LEVEL II SCOUR ANALYSIS FOR BRIDGE 20 (WALDTH00050020) on TOWN HIGHWAY 5, crossing STANNARD BROOK, WALDEN, VERMONT

Open-File Report 98-541

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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By RONDA L. BURNS and SCOTT A. OLSON

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Velocity and Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	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 20 (WALDTH00050020) ON TOWN HIGHWAY 5, CROSSING STANNARD BROOK, WALDEN, VERMONT

By **Ronda L. Burns and Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WALDTH00050020 on Town Highway 5 crossing Stannard Brook, Walden, 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 D.

The site is in the New England Upland section of the New England physiographic province in northeastern Vermont. The 7.77-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover on the left bank is forest upstream of the bridge and shrub and brushland downstream of the bridge. The surface cover on the right bank is pasture upstream and downstream of the bridge.

In the study area, Stannard Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 41 ft and an average bank height of 6 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 133.1 mm (0.437 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 26, 1995, indicated that the reach was stable.

The Town Highway 5 crossing of Stannard Brook is a 24-ft-long, one-lane bridge consisting of one 21-foot concrete slab span (Vermont Agency of Transportation, written communication, April 5, 1995). The opening length of the structure parallel to the bridge face is 20.3 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 20 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed underneath and just downstream of the bridge along the right side of the channel during the Level I assessment. The scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the upstream left wingwall, the left abutment, the downstream right wingwall, the downstream right bank, and at the downstream end of the downstream left wingwall. Type-3 stone fill (less than 48 inches diameter) was observed along the upstream left and right banks and the upstream 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. 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 was zero ft. Abutment scour ranged from 5.9 to 11.9 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. 46). 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 WALDTH00050020 ***Stream*** Stannard Brook

County Caledonia ***Road*** TH 5 ***District*** 7

Description of Bridge

Bridge length 24 ***ft*** ***Bridge width*** 18.2 ***ft*** ***Max span length*** 21 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 7/26/95

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

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a one foot deep scour hole along the right abutment. The footings on the left and right abutments are exposed, and the right abutment footing is undermined.

Yes 20

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

There is a moderate channel bend in the upstream reach.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	7/26/95	0	0
Level II	7/26/95	0	0

Potential for debris Moderate. The banks are well vegetated.

Describe any features near or at the bridge that may affect flow (include observation date) There is a railroad bridge 120 ft downstream from this bridge, as observed on 7/26/95.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley.

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

Date of inspection 7/26/95

DS left: Moderately sloped channel bank and overbank

DS right: Steep channel bank to Town Highway 4

US left: Steep channel bank to a moderately sloped overbank

US right: Steep channel bank to Town Highway 4

Description of the Channel

Average top width 41 *ft* ***Average depth*** 6 *ft*

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

Sinuous but stable

with semi-alluvial channel boundaries and narrow point bars.

7/26/95

Vegetative co

Trees with grass and shrubs on the overbank

DS left: Town Highway 4 and short grass

DS right: Trees

US left: Town Highway 4 and short grass

US right:

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

None observed on

7/26/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 7.77 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,630 ***ft³/s*** ***Q500*** 2,600 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(7.77/4.6)exp 0.67] with flood frequency estimates available from the VTAOT database (written communication, May 1995) for bridge number 6 in Stannard. Bridge number 6 crosses Stannard Brook upstream of this site and has a drainage area of 4.6 square miles. The values used were within a range defined by flood frequency curves developed from 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 upstream end of the right abutment (elev. 499.80 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 499.82 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	*Section Reference Distance (SRD) in feet*	*[2]Cross-section development*	*Comments*
EXIT	-180	1	Railroad bridge Exit section
FV1	-117	2	Railroad bridge Full-valley section (Templated from EXIT)
RRBRD	-117	1	Railroad bridge section
EXITX	-24	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPRO	44	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. 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 0.050 to 0.060, and overbank "n" values ranged from 0.030 to 0.095.

Normal depth at the railroad bridge exit section (EXIT) 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 0.015 ft/ft, which was estimated from thalweg points surveyed downstream of the bridge.

The surveyed approach section (APPRO) was modelled 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 all modeled discharges, WSPRO assumes critical depth at the railroad bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the railroad bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.9 *ft*
Average low steel elevation 498.3 *ft*

100-year discharge 1,630 *ft³/s*
Water-surface elevation in bridge opening 498.3 *ft*
Road overtopping? Yes *Discharge over road* 220 *ft³/s*
Area of flow in bridge opening 179 *ft²*
Average velocity in bridge opening 7.8 *ft/s*
Maximum WSPRO tube velocity at bridge 10.4 *ft/s*

Water-surface elevation at Approach section with bridge 499.5
Water-surface elevation at Approach section without bridge 497.8
Amount of backwater caused by bridge 1.7 *ft*

500-year discharge 2,600 *ft³/s*
Water-surface elevation in bridge opening 498.3 *ft*
Road overtopping? Yes *Discharge over road* 1,520 *ft³/s*
Area of flow in bridge opening 179 *ft²*
Average velocity in bridge opening 6.1 *ft/s*
Maximum WSPRO tube velocity at bridge 8.1 *ft/s*

Water-surface elevation at Approach section with bridge 501.3
Water-surface elevation at Approach section without bridge 500.4
Amount of backwater caused by bridge 0.9 *ft*

Incipient overtopping discharge 1,560 *ft³/s*
Water-surface elevation in bridge opening 496.9 *ft*
Area of flow in bridge opening 151 *ft²*
Average velocity in bridge opening 10.3 *ft/s*
Maximum WSPRO tube velocity at bridge 15.2 *ft/s*

Water-surface elevation at Approach section with bridge 498.5
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 0.9 *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 the incipient roadway-overtopping discharge 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-year discharge resulted in unsubmerged orifice flow and the 500-year discharge resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison, contraction scour for the discharges resulting in orifice flow also was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results from these computations are presented in appendix F. Furthermore, for the 100-year discharge contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution also are provided in appendix F.

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-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	0.9	0.1	3.1
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	5.9	7.0	6.7
Right abutment	8.0	11.9	8.4
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	1.3	0.7	2.0
Right abutment	1.3	0.7	2.0
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

