LEVEL II SCOUR ANALYSIS FOR BRIDGE 5 (STOCTH00360005) on TOWN HIGHWAY 36, crossing STONY BROOK, STOCKBRIDGE, VERMONT

Open-File Report 98-XXX

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

USGS
science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 5 (STOCTH00360005) on TOWN HIGHWAY 36, crossing STONY BROOK, STOCKBRIDGE, VERMONT

By LORA K. STRIKER AND MATTHEW A. WEBER

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

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 5 (STOCTH00360005) ON TOWN HIGHWAY 36, CROSSING STONY BROOK, STOCKBRIDGE, VERMONT

By **Lora K. Striker and Matthew A. Weber**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure STOCTH00360005 on Town Highway 36 crossing Stony Brook, Stockbridge, 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 central Vermont. The 23.0-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest on the left and right banks downstream and left bank upstream, while the right bank upstream is pasture with some shrubs and brush.

In the study area, Stony Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 109 ft and an average bank height of 11 ft. The channel bed material is predominantly gravel with a median grain size (D_{50}) of 71.7 mm (0.235 ft). The geomorphic assessment at the time of the Level I site visit on April 12, 1995, and Level II site visit on July 9, 1996, indicated that the reach was stable.

The Town Highway 36 crossing of Stony Brook is a 50-ft-long, one-lane bridge consisting of one 48-foot steel-beam span (Vermont Agency of Transportation, written communication, March 23, 1995). The opening length of the structure parallel to the bridge face is 46.3 ft. The bridge is supported by a vertical, concrete abutment on the left and a vertical, concrete abutment with wingwalls on the right. The channel is skewed approximately 5 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

A scour hole 2.0 ft deeper than the mean thalweg depth was observed during the Level I assessment along the left side of the channel at the downstream bridge face where the flow impacts a bedrock outcrop. Scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the right bank upstream and at the upstream and downstream ends of the left abutment, type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream right wingwall, and type-3 stone fill (less than 48 inches diameter) at the downstream end of the downstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. 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 2.0 to 3.2 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 9.7 to 22.2 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.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 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.

Bethel, VT. Quadrangle, 1:24,000, 1980

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 STOCTH00360005 ***Stream*** Stony Brook

County Windsor ***Road*** TH36 ***District*** 4

Description of Bridge

Bridge length 50 ***ft*** ***Bridge width*** 18.0 ***ft*** ***Max span length*** 48 ***ft***

Alignment of bridge to road (on curve or straight) Curve, left; Straight, right

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

Stone fill on abutment? Yes ***Date of inspection*** 04/12/95

Description of stone fill Type-1, at the upstream and downstream ends of the left abutment. Type-2, at the upstream end of the upstream right wingwall. Type-3, at the downstream end of the downstream right wingwall.

Brief description of piers/abutments The left abutment, the right abutment, and the right upstream and downstream wingwalls are concrete.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 5

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

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	04/12/95	0	0
Level II	07/09/96	0	0

Potential for debris Moderate. The upstream banks are heavily vegetated and are unstable beyond 200 ft upstream.

Describe any features near or at the bridge that may affect flow (include observation date) A large bedrock outcrop on the left bank at the downstream bridge face causes eddy currents which have resulted in a 2.0 ft scour hole, 04/12/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a narrow flood plain.

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

Date of inspection 04/12/95

DS left: Moderately sloping overbank to narrow flood plain

DS right: Moderately sloping overbank

US left: Steep channel bank to an irregular overbank

US right: Steep channel bank to a narrow flood plain

Description of the Channel

Average top width 109 ***ft*** ***Average depth*** 11 ***ft***

Predominant bed material Gravel ***Bank material*** Gravel

Sinuous but stable with semi-alluvial channel boundaries, local anabranching, random variation in width, and irregular point and lateral bars.

04/12/95

Vegetative cov Trees and brush

DS left: Trees and brush

DS right: Trees and brush

US left: Trees along the immediate banks with a pasture overbank

US right:

Do banks appear stable? Yes

date of observation.

The assessment of 04/12/95 noted that flow conditions are influenced by a bedrock outcrop on the left bank downstream.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 23.0 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p _ No

-

Calculated Discharges

Q100 4,260 ***ft³/s*** ***Q500*** 5,750 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(23.0/23.3)exp 0.67] with bridge number 9 in Stockbridge. Bridge number 9 crosses Stony Brook downstream of this site and has flood frequency estimates available from the VTAOT database (written communication, May 1995). The drainage area above bridge number 9 is 23.3 square miles. These discharges are within a range defined by several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887) Each curve was extended graphically to the 500-year event.

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

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

Datum tie between USGS survey and VTAOT plans None.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the curb at the downstream left corner of the bridge deck (elev. 500.80 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the right abutment (elev. 499.92 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	-46	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	64	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 0.055, and overbank "n" values ranged from 0.035 to 0.075.

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 0.0064 ft/ft, which was estimated from points surveyed downstream of the bridge site on July 9, 1996.

The approach section (APPRO) was surveyed 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.

