LEVEL II SCOUR ANALYSIS FOR BRIDGE 8 (SALITH00010008) on TOWN HIGHWAY 1, crossing OTTER CREEK, SALISBURY, VERMONT

Open-File Report 98-536

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 8 (SALITH00010008) on TOWN HIGHWAY 1, crossing OTTER CREEK, SALISBURY, VERMONT

By ERICK M. BOEHMLER AND LAURA MEDALIE

U.S. Geological Survey
Open-File Report 98-536

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

Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
Thomas J. Casadevall, Acting Director

For additional information
write to:

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

Copies of this report may be
purchased from:

U.S. Geological Survey
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

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	Max	maximum
D_{50}	median diameter of bed material	MC	main channel
DS	downstream	RAB	right abutment
elev.	elevation	RABUT	face of right abutment
f/p	flood plain	RB	right bank
ft^2	square feet	ROB	right overbank
ft/ft	feet per foot	RWW	right wingwall
FEMA	Federal Emergency Management Agency	TH	town highway
FHWA	Federal Highway Administration	UB	under bridge
JCT	junction	US	upstream
LAB	left abutment	USGS	United States Geological Survey
LABUT	face of left abutment	VTAOT	Vermont Agency of Transportation
LB	left bank	WSPRO	water-surface profile model
LOB	left overbank	yr	year

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 8 (SALITH00010008) ON TOWN HIGHWAY 1, CROSSING OTTER CREEK, SALISBURY, VERMONT

By **Erick M. Boehmler and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SALITH00010008 on Town Highway 1 crossing Otter Creek, Salisbury, 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 (FHWA, 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 C.

The site is in the Champlain section of the St. Lawrence Valley physiographic province in west-central Vermont. The 543-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture except for the upstream left overbank area where the surface cover is predominantly wetland. Approximately 800 feet left of the site, the surface cover upstream and downstream becomes forested wetland (Cedar Swamp).

In the study area, Otter Creek has a straight channel with a slope of approximately 0.0004 ft/ft, an average channel top width of 118 ft and an average bank height of 4 ft. The channel bed material ranges from organics to sand. Sieve analysis indicates that greater than 50% of the sample is silt and clay and thus a median grain size by use of sieve analysis was indeterminate. Therefore, the median grain was assumed to be medium silt with a size (D_{50}) of 0.0310 mm (0.000102 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 12, 1996, indicated that the reach was stable.

The Town Highway 1 crossing of Otter Creek is a 156-ft-long, one-lane bridge consisting of two 71-foot wooden thru-truss spans (Vermont Agency of Transportation, written communication, December 15, 1995). The opening length of the structure parallel to the bridge face is 133 ft. The bridge is supported by vertical abutments and one pier. The left abutment and the pier are concrete, and the right abutment is a mortared stone-block wall. The channel is skewed approximately 20 degrees to the opening while the computed opening-skew-to-roadway is 5 degrees.

The only scour protection measure at the site was type-1 stone fill (less than 12 inches diameter) on the left bank under the bridge in two isolated piles. Additional details describing conditions at the site are included in the Level II Summary and appendices C and D.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 8.8 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge. Abutment scour ranged from 1.9 to 5.1 ft. The worst-case abutment scour 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.

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 SALITH00010008 ***Stream*** Otter Creek

County Addison ***Road*** TH 1 ***District*** 5

Description of Bridge

Bridge length 156 ***ft*** ***Bridge width*** 13.0 ***ft*** ***Max span length*** 71 ***ft***

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

Abutment type Vertical ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 6/12/96

Description of stone fill Type-1 was observed along the left bank under the bridge in two isolated piles.

The right abutment is a stone wall with a concrete cap. The left abutment is concrete. The pier is concrete with a sharp upstream end.

Yes 20

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

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***
	6/12/96	100	25
Level I	6/12/96	--	--
Level II			

Potential for debris High. The channel flows through a forested swamp upstream. Debris was observed at the upstream bridge face.

Describe any features near or at the bridge that may affect flow (include observation date) None were observed on 6/12/96.

Description of the Geomorphic Setting

General topography The channel is located in a low relief valley setting with a wide flood plain and moderately sloped valley walls on both sides.

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

Date of inspection 6/12/96

DS left: Steep channel bank to an irregular flood plain

DS right: Steep channel bank to an irregular overbank

US left: Moderately sloped channel bank to an irregular flood plain

US right: Moderately sloped channel bank to an irregular overbank

Description of the Channel

Average top width 118 *ft* ***Average depth*** 4 *ft*

Predominant bed material Silt/Clay to Sand ***Bank material*** Silt/Clay

Perennial and straight with a constant width and alluvial channel boundaries.

6/12/96

Vegetative co Trees with shrubs and brush.

DS left: Shrubs and brush with a few trees.

DS right: Trees with shrubs and brush.

US left: Shrubs and brush with a few trees.

US right:

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

Describe any obstructions in channel and date of observation. A large mass of debris (whole trees) across the entire channel width at the upstream face of the bridge, was observed lodged on the pier on 6/12/96.

Hydrology

Drainage area 543 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
St. Lawrence Valley / Champlain	40
New England / Taconic	60

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

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

USGS gage description Otter Creek at Middlebury, VT

USGS gage number 04282500

Gage drainage area 628 ***mi²***

Is there a lake/ No

Calculated Discharges

Q100 10,200 ***ft³/s*** ***Q500*** 13,200 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(543/628)exp 0.67] with the gaged discharges at Middlebury. A log-Pearson Type III analysis of the peak discharges recorded at the Middlebury gage was conducted for the discontinuous period from 1904 - 1996 (81 years) in accordance with the guidelines documented by the Interagency Advisory Committee on Water Data (1982).

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 the right abutment concrete at the upstream end at the corner nearest the bank (elev. 500.15 ft, arbitrary survey datum). RM2 is a chiseled "X" on a boulder at the downstream end of the left abutment nearest the bank (elev. 503.76 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	*Section Reference Distance (SRD) in feet*	*[2]Cross-section development*	*Comments*
EXITX	-140	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	148	1	Approach section

[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. For each discharge modeled, flow through the bridge was assumed to align with the abutment walls. Flow through several culverts was assumed negligible for the discharges modeled. 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 0.035 to 0.040, and overbank "n" values ranged from 0.040 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 0.00032 ft/ft, which was estimated from records for the gage at Middlebury and topographic map contour lines (U.S. Geological Survey, 1943).

The surveyed approach section was moved with no elevation correction to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 504.8 ***ft***
Average low steel elevation 501.7 ***ft***

100-year discharge 10,200 ***ft^3/s***
Water-surface elevation in bridge opening 499.0 ***ft***
Road overtopping? Yes ***Discharge over road*** 6,810 ***ft^3/s***
Area of flow in bridge opening 1,430 ***ft^2***
Average velocity in bridge opening 2.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 2.9 ***ft/s***

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 499.0
Amount of backwater caused by bridge 0.3 ***ft***

500-year discharge 13,200 ***ft^3/s***
Water-surface elevation in bridge opening 499.6 ***ft***
Road overtopping? Yes ***Discharge over road*** 12,300 ***ft^3/s***
Area of flow in bridge opening 1,510 ***ft^2***
Average velocity in bridge opening 0.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 0.8 ***/s***

Water-surface elevation at Approach section with bridge 499.6
Water-surface elevation at Approach section without bridge 499.5
Amount of backwater caused by bridge 0.1 ***ft***

Incipient overtopping discharge 6,730 ***ft^3/s***
Water-surface elevation in bridge opening 497.6 ***ft***
Area of flow in bridge opening 1,240 ***ft^2***
Average velocity in bridge opening 5.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 6.6 ***ft/s***

Water-surface elevation at Approach section with bridge 498.6
Water-surface elevation at Approach section without bridge 498.0
Amount of backwater caused by bridge 0.6 ***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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for each modeled discharge was computed by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p. 30, equation 17). Variables for the live-bed contraction scour equation include the bottom width, depth, and discharge in the bridge opening and in the approach main channel, the shear velocity in the approach channel, and the fall velocity of the median sized particle of the bed material.