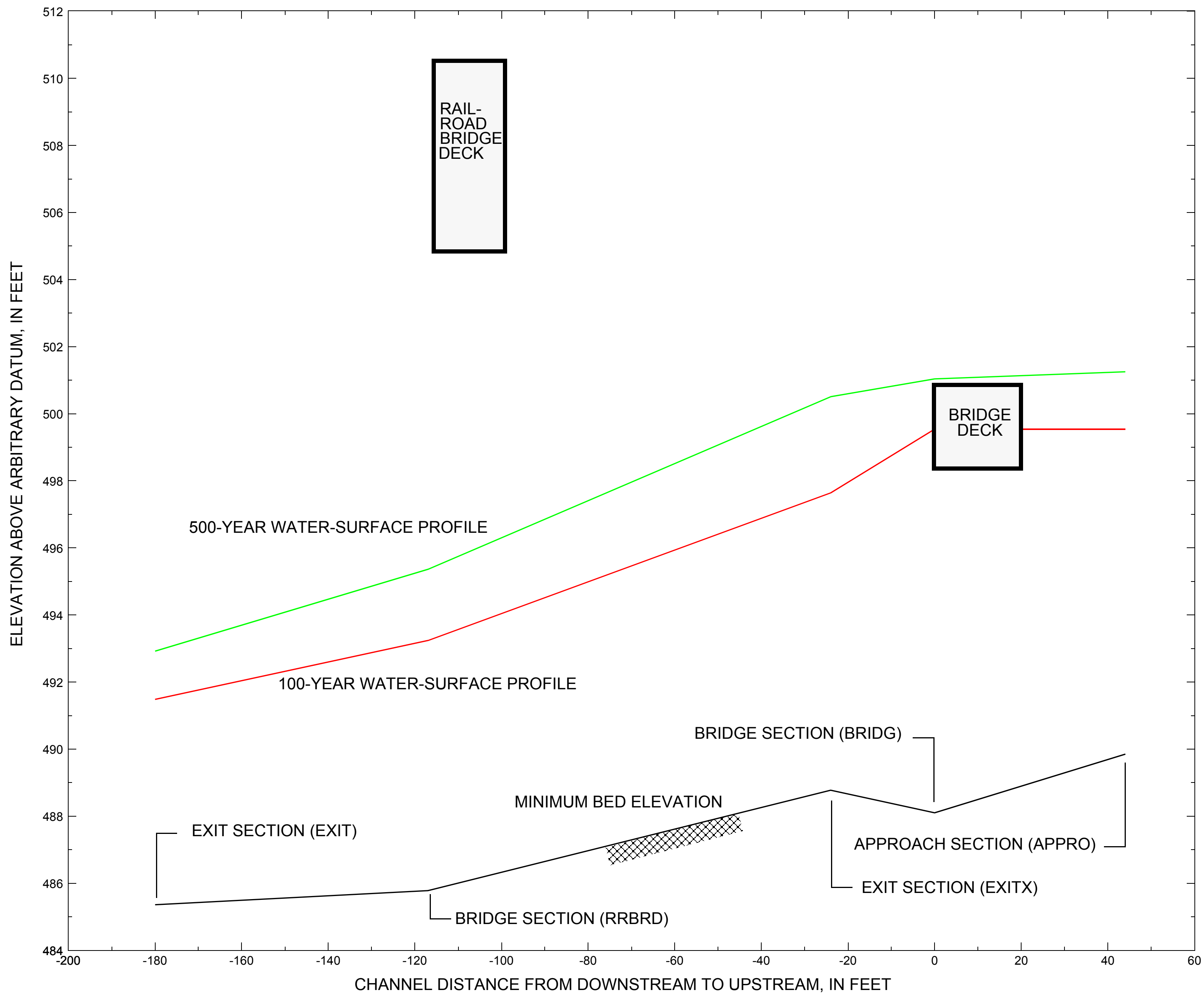

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure WALDTH00050020 on Town Highway 5, crossing Stannard Brook, Walden, Vermont.

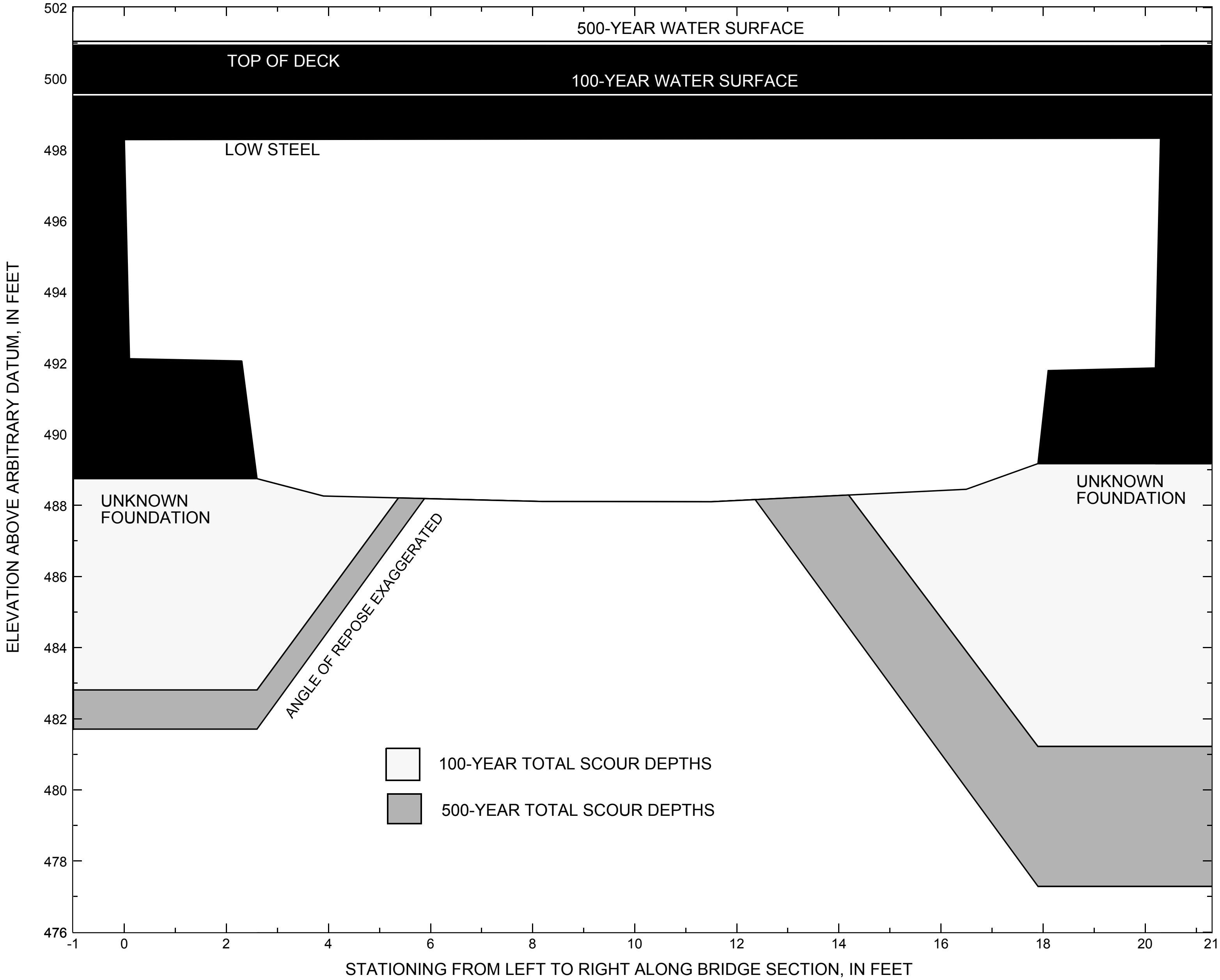

Figure 8. Scour elevations for the 100- and 500-year discharges at structure WALDTH00050020 on Town Highway 5, crossing Stannard Brook, Walden, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WALDTH00050020 on Town Highway 5, crossing Stannard Brook, Walden, 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 1,630 cubic-feet per second											
Left abutment	0.0	--	498.3	--	488.8	0.0	5.9	--	5.9	482.9	--
Right abutment	20.3	--	498.3	--	489.2	0.0	8.0	--	8.0	481.2	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure WALDTH00050020 on Town Highway 5, crossing Stannard Brook, Walden, 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 2,600 cubic-feet per second											
Left abutment	0.0	--	498.3	--	488.8	0.0	7.0	--	7.0	481.8	--
Right abutment	20.3	--	498.3	--	489.2	0.0	11.9	--	11.9	477.3	--

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, 1986, Caspian Lake, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