For the 500-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.1 ***ft***
Average low steel elevation 496.4 ***ft***

100-year discharge 4,260 ***ft^3/s***
Water-surface elevation in bridge opening 488.1 ***ft***
Road overtopping? No ***Discharge over road*** 0 ***ft^3/s***
Area of flow in bridge opening 304 ***ft^2***
Average velocity in bridge opening 14.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 18.3 ***ft/s***

Water-surface elevation at Approach section with bridge 491.2
Water-surface elevation at Approach section without bridge 489.8
Amount of backwater caused by bridge 1.4 ***ft***

500-year discharge 5,750 ***ft^3/s***
Water-surface elevation in bridge opening 489.4 ***ft***
Road overtopping? No ***Discharge over road*** 0 ***ft^3/s***
Area of flow in bridge opening 361 ***ft^2***
Average velocity in bridge opening 15.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 21.0 ***ft/s***

Water-surface elevation at Approach section with bridge 493.4
Water-surface elevation at Approach section without bridge 491.2
Amount of backwater caused by bridge 2.2 ***ft***

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 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 for the 100- and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100- and 500-year discharges resulted in free surface flow. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.0	3.2	--
Depth to armoring	35.5	57.3	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	9.7	11.0	--
Right abutment	18.9	22.2	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(D_{50} in feet)		
Abutments:			
Left abutment	2.9	3.3	--
Right abutment	2.9	3.3	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

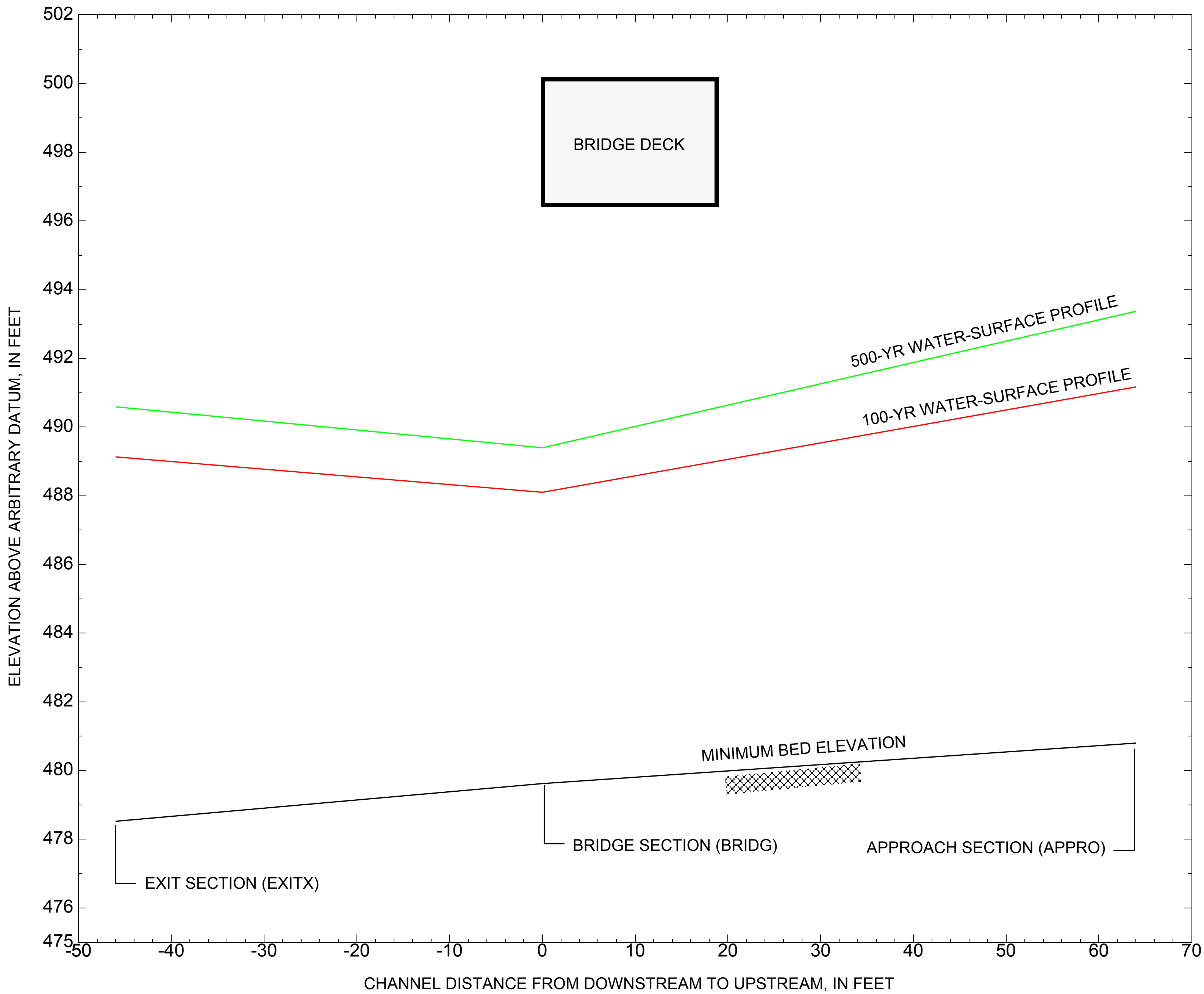


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure STOCTH00360005 on Town Highway 36, crossing Stony Brook, Stockbridge, Vermont.

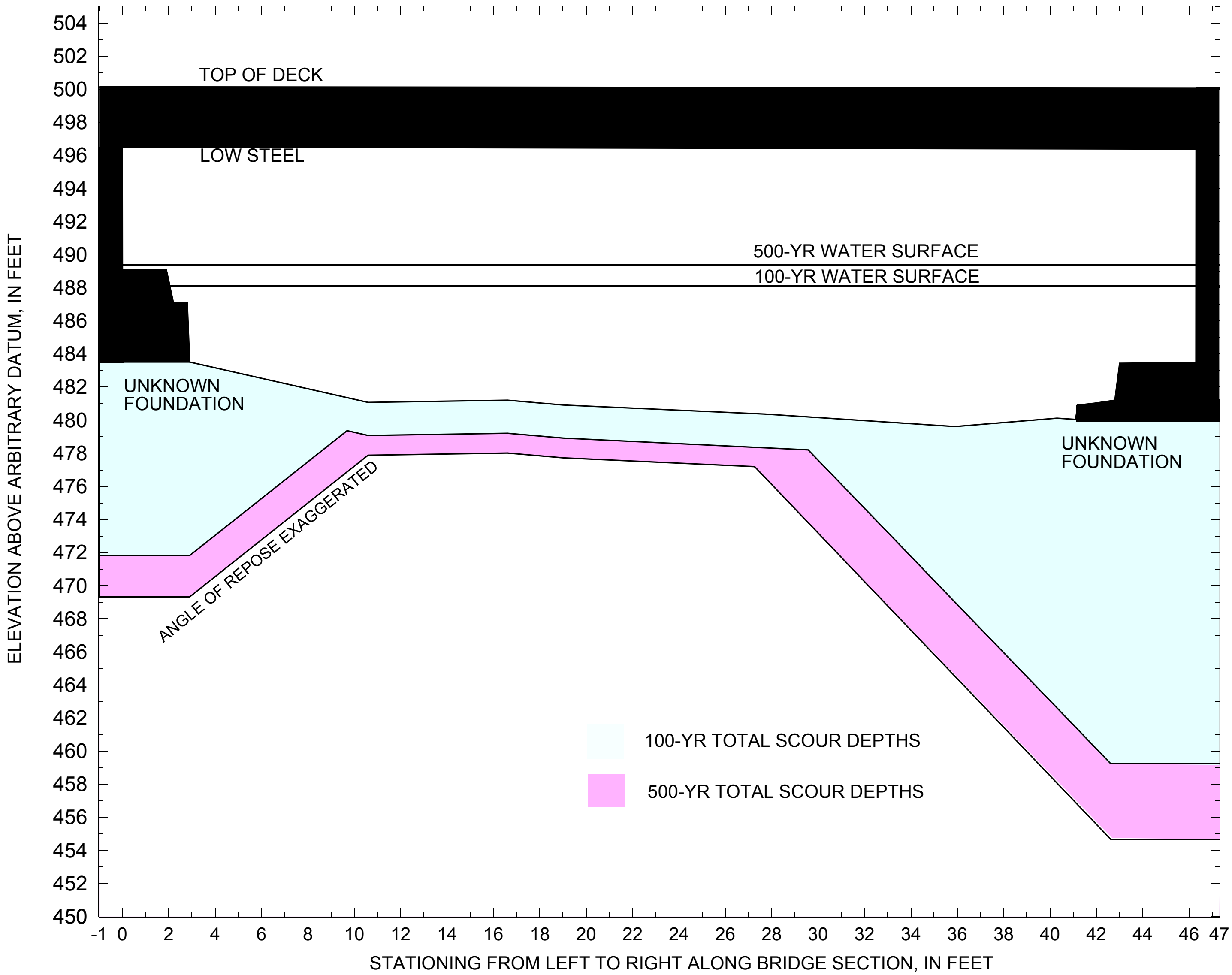


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure STOCTH00360005 on Town Highway 36, crossing Stony Brook, Stockbridge, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure STOCTH00360005 on Town Highway 36, crossing Stony Brook, Stockbridge, 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-yr. discharge is 4,260 cubic-feet per second											
Left abutment	0.0	--	496.5	--	483.5	2.0	9.7	--	11.7	471.8	--
Right abutment	46.3	--	496.4	--	480.0	2.0	18.9	--	20.9	459.1	--

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 STOCTH00360005 on Town Highway 36, crossing Stony Brook, Stockbridge, 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-yr. discharge is 5,750 cubic-feet per second											
Left abutment	0.0	--	496.5	--	483.5	3.2	11.0	--	14.2	469.3	--
Right abutment	46.3	--	496.4	--	480.0	3.2	22.2	--	25.4	454.6	--

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

U.S. Geological Survey, 1980, Bethel, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File stoc005.wsp
T2        Hydraulic analysis for structure STOCTHTH00360005   Date: 30-DEC-97
T3        TH 36 CROSSING STONY BROOK, 0.3 MILES TO JCT WITH VT 107,        LKS
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4260.0   5750.0
SK          0.0064   0.0064
*
XS   EXITX    -46           0.
GR         -184.7, 500.63   -164.9, 497.31   -151.4, 497.12   -121.1, 499.28
GR          -97.8, 498.87    -45.7, 496.26    -36.3, 494.26    -21.5, 491.43
GR            0.0, 484.21     20.2, 480.79     24.1, 480.13     26.1, 479.05
GR           29.5, 478.52     33.5, 479.01     49.9, 480.42     53.4, 480.85
GR           60.4, 481.94     66.4, 485.74     96.3, 492.92    124.3, 493.66
GR          137.6, 501.56    155.6, 502.86    167.9, 508.06
*
N           0.075        0.055        0.055
SA                 -45.7         96.3
*
*
XS   FULLV      0  * * *   0.0171
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.44       0.0
GR            0.0, 496.51      0.2, 489.11      1.9, 489.08      2.2, 487.10
GR            2.8, 487.10      2.9, 483.52     10.6, 481.08     16.6, 481.21
GR           19.0, 480.92     27.7, 480.37     35.9, 479.62     40.3, 480.12
GR           41.1, 480.04     41.2, 480.91     42.0, 481.04     42.8, 481.21
GR           43.0, 483.44     45.5, 483.48     46.3, 496.38      0.0, 496.51
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      23.2 * *     35.1     13.9
N           0.045
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      9      18.0     2
GR         -261.8, 506.80   -216.2, 502.96   -156.8, 501.18    -75.6, 500.55
GR            0.0, 500.14     47.4, 500.08    136.5, 501.48
*
*
AS   APPRO     64           0.
GR         -103.5, 506.16    -81.7, 504.48    -48.7, 499.71    -22.2, 494.46
GR           -3.9, 492.68      0.0, 488.53      8.0, 483.52     20.0, 482.32
GR           23.2, 482.07     35.6, 481.49     43.3, 481.22     49.1, 480.80
GR           53.5, 481.65     54.9, 482.15     63.0, 486.13     74.5, 491.10
GR           86.8, 491.13    134.9, 497.42    149.4, 500.29    189.1, 501.17
GR          211.6, 506.03    224.9, 509.43
*
N           0.065        0.055        0.040        0.035
SA                -3.9          74.5         149.4
*
HP 1 BRIDG  488.10 1 488.10
HP 2 BRIDG  488.10 * * 4260
HP 1 APPRO  491.17 1 491.17
HP 2 APPRO  491.17 * * 4260
*
HP 1 BRIDG  489.40 1 489.40
HP 2 BRIDG  489.40 * * 5750
HP 1 APPRO  493.37 1 493.37
HP 2 APPRO  493.37 * * 5750
```

APPENDIX B:

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File stoc005.wsp
        Hydraulic analysis for structure STOCTHTH00360005   Date: 30-DEC-97
        TH 36 CROSSING STONY BROOK, 0.3 MILES TO JCT WITH VT 107,         LKS
           *** RUN DATE & TIME: 01-05-98  09:16
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     304.   31124.    44.    56.                       4540.
   488.10          304.   31124.    44.    56.  1.00     2.    46.   4540.
1
  HP 2 BRIDG  488.10 * * 4260

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       488.10     2.0    45.8   303.6   31124.    4260.  14.03

 X STA.        2.0        9.2       11.1       13.0       14.9       16.7
   A(I)            35.8       13.1       13.4       12.9       13.0
   V(I)            5.94      16.20      15.87      16.47      16.43

 X STA.       16.7       18.6       20.4       22.2       23.8       25.5
   A(I)            13.0       12.9       13.0       12.6       12.8
   V(I)           16.35      16.50      16.41      16.94      16.70

 X STA.       25.5       27.2       28.9       30.4       31.9       33.4
   A(I)            12.9       12.7       12.4       12.3       12.1
   V(I)           16.54      16.81      17.24      17.34      17.60

 X STA.       33.4       34.9       36.3       37.7       39.2       45.8
   A(I)            12.1       11.7       11.9       12.2       40.9
   V(I)           17.53      18.25      17.90      17.43       5.21

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     566.   55710.    77.    82.                       8712.
             3       1.       4.    13.    13.                          1.
   491.17          567.   55714.    90.    94.  1.00    -2.    87.   8082.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

         WSEL     LEW     REW    AREA        K        Q    VEL
       491.17    -2.5    87.1   566.8   55714.    4260.   7.52

 X STA.       -2.5       10.0       13.3       16.3       19.2       21.9
   A(I)            60.1       26.3       25.1       24.8       23.7
   V(I)            3.54       8.09       8.48       8.58       8.97

 X STA.       21.9       24.6       27.1       29.7       32.2       34.7
   A(I)            24.7       23.4       24.5       23.7       24.0
   V(I)            8.63       9.09       8.70       9.00       8.89

 X STA.       34.7       37.2       39.6       41.9       44.3       46.5
   A(I)            23.5       23.7       23.3       22.9       22.7
   V(I)            9.08       9.00       9.14       9.30       9.37

 X STA.       46.5       48.7       51.0       53.3       56.0       87.1
   A(I)            22.3       23.3       22.7       24.9       77.2
   V(I)            9.54       9.14       9.40       8.56       2.76
```

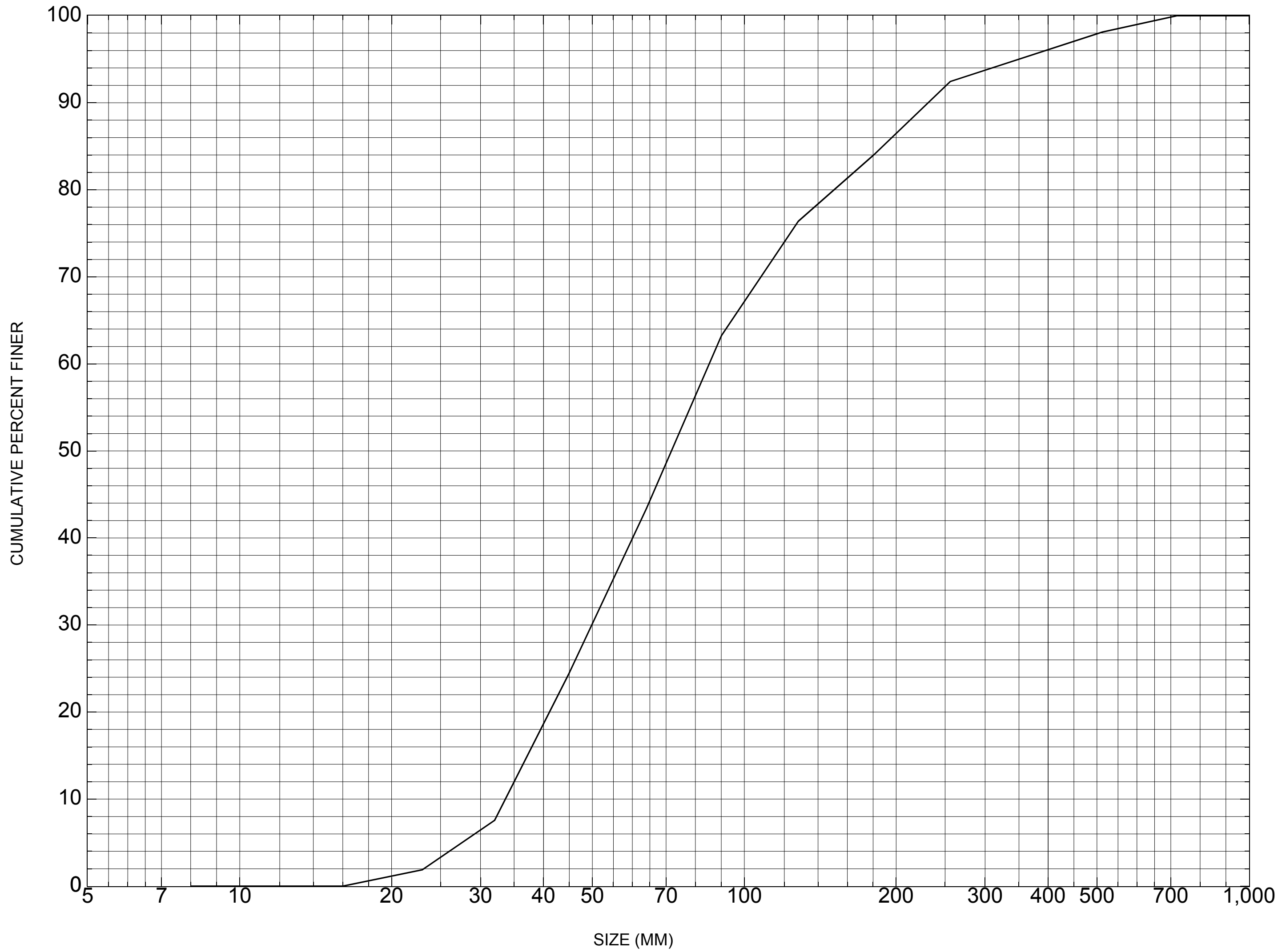
```
        U.S. Geological Survey WSPRO Input File stoc005.wsp
        Hydraulic analysis for structure STOCTHTH00360005   Date: 30-DEC-97
        TH 36 CROSSING STONY BROOK, 0.3 MILES TO JCT WITH VT 107,          LKS
           *** RUN DATE & TIME: 01-05-98  09:16
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     361.  39563.    46.    60.                          5764.
   489.40          361.  39563.    46.    60.  1.00     0.    46.   5764.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       489.40     0.2    45.9   361.2   39563.    5750.  15.92

X STA.         0.2        9.7       11.5       13.3       15.1       16.9
  A(I)            49.9       14.8       15.0       15.0       14.7
  V(I)            5.76      19.46      19.19      19.22      19.58

X STA.        16.9       18.7       20.5       22.2       23.8       25.5
  A(I)            15.2       14.9       14.6       14.6       14.8
  V(I)           18.97      19.25      19.65      19.64      19.40

X STA.        25.5       27.2       28.8       30.4       31.9       33.4
  A(I)            14.7       14.9       14.3       14.5       14.3
  V(I)           19.54      19.29      20.15      19.89      20.05

X STA.        33.4       34.9       36.3       37.7       39.2       45.9
  A(I)            14.1       14.0       13.8       13.7       49.4
  V(I)           20.43      20.58      20.78      21.01       5.82

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       2.      28.     7.     7.                            8.
             2     738.  85139.    78.    84.                         12837.
             3      47.   2378.    29.    30.                           336.
   493.37          787.  87544.   115.   121.  1.05   -11.   104.  11389.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.37   -11.0   103.9   786.9   87544.    5750.   7.31

X STA.       -11.0        9.3       12.7       16.0       19.1       22.0
  A(I)            84.9       35.0       34.3       32.9       32.3
  V(I)            3.39       8.22       8.37       8.73       8.90

X STA.        22.0       24.9       27.7       30.6       33.3       36.0
  A(I)            33.5       31.7       33.1       31.9       32.3
  V(I)            8.58       9.07       8.69       9.00       8.91

X STA.        36.0       38.7       41.4       44.0       46.5       49.0
  A(I)            32.0       32.2       31.7       31.3       31.1
  V(I)            8.99       8.92       9.06       9.18       9.26

X STA.        49.0       51.6       54.3       57.7       62.6      103.9
  A(I)            31.5       32.0       36.1       42.1      104.9
  V(I)            9.13       8.98       7.96       6.82       2.74
```

```
        U.S. Geological Survey WSPRO Input File stoc005.wsp
        Hydraulic analysis for structure STOCTHTH00360005   Date: 30-DEC-97
        TH 36 CROSSING STONY BROOK, 0.3 MILES TO JCT WITH VT 107,         LKS
           *** RUN DATE & TIME: 01-05-98  09:16

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

EXITX:XS   ******   -15.     593.  0.80 *****  489.93  486.23   4260.  489.13
      -46. ******    81.   53248.  1.00 ***** *******    0.51    7.18

FULLV:FV      46.   -13.     543.  0.96  0.33  490.33 *******   4260.  489.38
        0.    46.    78.   47258.  1.00  0.08    0.00    0.57    7.84
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      64.    -1.     462.  1.32  0.59  491.10 *******   4260.  489.78
       64.    64.    71.   41538.  1.00  0.18    0.00    0.64    9.21
         <<<<<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      46.     2.     304.  3.06  0.50  491.16  487.81   4260.  488.10
        0.    46.    46.   31137.  1.00  0.73    0.00    0.94   14.03

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.44 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<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      41.    -2.     567.  0.88  0.46  492.05  487.94   4260.  491.17
       64.    44.    87.   55753.  1.00  0.43    0.01    0.53    7.51

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.371  0.114   49267.    11.    55.  490.90

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -46.   -15.    81.   4260.   53248.     593.    7.18  489.13
   FULLV:FV       0.   -13.    78.   4260.   47258.     543.    7.84  489.38
   BRIDG:BR       0.     2.    46.   4260.   31137.     304.   14.03  488.10
   RDWAY:RG       9.**************       0.******************    2.00********
   APPRO:AS      64.    -2.    87.   4260.   55753.     567.    7.51  491.17

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      11.    55.   49267.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    486.23    0.51  478.52  508.06************  0.80  489.93  489.13
   FULLV:FV  ********    0.57  479.31  508.85  0.33  0.08  0.96  490.33  489.38
   BRIDG:BR    487.81    0.94  479.62  496.51  0.50  0.73  3.06  491.16  488.10
   RDWAY:RG  ****************  500.08  506.80**********************************
   APPRO:AS    487.94    0.53  480.80  509.43  0.46  0.43  0.88  492.05  491.17
```

```
        U.S. Geological Survey WSPRO Input File stoc005.wsp
        Hydraulic analysis for structure STOCTHTH00360005   Date: 30-DEC-97
        TH 36 CROSSING STONY BROOK, 0.3 MILES TO JCT WITH VT 107,         LKS
           *** RUN DATE & TIME: 01-05-98  09:16

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

 EXITX:XS   ******   -19.     740.  0.94 *****  491.53  487.41   5750.  490.59
       -46. ******    87.   71845.  1.00 ***** *******    0.52    7.77

 FULLV:FV      46.   -17.     684.  1.10  0.33  491.94 *******   5750.  490.84
         0.    46.    84.   64562.  1.00  0.08    0.00    0.57    8.41
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS      64.    -2.     567.  1.61  0.59  492.77 *******   5750.  491.17
        64.    64.    87.   55681.  1.00  0.25    0.00    0.71   10.15
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                    SECID "BRIDG"     Q,CRWS =    5750.     489.40

             <<<<<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      46.     0.     361.  3.94 *****  493.34  489.40   5750.  489.40
         0.    46.    46.   39563.  1.00 ***** *******    1.00   15.92

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  1.000 ******  496.44 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG       9.        <<<<<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      41.   -11.     787.  0.87  0.42  494.25  489.15   5750.  493.37
        64.    44.   104.   87616.  1.05  0.49    0.01    0.50    7.30

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.489  0.171   72533.    10.    56.  493.18

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -46.   -19.    87.   5750.   71845.     740.    7.77  490.59
    FULLV:FV       0.   -17.    84.   5750.   64562.     684.    8.41  490.84
    BRIDG:BR       0.     0.    46.   5750.   39563.     361.   15.92  489.40
    RDWAY:RG       9.**************      0.******************    2.00********
    APPRO:AS      64.   -11.   104.   5750.   87616.     787.    7.30  493.37

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS      10.    56.   72533.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX     HF    HO  VHD      EGL    WSEL
    EXITX:XS    487.41    0.52  478.52  508.06************  0.94  491.53  490.59
    FULLV:FV  ********    0.57  479.31  508.85  0.33  0.08  1.10  491.94  490.84
    BRIDG:BR    489.40    1.00  479.62  496.51************  3.94  493.34  489.40
    RDWAY:RG  ****************  500.08  506.80**********************************
    APPRO:AS    489.15    0.50  480.80  509.43  0.42  0.49  0.87  494.25  493.37
   ER
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure STOCTH00360005, in Stockbridge, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number STOCTH00360005

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 23 / 95

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 70375

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

Waterway *(I - 6)* STONY BROOK

Road Name *(I - 7)*: -

Route Number TH036

Vicinity *(I - 9)* 0.3 MI TO JCT W VT107

Topographic Map Bethel

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43457

Longitude *(i - 17; nnnnn.n)* 72424

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10141900051419

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

Maximum span length *(I - 48; nnnn)* 0048

Year built *(I - 27; YYYY)* 1992

Structure length *(I - 49; nnnnnn)* 000050

Average daily traffic, ADT *(I - 29; nnnnnn)* 000200

Deck Width *(I - 52; nn.n)* 180

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 015.0

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

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

Comments:

The structural inspection report of 7/14/94 indicates the structure is a single span, steel stringer type bridge with a concrete deck. The abutment walls and wingwalls are concrete and only have minor shrinkage cracks reported. The footings of both abutments are exposed with some undermining noted on the right abutment. The left abutment is doweled or sealed into bedrock, which outcrops at the base of the left abutment footing. The waterway is noted as proceeding straight through the crossing. The streambed consists of stone and gravel. The report mentions that some past undermining below the right abutment footing was corrected with some free poured concrete and steel railroad rails (Continued, page 31).

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:

Some of the gravel below the downstream end of the free poured concrete has been eroded. Other than this, the report does not mention anything significant concerning channel scour, bank erosion, or debris accumulation at this bridge site.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **22.96** mi^2 Lake/pond/swamp area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **700** ft Headwater elevation **2625** ft

Main channel length **9.02** mi

10% channel length elevation **750** ft 85% channel length elevation **1700** ft

Main channel slope *(S)* **140.43** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:
There is no benchmark information available.

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:
There is no foundation material information available.

Comments:
There are no bridge plans available.

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: **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	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **10/04/96**
Computerized by: **RB** Date: **10/04/96**
Reviewd by: **LKS** Date: **12/29/97**

Structure Number **STOCTH00360005**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. WEBER** Date *(MM/DD/YY)* **04** / **12** / 19**95**
2. Highway District Number **04** Mile marker **00000**
County **Windsor (027)** Town **Stockbridge (70375)**
Waterway *(I - 6)* **Stony Brook** Road Name **-**
Route Number **TH036** Hydrologic Unit Code: **01080105**
3. Descriptive comments:
The bridge is located 0.3 miles from the junction with VT 107.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **4** 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 **2** DS **1** *(**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 **50** *(feet)* Span length **48** *(feet)* Bridge width **18** *(feet)*

Road approach to bridge:

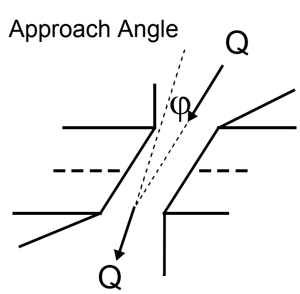
8. LB **0** RB **2** *(**0** even, **1**- lower, **2**- higher)*
9. LB **2** RB **2** *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

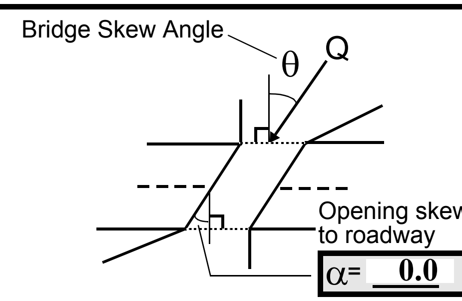
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	1	1	0	0
RBUS	2	1	2	1
RBDS	3	1	0	0
LBDS	1	1	0	0

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*
*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: **10** 16. Bridge skew: **5**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **5** feet **UB** *(US, UB, DS)* to **20** 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**

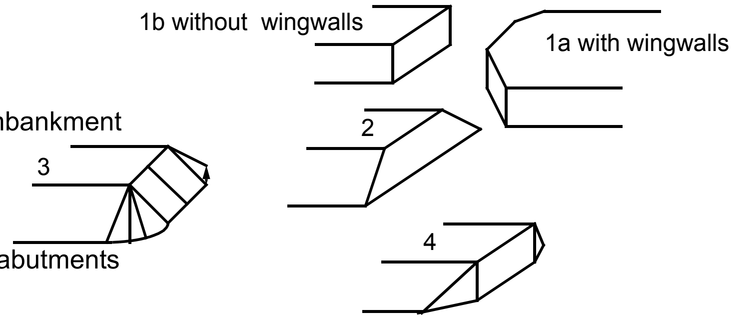
1a- Vertical abutments with wingwalls

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.)

7. Bridge dimension values are from the VT AOT files. Measured bridge length is 59.5 ft, span length is 46.5 ft, and the bridge width is 18 ft.
4. The US and DS left bank surface cover is forest. The forest is partially cleared. Along the DS left bank many of the trees are young. The DS right bank is also forested. There are two dirt roads within the 2 bridge lengths of the DS right bank. The US right bank is pasture with some shrubs and brush.
5. The DS water surface is pooled to about 75 ft DS and is riffled further DS.
17. Impact zone 1 is a bedrock outcrop under the bridge. There is a severe channel bend to the left beginning about 100 ft DS. There is a low area on the outside of the bend which will be submerged at high flows.
11. Road approach protection on the US left bank is type 1 and type 2.
18. The level II bridge type is 1b on the left abutment and 1a on the right abutment.

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
50.0	**9.0**			**9.0**	**3**	**3**	**3**	**3**	**1**	**1**

23. Bank width **35.0** 24. Channel width **25.0** 25. Thalweg depth **79.0** 29. Bed Material **3**

30 .Bank protection type: LB **0** RB **1** 31. Bank protection condition: LB **-** 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.):

27. Bank material is gravel, sand, cobble and boulder.
28. Bed material is gravel, cobble, boulder and sand.
30. The right bank protection is mainly natural streambed material placed by man. Near the bridge are some larger boulders and blocks of concrete. The right bank protection goes from 0 ft US to approximately 175 ft US. On the left bank US there is natural protection from bedrock and boulders to 200 ft US, then there is a gravel side bar. There is a large bedrock exposure at 225 ft US where the channel makes a severe right turn.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 150 35. Mid-bar width: 35

36. Point bar extent: 20 feet US (US, UB) to 200 feet US (US, UB, DS) positioned 0 %LB to 40 %RB

37. Material: 3

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

The bar material is gravel, sand, and cobble with boulders and bedrock at the US end. There is some brushy vegetation on the bar.

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.):

There are no cut-banks upstream at this site.

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.):

There is some channel scour 250 ft US at the base of the bedrock outcrop.

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):

There are no major confluences upstream at this site.

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
47.0		1.5		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.):

3

63. The bed material is gravel, cobble, and boulder with bedrock exposed on the left side of the channel.

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

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

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

70. Debris and Ice Comments:

1

The debris potential is moderate since the reach beyond 200 ft US is laterally unstable. Capture efficiency is low since the bridge will barely constrict bank full flow.

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		-	90	0	2	0	6	90.0
RABUT	1	-	90			2	3	45.5

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

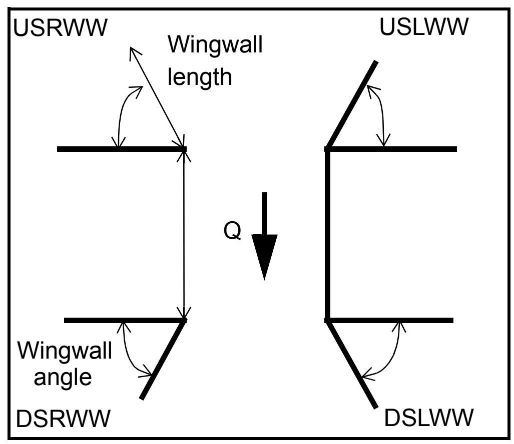
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
3
1

The left abutment footing was poured directly on the exposed bedrock. The left abutment footing is actually two footings, the bottom footing is 4 ft high on top of the bedrock then set back 1 ft on top of this footing is another 2 ft high footing. The right abutment footing is exposed along its entire length. The footing is 2 ft thick. Below the right footing is a free poured subfooting of concrete and railroad track which is also exposed up to an additional 1 ft. Maximum exposure is at the DS end of the right abutment where it is also undermined by a maximum penetration of 3 ft. Vertical undermined distance is minimal, thus 1 ft is the subfooting thickness. During high flows, the water forms an eddy upon exiting the channel under the bridge along the

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	right		abut		ment	45.5	
USRWW:	.					1.5	
DSLWW:	N		-		-	18.0	
DSRWW:	-		-		Y	18.5	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	1	2	-	Y	0	-	1	1
Condition	2	N	-	1	3	-	2	4
Extent	0	-	-	3	-	2	1	0

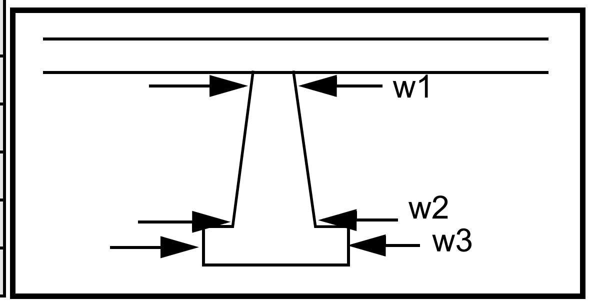
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? 3 (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	-			-	35.0	17.0
Pier 2	-			-	45.0	16.5
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	1	wall, 2	sub-	ment.	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	3	ft of	foot-	At	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	80.	the	ing is	the	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	At	foot-	visi-	junc-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	the	ing is	ble	tion	*Y- yes; N- no*
91. Attack ∠ (BF)	DS	expo	at	of	
92. Pushed	end	sed	the	the	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	of	and	junc-	DS	
95. Cross-members	the	the	tion	right	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	US	free	with	wing	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	right	pour	the	wall	
98. Exposure depth	wing	ed	abut	and	

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

the right abutment, 3 ft of the footing is exposed, 1 ft of which is the free poured subfooting which is also undermined with a maximum of 3 ft penetration. The vertical extent of the undermining is minimal.
82. The US and DS ends of the left abutment are protected with type 1 and type 2 rip rap and its base length is set on bedrock. Some type 3 protection is at the extreme DS end of the DS right wingwall.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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? Th (Y or if N type ctrl-n cb) Where? ere (LB or RB) Mid-bank distance: are

Cut bank extent: no feet pie (US, UB, DS) to rs. feet ____ (US, UB, DS)

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

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

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

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

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

3
1
3
0

Are there major confluences? 0 (Y or if N type ctrl-n mc) How many? -

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

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

Confluence comments (eg. confluence name):

k material is gravel, sand, cobble and boulder. Some areas on the left bank have exposed bedrock. The bed material is gravel, cobble, boulder, and sand with some bedrock exposures. Some natural boulder protection

F. Geomorphic Channel Assessment

107. Stage of reach evolution is

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)*:

on the right bank DS. The left bank heavy fluvial erosion begins at 100 ft DS.

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 F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number:	STOCTH00360005	Town:	STOCKBRIDGE
Road Number:	TH 36	County:	WINDSOR
Stream:	STONY BROOK		

Initials LKS   Date: 01/05/98 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	4260	5750	0
Main Channel Area, ft2	566	736	0
Left overbank area, ft2	0	4	0
Right overbank area, ft2	1	47	0
Top width main channel, ft	77	77	0
Top width L overbank, ft	0	8	0
Top width R overbank, ft	13	29	0
D50 of channel, ft	0.2352	0.2352	0.2352
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.4	9.6	ERR
y1, average depth, LOB, ft	ERR	0.5	ERR
y1, average depth, ROB, ft	0.1	1.6	ERR
Total conveyance, approach	55714	88329	0
Conveyance, main channel	55710	85904	0
Conveyance, LOB	0	48	0
Conveyance, ROB	4	2378	0
Percent discrepancy, conveyance	0.0000	-0.0011	ERR
Qm, discharge, MC, cfs	4259.7	5592.1	ERR
Ql, discharge, LOB, cfs	0.0	3.1	ERR
Qr, discharge, ROB, cfs	0.3	154.8	ERR
Vm, mean velocity MC, ft/s	7.5	7.6	ERR
Vl, mean velocity, LOB, ft/s	ERR	0.8	ERR
Vr, mean velocity, ROB, ft/s	0.3	3.3	ERR
Vc-m, crit. velocity, MC, ft/s	9.6	10.1	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	4260	5750	0
(Q) discharge thru bridge, cfs	4260	5750	0
Main channel conveyance	31124	39563	0
Total conveyance	31124	39563	0
Q2, bridge MC discharge,cfs	4260	5750	ERR
Main channel area, ft2	304	361	0
Main channel width (normal), ft	43.8	45.7	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	43.8	45.7	0
y_bridge (avg. depth at br.), ft	6.93	7.90	ERR
Dm, median (1.25*D50), ft	0.294	0.294	0.294
y2, depth in contraction,ft	8.88	11.07	ERR
ys, scour depth (y2-ybridge), ft	1.95	3.17	N/A

Armoring
Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	4260	5750	N/A
Main channel area (DS), ft2	303.6	361.2	0
Main channel width (normal), ft	43.8	45.7	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	43.8	45.7	0.0
D90, ft	0.7586	0.7586	0.0000
D95, ft	1.1415	1.1415	0.0000
Dc, critical grain size, ft	0.8934	1.0885	ERR
Pc, Decimal percent coarser than Dc	0.070	0.054	0.000
Depth to armoring, ft	35.45	57.32	ERR

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	4260	5750	0	4260	5750	0
a', abut.length blocking flow, ft	4.5	11.2	0	41.3	58	0
Ae, area of blocked flow ft2	21.64	46.84	0	177.62	285.21	0
Qe, discharge blocked abut.,cfs	76.68	158.62	0	1132.77	1794	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.54	3.39	ERR	6.38	6.29	ERR
ya, depth of f/p flow, ft	4.81	4.18	ERR	4.30	4.92	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.285	0.292	ERR	0.542	0.500	ERR
ys, scour depth, ft	9.74	11.02	N/A	18.87	22.24	N/A

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)	4.5	11.2	0	41.3	58	0
y1 (depth f/p flow, ft)	4.81	4.18	ERR	4.30	4.92	ERR
a'/y1	0.94	2.68	ERR	9.60	11.79	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.28	0.29	N/A	0.54	0.50	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR

spill-through	ERR	ERR	ERR	ERR	ERR	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 Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.94	1	0	0.94	1	0
y, depth of flow in bridge, ft	6.93	7.90	0.00	6.93	7.90	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (vertical abut.)	2.85	3.30	ERR	2.85	3.30	ERR