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

Abutment scour was computed by use of the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE 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-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	0.0	0.0	8.8
Clear-water scour	--	--	--
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
Abutment scour			
Left abutment	4.7	5.1	3.8
Right abutment	3.5	5.0	1.9
Pier scour			
Pier 1	10.4	5.9	14.7
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	0.3	0.0	1.1
Right abutment	0.3	0.0	1.1
Piers:			
Pier 1	0.2	0.0	0.9
Pier 2	--	--	--
	--	--	--

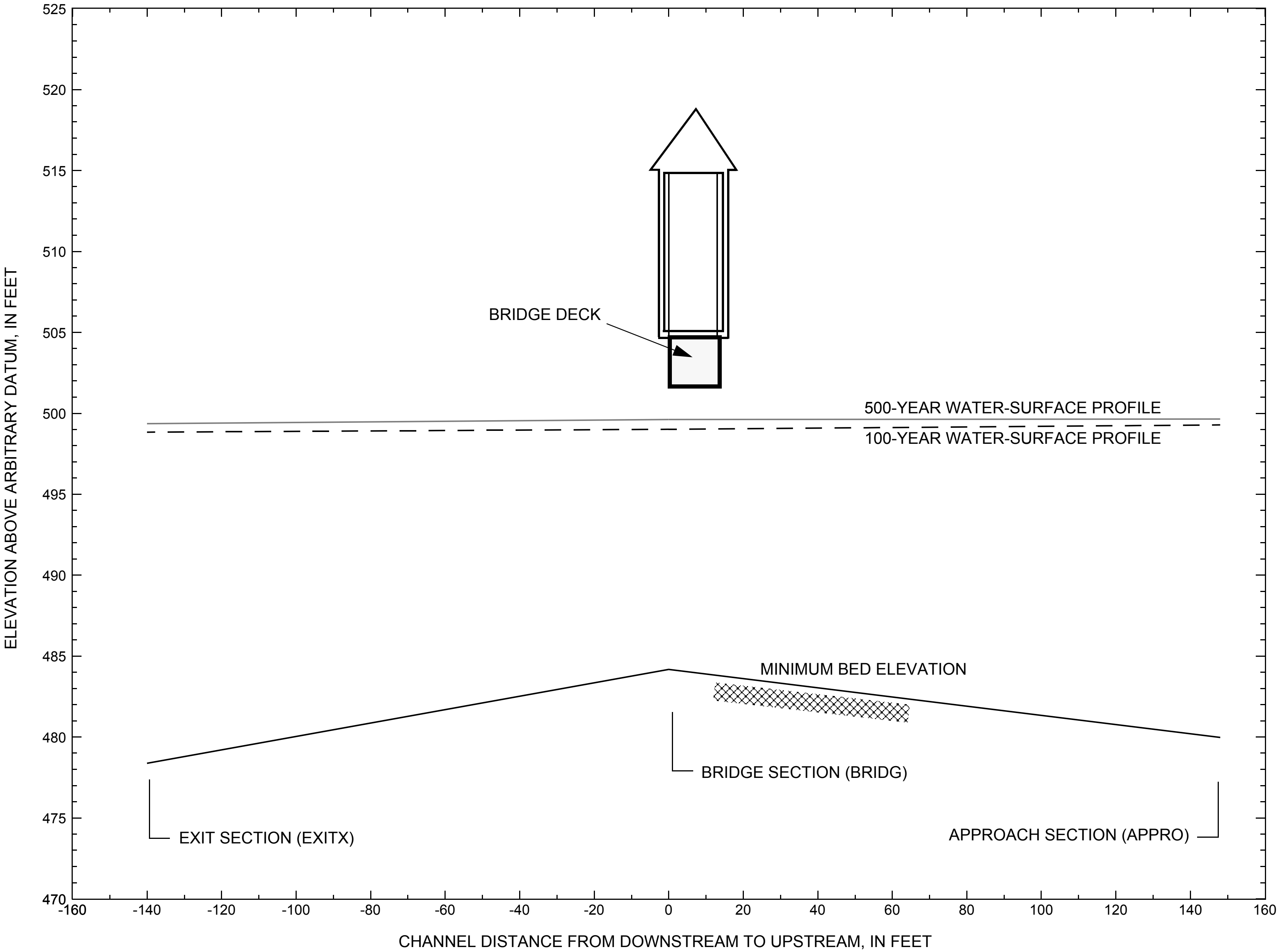


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure SALITH00010008 on Town Highway 1, crossing Otter Creek, Salisbury, Vermont.

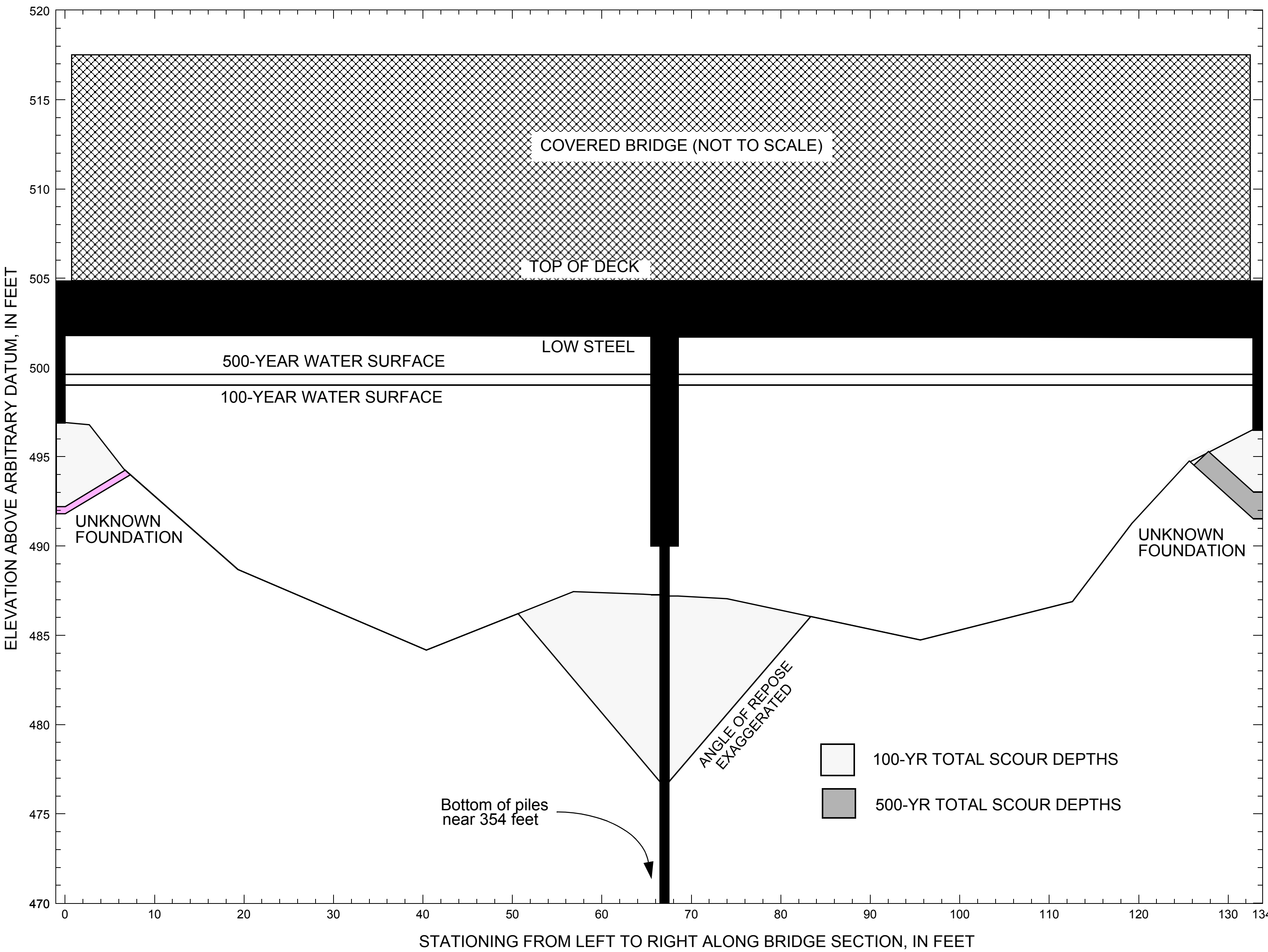


Figure 8. Scour elevations for the 100- and 500-year discharges at structure SALITH00010008 on Town Highway 1, crossing Otter Creek, Salisbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SALITH00010008 on Town Highway 1, crossing Otter Creek, Salisbury, 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/pile 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-year discharge is 10,200 cubic-feet per second											
Left abutment	0.0	--	501.8	--	496.9	0.0	4.7	--	4.7	492.2	--
Pier	67.0	--	500.0	354.	487.2	0.0	--	10.4	--	476.8	~344.
Right abutment	132.8	--	501.6	--	496.5	0.0	3.5	--	3.5	493.0	--

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 SALITH00010008 on Town Highway 1, crossing Otter Creek, Salisbury, 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/pile 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-year discharge is 13,200 cubic-feet per second											
Left abutment	0.0	--	501.8	--	496.9	0.0	5.1	--	5.1	491.8	--
Pier	67.0	--	500.0	354.	487.2	0.0	--	5.9	5.9	481.3	~348.
Right abutment	132.8	--	501.6	--	496.5	0.0	5.0	--	5.0	491.5	--

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.

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

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.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 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., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

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. Geological Survey, 1943, Cornwall, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Contour Interval, 20 feet, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File sali008.1.wsp
T2        Hydraulic analysis for structure SALITH00010008   Date: 27-JUN-97
T3        Town Highway 1 Crossing Otter Creek, Salisbury, VT                JRD
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           10200.0   6730.0    6740.0
SK          0.00032   0.00032   0.00032
WS          498.83    497.81    497.81
*
XS   EXITX      -140
GR         -5600.0, 508.00  -5500.0, 497.63   -872.2, 497.63   -672.8, 497.63
GR          -195.2, 497.62    -70.6, 497.63     -7.3, 498.14      0.0, 497.42
GR             4.6, 494.15     19.7, 481.65     43.2, 478.38     66.8, 478.59
GR            85.4, 481.12    109.6, 495.14    116.2, 499.38    395.1, 498.69
GR           606.5, 498.31   1000.9, 498.53   1020.9, 508.03
*
N             0.070    0.035    0.040
SA                  -7.3    116.2
*
XS   FULLV        0    * * *  0.0
*
*              SRD     LSEL    XSSKEW
BR   BRIDG        0    501.72       5.0
GR             0.0, 501.79      0.0, 496.91      2.7, 496.80      6.6, 494.30
GR            19.3, 488.70     40.4, 484.17     56.8, 487.45     64.6, 487.30
GR            74.0, 487.05     95.6, 484.73    112.6, 486.89    119.3, 491.31
GR           124.0, 494.36    132.8, 496.53    132.8, 501.64      0.0, 501.79
*
*            BRTYPE   BRWDTH
CD              1       15.6
N            0.040
PW           487.30,1.0 491.6,1.0 491.6,3.0 501.72,3.0 501.72,0.0
*
*              SRD  EMBWID    IPAVE
XR   RDWAY        8     13.0       2
GR         -5600.0, 507.00  -5500.0, 498.83   -855.2, 498.53   -669.9, 498.90
GR          -660.0, 498.94   -227.1, 498.96    -70.6, 501.06    -14.6, 504.47
GR             0.0, 504.82    145.2, 504.82    193.6, 503.20    273.7, 501.65
GR           308.5, 501.37   1010.9, 500.90   1020.9, 508.00
*
*           The approach section below was surveyed at 176 feet upstream of
*           the bridge but placed at 148 feet upstream (1 bridge width)
*           instead of templating due to no bed elevation change between 176
*           and 148 feet upstream.
*
AS   APPRO    148
GR         -5600.0, 508.00  -5500.0, 497.12   -872.2, 497.12   -230.1, 497.12
GR             0.0, 498.61      8.7, 494.52
GR             9.3, 492.76     32.0, 482.72     67.4, 479.97     91.9, 483.12
GR           106.1, 491.50    108.6, 494.92    120.3, 498.46    395.1, 498.69
GR           606.5, 498.31   1000.9, 498.31   1020.9, 508.03
*              -100.0, 499.56    -19.2, 499.67
*
N                0.070   0.035    0.040
SA                    0.0    120.3
*
HP 1 BRIDG 499.01 1 499.01
HP 2 BRIDG 499.01 * * 3386
HP 2 RDWAY 499.18 * * 6814
HP 1 APPRO 499.28 1 499.28
HP 2 APPRO 499.28 * * 10200
*
HP 1 BRIDG 497.62 1 497.62
HP 2 BRIDG 497.62 * * 6730
HP 2 BRIDG 497.64 * * 6730
HP 1 APPRO 498.58 1 498.58
HP 2 APPRO 498.58 * * 6730
*
EX
ER
```

```
T1        U.S. Geological Survey WSPRO Input File sali008.2.wsp
T2        Hydraulic analysis for structure SALITH00010008   Date: 27-JUN-97
T3        Town Highway 1 Crossing Otter Creek, Salisbury, VT                JRD
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           13200.0
SK          0.00032
WS          499.35
*
XS   EXITX      -140
GR         -5600.0, 508.00  -5500.0, 497.63   -872.2, 497.63   -672.8, 497.63
GR          -195.2, 497.62    -70.6, 497.63     -7.3, 498.14      0.0, 497.42
GR             4.6, 494.15     19.7, 481.65     43.2, 478.38     66.8, 478.59
GR            85.4, 481.12    109.6, 495.14    116.2, 499.38    395.1, 498.69
GR           606.5, 498.31   1000.9, 498.53   1020.9, 508.03
*
N             0.070    0.035    0.040
SA                  -7.3    116.2
*
XS   FULLV       0    * * *  0.0
*
*              SRD      LSEL    XSSKEW
BR   BRIDG       0    501.72       5.0
GR             0.0, 501.79      0.0, 496.91      2.7, 496.80      6.6, 494.30
GR            19.3, 488.70     40.4, 484.17     56.8, 487.45     64.6, 487.30
GR            74.0, 487.05     95.6, 484.73    112.6, 486.89    119.3, 491.31
GR           124.0, 494.36    132.8, 496.53    132.8, 501.64      0.0, 501.79
*
*            BRTYPE   BRWDTH
CD              1       15.6
N            0.040
PW           487.30,1.0 491.6,1.0 491.6,3.0 501.72,3.0 501.72,0.0
*
*             The roadway section across the flood plain to the left of the
*             bridge was truncated at a station nearer to the bridge than
*             for other models. This was done assuming the area removed is
*             ineffective flow area. Otherwise, WSPRO provides a solution
*             which has no road overflow modeled.
*              SRD  EMBWID    IPAVE
XR   RDWAY       8     13.0       2
GR         -4700.0, 507.00  -4600.0, 498.83   -855.2, 498.53   -669.9, 498.90
GR          -660.0, 498.94   -227.1, 498.96    -70.6, 501.06    -14.6, 504.47
GR             0.0, 504.82    145.2, 504.82    193.6, 503.20    273.7, 501.65
GR           308.5, 501.37   1010.9, 500.90   1020.9, 508.00
*
*           The approach section below was surveyed 176 feet upstream of
*           the bridge but placed at 148 feet upstream (1 bridge width)
*           instead of templating due to no bed elevation change between 176
*           and 148 feet upstream. Like the roadway section, the section was
*           truncated on the left flood plain assuming the area removed is
*           ineffective flow area.
*
AS   APPRO    148
GR         -4700.0, 508.00  -4600.0, 497.12   -872.2, 497.12   -230.1, 497.12
GR          -100.0, 499.56    -19.2, 499.67      0.0, 498.61      8.7, 494.52
GR             9.3, 492.76     32.0, 482.72     67.4, 479.97     91.9, 483.12
GR           106.1, 491.50    108.6, 494.92    120.3, 498.46    395.1, 498.69
GR           606.5, 498.31   1000.9, 498.31   1020.9, 508.03
*
*              -100.0, 499.56    -19.2, 499.67
*             -5600.0, 508.00  -5500.0, 497.12
N                0.070  0.035   0.040
SA                  0.0    120.3
*
HP 1 BRIDG 499.61 1 499.61
HP 2 BRIDG 499.61 * * 931
HP 2 RDWAY 499.51 * * 12269
HP 1 APPRO 499.64 1 499.64
HP 2 APPRO 499.64 * * 13200
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File sali008.1.wsp
        Hydraulic analysis for structure SALITH00010008   Date: 27-JUN-97
        Town Highway 1 Crossing Otter Creek, Salisbury, VT                JRD
           *** RUN DATE & TIME: 05-14-98  13:38

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     1428.  247289.   132.   142.                      26612.
   499.01          1428.  247289.   132.   142.  1.00     0.   133.  26612.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.01     0.0   132.8  1427.6  247289.    3386.   2.37

X STA.         0.0       23.1       28.8       33.6       38.0       42.0
  A(I)            155.2       66.6       61.7       59.9       58.4
  V(I)             1.09       2.54       2.74       2.83       2.90

X STA.        42.0       46.1       50.9       56.1       61.7       67.3
  A(I)             58.4       62.1       64.2       64.7       65.2
  V(I)             2.90       2.73       2.64       2.62       2.60

X STA.        67.3       72.8       78.2       83.1       87.8       92.1
  A(I)             65.2       64.7       62.4       60.9       59.4
  V(I)             2.60       2.62       2.71       2.78       2.85

X STA.        92.1       96.3      100.6      105.2      110.0      132.8
  A(I)             59.0       59.5       61.0       61.5      157.7
  V(I)             2.87       2.85       2.77       2.75       1.07

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.18 -5504.3  -210.7  2513.2   32557.    6814.   2.71

X STA.     -5504.3    -5065.4    -4681.8    -4348.2    -4038.7    -3747.4
  A(I)            159.0      149.8      137.9      134.5      132.2
  V(I)             2.14       2.27       2.47       2.53       2.58

X STA.     -3747.4    -3475.5    -3229.0    -2989.3    -2761.4    -2547.3
  A(I)            128.3      120.5      120.9      118.4      114.3
  V(I)             2.65       2.83       2.82       2.88       2.98

X STA.     -2547.3    -2342.0    -2136.8    -1936.3    -1749.2    -1565.0
  A(I)            112.4      115.1      115.0      109.7      110.2
  V(I)             3.03       2.96       2.96       3.11       3.09

X STA.     -1565.0    -1383.1    -1210.9    -1040.1     -877.0     -210.7
  A(I)            111.0      107.1      108.0      104.9      204.3
  V(I)             3.07       3.18       3.15       3.25       1.67

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     148.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    11730.  412695.  5520.  5520.                      97032.
             2     1574.  354248.   120.   129.                      32302.
             3      742.   24625.   883.   883.                       3862.
   499.28         14046.  791568.  6523.  6532.  7.35 -5520.  1003.  43132.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     148.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.28 -5519.9  1002.9 14046.0  791568.   10200.   0.73

X STA.     -5519.9    -4994.2    -4467.5    -3952.1    -3444.7    -2924.0
  A(I)           1113.9     1137.8     1113.2     1095.9     1124.9
  V(I)             0.46       0.45       0.46       0.47       0.45

X STA.     -2924.0    -2410.1    -1893.6    -1385.3     -864.8     -344.3
  A(I)           1110.1     1115.5     1098.1     1124.2     1124.2
  V(I)             0.46       0.46       0.46       0.45       0.45

X STA.      -344.3       23.1       35.4       44.7       53.0       60.9
  A(I)            731.9      185.7      159.9      149.1      146.4
  V(I)             0.70       2.75       3.19       3.42       3.48

X STA.        60.9       68.2       75.8       83.7       92.5     1002.9
  A(I)            138.4      142.1      140.8      145.5      948.6
  V(I)             3.69       3.59       3.62       3.50       0.54
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File sali008.1.wsp
        Hydraulic analysis for structure SALITH00010008   Date: 27-JUN-97
        Town Highway 1 Crossing Otter Creek, Salisbury, VT                JRD
           *** RUN DATE & TIME: 06-25-98  16:14

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1244.  199115.   132.   140.                      21640.
   497.62         1244.  199115.   132.   140.  1.00     0.   133.  21640.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.62     0.0   132.8  1243.7  199115.    6730.   5.41

X STA.         0.0       24.8       29.9       34.5       38.6       42.4
  A(I)           139.3       54.8       52.9       51.8       50.6
  V(I)            2.42       6.14       6.36       6.50       6.65

X STA.        42.4       46.5       51.1       56.3       62.0       67.4
  A(I)            51.7       53.6       56.2       57.4       56.2
  V(I)            6.51       6.28       5.98       5.86       5.98

X STA.        67.4       73.0       78.1       83.0       87.6       91.7
  A(I)            57.6       55.5       54.7       53.5       51.0
  V(I)            5.85       6.06       6.16       6.29       6.60

X STA.        91.7       95.9       99.9      104.2      108.9      132.8
  A(I)            51.9       51.0       51.8       53.8      138.4
  V(I)            6.48       6.60       6.49       6.25       2.43

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.64     0.0   132.8  1246.4  199784.    6730.   5.40

X STA.         0.0       24.6       30.0       34.5       38.6       42.5
  A(I)           138.4       56.8       53.0       51.9       50.6
  V(I)            2.43       5.92       6.35       6.49       6.65

X STA.        42.5       46.6       51.1       56.3       62.0       67.4
  A(I)            51.6       53.6       56.2       57.4       56.3
  V(I)            6.52       6.28       5.98       5.86       5.98

X STA.        67.4       73.0       78.1       83.0       87.6       91.7
  A(I)            57.7       55.6       54.8       53.6       51.1
  V(I)            5.83       6.05       6.15       6.27       6.59

X STA.        91.7       95.9       99.9      104.2      108.9      132.8
  A(I)            52.0       51.0       51.9       53.9      138.9
  V(I)            6.47       6.59       6.48       6.24       2.42

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     148.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    7868.  212417.  5509.  5509.                      53362.
             2    1490.  323341.   120.   129.                      29752.
             3     135.    1706.   689.   689.                        341.
   498.58         9493.  537465.  6318.  6327.  8.93 -5513.  1001.  22094.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     148.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.58 -5513.4  1001.5  9493.4  537465.    6730.   0.71

X STA.     -5513.4    -4819.7    -4155.7    -3484.3    -2824.1    -2131.3
  A(I)          1003.1      969.3      980.3      963.8     1011.5
  V(I)            0.34       0.35       0.34       0.35       0.33

X STA.     -2131.3    -1470.8     -787.7       22.1       30.9       36.6
  A(I)           964.4      997.2     1110.0      118.6       90.3
  V(I)            0.35       0.34       0.30       2.84       3.72

X STA.        36.6       42.6       48.9       55.0       60.6       66.0
  A(I)            98.5      107.9      105.1      100.6       98.8
  V(I)            3.42       3.12       3.20       3.35       3.40

X STA.        66.0       71.3       76.8       82.5       88.7     1001.5
  A(I)            97.4       97.6       97.8       99.3      381.9
  V(I)            3.46       3.45       3.44       3.39       0.88
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File sali008.1.wsp
        Hydraulic analysis for structure SALITH00010008   Date: 27-JUN-97
        Town Highway 1 Crossing Otter Creek, Salisbury, VT                JRD
           *** RUN DATE & TIME: 05-14-98  13:38

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1242.  198781.   132.   140.                       21605.
   497.61         1242.  198781.   132.   140.  1.00     0.   133.  21605.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.61     0.0   132.8  1242.4  198781.    6730.   5.42

X STA.         0.0        24.8        29.9        34.5        38.6        42.4
  A(I)           139.1        54.8        52.9        51.8        50.6
  V(I)            2.42        6.14        6.36        6.50        6.66

X STA.        42.4        46.5        51.1        56.4        61.9        67.5
  A(I)            51.6        53.6        56.2        56.5        57.1
  V(I)            6.52        6.28        5.99        5.96        5.89

X STA.        67.5        73.0        78.1        83.0        87.5        91.8
  A(I)            57.3        55.2        54.4        53.3        52.2
  V(I)            5.87        6.09        6.19        6.32        6.45

X STA.        91.8        95.8        99.8       104.3       108.8       132.8
  A(I)            50.3        50.8        53.6        51.8       139.5
  V(I)            6.69        6.63        6.28        6.50        2.41

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.63     0.0   132.8  1245.1  199449.    6730.   5.41

X STA.         0.0        24.8        29.9        34.5        38.6        42.4
  A(I)           139.5        54.9        52.9        51.8        50.6
  V(I)            2.41        6.13        6.36        6.49        6.65

X STA.        42.4        46.5        51.1        56.3        62.0        67.4
  A(I)            51.7        53.7        56.3        57.5        56.3
  V(I)            6.51        6.27        5.98        5.86        5.98

X STA.        67.4        73.0        78.1        83.0        87.6        91.7
  A(I)            57.6        55.6        54.7        53.6        51.0
  V(I)            5.84        6.06        6.15        6.28        6.59

X STA.        91.7        95.9        99.9       104.2       108.9       132.8
  A(I)            52.0        51.0        51.9        53.9       138.7
  V(I)            6.47        6.60        6.49        6.25        2.43

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     148.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    7868.  212417.  5509.  5509.                       53362.
             2    1490.  323341.   120.   129.                       29752.
             3     135.    1706.   689.   689.                         341.
   498.58         9493.  537465.  6318.  6327.  8.93 -5513.  1001.  22094.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     148.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.58 -5513.4  1001.5  9493.4  537465.    6730.   0.71

X STA.     -5513.4     -4819.7     -4155.7     -3484.3     -2824.1     -2131.3
  A(I)          1003.1       969.3       980.3       963.8      1011.5
  V(I)            0.34        0.35        0.34        0.35        0.33

X STA.     -2131.3     -1470.8      -787.7        22.1        30.9        36.6
  A(I)           964.4       997.2      1110.0       118.6        90.3
  V(I)            0.35        0.34        0.30        2.84        3.72

X STA.        36.6        42.6        48.9        55.0        60.6        66.0
  A(I)            98.5       107.9       105.1       100.6        98.8
  V(I)            3.42        3.12        3.20        3.35        3.40

X STA.        66.0        71.3        76.8        82.5        88.7      1001.5
  A(I)            97.4        97.6        97.8        99.3       381.9
  V(I)            3.46        3.45        3.44        3.39        0.88
```

WSPRO OUTPUT FILE (continued)

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File sali008.1.wsp
        Hydraulic analysis for structure SALITH00010008   Date: 27-JUN-97
        Town Highway 1 Crossing Otter Creek, Salisbury, VT                JRD
           *** RUN DATE & TIME: 05-14-98  13:38

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

EXITX:XS   ****** -5512.    8563.  0.20 *****  499.03  488.28  10200.  498.83
     -140. ******  1002.  569814.  8.95 ***** *******    0.54    1.19

FULLV:FV     140. -5512.    8946.  0.18  0.04  499.07 *******  10200.  498.89
        0.   140.  1002.  587304.  9.03  0.00    0.00    0.51    1.14
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     148. -5517.   12268.  0.09  0.04  499.09 *******  10200.  499.01
      148.   148.  1002.  683272.  8.11  0.00   -0.02    0.30    0.83
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   500.71       0.00     498.65     498.53

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =     6814.      3434.    1.98

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

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

BRIDG:BR     140.     0.    1428.  0.21  0.05  499.22  489.73   3386.  499.01
        0.   140.   133.  247455.  2.36  0.15    0.00    0.20    2.37

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   4.  0.651  0.019  501.72 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.   135.  0.02  0.06  499.31    0.00   6814.  499.18

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   6814.  5294. -5504.  -211.   0.7   0.5   3.2   2.7   0.6   2.7
   RT:      0.   783.   230.  1013.   1.6   1.3   6.4   6.9   2.1   3.0

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

APPRO:AS     132. -5520.   14047.  0.06  0.12  499.34  490.55  10200.  499.28
      148.   495.  1003.  791619.  7.35  0.00    0.00    0.24    0.73

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.980  0.597  318734.   -45.    88. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -140. -5512.  1002.  10200.  569814.    8563.    1.19  498.83
   FULLV:FV       0. -5512.  1002.  10200.  587304.    8946.    1.14  498.89
   BRIDG:BR       0.     0.   133.   3386.  247455.    1428.    2.37  499.01
   RDWAY:RG       8.*******  6814.   6814.*********       0.    2.00  499.18
   APPRO:AS     148. -5520.  1003.  10200.  791619.   14047.    0.73  499.28

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -45.    88.  318734.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    488.28    0.54  478.38  508.03************  0.20  499.03  498.83
   FULLV:FV  ********    0.51  478.38  508.03  0.04  0.00  0.18  499.07  498.89
   BRIDG:BR    489.73    0.20  484.17  501.79  0.05  0.15  0.21  499.22  499.01
   RDWAY:RG  ****************  498.53  508.00  0.02******  0.06  499.31  499.18
   APPRO:AS    490.55    0.24  479.97  508.03  0.12  0.00  0.06  499.34  499.28
```

WSPRO OUTPUT FILE (continued)

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File sali008.2.wsp
        Hydraulic analysis for structure SALITH00010008   Date: 27-JUN-97
        Town Highway 1 Crossing Otter Creek, Salisbury, VT                JRD
           *** RUN DATE & TIME: 05-14-98  13:38

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

EXITX:XS   ****** -5517.   11879.  0.17 *****  499.52  489.83  13200.  499.35
     -140. ******  1003.  737543.  8.79 ***** *******    0.43    1.11

FULLV:FV     140. -5517.   12231.  0.16  0.04  499.56 *******  13200.  499.40
        0.   140.  1003.  757599.  8.70  0.00    0.00    0.41    1.08
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     148. -4622.   13061.  0.11  0.04  499.59 *******  13200.  499.49
      148.   148.  1003.  792767.  6.65  0.00   -0.01    0.30    1.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   502.16       0.00     499.11     498.53

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =    12269.      5615.    2.19

            <<<<<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     140.     0.    1507.  0.01  0.04  499.63  487.63    931.  499.61
        0.   140.   133.  269224.  2.51  0.07   -0.02    0.05    0.62

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   4.  0.631  0.019  501.72 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.   135.  0.03  0.09  499.70    0.00  12269.  499.51

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:  12269.  4422. -4608.  -186.   1.0   0.8   4.2   3.5   1.0   2.8
   RT:      0.   783.   230.  1013.   1.6   1.3   6.4   6.9   2.1   3.0

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

APPRO:AS     132. -4623.   13897.  0.09  0.10  499.73  492.06  13200.  499.64
      148.   462.  1004.  847936.  6.40  0.00   -0.01    0.27    0.95

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.976  0.649  298663.    -52.    81. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -140. -5517.  1003.  13200.  737543.   11879.    1.11  499.35
   FULLV:FV       0. -5517.  1003.  13200.  757599.   12231.    1.08  499.40
   BRIDG:BR       0.     0.   133.    931.  269224.    1507.    0.62  499.61
   RDWAY:RG       8.******* 12269.  12269.       0.       0.    2.00  499.51
   APPRO:AS     148. -4623.  1004.  13200.  847936.   13897.    0.95  499.64

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -52.    81.  298663.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    489.83    0.43  478.38  508.03************  0.17  499.52  499.35
   FULLV:FV  ********    0.41  478.38  508.03  0.04  0.00  0.16  499.56  499.40
   BRIDG:BR    487.63    0.05  484.17  501.79  0.04  0.07  0.01  499.63  499.61
   RDWAY:RG  ****************  498.53  508.00  0.03******  0.09  499.70  499.51
   APPRO:AS    492.06    0.27  479.97  508.03  0.10  0.00  0.09  499.73  499.64
```

WSPRO OUTPUT FILE (continued)

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File sali008.1.wsp
        Hydraulic analysis for structure SALITH00010008   Date: 27-JUN-97
        Town Highway 1 Crossing Otter Creek, Salisbury, VT                JRD
           *** RUN DATE & TIME: 05-14-98  13:38

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

EXITX:XS   ****** -5502.    2590.  0.26 *****  498.07  486.22   6730.  497.81
     -140. ******   114.  376071.  2.46 ***** *******    1.05    2.60

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.97     497.87     486.22

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   497.31     508.03    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   497.31     508.03     486.22

FULLV:FV     140. -5502.    2945.  0.25  0.04  498.12  486.22   6730.  497.87
        0.   140.   114.  381842.  3.04  0.00    0.01    0.97    2.29
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     148. -5508.    6100.  0.16  0.04  498.16 *******   6730.  498.00
      148.   148.   119.  393645.  8.46  0.00   -0.01    0.54    1.10
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.58       0.00     497.62     498.53

 ===260 ATTEMPTING FLOW CLASS 4 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     140.     0.    1243.  0.87  0.08  498.49  491.67   6730.  497.62
        0.   140.   133.  199013.  1.91  0.33    0.00    0.43    5.41

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   4.  0.724  0.018  501.72 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<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     132. -5513.    9514.  0.07  0.15  498.65  488.50   6730.  498.58
      148.   351.  1001.  538428.  8.93  0.02    0.01    0.30    0.71

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.976  0.384  330529.   -17.   115. ********

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -140. -5502.   114.   6730.  376071.    2590.    2.60  497.81
   FULLV:FV       0. -5502.   114.   6730.  381842.    2945.    2.29  497.87
   BRIDG:BR       0.     0.   133.   6730.  199013.    1243.    5.41  497.62
   RDWAY:RG       8.**************      0.       0.       0.    2.00********
   APPRO:AS     148. -5513.  1001.   6730.  538428.    9514.    0.71  498.58

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -17.   115.  330529.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    486.22    1.05  478.38  508.03************  0.26  498.07  497.81
   FULLV:FV    486.22    0.97  478.38  508.03  0.04  0.00  0.25  498.12  497.87
   BRIDG:BR    491.67    0.43  484.17  501.79  0.08  0.33  0.87  498.49  497.62
   RDWAY:RG  ****************  498.53  508.00  0.02******  0.07  498.62********
   APPRO:AS    488.50    0.30  479.97  508.03  0.15  0.02  0.07  498.65  498.58
```

APPENDIX C:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SALITH00010008

General Location Descriptive

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

Date *(MM/DD/YY)* 12 / 15 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 62575

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

Waterway *(I - 6)* OTTER CREEK

Road Name *(I - 7):* -

Route Number C2001

Vicinity *(I - 9)* 0.7 MI TO JCT W CL3 TH14

Topographic Map Cornwall

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 43552

Longitude *(i - 17; nnnnn.n)* 73105

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011700080117

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

Maximum span length *(I - 48; nnnn)* 0071

Year built *(I - 27; YYYY)* 1865

Structure length *(I - 49; nnnnnn)* 000156

Average daily traffic, ADT *(I - 29; nnnnnn)* 000500

Deck Width *(I - 52; nn.n)* 130

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

Channel & Protection *(I - 61; n)* 6

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

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

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

Underwater Inspection Frequency *(I - 92B; XYY)* Y24

Structure type *(I - 43; nnn)* 710

Year Reconstructed *(I - 106)* 1966

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

Clear span (*nnn.n ft*) 132.4

Number of spans *(I - 45; nnn)* 002

Vertical clearance from streambed (*nnn.n ft*) 16

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

Waterway of full opening (*nnn.n* ft^2) 1810

Comments:

According to the structural inspection report dated 12/8/94, the structure is a wooden lattice work thru-truss covered bridge. The LABUT and its backwall are concrete. They have minor cracks and spalls. The RABUT is grouted laid up stone with a concrete backwall and concrete pads under the bearing areas. The back-wall has a few cracks and spalls overall. The pier is a solid concrete column. The bearing blocks and bearing beams under the bottom chord, on top of the pier, were originally creosote coated, except for a couple of blocks on the right side. Both abutments have small earth embankments in front of them, with a few boulders showing. Some possible local scour is noted around the pier.

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 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)* 542.69 mi^2 Lake/pond/swamp area 23.24 mi^2

Watershed storage *(ST)* 4.28 %

Bridge site elevation 340 ft   Headwater elevation 3051 ft

Main channel length 73.26 mi

10% channel length elevation 350 ft   85% channel length elevation 659 ft

Main channel slope *(S)* 5.62 ft / mi

Watershed Precipitation Data

Average site precipitation - in   Average headwater precipitation - in

Maximum 2yr-24hr precipitation event *(I24,2)* - in

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:

Ther are no elevations noted on the plans.

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

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

If 1: Footing Thickness - Footing bottom elevation: -

If 2: Pile Type: 2 (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: 140

If 3: Footing bottom elevation: ______

Is boring information available? Y *If no, type ctrl-n bi* Number of borings taken: 3

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

Briefly describe material at foundation bottom elevation or around piles:

Very soft clay for material around the piles at the pier.

Comments:

***Five piles were driven at the pier. There is a 2-foot thick footing on the LABUT and no footing on the RABUT.**

Cross-sectional Data

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

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

Comments: **There is no cross section information available.**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX D:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **9/27/96**

Computerized by: **EW** Date: **9/27/96**

Reviewd by: **EMB** Date: **2/27/98**

Structure Number **SALITH00010008**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. MEDALIE** Date *(MM/DD/YY)* **06** / **12** / 19**96**

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

County **ADDISON (001)** Town **SALISBURY (62575)**

Waterway *(I - 6)* **OTTER CREEK** Road Name **-**

Route Number **TH 1** Hydrologic Unit Code: **02010002**

3. Descriptive comments:

This structure is a covered bridge located 0.7 mile from the junction of TH 1 with TH14. A local resident mentioned that this road (Town Highway 1) has been overtopped 5 or 6 times by streamflows since August of 1995. The left road approach is gravel fill and has been washed out at least once during high flows.

B. Bridge Deck Observations

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

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

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

7. Bridge length **156** *(feet)* Span length **71** *(feet)* Bridge width **13** *(feet)*

Road approach to bridge:

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

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

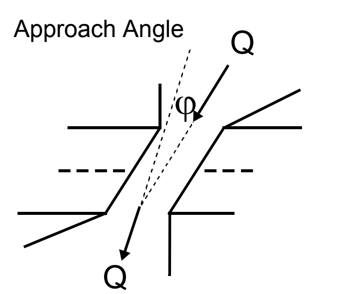
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

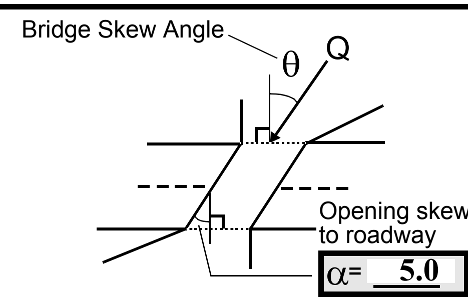
	Protection 11.Type	Protection 12.Cond.	13.Erosion	14.Severity
LBUS	0	-	2	1
RBUS	1	1	2	1
RBDS	0	-	2	1
LBDS	2	1	2	1

*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: **10** 16. Bridge skew: **20**





α= **5.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **75** feet **DS** *(US, UB, DS)* to **175** feet **DS**

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

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

18. Bridge Type: **1b**

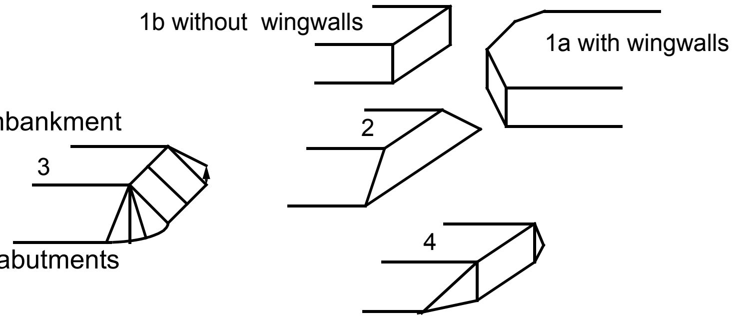
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4: The left overbank downstream is a wet, low lying area near the river approximately 100 feet wide with pasture beyond 100 feet from the river. The area near the bridge on the left bank upstream is an 80 square foot dirt parking lot with wetland further toward the left side of the valley. All of the overbank areas are saturated with water, but classified as pasture because vegetation is grass.

7: The bridge length, span length, and bridge width measured at the time of this assessment were 153.5 feet, 65 feet, and 15.1 feet, respectively. The length of the span was measured between the pier and the left abutment and the width was measured from the outside edges of the horizontal planks.

11: The LBDS protection is a single boulder, in which RM2 is chiseled, placed at the end of the bridge beneath the road surface. The road is built-up with stone fill. The stone fill extends 2 to 4 feet along the road edges on either side.

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
148.5	**4.0**			**3.5**	**3**	**1**	**01**	**01**	**2**	**2**

23. Bank width **25.0** 24. Channel width **15.0** 25. Thalweg depth **120.5** 29. Bed Material **01**

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.):

26: A few large trees are observed along the left bank.

Water depths vary from the approach to the upstream end of the debris pile:

At 8 feet from left bank, the water depth changes from 7 feet to 12 feet.

At 8 feet from right bank, the water depth changes from 11 feet to 13 feet.

A culvert drainage channel for run-off from the parking area enters the left bank of the channel from 23 feet to 29 feet upstream of bridge. The culvert is located 75 feet from the left bank of channel.

A boat launch exists along the upstream left bank from 75 feet to 55 feet from bridge.

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? N (Y or if N type ctrl-n cb) 40. Where? - (LB or RB)

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

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

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

NO CUT BANKS

Channel is straight for approximately 2000 feet upstream.

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
100.0		15.0		2	7	7	-

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

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

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

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

312

A few stones have been placed along the left bank.

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

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

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

70. Debris and Ice Comments:

3

A large debris pile exists across the entire channel width, just upstream of bridge. Debris also is caught in branches 3 to 4 feet above the road (as a result of weir flow). Debris is caught in trees along the banks about 4 to 5 feet above the water surface.

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	**The**	**trees**	**all**	**have**	**visi-**	**ble**	**scars**	**90.0**
RABUT	**abou**	**t 9**	**feet**			**abov**	**e the**	**-**

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

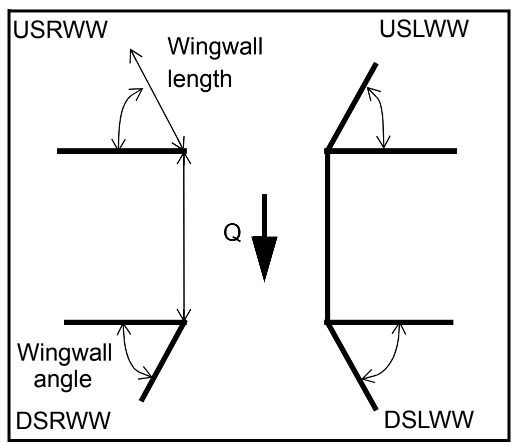
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

channel bed, or 5 feet above the present water surface.

0
70
0
0
0
-
-
1
0
90

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	**0**		**0**		**-**	**-**	
USRWW:	**-**		**2**		**73:**	**9.5**	
DSLWW:	**Abut**		**ment**		**s rest**	**17.5**	
DSRWW:	**on**		**the**		**top**	**14.0**	



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	**of**	**ks.**	**left**	**t is**	**e**	**righ**	**men**	**e**
Condition	**the**	**77:**	**abut**	**con-**	**and**	**t**	**t is**	**mas**
Extent	**ban**	**The**	**men**	**cret**	**the**	**abut**	**ston**	**onr**

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

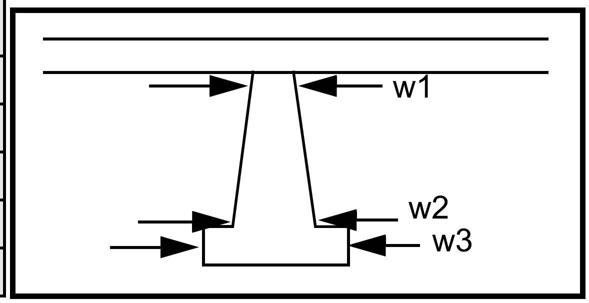
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
y, capped with concrete.

N
-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	**1.0**	**3.0**	-	**487.3**	**491.6**
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

of two groups of stones about 5 feet apart, each extending about 4 feet across the bank and 2 feet down.

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
-	-			-	Y	MC	M	1	2	3

Bank width (BF) - Channel width 17.8 Thalweg depth - Bed Material N

Bank protection type (Qmax): LB 30 RB - Bank protection condition: LB 5 RB 0

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.):

0
-
-

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

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

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

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

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

Material: _____

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

Is a cut-bank present? _____ *(Y or if N type ctrl-n cb)* Where? _____ *(LB or RB)* Mid-bank distance: **94:**

Cut bank extent: **Data** feet **fro** *(US, UB, DS)* to **m** feet **his-** *(US, UB, DS)*

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

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

cal form.

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

Scour dimensions: Length ______ Width ______ Depth: _____ Positioned ____ %LB to **3** %RB

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

3
01
01
2

Are there major confluences? **2** *(Y or if N type ctrl-n mc)* How many? **102**

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

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

Confluence comments (eg. confluence name):

feet from left bank, the water depth changes from 10 feet to 13 feet to 16 feet between the downstream bridge face and 100 feet downstream. At 10 feet from right bank, the water depth changes from 10 feet to 12 feet to 8

F. Geomorphic Channel Assessment

107. Stage of reach evolution **fee**

***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)*:

t over the same 100 feet downstream from the downstream bridge face. At the center of the channel the water depth measured varied from 10 feet to greater than 16 feet from the downstream bridge face to 100 feet downstream.

109. G. Plan View Sketch

N

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 E:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: SALITH00010008 Town: Salisbury
Road Number: TH 1 County: Addison
Stream: Otter Creek

Initials EMB Date: 4/30/98 Checked: RLB

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

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

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	10200	13200	6730
Main Channel Area, ft2	1574	1617	1490
Left overbank area, ft2	11730	11223	7868
Right overbank area, ft2	742	1060	135
Top width main channel, ft	120	120	120
Top width L overbank, ft	5520	4601	5509
Top width R overbank, ft	883	883	689
D50 of channel, ft	0.000102	0.000102	0.000102
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	13.1	13.5	12.4
y1, average depth, LOB, ft	2.1	2.4	1.4
y1, average depth, ROB, ft	0.8	1.2	0.2
Total conveyance, approach	791568	848088	537465
Conveyance, main channel	354248	370644	323341
Conveyance, LOB	412695	432864	212417
Conveyance, ROB	24625	44581	1706
Percent discrepancy, conveyance	0.0000	-0.0001	0.0002
Qm, discharge, MC, cfs	4564.8	5768.9	4048.8
Ql, discharge, LOB, cfs	5317.9	6737.3	2659.8
Qr, discharge, ROB, cfs	317.3	693.9	21.4
Vm, mean velocity MC, ft/s	2.9	3.6	2.7
Vl, mean velocity, LOB, ft/s	0.5	0.6	0.3
Vr, mean velocity, ROB, ft/s	0.4	0.7	0.2
Vc-m, crit. velocity, MC, ft/s	0.8	0.8	0.8
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and Davis, 1995, p. 30, eq. 17 and 18)

Characteristic	Approach 100 yr	500 yr	Other Q	Bridge 100 yr	500 yr	Other Q
Q1, discharge, cfs	10200	13200	6730	3386	931	6730
Total conveyance	791568	848088	537465	247289	269116	198781
Main channel conveyance	354248	370644	323341	247289	269116	198781
Main channel discharge	4565	5769	4049	3386	931	6730
Area - main channel, ft2	1574	1617	1490	1401	1479	1220
(W1) channel width, ft	120	120	120	132.3	132.3	132.3
(Wp) cumulative pier width, ft	0	0	0	3	3	3
W1, adjusted bottom width(ft)	120	120	120	129.3	129.3	129.3
D50, ft	0.000102	0.000102	0.000102			
w, fall velocity, ft/s (p. 32)	0.0033	0.0033	0.0033			
y, ave. depth flow, ft	13.12	13.48	12.42	10.84	11.44	9.44
S1, slope EGL	0.00014	0.0002	0.00027			
P, wetted perimeter, MC, ft	129	129	129			
R, hydraulic Radius, ft	12.202	12.535	11.550			
V*, shear velocity, ft/s	0.235	0.284	0.317			
V*/w	71.070	86.097	96.027			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.69	0.69	0.69			
y2,depth in contraction, ft	9.64	2.68	18.23			
ys, scour depth, ft (y2-y_bridge)	-1.19	-8.76	8.80			

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 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	10200	13200	6730	10200	13200	6730
a', abut.length blocking flow, ft	5519.9	4623.2	5513.4	870.6	871.4	869.2
Ae, area of blocked flow ft2	9330.5	7873.3	7969.3	907.1	1181.1	363.7
Qe, discharge blocked abut.,cfs	--	--	2682.8	487.7	997.9	320.4
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	0.47	0.63	0.34	0.54	0.84	0.88
ya, depth of f/p flow, ft	1.69	1.70	1.45	1.04	1.36	0.42
--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	85	85	85	95	95	95
K2	0.99	0.99	0.99	1.01	1.01	1.01
Fr, froude number f/p flow	0.057	0.071	0.049	0.093	0.128	0.240
ys, scour depth, ft	23.21	24.60	19.46	11.13	15.61	11.11

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

a'(abut length blocked, ft)	5519.9	4623.2	5513.4	870.6	871.4	869.2
y1 (depth f/p flow, ft)	1.69	1.70	1.45	1.04	1.36	0.42
a'/y1	3265.56	2714.74	3814.33	835.57	642.91	2077.29
Skew correction (p. 49, fig. 16)	0.98	0.98	0.98	1.01	1.01	1.01
Froude no. f/p flow	0.06	0.07	0.05	0.09	0.13	0.24
Ys w/ corr. factor K1/0.55:						
vertical	4.68	5.07	3.82	3.49	5.05	1.92
vertical w/ ww's	3.84	4.16	3.13	2.86	4.14	1.57
spill-through	2.57	2.79	2.10	1.92	2.78	1.06

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.2	0.05	0.43	0.2	0.05	0.43
y, depth of flow in bridge, ft	10.84	11.44	9.44	10.84	11.44	9.44
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	0.27	0.02	1.08	0.27	0.02	1.08
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR

Pier Scour

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

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

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

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

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)

V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

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

Pier 1	Q100	Q500	Qother
Pier stationing, ft	67	67	67
Area of WSPRO flow tube, ft2	58.4	61.2	50.6
Skewed width of flow tube, ft	4	4	3.8
y1, pier approach depth, ft	14.60	15.30	13.32
y1 in meters	4.450	4.663	4.058
V1, pier approach velocity, ft/s	2.9	0.76	6.65
a, pier width, ft	3	3	3
L, pier length, ft	17.8	17.8	17.8
Fr1, Froude number at pier	0.134	0.034	0.321
Pier attack angle, degrees	30	30	30
K1, shape factor	0.9	0.9	0.9
K2, attack factor	2.39	2.39	2.39
K3, bed condition factor	1.1	1.1	1.1
D50, ft	0.000102	0.000102	0.000102
D50, m	0.000031	0.000031	0.000031
D90, ft	0	0	0
D90, m	0	0	0
Vc50,critical velocity(D50),m/s	0.250	0.252	0.246
Vc90,critical velocity(D90),m/s	0.000	0.000	0.000
Vi,incipient velocity,m/s	0.093	0.094	0.092
Vr, velocity ratio	-8.471	-1.463	-21.053
K4, armor factor	0.70	0.70	0.70
ys, scour depth (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth (K4 not applied)ft	10.42	5.90	14.71

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

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

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	1.5
V, velocity on pier, ft/s	3.304	1.008	7.7
D50, median stone diameter, ft	0.16	0.01	0.87