U.S. Geological Survey, 1986, Stannard, 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 wald020.wsp
T2        CREATED ON 15-AUG-95 FOR BRIDGE WALDTH00050020 USING FILE wald020.dca
T3        HYDRAULIC ANALYSIS OF WALD020    SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          1630 2600 1560
SK         0.015 0.015 0.015
*
XS    EXIT    -180
GR          -80.9, 510.09    -71.2, 497.30     -9.5, 490.49     -2.9, 487.12
GR            0.0, 486.65      3.2, 486.28      6.4, 486.65     10.7, 486.75
GR           15.2, 486.19     19.9, 485.36     25.0, 486.23     28.6, 486.42
GR           33.3, 494.41     56.6, 494.85     79.7, 494.64    110.4, 492.98
GR          139.1, 497.46    139.1, 509.17
N                0.055    0.055     0.040
SA                  -9.5       33.3
*
XS    FV1       -117 * * * 0.012
*
BR    RRBRD    -117  504.87
GR            0.0, 505.09      0.2, 504.86      0.9, 491.36      1.6, 491.33
GR            1.7, 487.96      9.2, 487.78     11.7, 487.35     13.8, 486.39
GR           16.7, 486.13     19.6, 485.78     19.9, 488.89     21.4, 488.93
GR           21.7, 496.05     24.0, 496.26     42.8, 496.26     42.8, 504.65
GR            0.0, 505.09
N             0.050     0.030
SA                    21.7
CD            4 18 1 505 66
*
AS    EXITX    -24
GR         -246.2, 518.32   -159.4, 508.99    -88.6, 503.75    -64.7, 497.88
GR          -10.0, 496.14     -5.1, 494.48      0.0, 490.89      6.8, 489.80
GR            8.8, 489.40     12.0, 489.49     15.6, 488.77     20.2, 488.91
GR           23.9, 489.21     25.5, 489.73     27.9, 490.36     31.2, 494.76
GR           34.8, 497.12     54.7, 497.29    153.8, 498.29    167.5, 508.05
N            0.085     0.060     0.035
SA                 -10.0    34.8
*
XS    FULLV      0
*
BR    BRIDG   0 498.28 15
GR            0.0, 498.28      0.1, 492.12      2.3, 492.06      2.5, 489.72
GR            2.6, 488.75      3.9, 488.26      8.2, 488.11     11.5, 488.10
GR           16.5, 488.45     17.9, 489.17     18.1, 491.79     20.3, 491.86
GR           20.3, 498.32      0.0, 498.28
N            0.055
CD           1 27 * * 37.5 10
*
XR    RDWAY   10 18.2 2
GR         -246.2, 518.32   -159.4, 508.99    -88.6, 503.75    -31.4, 501.12
GR           -3.7, 499.87     -3.5, 500.94     19.8, 500.92     20.6, 500.12
GR           50.4, 498.71     62.3, 498.74    169.7, 500.08    177.8, 504.70
GR          192.0, 508.31
*
AS    APPRO     44
GR         -168.0, 517.27   -157.0, 512.46   -146.7, 507.63   -122.6, 505.17
```

```
GR          -81.5, 502.25    -48.0, 500.90     -6.3, 498.27     -3.0, 495.39
GR            0.0, 490.98      3.0, 490.07      7.5, 489.85     12.0, 490.61
GR           16.5, 491.65     21.8, 492.17     26.3, 495.81     28.7, 498.10
GR           44.9, 498.78     65.6, 499.25    169.7, 500.08    177.8, 504.70
GR          192.0, 508.31
N           0.095     0.060     0.035
SA              -6.3        29.
BP          0
*
HP 1 BRIDG   498.32 1 498.32
HP 2 BRIDG   498.32 * * 1396
HP 1 BRIDG   497.76 1 497.76
HP 2 RDWAY   499.54 * * 220
HP 1 APPRO   499.54 1 499.54
HP 2 APPRO   499.54 * * 1630
*
HP 1 BRIDG   498.32 1 498.32
HP 2 BRIDG   498.32 * * 1093
HP 2 RDWAY   501.04 * * 1519
HP 1 APPRO   501.25 1 501.25
HP 2 APPRO   501.25 * * 2600
*
HP 1 BRIDG   496.88 1 496.88
HP 2 BRIDG   496.88 * * 1560
HP 1 APPRO   498.51 1 498.51
HP 2 APPRO   498.51 * * 1560
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE wald020.wsp
        CREATED ON 15-AUG-95 FOR BRIDGE WALDTH00050020 USING FILE wald020.dca
        HYDRAULIC ANALYSIS OF WALD020    SAO
           *** RUN DATE & TIME: 12-08-97  11:42

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     179.   10352.     0.    57.                     9850874.
   498.32          179.   10352.     0.    57.  1.00     0.   20.9850874.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA         K        Q    VEL
      498.32     0.0    20.3   179.1    10352.    1396.   7.79

X STA.        0.0        3.9        4.6        5.3        6.0        6.7
  A(I)            27.7        6.7        6.9        6.8        6.8
  V(I)            2.52      10.38      10.17      10.31      10.25

X STA.        6.7        7.4        8.1        8.8        9.5       10.2
  A(I)             6.9        7.0        6.9        7.1        7.1
  V(I)           10.07      10.00      10.14       9.90       9.90

X STA.       10.2       10.9       11.6       12.3       13.1       13.8
  A(I)             7.1        7.1        6.9        6.9        7.0
  V(I)            9.90       9.90      10.16      10.05       9.91

X STA.       13.8       14.5       15.2       15.9       16.6       20.3
  A(I)             6.8        6.9        6.8        6.9       26.9
  V(I)           10.30      10.05      10.22      10.06       2.60

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     169.   12591.    20.    37.                        2805.
   497.76          169.   12591.    20.    37.  1.00     0.    20.    2805.

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = RDWAY;  SRD =      10.
        WSEL     LEW     REW    AREA         K        Q    VEL
      499.54    32.9   126.4    42.6     1086.     220.   5.16

X STA.       32.9       44.4       47.4       49.6       51.7       53.7
  A(I)             3.2        1.8        1.7        1.7        1.6
  V(I)            3.46       6.05       6.64       6.55       6.73

X STA.       53.7       55.7       57.8       59.9       62.1       63.8
  A(I)             1.7        1.7        1.7        1.8        1.3
  V(I)            6.54       6.51       6.33       6.27       8.44

X STA.       63.8       65.1       67.2       69.4       71.7       74.3
  A(I)             1.0        1.6        1.6        1.6        1.7
  V(I)           10.58       6.97       6.87       6.87       6.50

X STA.       74.3       76.9       80.0       83.3       87.4      126.4
  A(I)             1.7        1.8        1.9        2.1        9.5
  V(I)            6.49       6.05       5.86       5.29       1.16

    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = APPRO;  SRD =      44.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      13.     148.    20.    20.                          58.
             2     250.   20625.    35.    41.                        3774.
             3      34.     850.    73.    73.                         129.
   499.54          296.   21623.   128.   134.  1.22   -26.   102.   2308.

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = APPRO;  SRD =      44.
        WSEL     LEW     REW    AREA         K        Q    VEL
      499.54   -26.4   102.0   296.3    21623.    1630.   5.50

X STA.      -26.4        0.6        1.8        2.9        4.0        5.1
  A(I)            46.2       10.7       10.1       10.5       10.2
  V(I)            1.76       7.58       8.04       7.77       7.96

X STA.        5.1        6.2        7.2        8.3        9.4       10.6
  A(I)            10.2       10.3       10.3       10.5       10.7
  V(I)            7.95       7.93       7.92       7.73       7.64

X STA.       10.6       11.7       13.0       14.2       15.6       17.0
  A(I)            10.7       10.8       10.8       11.0       11.1
  V(I)            7.59       7.54       7.56       7.44       7.33

X STA.       17.0       18.4       19.9       21.5       23.6      102.0
  A(I)            11.5       11.4       11.5       14.5       53.2
  V(I)            7.11       7.13       7.11       5.64       1.53
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WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE wald020.wsp
        CREATED ON 15-AUG-95 FOR BRIDGE WALDTH00050020 USING FILE wald020.dca
        HYDRAULIC ANALYSIS OF WALD020    SAO
           *** RUN DATE & TIME: 12-08-97  11:42

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      179.   10352.     0.    57.                   9850874.
   498.32           179.   10352.     0.    57.  1.00     0.    20.9850874.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA         K        Q    VEL
       498.32     0.0    20.3   179.1   10352.    1093.   6.10

X STA.         0.0        3.9        4.6        5.3        6.0        6.7
  A(I)             27.7        6.7        6.9        6.8        6.8
  V(I)             1.97       8.13       7.96       8.07       8.03

X STA.         6.7        7.4        8.1        8.8        9.5       10.2
  A(I)              6.9        7.0        6.9        7.1        7.1
  V(I)             7.89       7.83       7.94       7.75       7.75

X STA.        10.2       10.9       11.6       12.3       13.1       13.8
  A(I)              7.1        7.1        6.9        6.9        7.0
  V(I)             7.75       7.75       7.96       7.87       7.76

X STA.        13.8       14.5       15.2       15.9       16.6       20.3
  A(I)              6.8        6.9        6.8        6.9       26.9
  V(I)             8.07       7.87       8.00       7.87       2.03

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = RDWAY;  SRD =      10.
         WSEL     LEW     REW    AREA         K        Q    VEL
       501.04   -29.6   171.4   270.1   14815.    1519.   5.62

X STA.       -29.6       36.6       43.0       48.1       52.7       57.1
  A(I)             39.0       11.7       10.9       10.6       10.2
  V(I)             1.95       6.50       6.99       7.19       7.47

X STA.        57.1       61.7       66.4       71.2       76.3       80.8
  A(I)             10.7       10.5       10.8       11.0        9.4
  V(I)             7.12       7.23       7.06       6.91       8.06

X STA.        80.8       85.2       90.8       96.8      103.0      110.1
  A(I)              8.9       11.1       11.4       11.4       12.4
  V(I)             8.51       6.83       6.64       6.63       6.12

X STA.       110.1      117.8      126.5      136.6      149.4      171.4
  A(I)             12.7       13.6       14.4       16.6       22.8
  V(I)             5.99       5.58       5.28       4.56       3.33

    CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = APPRO;  SRD =      44.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       71.    1396.    50.    50.                       478.
             2      310.   29578.    35.    41.                      5221.
             3      257.   16171.   143.   143.                      1957.
   501.25           638.   47145.   228.   235.  1.30   -57.   172.   5319.

    VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = APPRO;  SRD =      44.
         WSEL     LEW     REW    AREA         K        Q    VEL
       501.25   -56.7   171.8   638.3   47145.    2600.   4.07

X STA.       -56.7       -0.5        1.7        3.6        5.3        7.0
  A(I)            105.1       22.6       20.4       19.4       19.6
  V(I)             1.24       5.75       6.38       6.70       6.63

X STA.         7.0        8.8       10.6       12.6       14.7       16.9
  A(I)             20.2       20.3       21.1       21.8       21.5
  V(I)             6.44       6.39       6.17       5.95       6.06

X STA.        16.9       19.1       21.4       25.3       36.7       48.2
  A(I)             20.2       21.7       30.0       40.2       29.6
  V(I)             6.42       5.99       4.33       3.24       4.39

X STA.        48.2       62.9       81.5      104.0      130.6      171.8
  A(I)             32.8       36.4       40.0       42.3       53.0
  V(I)             3.96       3.57       3.25       3.07       2.45
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      U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE wald020.wsp
      CREATED ON 15-AUG-95 FOR BRIDGE WALDTH00050020 USING FILE wald020.dca
      HYDRAULIC ANALYSIS OF WALD020    SAO
         *** RUN DATE & TIME: 12-08-97  11:42

  CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA       K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     151.   10868.    20.    35.                        2386.
 496.88          151.   10868.    20.    35.  1.00     0.    20.   2386.

  VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = BRIDG;  SRD =       0.
       WSEL     LEW     REW    AREA        K        Q    VEL
     496.88     0.0    20.3   151.3   10868.    1560.  10.31

X STA.        0.0        4.5        5.1        5.7        6.3        7.0
  A(I)           27.4        5.3        5.4        5.1        5.3
  V(I)           2.85      14.86      14.56      15.17      14.61

X STA.        7.0        7.6        8.3        8.9        9.5       10.2
  A(I)            5.3        5.5        5.4        5.6        5.6
  V(I)          14.64      14.18      14.39      14.05      14.05

X STA.       10.2       10.9       11.5       12.2       12.8       13.5
  A(I)            5.6        5.6        5.4        5.5        5.3
  V(I)          13.95      13.94      14.31      14.16      14.66

X STA.       13.5       14.1       14.8       15.4       16.0       20.3
  A(I)            5.3        5.4        5.2        5.4       26.6
  V(I)          14.67      14.32      15.10      14.39       2.93

  CROSS-SECTION PROPERTIES:  ISEQ =  8;  SECID = APPRO;  SRD =      44.
   WSEL  SA#     AREA       K   TOPW   WETP  ALPH    LEW    REW     QCR
           1       0.       2.     4.     4.                           1.
           2     214.   15871.    35.    41.                        2981.
           3       2.      27.     9.     9.                           5.
 498.51          216.   15900.    49.    55.  1.02   -10.    38.   2562.

  VELOCITY DISTRIBUTION:  ISEQ =  8;  SECID = APPRO;  SRD =      44.
       WSEL     LEW     REW    AREA        K        Q    VEL
     498.51   -10.1    38.5   215.9   15900.    1560.   7.22

X STA.      -10.1        1.2        2.2        3.2        4.2        5.1
  A(I)           30.9        8.4        8.5        8.2        8.2
  V(I)           2.53       9.30       9.23       9.57       9.49

X STA.        5.1        6.1        7.1        8.0        9.0       10.1
  A(I)            8.2        8.3        8.3        8.4        8.7
  V(I)           9.48       9.45       9.41       9.31       8.93

X STA.       10.1       11.1       12.2       13.3       14.5       15.7
  A(I)            8.4        8.7        8.6        8.7        8.9
  V(I)           9.30       8.94       9.06       8.92       8.79

X STA.       15.7       17.0       18.4       19.8       21.2       38.5
  A(I)            9.0        9.2        9.3        9.3       29.8
  V(I)           8.67       8.48       8.41       8.39       2.61
```

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       U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE wald020.wsp
       CREATED ON 15-AUG-95 FOR BRIDGE WALDTH00050020 USING FILE wald020.dca
       HYDRAULIC ANALYSIS OF WALD020    SAO
          *** RUN DATE & TIME: 12-08-97  11:42

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

EXIT :XS   ******   -19.     193.  1.15 *****  492.63  490.54   1630.  491.48
     -180. ******    32.   13308.  1.03 ***** *******    0.77    8.46

FV1  :FV      63.   -21.     205.  1.03  0.87  493.50 *******   1630.  492.48
     -117.    63.    32.   14469.  1.04  0.00    0.00    0.72    7.96
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.06     494.03     494.20
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.98     518.32    0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.98     518.32     494.20
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "EXITX"
                  WSBEG,WSEND,CRWS =   494.20     518.32     494.20

EXITX:AS      93.    -5.     143.  2.01 *****  496.21  494.20   1630.  494.20
      -24.    93.    31.    8495.  1.00 ***** *******    1.00   11.38
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "RRBRD"     Q,CRWS =    1630.     493.24

            <<<<<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

RRBRD:BR      63.     1.     120.  2.88 *****  496.13  493.24   1630.  493.24
     -117.    63.    22.    8405.  1.00 ***** *******    1.00   13.62

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  504.87 ****** ****** ******

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

EXITX:AS      75.   -57.     336.  0.46  1.02  498.10  494.20   1630.  497.64
      -24.    76.    89.   23599.  1.25  0.95   -0.01    0.63    4.85

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.416  0.256   17607.     3.    24.   497.28

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

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

FULLV:FV      24.   -52.     313.  0.50  0.12  498.26 *******   1630.  497.76
        0.    24.    73.   22292.  1.19  0.02    0.02    0.63    5.21
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.60

APPRO:AS      44.    -6.     190.  1.15  0.39  498.97 *******   1630.  497.82
       44.    44.    28.   13304.  1.00  0.32   -0.01    0.64    8.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   498.80       0.00     497.11     498.71
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   497.11     498.56     498.80     498.28
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      24.     0.     179.  0.95 *****  499.27  494.55   1396.  498.32
        0. ******    20.   10352.  1.00 ***** *******    0.46    7.80

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.395 ******  498.28 ****** ****** ******
```

```
   XSID:CODE     SRD    FLEN     HF    VHD      EGL      ERR        Q    WSEL
  RDWAY:RG       10.     26.   0.15   0.58   499.97    -0.01     220.  499.54

          Q    WLEN     LEW     REW   DMAX   DAVG   VMAX   VAVG   HAVG   CAVG
  LT:      0.     13.    -17.     -4.    0.6    0.3    3.3    4.8    0.7    2.7
  RT:    220.     94.     33.    127.    0.8    0.5    4.0    5.2    0.9    2.8

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

APPRO:AS      17.   -26.      296.  0.58  0.18  500.12  496.17   1630.  499.54
       44.    18.   102.   21630.  1.22  0.56   -0.01    0.71    5.50

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

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

  FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT :XS   -180.   -19.    32.   1630.   13308.     193.    8.46  491.48
   FV1  :FV   -117.   -21.    32.   1630.   14469.     205.    7.96  492.48
   RRBRD:BR   -117.     1.    22.   1630.    8405.     120.   13.62  493.24
   EXITX:AS    -24.   -57.    89.   1630.   23599.     336.    4.85  497.64

   XSID:CODE   XLKQ   XRKQ       KQ
   EXITX:AS      3.    24.   17607.

   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   FULLV:FV      0.   -52.    73.   1630.   22292.     313.    5.21  497.76
   BRIDG:BR      0.     0.    20.   1396.   10352.     179.    7.80  498.32
   RDWAY:RG     10.*******     0.    220.       0.       0.    2.00  499.54
   APPRO:AS     44.   -26.   102.   1630.   21630.     296.    5.50  499.54

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

 SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX     HF    HO   VHD      EGL    WSEL
   EXIT :XS   490.54    0.77  485.36  510.09************  1.15  492.63  491.48
   FV1  :FV  ********   0.72  486.12  510.85   0.87  0.00  1.03  493.50  492.48
   RRBRD:BR   493.24    1.00  485.78  505.09************  2.88  496.13  493.24
   EXITX:AS   494.20    0.63  488.77  518.32   1.02  0.95  0.46  498.10  497.64
   FULLV:FV  ********   0.63  489.06  518.61   0.12  0.02  0.50  498.26  497.76
   BRIDG:BR   494.55    0.46  488.10  498.32************  0.95  499.27  498.32
   RDWAY:RG  ****************  498.71  518.32   0.15******  0.58  499.97  499.54
   APPRO:AS   496.17    0.71  489.85  517.27   0.18  0.56  0.58  500.12  499.54

       U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE wald020.wsp
       CREATED ON 15-AUG-95 FOR BRIDGE WALDTH00050020 USING FILE wald020.dca
       HYDRAULIC ANALYSIS OF WALD020     SAO
          *** RUN DATE & TIME: 12-08-97  11:42

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

EXIT :XS   ******   -31.      274.  1.53 *****  494.45  492.09   2600.  492.92
     -180. ******    32.   21212.  1.10 ***** *******    0.84    9.48

 ===125 FR# EXCEEDS FNTEST AT SECID "FV1  ":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80     0.82     493.97     492.84
 ===110 WSEL NOT FOUND AT SECID "FV1  ":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   492.42     510.85     0.50
 ===115 WSEL NOT FOUND AT SECID "FV1  ":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   492.42     510.85     492.84

FV1  :FV      63.   -34.      294.  1.35  0.87  495.31  492.84   2600.  493.96
     -117.    63.   112.   23089.  1.11  0.00    0.00    0.82    8.85
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80     1.13     495.36     495.84
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   493.46     518.32     0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   493.46     518.32     495.84
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
            ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "EXITX"
                 WSBEG,WSEND,CRWS =   495.84     518.32     495.84

EXITX:AS      93.    -9.      206.  2.47 *****  498.31  495.84   2600.  495.84
      -24.    93.    33.   13888.  1.00 ***** *******    1.00   12.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
```

```
                 SECID "RRBRD"     Q,CRWS =    2600.     495.36

          <<<<<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

RRBRD:BR      63.     1.     164.  3.91 *****  499.27  495.36   2600.  495.36
     -117.    63.    22.   13104.  1.00 ***** *******    1.00   15.86

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  504.87 ****** ****** ******

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

EXITX:AS      75.   -75.     960.  0.14  0.50  500.66  495.84   2600.  500.51
      -24.    76.   157.   78594.  1.24  0.88   -0.01    0.26    2.71

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.503  0.631   29102.     3.    24.   500.43

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

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

FULLV:FV      24.   -74.     897.  0.16  0.03  500.70 *******   2600.  500.53
        0.    24.   157.   71148.  1.26  0.01    0.00    0.29    2.90
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80     0.83     500.38     497.92
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   500.03     517.27    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   500.03     517.27     497.92
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.43

APPRO:AS      44.   -40.     448.  0.73  0.14  501.11  497.92   2600.  500.38
       44.    44.   170.   30902.  1.40  0.28    0.00    0.83    5.80
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   500.53     498.28

          <<<<<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      24.     0.     179.  0.58 *****  498.90  493.75   1093.  498.32
        0. ******    20.   10352.  1.00 ***** *******    0.36    6.10

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800 ******  498.28 ****** ****** ******

   XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
  RDWAY:RG      10.    26.  0.08  0.33  501.51    0.00   1519.  501.04

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
  LT:     96.    40.   -30.    10.   1.2   0.4   4.1   5.7   0.9   2.9
  RT:   1423.   161.    10.   171.   2.3   1.6   6.5   5.6   2.0   3.0

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

APPRO:AS      17.   -57.     638.  0.33  0.15  501.58  497.92   2600.  501.25
       44.    22.   172.   47158.  1.30  0.88    0.00    0.49    4.07

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

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

  FIRST USER DEFINED TABLE.
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
  EXIT :XS    -180.   -31.    32.   2600.   21212.     274.    9.48  492.92
  FV1  :FV    -117.   -34.   112.   2600.   23089.     294.    8.85  493.96
  RRBRD:BR    -117.     1.    22.   2600.   13104.     164.   15.86  495.36
  EXITX:AS     -24.   -75.   157.   2600.   78594.     960.    2.71  500.51

   XSID:CODE   XLKQ   XRKQ       KQ
  EXITX:AS       3.    24.   29102.
```

```
   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
  FULLV:FV       0.   -74.   157.   2600.   71148.     897.    2.90  500.53
  BRIDG:BR       0.     0.    20.   1093.   10352.     179.    6.10  498.32
  RDWAY:RG      10.*******    96.   1519.*****************    2.00  501.04
  APPRO:AS      44.   -57.   172.   2600.   47158.     638.    4.07  501.25

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

 SECOND USER DEFINED TABLE.
   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
  EXIT :XS    492.09    0.84  485.36  510.09************  1.53  494.45  492.92
  FV1  :FV    492.84    0.82  486.12  510.85  0.87  0.00  1.35  495.31  493.96
  RRBRD:BR    495.36    1.00  485.78  505.09************  3.91  499.27  495.36
  EXITX:AS    495.84    0.26  488.77  518.32  0.50  0.88  0.14  500.66  500.51
  FULLV:FV  ********    0.29  489.06  518.61  0.03  0.01  0.16  500.70  500.53
  BRIDG:BR    493.75    0.36  488.10  498.32************  0.58  498.90  498.32
  RDWAY:RG  ****************  498.71  518.32  0.08******  0.33  501.51  501.04
  APPRO:AS    497.92    0.49  489.85  517.27  0.15  0.88  0.33  501.58  501.25

      U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE wald020.wsp
      CREATED ON 15-AUG-95 FOR BRIDGE WALDTH00050020 USING FILE wald020.dca
      HYDRAULIC ANALYSIS OF WALD020    SAO
         *** RUN DATE & TIME: 12-08-97  11:42

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

EXIT :XS   ******   -17.     187.  1.11 *****  492.48  490.44   1560.  491.36
     -180. ******    32.   12735.  1.03 ***** *******    0.76    8.35

FV1  :FV      63.   -20.     198.  1.00  0.87  493.35 *******   1560.  492.35
     -117.    63.    32.   13848.  1.04  0.00    0.00    0.72    7.86
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     1.05     493.92     494.06
 ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.85     518.32    0.50
 ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.85     518.32     494.06
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "EXITX"
                  WSBEG,WSEND,CRWS =   494.06     518.32     494.06

EXITX:AS      93.    -5.     138.  1.98 *****  496.03  494.06   1560.  494.06
      -24.    93.    31.    8078.  1.00 ***** *******    1.00   11.27
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "RRBRD"     Q,CRWS =    1560.     493.09

            <<<<<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

RRBRD:BR      63.     1.     117.  2.79 *****  495.88  493.09   1560.  493.09
     -117.    63.    22.    8087.  1.00 ***** *******    1.00   13.39

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  504.87 ****** ****** ******

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

EXITX:AS      75.   -50.     305.  0.47  1.05  497.88  494.06   1560.  497.40
      -24.    76.    66.   21812.  1.17  0.95   -0.01    0.60    5.12

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.412  0.233   16779.     3.    24.   497.02

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

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

FULLV:FV      24.   -45.     288.  0.51  0.13  498.04 *******   1560.  497.53
        0.    24.    49.   20733.  1.12  0.02    0.02    0.58    5.42
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.61
```

WSPRO OUTPUT FILE (continued)

```
 APPRO:AS      44.    -6.     183.  1.13  0.41  498.75 *******   1560.  497.62
        44.    44.    28.   12637.  1.00  0.31   -0.01    0.65    8.54
          <<<<<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      24.     0.     151.  1.65  0.25  498.54  494.97   1560.  496.88
         0.    24.    20.   10875.  1.00  0.41    0.00    0.65   10.30

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  1.000 ******  498.28 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
    RDWAY:RG      10.        <<<<<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      17.   -10.     216.  0.82  0.25  499.34  496.01   1560.  498.51
        44.    18.    38.   15905.  1.02  0.56    0.01    0.61    7.22

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.399  0.044   15159.     0.    20.  498.26

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
   FIRST USER DEFINED TABLE.
     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXIT :XS    -180.   -17.    32.   1560.   12735.     187.    8.35  491.36
    FV1  :FV    -117.   -20.    32.   1560.   13848.     198.    7.86  492.35
    RRBRD:BR    -117.     1.    22.   1560.    8087.     117.   13.39  493.09
    EXITX:AS     -24.   -50.    66.   1560.   21812.     305.    5.12  497.40

     XSID:CODE   XLKQ   XRKQ       KQ
    EXITX:AS       3.    24.   16779.

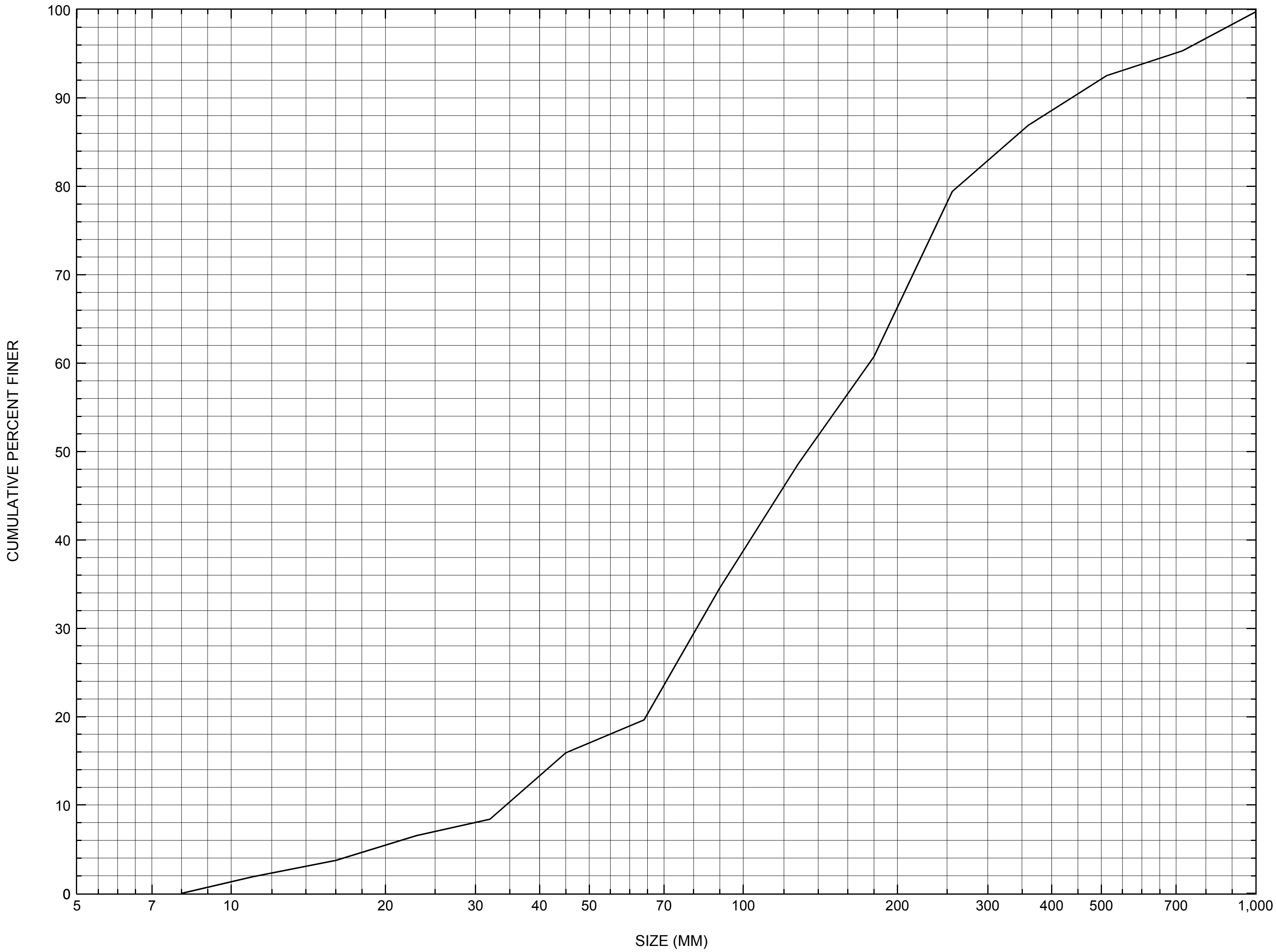
     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    FULLV:FV       0.   -45.    49.   1560.   20733.     288.    5.42  497.53
    BRIDG:BR       0.     0.    20.   1560.   10875.     151.   10.30  496.88
    RDWAY:RG      10.**************      0.*****************    2.00********
    APPRO:AS      44.   -10.    38.   1560.   15905.     216.    7.22  498.51

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS       0.    20.   15159.

  SECOND USER DEFINED TABLE.
     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXIT :XS    490.44    0.76  485.36  510.09************  1.11  492.48  491.36
    FV1  :FV  ********    0.72  486.12  510.85  0.87  0.00  1.00  493.35  492.35
    RRBRD:BR    493.09    1.00  485.78  505.09************  2.79  495.88  493.09
    EXITX:AS    494.06    0.60  488.77  518.32  1.05  0.95  0.47  497.88  497.40
    FULLV:FV  ********    0.58  489.06  518.61  0.13  0.02  0.51  498.04  497.53
    BRIDG:BR    494.97    0.65  488.10  498.32  0.25  0.41  1.65  498.54  496.88
    RDWAY:RG  ****************  498.71  518.32**********************************
    APPRO:AS    496.01    0.61  489.85  517.27  0.25  0.56  0.82  499.34  498.51
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WALDTH00050020, in Walden, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WALDTH00050020

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. IVANOFF

Date *(MM/DD/YY)* 04 / 05 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 75700

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

Waterway *(I - 6)* STANNARD BROOK

Road Name *(I - 7)*: -

Route Number TH005

Vicinity *(I - 9)* AT JCT TH 5 + TH 4

Topographic Map Caspian Lake

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44324

Longitude *(i - 17; nnnnn.n)* 72159

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10031500200315

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

Maximum span length *(I - 48; nnnn)* 0021

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

Structure length *(I - 49; nnnnnn)* 000024

Average daily traffic, ADT *(I - 29; nnnnnn)* 000350

Deck Width *(I - 52; nn.n)* 182

Year of ADT *(I - 30; YY)* 93

Channel & Protection *(I - 61; n)* 5

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

Waterway adequacy *(I - 71; n)* 6

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

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

Structure type *(I - 43; nnn)* 101

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*) 8.8

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

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

Comments:

The structural inspection report of 06/03/93 indicates the structure is a steel stringer type bridge with a concrete deck. The abutment walls and wingwalls are concrete. There are minor fine cracks, small leaks, and spalls reported overall. The footings are exposed, but the concrete appears fairly new. The downstream right wingwall has a new concrete cap and the entire upstream right wingwall is new. Some boulder stone fill is present in front of the wingwalls and along the channel banks.

Bridge Hydrologic Data

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

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} (*ft³/ sec*): -

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

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

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

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft²*): -

Downstream distance (*miles*): - Town: - Year Built: -

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **7.77** mi^2

Lake/pond/swamp area **.032** mi^2

Watershed storage *(ST)* **.41** %

Bridge site elevation **1180** ft

Headwater elevation **2451** ft

Main channel length **6.273** mi

10% channel length elevation **1266** ft

85% channel length elevation **2159** ft

Main channel slope *(S)* **189.81** 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:

NO BENCHMARK INFORMATION

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS

Cross-sectional Data

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

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

Comments: **This is a cross-section of the upstream face. The low chord elevation is from the survey log done for this report dated 7/27/95. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 06/03/93.**

Station	0	2	8	18	20	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	498.3	498.3	498.3	498.3	498.3	-	-	-	-	-	-
Bed elevation	492.3	489.5	488.8	489.6	491.9	-	-	-	-	-	-
Low chord to bed	6	8.8	9.5	8.7	6.4	-	-	-	-	-	-

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 E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **3/22/96**
Computerized by: **RB** Date: **4/11/96**
Reviewd by: **RB** Date: **7/2/98**

Structure Number **WALDTH00050020**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E**. **BOEHMLER** Date *(MM/DD/YY)* **7** / **26** / 19**95**

2. Highway District Number **07** Mile marker **-**

County **CALEDONIA (005)** Town **WALDEN (75700)**

Waterway *(I - 6)* **STANNARD BROOK** Road Name **-**

Route Number **TH05** Hydrologic Unit Code: **01080102**

3. Descriptive comments:

The bridge is located at the intersection of TH05 with TH04.

B. Bridge Deck Observations

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

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

7. Bridge length **24** *(feet)* Span length **21** *(feet)* Bridge width **18.2** *(feet)*

Road approach to bridge:

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

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

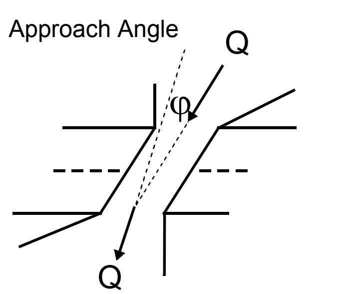
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

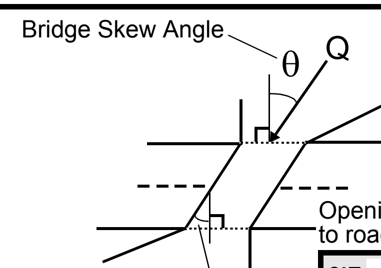
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	2
RBUS	0	-	2	1
RBDS	0	-	2	2
LBDS	0	-	2	2

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

Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **20**





Opening skew to roadway α= **15.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **190** feet **US** *(US, UB, DS)* to **120** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **47** feet **US** *(US, UB, DS)* to **0** feet **US**

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

18. Bridge Type: **1a**

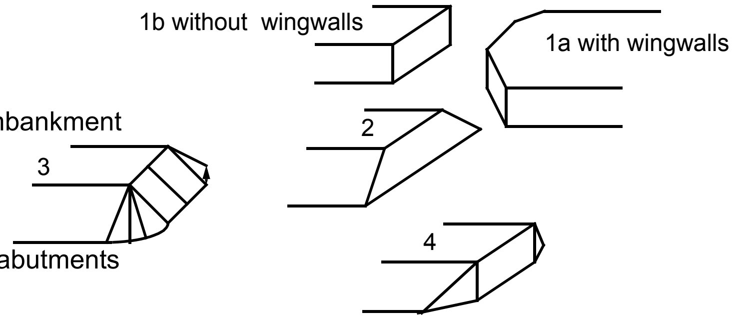
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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. Values are from the VTAOT files. Measured bridge length is 23 feet, bridge span is 21.5 feet and the width is 18.2 feet.

4. On both the US and DS right bank, the gravel roadway, TH04, runs along the top of the bank. On the US right bank there is also a home with a gravel driveway and a lawn. On the DS right bank there is a garage.

17. A third impact zone is on the right abutment from the US end to the DS end. The severity is slight.

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
24.0	**7.5**			**6.0**	**3**	**1**	**324**	**7**	**1**	**1**

23. Bank width **45.0** 24. Channel width **40.0** 25. Thalweg depth **37.0** 29. Bed Material **435**

30 .Bank protection type: LB **3** RB **3** 31. Bank protection condition: LB **1** RB **2**

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.):

30. The right bank protection extends from the bridge to 157 feet US. The left bank protection stretches from the bridge to 42 feet US.

31. The protection on the right bank is slumped such that in places there is a vertical slip face where stone fill has dropped down particularly between the bridge and 50 feet US.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **105** 35. Mid-bar width: **12**
36. Point bar extent: **135** feet **US** *(US, UB)* to **75** feet **US** *(US, UB, DS)* positioned **0** %LB to **15** %RB
37. Material: **342**
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
This is a narrow point bar with no vegetation.

39. Is a cut-bank present? **Y** *(Y or if N type ctrl-n cb)* 40. Where? **LB** *(LB or RB)*
41. Mid-bank distance: **25** 42. Cut bank extent: **75** feet **US** *(US, UB)* to **10** feet **US** *(US, UB, DS)*
43. Bank damage: **1** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*
44. Cut bank comments (eg. additional cut banks, protection condition, etc.):
The left bank protection is slightly slumped and the bank is eroded slightly.

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) 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
23.5		**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.):
453
There is a scour hole along the right abutment side of the channel under the bridge and is described in the DS channel assessment section.

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

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

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

70. Debris and Ice Comments:

2

Small bends in the channel just US from the bridge contribute to ice and debris accumulation. There are also large boulders and some stone fill on the bed that obstructs flow and helps catch debris and ice. Many trees and a sinuous stream make for moderate debris potential.

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	2	2	0	2.75	90.0
RABUT	1	10	90			2	3	19.5

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.):

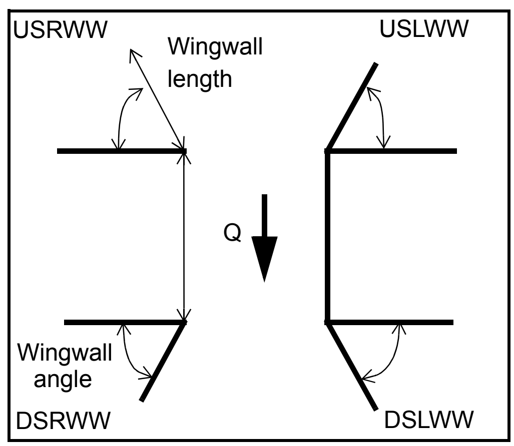
1.0
3.5
1

74. Penetration under the right abutment footing is 0.5 feet at the DS end and 1.5 feet near the centerline of the road.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						19.5	
USRWW:	Y		1		2	1.5	
DSLWW:	0		3		Y	19.5	
DSRWW:	1		2		0	20.0	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	2	2	Y	0	1	1	1	-
Condition	Y	0	1	2.5	1	1	4	-
Extent	1	2.5	2	2	3	2	0	-

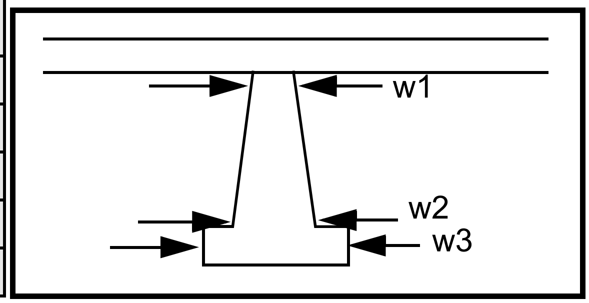
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
3
2
1
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**25.0**	**12.0**	**50.0**
Pier 2			**8.5**	**13.0**	**60.0**	**25.0**
Pier 3	**9.0**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**condi-**	**effec-**	**ly**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**pro-**	**tion**	**tive.**	**arou**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**tec-**	**and**	**The**	**nd**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**tion**	**alon**	**DS**	**the**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**on**	**g the**	**left**	**DS**	*Y- yes; N- no*
91. Attack ∠ (BF)	**the**	**entir**	**wing**	**cor-**	
92. Pushed	**US**	**e**	**wall**	**ner**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**left**	**base,**	**pro-**	**but**	
95. Cross-members	**wing**	**but**	**tec-**	**there**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**wall**	**is**	**tion**	**are**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**is in**	**not**	**is**	**two**	
98. Exposure depth	**good**	**very**	**main**	**boul-**	

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

ders in front of the wall. The protection on the US and DS right wingwalls is good. There are only a few boulders placed along the left abutment footing and one boulder on the right abutment footing near the centerline. The boulders on the left abutment footing are sparse and do not completely cover the left abutment.

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? N (Y or if N type ctrl-n cb) Where? O (LB or RB) Mid-bank distance: PIE

Cut bank extent: RS feet ____ (US, UB, DS) to ____ feet ____ (US, UB, DS)

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

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

Is channel scour present? ____ (Y or if N type ctrl-n cs) Mid-scour distance: 3

Scour dimensions: Length 1 Width 324 Depth: 7 Positioned 1 %LB to 0 %RB

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

453
0
2
-

Are there major confluences? 1 (Y or if N type ctrl-n mc) How many? The

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

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

Confluence comments (eg. confluence name):

extends from the bridge to 61 feet DS, then at 67 feet DS there is a retaining wall that ends at 150 feet DS. The right bank material is completely covered by stone fill. The retaining wall is located where the railroad bridge

F. Geomorphic Channel Assessment

107. Stage of reach evolution cro

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)*:

sses the brook about 80 feet DS. The roadway for TH04 and the channel are squeezed through the rail-road bridge. A storm drain culvert enters on the right bank at 63 feet 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: WALDTH00050020 Town: Walden
Road Number: TH5 County: Caledonia
Stream: Stannard Brook

Initials SAO Date: 12/8/97 Checked: EMB

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1630	2600	1560
Main Channel Area, ft2	250	310	214
Left overbank area, ft2	13	71	0
Right overbank area, ft2	34	257	2
Top width main channel, ft	35	35	35
Top width L overbank, ft	20	50	0
Top width R overbank, ft	73	143	9
D50 of channel, ft	0.437	0.437	0.437
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.1	8.9	6.1
y1, average depth, LOB, ft	0.7	1.4	ERR
y1, average depth, ROB, ft	0.5	1.8	0.2
Total conveyance, approach	21623	47145	15900
Conveyance, main channel	20625	29578	15871
Conveyance, LOB	148	1396	0
Conveyance, ROB	850	16171	27
Percent discrepancy, conveyance	0.0000	0.0000	0.0126
Qm, discharge, MC, cfs	1554.8	1631.2	1557.2
Ql, discharge, LOB, cfs	11.2	77.0	0.0
Qr, discharge, ROB, cfs	64.1	891.8	2.6
Vm, mean velocity MC, ft/s	6.2	5.3	7.3
Vl, mean velocity, LOB, ft/s	0.9	1.1	ERR
Vr, mean velocity, ROB, ft/s	1.9	3.5	1.3
Vc-m, crit. velocity, MC, ft/s	11.8	12.2	11.5
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	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

```
Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation        Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

                                    Q100     Q500     OtherQ
Q, total, cfs                       1630     2600     1560
Q, thru bridge MC, cfs              1396     1093     1560
Vc, critical velocity, ft/s         11.81    12.24    11.50
Va, velocity MC approach, ft/s      6.22     5.26     7.28
Main channel width (normal), ft     19.6     19.6     19.6
Cum. width of piers in MC, ft       0.0      0.0      0.0
W, adjusted width, ft               19.6     19.6     19.6
qbr, unit discharge, ft2/s          71.2     55.8     79.6
Area of full opening, ft2           179.0    179.0    151.0
Hb, depth of full opening, ft       9.13     9.13     7.70
Fr, Froude number, bridge MC        0.46     0.36     0
Cf, Fr correction factor (<=1.0)    1.00     0.97     0.00
**Area at downstream face, ft2      169      N/A      N/A
**Hb, depth at downstream face, ft  8.62     N/A      N/A
**Fr, Froude number at DS face      0.50     ERR      ERR
**Cf, for downstream face (<=1.0)   1.00     N/A      N/A
Elevation of Low Steel, ft          498.28   498.28   0
Elevation of Bed, ft                489.15   489.15   -7.70
Elevation of Approach, ft           499.54   501.25   0
Friction loss, approach, ft         0.18     0.15     0
Elevation of WS immediately US, ft  499.36   501.10   0.00
ya, depth immediately US, ft        10.21    11.95    7.70
Mean elevation of deck, ft          500.93   500.93   0
w, depth of overflow, ft (>=0)      0.00     0.17     0.00
Cc, vert contrac correction (<=1.0) 0.97     0.94     1.00
**Cc, for downstream face (<=1.0)   0.958609 ERR      ERR

Ys, scour w/Chang equation, ft      -2.93    -4.10    N/A
Ys, scour w/Umbrell equation, ft    -1.49    -1.28    N/A

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.
**Ys, scour w/Chang equation, ft    -2.33    N/A      N/A
**Ys, scour w/Umbrell equation, ft  -0.98    N/A      ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen
equation results and the estimated downstream bridge face properties
can also be computed (ys=y2-ybridgeDS)
   y2, from Laursen's equation, ft  5.70     4.62     6.27
   WSEL at downstream face, ft      497.76   --       --
   Depth at downstream face, ft     8.62     N/A      N/A
Ys, depth of scour (Laursen), ft    -2.93    N/A      N/A
```

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1630	2600	1560
(Q) discharge thru bridge, cfs	1396	1093	1560
Main channel conveyance	10352	10352	10868
Total conveyance	10352	10352	10868
Q2, bridge MC discharge,cfs	1396	1093	1560
Main channel area, ft2	179	179	151
Main channel width (normal), ft	19.6	19.6	19.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19.6	19.6	19.6
y_bridge (avg. depth at br.), ft	9.13	9.13	7.70
Dm, median (1.25*D50), ft	0.54625	0.54625	0.54625
y2, depth in contraction,ft	5.70	4.62	6.27
ys, scour depth (y2-ybridge), ft	-3.44	-4.51	-1.44

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	1396	1093	1560
Main channel area (DS), ft2	169	179	151
Main channel width (normal), ft	19.6	19.6	19.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	19.6	19.6	19.6
D90, ft	1.4336	1.4336	1.4336
D95, ft	2.2701	2.2701	2.2701
Dc, critical grain size, ft	0.3728	0.1983	0.6148
Pc, Decimal percent coarser than Dc	0.561	0.810	0.371

Depth to armoring, ft	0.88	0.14	3.13

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1630	2600	1560	1630	2600	1560
a', abut.length blocking flow, ft	26.8	57.1	10.5	24.9	24.9	18.5
Ae, area of blocked flow ft2	45.9	99	28.7	36.2	78.9	37.8
Qe, discharge blocked abut.,cfs	80.9	--	72.5	--	--	145
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.76	1.60	2.53	3.05	3.52	3.84
ya, depth of f/p flow, ft	1.71	1.73	2.73	1.45	3.17	2.04
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	75	75	75	105	105	105
K2	0.98	0.98	0.98	1.02	1.02	1.02
Fr, froude number f/p flow	0.237	0.200	0.269	0.549	0.429	0.473
ys, scour depth, ft	5.94	7.04	6.71	7.95	11.88	8.38

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

a'(abut length blocked, ft)	26.8	57.1	10.5	24.9	24.9	18.5
y1 (depth f/p flow, ft)	1.71	1.73	2.73	1.45	3.17	2.04
a'/y1	15.65	32.93	3.84	17.13	7.86	9.05
Skew correction (p. 49, fig. 16)	0.95	0.95	0.95	1.03	1.03	1.03
Froude no. f/p flow	0.24	0.20	0.27	0.55	0.43	0.47
Ys w/ corr. factor K1/0.55:						
vertical	ERR	7.04	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	5.78	ERR	ERR	ERR	ERR
spill-through	ERR	3.87	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 others, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.5	0.36	0.65	0.5	0.36	0.65
y, depth of flow in bridge, ft	8.62	9.13	7.70	8.62	9.13	7.70
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.33	0.73	2.01	1.33	0.73	2.01
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.16	0.64	1.75	1.16	0.64	1.75
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR