsp
Hydraulic analysis for structure SUNDFLR0030012 Date: 08-JAN-97
FLR 3 (FAS 114) over the Roaring Branch Brook, Sunderland, VT RHF
*** RUN DATE & TIME: 01-27-97 09:19

SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
EXITX:XS	495.32	0.75	488.90	513.33	*****	0.65	496.54	495.89	
FULLV:FV	*****	0.77	489.26	513.69	0.31	0.01	0.68	496.88	
BRIDG:BR	495.02	0.66	489.21	496.52	*****	1.21	497.73	496.52	
RDWAY:RG	*****	*****	499.45	514.96	*****	0.11	501.11	*****	
APPRO:AS	495.83	0.53	489.63	514.67	0.31	0.46	0.43	499.19	

1 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 SUNDFLR0030012, in Sunderland, Vermont.

APPENDIX D:
HISTORICAL DATA FORM

Structure Number SUNDFLR0030012

General Location Descriptive

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

Date (MM/DD/YY) 12 / 14 / 95

Highway District Number (I - 2; nn) 01

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

Town (FIPS place code; I - 4; nnnnn) 71425

Mile marker (I - 11; nnn.nnn) 006700

Waterway (I - 6) ROARING BRANCH BRK

Road Name (I - 7): FLR 03 FAS 114

Route Number -

Vicinity (I - 9) 8.5 MI E JCT US 7

Topographic Map Sunderland

Hydrologic Unit Code: 43033

Latitude (I - 16; nnnn.n) 73035

Longitude (I - 17; nnnnn.n) 2001140

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 0120215

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0035

Year built (I - 27; YYYY) 1966

Structure length (I - 49; nnnnnn) 000037

Average daily traffic, ADT (I - 29; nnnnnn) 000110

Deck Width (I - 52; nn.n) 273

Year of ADT (I - 30; YY) 91

Channel & Protection (I - 61; n) 8

Opening skew to Roadway (I - 34; nn) 15

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) 0000

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

Clear span (nnn.n ft) 34

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 6

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

Waterway of full opening (nnn.n ft²) 162

Comments:

According to the structural inspection report dated 6/2/94, the structure is a single span rolled beam bridge. The structure has been widened upstream. The bridge seat at the left abutment is newer for its entire width. The stem of the abutment in the widened portion has light scaling. The stem in the original portion also is in good condition. The wingwalls at the left abutment have some minor cracking and scaling. The bridge seat stem and wingwalls at the right abutment are similar to the left abutment. Both abutments are protected with heavy stone fill. The channel takes a moderate turn into the structure and is straight leaving the structure.

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: -

Discharge Data (cfs): $Q_{2.33}$ - Q_{10} - Q_{25} -
 Q_{50} - Q_{100} - Q_{500} -

Record flood date (MM / DD / YY): - / - / - Water surface elevation (ft): -

Estimated Discharge (cfs): - Velocity at Q - (ft/s): -

Ice conditions (Heavy, Moderate, Light) : - Debris (Heavy, Moderate, Light): -

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

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

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

Watershed storage area (in percent): - %

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

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

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

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

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

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

Downstream distance (*miles*): - _____ Town: - _____ Year Built: - _____
Highway No. : - _____ Structure No. : - _____ Structure Type: - _____
Clear span (*ft*): - _____ Clear Height (*ft*): - _____ Full Waterway (*ft*²): - _____
Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area (*DA*) 4.93 mi² Lake and pond area .255 mi²
Watershed storage (*ST*) 5.1 %
Bridge site elevation 2160 ft Headwater elevation 3412 ft
Main channel length 3.24 mi
10% channel length elevation 2180 ft 85% channel length elevation 2760 ft
Main channel slope (*S*) 172.01 ft / mi

Watershed Precipitation Data

Average site precipitation - _____ in Average headwater precipitation - _____ in
Maximum 2yr-24hr precipitation event (*I*_{24,2}) - _____ in
Average seasonal snowfall (*Sn*) - _____ ft

Bridge Plan Data

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

Project Number SAB 6543 Minimum channel bed elevation: 494

Low superstructure elevation: USLAB 499.85 DSLAB 499.85 USRAB 499.85 DSRAB 499.85

Benchmark location description:

No benchmark information.

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

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

If 1: Footing Thickness 1.5 Footing bottom elevation: 492.5

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

No drill boring information,

Comments:

Footing bottom elevation at the right abutment is 492.5' and at the left abutment is 492.25'.

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

The elevation of the top of the wing wall at the abutment corners is 502.70, at each wingwall, according to the bridge plans.

Cross-sectional Data

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

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	-	-	-	-	-	-	-	-	-	-	-

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

Structure Number SUNDFLP0030012

Qa/Qc Check by: EW Date: 10/17/96

Computerized by: EW Date: 10/23/96

Reviewed by: RF Date: 01/27/97

A. General Location Descriptive

1. Data collected by (First Initial, Full last name) L. Medalie Date (MM/DD/YY) 07 / 30 / 1996
2. Highway District Number 01 Mile marker 006700
County Bennington 003 Town Sunderland 71425
Waterway (I - 6) Roaring Brook Branch Road Name Forest Land Road 3
Route Number FAS114 Hydrologic Unit Code: 02020003
3. Descriptive comments:
Located 8.5 miles east of the junction with US 7.

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 37 (feet) Span length 35 (feet) Bridge width 27.3 (feet)

Road approach to bridge:

8. LB 2 RB 1 (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		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	<u>0</u>	<u>-</u>	<u>0</u>	<u>-</u>
RBUS	<u>0</u>	<u>-</u>	<u>0</u>	<u>-</u>
RBDS	<u>0</u>	<u>-</u>	<u>0</u>	<u>-</u>
LBDS	<u>0</u>	<u>-</u>	<u>0</u>	<u>-</u>

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

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

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

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

Channel approach to bridge (BF):

15. Angle of approach: 20

16. Bridge skew: 30

17. Channel impact zone 1: Exist? Y (Y or N)
Where? LB (LB, RB) Severity 1
Range? 90 feet US (US, UB, DS) to 15 feet US
- Channel impact zone 2: Exist? Y (Y or N)
Where? RB (LB, RB) Severity 2
Range? 90 feet DS (US, UB, DS) to 110 feet DS

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

18. Bridge Type: 1a

1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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

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

#4. Significant shrub and brush also on all banks except LBUS.

#7. Measured deck width = 27.3 feet; bridge length 37 feet; and bridge span = 34 feet.

#18. Wingwalls are all angled back at 90 degrees from abutment face.

C. Upstream Channel Assessment

21. Bank height (BF)		22. Bank angle (BF)		26. % Veg. cover (BF)		27. Bank material (BF)		28. Bank erosion (BF)			
20. SRD	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	
34.0	5.0			3.5	4	3	546	5	2	0	
23. Bank width		35.0	24. Channel width		35.0	25. Thalweg depth		35.0	29. Bed Material		456
30. Bank protection type:		LB	2	RB	2	31. Bank protection condition:		LB	1	RB	1

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

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

#26. The right bank is covered with shrubs. Only small trees are present along the right bank from 75 feet upstream to upstream bridge face.

#27. Bedrock extends to mid-channel from left bank at 40 feet and at 16 feet upstream.

#30. Right bank protection extends to 27 feet upstream from bridge face.
 Left bank protection extends to 16 feet upstream from bridge face.

Large anabranching island begins at 80 feet upstream and extends beyond 200 feet upstream. The channel to the left has standing water.

33. Point/Side bar present? N (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: - 35. Mid-bar width: -
 36. Point bar extent: - feet - (US, UB) to - feet - (US, UB, DS) positioned - %LB to - %RB
 37. Material: -
 38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
NO POINT BARS

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: 60 42. Cut bank extent: 115 feet US (US, UB) to 12 feet US (US, UB, DS)
 43. Bank damage: 2 (1- eroded and/or creep; 2- slip failure; 3- block failure)
 44. Cut bank comments (eg. additional cut banks, protection condition, etc.):
Some bedrock is present in channel along cut-bank. Cut-bank is indicted in two areas on sketch due to the anabranch along the left side of the channel.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 38
 47. Scour dimensions: Length 2 Width 2 Depth : 1 Position 45 %LB to 55 %RB
 48. Scour comments (eg. additional scour areas, local scouring process, etc.):
Two areas of scour exist as a result of bedrock control. The second scour hole has a mid-scour distance at 70 feet upstream. It is also 2 feet in length and width and 1 foot deep. The scour hole is positioned 45% LB to 55% RB.

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 (1- natural bank; 2- abutment; 3- artificial levee)

56. Height (BF)		57. Angle (BF)	
LB	RB	LB	RB
<u>23.5</u>		<u>1.5</u>	

61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB
<u>2</u>	<u>7</u>	<u>7</u>	<u>-</u>

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.):
453

Most of the stream flow is along the left side of the channel (20% LB to 40% RB).

65. **Debris and Ice** Is there debris accumulation? ____ (Y or N) 66. Where? N (1- Upstream; 2- At bridge; 3- Both)
67. Debris Potential - ____ (1- Low; 2- Moderate; 3- High) 68. Capture Efficiency 2 (1- Low; 2- Moderate; 3- High)
69. Is there evidence of ice build-up? 2 (Y or N) Ice Blockage Potential Y (1- Low; 2- Moderate; 3- High)
70. Debris and Ice Comments:
2

<u>Abutments</u>	71. Attack ∠(BF)	72. Slope ∠(Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		15	90	2	0	-	-	90.0
RABUT	1	0	90			2	0	32.0

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

#72. Both abutments are protected by large boulders placed at a 30 degree angle. Protection on the RABUT extends out 6 feet horizontally, and 8 feet from the LABUT.

#74. Although water flows mainly towards the left side under the bridge, there is no scour evident. The average water depth is 1 foot.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?
USLWW:	_____	_____	_____	_____	_____
USRWW:	<u>Y</u>	_____	<u>1</u>	_____	<u>0</u>
DSLWW:	-	_____	-	_____	<u>Y</u>
DSRWW:	<u>1</u>	_____	<u>0</u>	_____	-

81.	Angle?	Length?
	<u>32.0</u>	_____
	<u>1.0</u>	_____
	<u>30.5</u>	_____
	<u>30.5</u>	_____

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

82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	1	1	1	1
Condition	Y	-	1	-	1	1	1	1
Extent	1	-	0	3	4	3	3	-

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.):

-
-
-
-
4
1
1
3
1
1

Piers:

84. Are there piers? Wi (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	0.0	0.0	0.0	7.0	7.0	6.5
Pier 2	0.0	-	-	7.0	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-

Level 1 Pier Descr.	1	2	3	4
86. Location (BF)	ngw	pro-		-
87. Type	all	tec-	N	-
88. Material	pro-	tion.	-	-
89. Shape	tec-		-	-
90. Inclined?	tion		-	-
91. Attack ∠ (BF)	is the		-	-
92. Pushed	same		-	-
93. Length (feet)	-	-	-	-
94. # of piles	as		-	-
95. Cross-members	dow		-	-
96. Scour Condition	nstre		-	-
97. Scour depth	am		-	-
98. Exposure depth	bank		-	-

LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP

1- Solid pier, 2- column, 3- bent

1- Wood; 2- concrete; 3- metal; 4- stone

1- Round; 2- Square; 3- Pointed

Y- yes; N- no

LB or RB

0- none; 1- laterals; 2- diagonals; 3- both

0- not evident; 1- evident (comment);
2- footing exposed; 3- piling exposed;
4- undermined footing; 5- settled; 6- failed

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

-
-
-
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

SRD	Bank height (BF)		Bank angle (BF)		% Veg. cover (BF)		Bank material (BF)		Bank erosion (BF)		
	LB	RB	LB	RB	LB	RB	LB	RB	LB	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? 3 (Y or N, if N type ctrl-n ds)

102. Distance: - feet

103. Drop: - feet

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

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

45
43
0
0
45
4

106. Point/Side bar present? 3 (Y or N. if N type ctrl-n pb) Mid-bar distance: 1 Mid-bar width: 1

Point bar extent: Both feet ban (US, UB, DS) to ks feet are (US, UB, DS) positioned cov %LB to ere %RB

Material: d

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

with shrubs.

Left bank protection extends from downstream bridge face to 18 feet downstream.

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

Cut bank extent: k feet pro (US, UB, DS) to tec- feet tio (US, UB, DS)

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

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

extends from downstream bridge face to 7 feet downstream.

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

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

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

N

-

NO DROP STRUCTURE

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

Confluence 1: Distance _____ Enters on _____ (LB or RB)

Type Y (1- perennial; 2- ephemeral)

Confluence 2: Distance 20UB Enters on 10 (LB or RB)

Type 5 (1- perennial; 2- ephemeral)

Confluence comments (eg. confluence name):

UB

15

F. Geomorphic Channel Assessment

107. Stage of reach evolution DS

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*):

50

80

435

The section of the point bar which is not under the bridge is covered by grass.

The mid-bar distance and the point bar extent value were measured from the upstream bridge face.

N

-

-

-

-

-

109. G. Plan View Sketch

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: SUNDFLR0030012 Town: Sunderland
 Road Number: Forest Land Road 03 County: Bennington
 Stream: Roaring Branch Brook

Initials RF Date: 1/27/97 Checked: EB

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

Critical Velocity of Bed Material (converted to English units)
 $V_c = 11.21 \cdot y_1^{0.1667} \cdot D_{50}^{0.33}$ with $S_s = 2.65$
 (Richardson and others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	960	1630	0
Main Channel Area, ft ²	139.9	245	0
Left overbank area, ft ²	0	8	0
Right overbank area, ft ²	0	114	0
Top width main channel, ft	34	35	0
Top width L overbank, ft	0	8	0
Top width R overbank, ft	4	81	0
D50 of channel, ft	0.4573	0.4573	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y ₁ , average depth, MC, ft	4.1	7.0	ERR
y ₁ , average depth, LOB, ft	ERR	1.0	ERR
y ₁ , average depth, ROB, ft	0.0	1.4	ERR
Total conveyance, approach	8382	24676	0
Conveyance, main channel	8380	20909	0
Conveyance, LOB	0	174	0
Conveyance, ROB	1	3593	0
Percent discrepancy, conveyance	0.0119	0.0000	ERR
Q _m , discharge, MC, cfs	959.8	1381.2	ERR
Q _l , discharge, LOB, cfs	0.0	11.5	ERR
Q _r , discharge, ROB, cfs	0.1	237.3	ERR
V _m , mean velocity MC, ft/s	6.9	5.6	ERR
V _l , mean velocity, LOB, ft/s	ERR	1.4	ERR
V _r , mean velocity, ROB, ft/s	ERR	2.1	ERR
V _{c-m} , crit. velocity, MC, ft/s	10.9	11.9	N/A
V _{c-l} , crit. velocity, LOB, ft/s	ERR	ERR	ERR
V _{c-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
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

$y_2 = (Q_2^2 / (131 * D_m^{(2/3)} * W_2^2))^{(3/7)}$ Converted to English Units
 $y_s = y_2 - y_{\text{bridge}}$
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Approach Section	Q100	Q500	Qother
Main channel Area, ft ²	139.9	245	0
Main channel width, ft	34	35	0
y1, main channel depth, ft	4.11	7.00	ERR

Bridge Section

(Q) total discharge, cfs	960	1630	0
(Q) discharge thru bridge, cfs	960	1634	0
Main channel conveyance	11281	11480	0
Total conveyance	11281	11480	0
Q2, bridge MC discharge, cfs	960	1634	ERR
Main channel area, ft ²	141	185	0
Main channel width (skewed), ft	31.9	32.0	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	31.875	31.972	0
y _{bridge} (avg. depth at br.), ft	4.44	5.80	ERR
D _m , median (1.25*D ₅₀), ft	0.571625	0.571625	0
y ₂ , depth in contraction, ft	2.69	4.23	ERR
y _s , scour depth (y ₂ -y _{bridge}), ft	-1.75	-1.57	N/A

ARMORING

D90	1.5528	1.5528	0
D95	2.2444	2.2444	0
Critical grain size, D _c , ft	0.3682	0.5367	ERR
Decimal-percent coarser than D _c	0.59609	0.42246	0
Depth to armoring, ft	0.75	2.20	ERR

Pressure Flow Scour (contraction scour for orifice flow conditions)

$H_b + Y_s = C_q * q_{br} / V_c$ $C_q = 1 / (C_f * C_c)$ $C_f = 1.5 * Fr^{0.43} \quad (<=1)$
Chang Equation $C_c = \text{SQRT}[0.10 (H_b / (y_a - w) - 0.56)] + 0.79 \quad (<=1)$
(Richarson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q, total, cfs	960	1630	0
Q, thru bridge, cfs	960	1634	0
Total Conveyance, bridge	11281	11480	0
Main channel (MC) conveyance, bridge	11281	11480	0
Q, thru bridge MC, cfs	960	1634	ERR
V _c , critical velocity, ft/s	10.93	11.95	N/A

Vc, critical velocity, m/s	3.33	3.64	N/A
Main channel width (skewed), ft	31.9	32.0	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	31.9	32.0	0.0
qbr, unit discharge, ft ² /s	30.1	51.1	ERR
qbr, unit discharge, m ² /s	2.8	4.7	N/A
Area of full opening, ft ²	141.4	185.4	0.0
Hb, depth of full opening, ft	4.44	5.80	ERR
Hb, depth of full opening, m	1.35	1.77	N/A
Fr, Froude number, bridge MC	0	0.66	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
Elevation of Low Steel, ft	0	496.49	0
Elevation of Bed, ft	-4.44	490.69	N/A
Elevation of Approach, ft	0	498.76	0
Friction loss, approach, ft	0	0.31	0
Elevation of WS immediately US, ft	0.00	498.45	0.00
ya, depth immediately US, ft	4.44	7.76	N/A
ya, depth immediately US, m	1.35	2.36	N/A
Pressure Flow Scour (con't)	Q100	Q500	OtherQ
Mean elevation of deck, ft	0	499.457	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.93	ERR
Ys, depth of scour, ft	N/A	-1.18	N/A

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			Right Abutment		
	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	960	1630	0	960	1630	0
a', abut.length blocking flow, ft	0.8	9.6	0	5.92	81.73	0
Ae, area of blocked flow ft ²	1.74	21.49	0	7.9	119.38	0
Qe, discharge blocked abut., cfs	6.86	62.1	0	30.58	253.44	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.94	2.89	ERR	3.87	2.12	ERR
ya, depth of f/p flow, ft	2.19	2.24	ERR	1.33	1.46	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.469	0.340	ERR	0.591	0.310	ERR
ys, scour depth, ft	4.26	7.26	N/A	5.41	10.40	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)	0.8	9.6	0	5.92	81.73	0
y1 (depth f/p flow, ft)	2.18	2.24	ERR	1.33	1.46	ERR

a'/y _l	0.37	4.29	ERR	4.44	55.95	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.47	0.34	N/A	0.59	0.31	N/A
Ys w/ corr. factor K ₁ /0.55:						
vertical	ERR	ERR	ERR	ERR	7.21	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	5.92	ERR
spill-through	ERR	ERR	ERR	ERR	3.97	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	Q100	Q500	Qother
Fr, Froude Number	0.57	0.66	0	0.57	0.66	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	4.44	5.80	0.00	4.44	5.80	0.00
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	0.89	1.56	0.00	0.89	1.56	0.00
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	0.78	1.36	0.00	0.78	1.36	0.00
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR