LEVEL II SCOUR ANALYSIS FOR BRIDGE 26 (JAMATH00010026) on TOWN HIGHWAY 1, crossing BALL MOUNTAIN BROOK, JAMAICA, VERMONT

U.S. Geological Survey
Open-File Report 97-395

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 26 (JAMATH00010026) on TOWN HIGHWAY 1, crossing BALL MOUNTAIN BROOK, JAMAICA, VERMONT

By Ronda L. Burns and Laura Medalie

U.S. Geological Survey
Open-File Report 97-395

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

Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information write to:

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

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

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 26 (JAMATH00010026) ON TOWN HIGHWAY 1, CROSSING BALL MOUNTAIN BROOK, JAMAICA, VERMONT

By **Ronda L. Burns and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure JAMATH00010026 on Town Highway 1 crossing Ball Mountain Brook, Jamaica, 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 southern Vermont. The 29.3-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, Ball Mountain Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 74 ft and an average bank height of 6 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 82.6 mm (0.271 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 12, 1996, indicated that the reach was stable.

The Town Highway 1 crossing of Ball Mountain Brook is a 80-ft-long, two-lane bridge consisting of one 78-foot steel-beam span (Vermont Agency of Transportation, written communication, March 29, 1995). The opening length of the structure parallel to the bridge face is 75.7 ft. The bridge is supported by vertical, concrete abutments with wingwalls. A scour hole 2 ft deeper than the mean thalweg depth was observed along the right abutment during the Level I assessment. The scour protection measures at the site were type-4 stone fill (less than 60 inches diameter) along the left bank upstream and extending underneath the bridge and along the bank downstream and also along the right bank upstream tapering to type-3 stone fill (less than 48 inches diameter) at the upstream end of 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 others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for the modelled flows ranged from 1.0 to 2.7 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge. Abutment scour ranged from 8.4 to 17.6 ft. The worst-case abutment scour for the right abutment occurred at the incipient-overtopping discharge. For the left abutment, 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 others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number JAMATH00010026 ***Stream*** Ball Mountain Brook

County Windham ***Road*** TH 1 ***District*** 2

Description of Bridge

Bridge length 80 ***ft*** ***Bridge width*** 29.3 ***ft*** ***Max span length*** 78 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 08/12/96

Description of stone fill Type-4, around the upstream left wingwall, left abutment and downstream left wingwall. The stone fill is sloped to create a spill through abutment. Also, along the right upstream bank tappering to type-3 at the upstream right wingwall.

Abutments and wingwalls are concrete. There is a one foot deep scour hole along the right abutment.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 10

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	08/12/96	0	0
Level II	08/12/96	0	0

Potential for debris Moderate.

Describe any features near or at the bridge that may affect flow (include observation date) None 08/12/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with steep valley walls on both sides.

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

Date of inspection 08/12/96

DS left: Steep valley wall.

DS right: Steep valley wall.

US left: Steep valley wall.

US right: Steep valley wall.

Description of the Channel

Average top width 74 *ft* ***Average depth*** 6 *ft*

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

Sinuous but stable with semi-alluvial channel boundaries.

08/12/96

Vegetative co Trees.

DS left: Trees.

DS right: Trees

US left: Trees.

US right:

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

None 08/12/97.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 29.3 ***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 8,550 ***ft³/s*** ***Q500*** 12,280 ***ft³/s***

The 100-year discharge is from the flood frequency estimates available from the VTAOT database. The 500-year event was extrapolated from these estimates. 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).

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 Subtract 16.7 from the USGS arbitrary survey datum to obtain the VT AOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a brass survey disk on top of the downstream end of the right abutment (elev. 517.35 ft, arbitrary survey datum). RM2 is a nail in a telephone pole on the downstream right bank (elev. 514.61 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	-76	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	16	1	Road Grade section
APPRO	109	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 0.060 to 0.065, 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 for the 100-year and incipient over-topping discharges. 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 0.022 ft/ft which was estimated from the 100-year water-surface profile slope downstream of the bridge in the Flood Insurance Study for Jamaica, VT (Federal Emergency Management Agency, 1988). Critical depth was used for the starting water surfaces at the exit section (EXITX) for the 500-year discharge. Normal depth was computed as approximately 0.3 ft below critical depth by use of the slope-conveyance method.

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

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. By 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 519.0 *ft*
Average low steel elevation 515.0 *ft*

100-year discharge 8,550 *ft³/s*
Water-surface elevation in bridge opening 509.6 *ft*
Road overtopping? No *Discharge over road* - *ft³/s*
Area of flow in bridge opening 557 *ft²*
Average velocity in bridge opening 15.4 *ft/s*
Maximum WSPRO tube velocity at bridge 19.4 *ft/s*

Water-surface elevation at Approach section with bridge 513.8
Water-surface elevation at Approach section without bridge 511.8
Amount of backwater caused by bridge 2.0 *ft*

500-year discharge 12,280 *ft³/s*
Water-surface elevation in bridge opening 515.0 *ft*
Road overtopping? Yes *Discharge over road* 1,679 *ft³/s*
Area of flow in bridge opening 926 *ft²*
Average velocity in bridge opening 11.5 *ft/s*
Maximum WSPRO tube velocity at bridge 15.5 *ft/s*

Water-surface elevation at Approach section with bridge 518.3
Water-surface elevation at Approach section without bridge 514.0
Amount of backwater caused by bridge 4.3 *ft*

Incipient overtopping discharge 9,250 *ft³/s*
Water-surface elevation in bridge opening 509.9 *ft*
Area of flow in bridge opening 574 *ft²*
Average velocity in bridge opening 16.1 *ft/s*
Maximum WSPRO tube velocity at bridge 20.4 *ft/s*

Water-surface elevation at Approach section with bridge 514.6
Water-surface elevation at Approach section without bridge 512.2
Amount of backwater caused by bridge 2.4 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year and incipient over-topping discharges was computed by use of the live-bed contraction scour equation (Richardson and others, 1995, p. 30, equation 17). At this site, the 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 500-year event was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, estimates of contraction scour at the 500-year discharge were also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and are presented in Appendix F. Furthermore, since the 500-year discharge was unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in Appendix F.

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

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the left vertical concrete abutment wall is unknown. Therefore, the total scour depth computed at the toe of the embankment was applied for the entire spill-through embankment as shown in figure 8.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	2.0	--	2.7
Clear-water scour	--	1.0	--
Depth to armoring	34.9	12.0	47.8
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	8.4	11.2	8.9
Right abutment	16.7	17.0	17.6
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	3.2	3.2	3.3
Right abutment	3.6	3.6	3.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

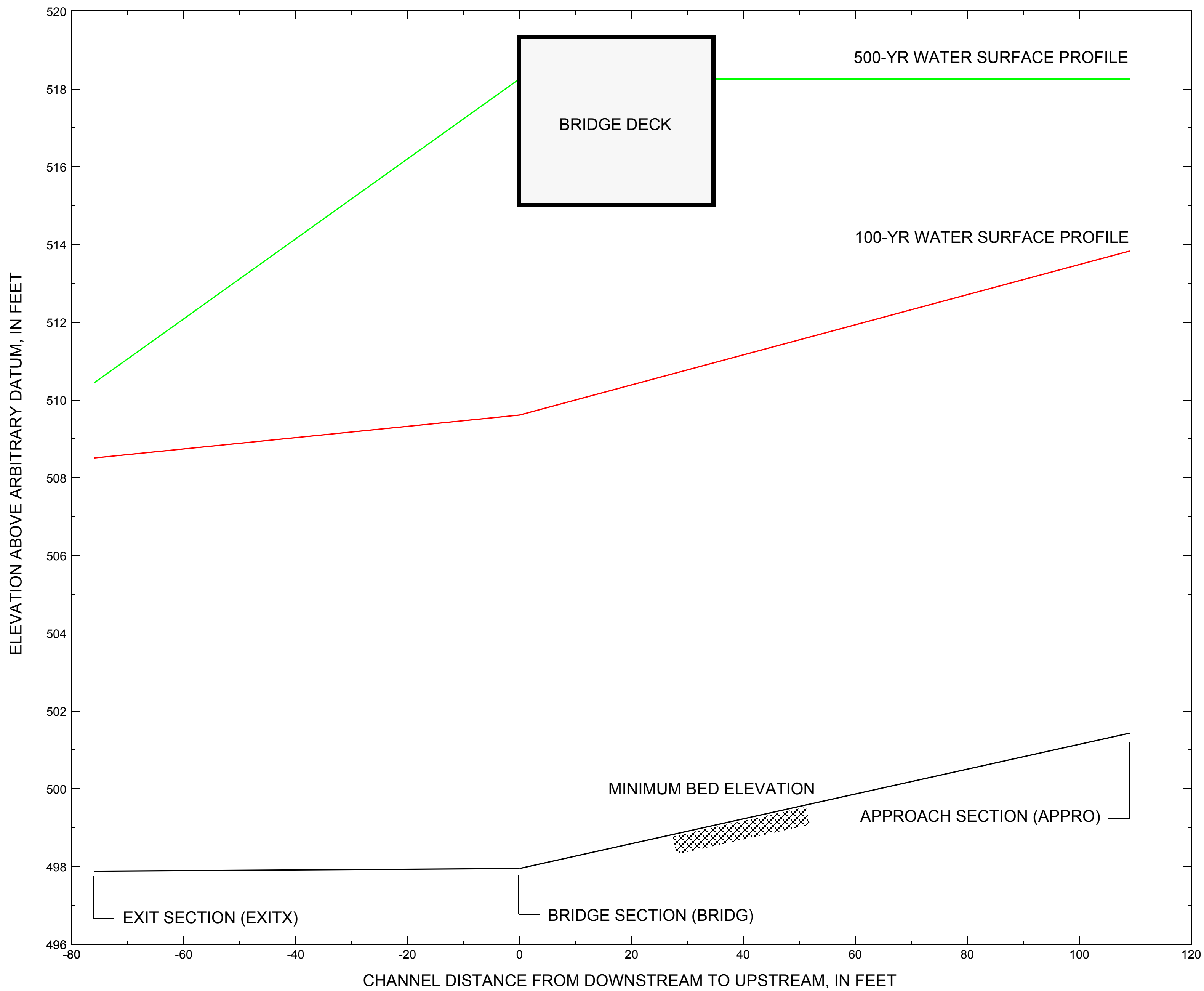


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure JAMATH00010026 on Town Highway 1, crossing Ball Mountain Brook, Jamaica, Vermont.

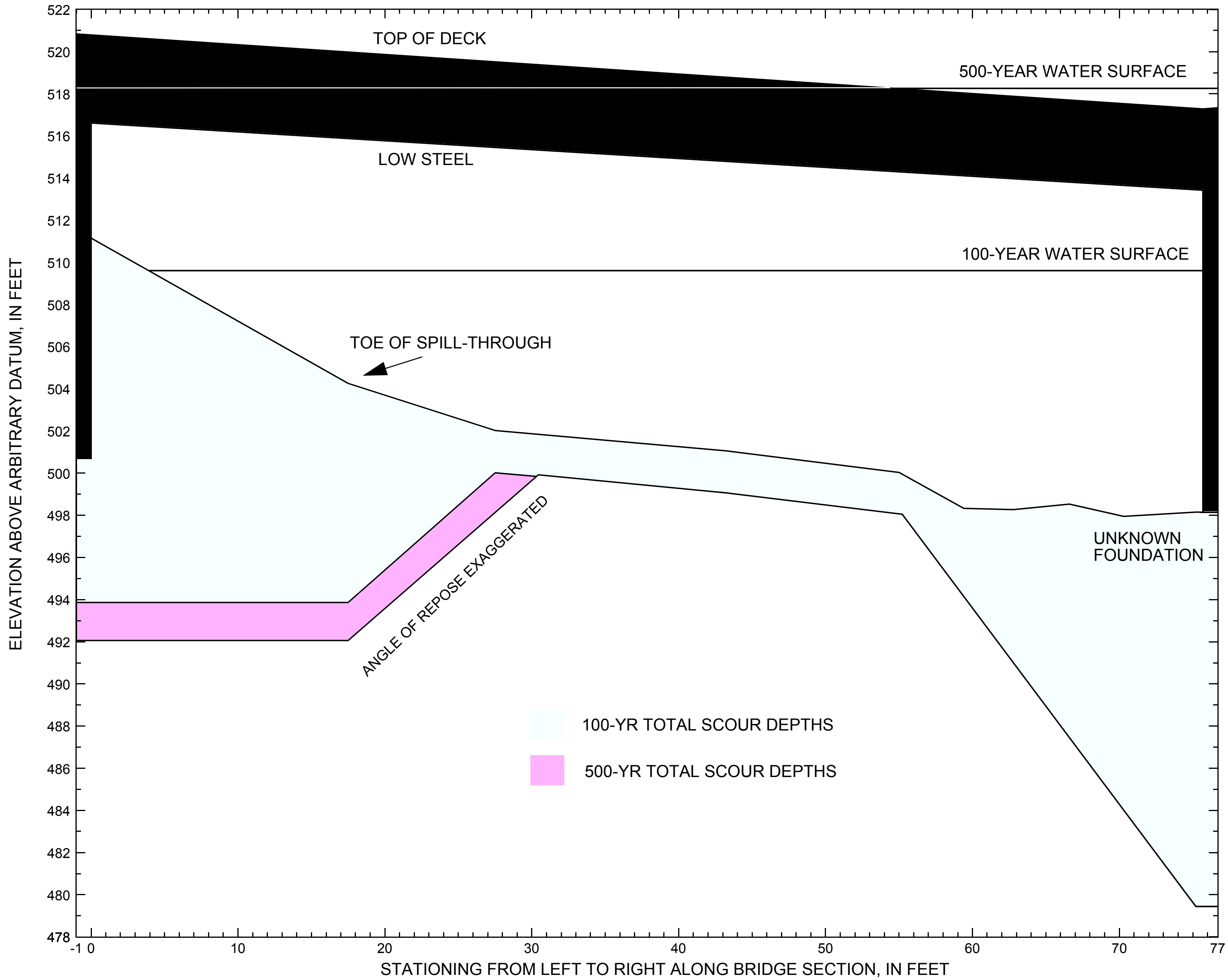


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure JAMATH00010026 on Town Highway 1, crossing Ball Mountain Brook, Jamaica, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure JAMATH00010026 on Town Highway 1, crossing Ball Mountain Brook, Jamaica, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 8,550 cubic-feet per second											
Left abutment	0.0	500.0	516.6	500.7	511.2	--	--	--	--	--	-6.8
LABUT toe	17.5	--	--	--	504.3	2.0	8.4	--	10.4	493.9	--
Right abutment	75.7	496.6	513.4	--	498.2	2.0	16.7	--	18.7	479.5	--

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 JAMATH00010026 on Town Highway 1, crossing Ball Mountain Brook, Jamaica, Vermont.

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

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 12,280 cubic-feet per second											
Left abutment	0.0	500.0	516.6	500.7	511.2	--	--	--	--	--	-8.6
LABUT toe	17.5	--	--	--	504.3	1.0	11.2	--	12.2	492.1	--
Right abutment	75.7	496.6	513.4	--	498.2	1.0	17.1	--	18.1	480.1	--

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.

Federal Emergency Management Agency, 1988, Flood Insurance Study, Town of Jamaica, Windham County, Vermont: Washington, D.C., May 17, 1988.

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, 1986, Jamaica, 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 jama026.wsp
T2        Hydraulic analysis for structure JAMATH00010026   Date: 20-MAR-97
T3        TH001 crossing Ball Mountain Brook in Jamaica, Vermont             RLB
*
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           8550.0  12280.0    9250.0
SK          0.022    0.022     0.022
*
XS   EXITX    -76           0.
GR          -22.1, 529.35      0.0, 511.63      3.2, 508.74     25.6, 508.29
GR           37.0, 501.04     46.3, 498.99     50.2, 498.48     55.7, 497.88
GR           61.2, 498.44     67.9, 498.14     78.0, 498.55     80.9, 499.08
GR           99.3, 502.16    103.6, 506.54    125.8, 508.95    142.4, 508.09
GR          176.9, 511.33    208.9, 511.31    241.2, 529.56
*
N           0.075        0.065        0.043
SA                 25.6         103.6
*
*
XS   FULLV      0  * * *   0.010
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    515.02      8.0
GR            0.0, 516.61      0.9, 511.15     17.5, 504.26     27.5, 502.02
GR           43.2, 501.06     55.0, 500.03     59.4, 498.33     62.8, 498.27
GR           66.6, 498.53     70.3, 497.95     75.2, 498.15     75.5, 500.01
GR           75.7, 513.42      0.0, 516.61
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      44.5 * *     48.9      8.6
N           0.060
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     16      29.3     1
GR         -120.0, 543.95    -81.3, 524.20     -2.1, 520.79     -2.0, 521.19
GR            0.0, 521.22     75.7, 518.12     77.5, 518.03     77.7, 517.28
GR          164.2, 514.59    219.6, 545.33
*
*
AS   APPRO    109
GR          -37.6, 533.20    -22.6, 517.76      0.0, 511.85     18.3, 508.99
GR           25.9, 504.42     36.7, 502.73     43.4, 502.28     50.5, 501.43
GR           53.2, 501.98     58.5, 502.36     62.5, 502.01     66.4, 501.60
GR           70.9, 502.07     73.6, 502.61     87.1, 510.38     97.1, 515.36
GR          130.1, 515.41    175.9, 537.41
*
N           0.075        0.060      0.035
SA                 18.3        97.1
*
HP 1 BRIDG  509.61 1 509.61
HP 2 BRIDG  509.61 * * 8550
HP 1 APPRO  513.83 1 513.83
HP 2 APPRO  513.83 * * 8550
*
HP 1 BRIDG  515.02 1 515.02
HP 2 BRIDG  515.02 * * 10652
HP 1 BRIDG  512.55 1 512.55
HP 2 RDWAY  518.26 * * 1679
HP 1 APPRO  518.26 1 518.26
HP 2 APPRO  518.26 * * 12280
*
HP 1 BRIDG  509.85 1 509.85
HP 2 BRIDG  509.85 * * 9250
HP 1 APPRO  514.58 1 514.58
HP 2 APPRO  514.58 * * 9250
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File jama026.wsp
      Hydraulic analysis for structure JAMATH00010026   Date: 20-MAR-97
      TH001 crossing Ball Mountain Brook in Jamaica, Vermont             RLB
         *** RUN DATE & TIME: 06-19-97  14:02

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      557     49128     70     83                         8891
  509.61           557     49128     70     83  1.00      5     76     8891

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      509.61     4.6    75.6   556.9   49128.    8550.  15.35

X STA.         4.6        20.3        25.6        29.6        33.3        36.7
  A(I)            49.7        34.6        29.8        28.8        26.8
  V(I)            8.61       12.36       14.33       14.83       15.97

X STA.        36.7        39.9        43.0        45.9        48.6        51.2
  A(I)            26.0        26.0        24.9        24.4        23.5
  V(I)           16.44       16.45       17.17       17.55       18.21

X STA.        51.2        53.8        56.2        58.4        60.4        62.4
  A(I)            23.6        23.6        22.7        22.3        22.0
  V(I)           18.15       18.13       18.79       19.15       19.42

X STA.        62.4        64.5        66.6        68.8        71.4        75.6
  A(I)            23.1        23.2        25.3        28.9        47.8
  V(I)           18.47       18.45       16.90       14.81        8.95

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       70      2661     26     26                          652
            2      710     75377     76     80                        12331
  513.83           780     78038    102    107  1.09     -7     94    11727

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

        WSEL     LEW     REW    AREA        K        Q    VEL
      513.83    -7.6    94.0   779.7   78038.    8550.  10.97

X STA.        -7.6        21.4        26.6        30.3        33.7        36.7
  A(I)            87.6        42.8        36.4        34.9        33.2
  V(I)            4.88        9.98       11.75       12.26       12.86

X STA.        36.7        39.6        42.4        45.1        47.8        50.3
  A(I)            32.1        32.5        31.5        31.8        30.7
  V(I)           13.30       13.16       13.59       13.44       13.95

X STA.        50.3        52.9        55.7        58.5        61.3        64.1
  A(I)            31.6        32.5        32.5        32.9        33.2
  V(I)           13.54       13.15       13.17       13.01       12.87

X STA.        64.1        67.0        69.9        73.3        77.8        94.0
  A(I)            34.7        34.9        39.6        45.5        68.8
  V(I)           12.31       12.25       10.80        9.39        6.21
```

```
       U.S. Geological Survey WSPRO Input File jama026.wsp
       Hydraulic analysis for structure JAMATH00010026   Date: 20-MAR-97
       TH001 crossing Ball Mountain Brook in Jamaica, Vermont             RLB
          *** RUN DATE & TIME: 06-19-97  14:02

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      926     84022     37    133                        26242
   515.02           926     84022     37    133  1.00      0     76    26242

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      515.02     0.3    75.7   925.8   84022.   10652.  11.51

X STA.        0.3       11.5       16.5       20.2       23.5       26.4
  A(I)            65.0       45.5       40.2       38.3       35.5
  V(I)            8.19      11.70      13.25      13.91      15.00

X STA.       26.4       29.1       31.7       34.3       36.9       40.3
  A(I)            34.9       34.2       34.5       34.8       45.3
  V(I)           15.26      15.56      15.45      15.29      11.77

X STA.       40.3       43.8       47.4       50.8       54.2       57.5
  A(I)            48.1       48.5       48.0       47.2       47.6
  V(I)           11.07      10.97      11.11      11.28      11.20

X STA.       57.5       60.5       63.6       66.8       70.3       75.7
  A(I)            46.2       48.1       49.1       54.0       80.8
  V(I)           11.52      11.06      10.85       9.86       6.60

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      772     79427     74     92                        14119
   512.55           772     79427     74     92  1.00      1     76    14119

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      16.

        WSEL     LEW     REW    AREA        K        Q    VEL
      518.26    72.3   170.8   213.9   12546.    1679.   7.85

X STA.       72.3       98.0      107.1      113.1      118.1      122.7
  A(I)            26.9       16.1       11.7       11.0       10.6
  V(I)            3.12       5.21       7.15       7.65       7.92

X STA.      122.7      126.8      130.7      134.3      137.6      140.7
  A(I)            10.0       10.1        9.4        9.3        9.1
  V(I)            8.42       8.34       8.88       8.98       9.23

X STA.      140.7      143.7      146.5      149.2      151.8      154.3
  A(I)             8.9        8.6        8.6        8.4        8.3
  V(I)            9.46       9.78       9.78       9.97      10.14

X STA.      154.3      156.7      159.1      161.5      164.0      170.8
  A(I)             8.3        8.2        8.7        8.9       12.9
  V(I)           10.13      10.20       9.70       9.44       6.53

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     109.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      222     13229     41     43                         2911
             2     1057    142242     79     84                        21953
             3      103      8340     39     40                          955
   518.26          1382    163811    159    166  1.16    -22    136    21415

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

        WSEL     LEW     REW    AREA        K        Q    VEL
      518.26   -23.1   136.0  1381.5  163811.   12280.   8.89

X STA.      -23.1       10.5       21.3       26.7       30.7       34.5
  A(I)           154.4       97.9       67.8       57.2       57.0
  V(I)            3.98       6.27       9.05      10.73      10.76

X STA.       34.5       38.0       41.4       44.7       48.0       51.1
  A(I)            54.1       53.1       53.4       52.9       52.4
  V(I)           11.36      11.56      11.50      11.60      11.71

X STA.       51.1       54.4       57.7       61.2       64.6       68.0
  A(I)            54.3       53.3       55.5       54.9       56.9
  V(I)           11.30      11.53      11.05      11.19      10.79

X STA.       68.0       71.5       75.8       81.6       97.6      136.0
  A(I)            57.2       65.4       74.3      107.4      102.0
  V(I)           10.74       9.39       8.27       5.72       6.02
```

```
        U.S. Geological Survey WSPRO Input File jama026.wsp
        Hydraulic analysis for structure JAMATH00010026   Date: 20-MAR-97
        TH001 crossing Ball Mountain Brook in Jamaica, Vermont             RLB
           *** RUN DATE & TIME: 06-19-97  14:02

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      574     51293     71     84                          9262
   509.85           574     51293     71     84  1.00      4     76     9262

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       509.85     4.0    75.6   573.8   51293.    9250.  16.12

X STA.         4.0        20.0       25.3       29.3       32.9       36.3
  A(I)            51.7       35.5       30.6       29.0       27.6
  V(I)            8.95      13.01      15.09      15.95      16.73

X STA.        36.3        39.5       42.7       45.5       48.3       51.0
  A(I)            26.8       26.8       25.1       25.4       24.5
  V(I)           17.23      17.25      18.44      18.23      18.91

X STA.        51.0        53.5       56.0       58.2       60.3       62.3
  A(I)            24.1       24.0       23.9       23.0       22.7
  V(I)           19.20      19.26      19.33      20.12      20.36

X STA.        62.3        64.3       66.5       68.8       71.3       75.6
  A(I)            23.2       24.6       26.1       29.8       49.3
  V(I)           19.93      18.78      17.73      15.54       9.38

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       90      3804     29     29                           909
             2      767     84622     77     82                         13720
   514.58           858     88425    106    111  1.10     -9     96    13184

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

         WSEL     LEW     REW    AREA        K        Q    VEL
       514.58   -10.4    95.5   857.5   88425.    9250.  10.79

X STA.       -10.4        19.8       25.7       29.5       32.9       36.1
  A(I)            99.5       48.9       39.6       37.0       37.0
  V(I)            4.65       9.47      11.67      12.49      12.49

X STA.        36.1        39.0       41.9       44.7       47.4       50.1
  A(I)            35.0       34.3       34.6       34.3       34.1
  V(I)           13.21      13.47      13.38      13.47      13.55

X STA.        50.1        52.7       55.5       58.3       61.3       64.2
  A(I)            34.1       35.1       35.1       36.9       36.2
  V(I)           13.57      13.17      13.18      12.53      12.78

X STA.        64.2        67.0       70.2       73.6       78.5       95.5
  A(I)            36.8       40.1       41.9       51.6       75.3
  V(I)           12.58      11.53      11.05       8.96       6.14
```

```
        U.S. Geological Survey WSPRO Input File jama026.wsp
        Hydraulic analysis for structure JAMATH00010026   Date: 20-MAR-97
        TH001 crossing Ball Mountain Brook in Jamaica, Vermont            RLB
           *** RUN DATE & TIME: 06-19-97  14:02

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

EXITX:XS   ******     14      659  2.72 *****  511.24  507.65    8550  508.51
       -75 ******    147    57617  1.04 ***** *******    1.00   12.97

FULLV:FV       76      2      881  1.66  1.20  512.42 *******    8550  510.76
         0     76    163    80643  1.13  0.00   -0.01    0.78    9.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80     1.06     511.66     511.76
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   510.26     537.41    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   510.26     537.41     511.76
 ===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 "APPRO"
                 WSBEG,WSEND,CRWS =    511.76     537.41     511.76

APPRO:AS      109      1      582  3.54 *****  515.30  511.76    8550  511.76
       109    109     90    53016  1.05 ***** *******    1.04   14.69
         <<<<<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       76      5      557  3.67  1.96  513.28  509.39    8550  509.61
         0     76     76    49099  1.00  0.07    0.00    0.96   15.36

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  515.02 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.        <<<<<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       65     -7      780  2.04  1.26  515.87  511.76    8550  513.83
       109     66     94    78061  1.09  1.35    0.02    0.73   10.96

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.173  0.010   77025.     6.    77.   512.87

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -76.    14.   147.   8550.   57617.     659.   12.97  508.51
   FULLV:FV       0.     2.   163.   8550.   80643.     881.    9.70  510.76
   BRIDG:BR       0.     5.    76.   8550.   49099.     557.   15.36  509.61
   RDWAY:RG      16.**************      0.******************    1.00********
   APPRO:AS     109.    -8.    94.   8550.   78061.     780.   10.96  513.83

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       6.    77.   77025.

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS      FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    507.65     1.00  497.88  529.56************  2.72   511.24  508.51
   FULLV:FV  ********     0.78  498.64  530.32  1.20  0.00  1.66   512.42  510.76
   BRIDG:BR    509.39     0.96  497.95  516.61  1.96  0.07  3.67   513.28  509.61
   RDWAY:RG  ****************  514.59  545.33**********************************
   APPRO:AS    511.76     0.73  501.43  537.41  1.26  1.35  2.04   515.87  513.83
```

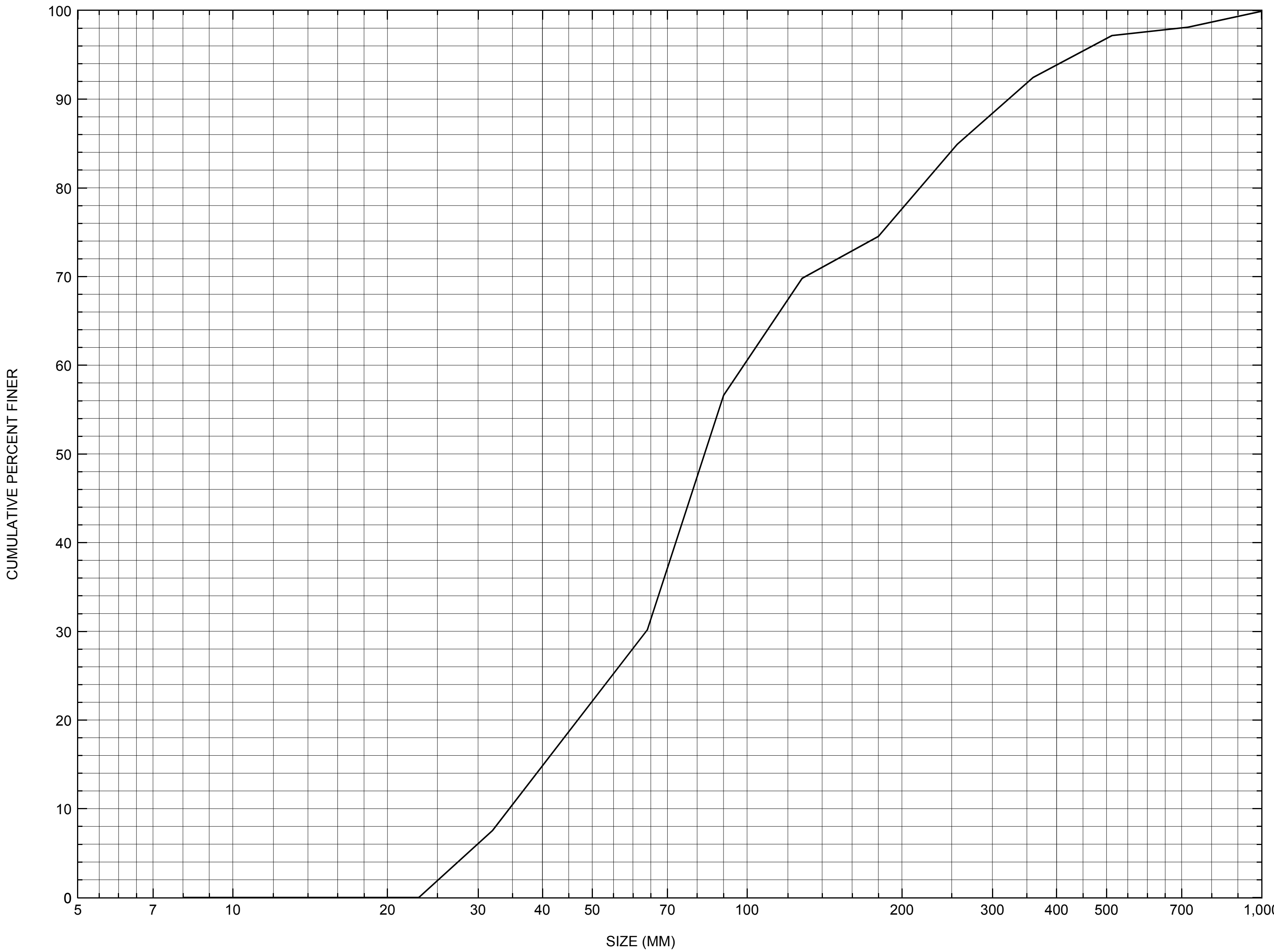
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File jama026.wsp
        Hydraulic analysis for structure JAMATH00010026   Date: 20-MAR-97
        TH001 crossing Ball Mountain Brook in Jamaica, Vermont             RLB
           *** RUN DATE & TIME: 06-19-97  14:02

 ===015 WSI IN WRONG FLOW REGIME AT SECID “EXITX”:  USED WSI = CRWS.
                           WSI,CRWS =   510.12     510.44

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

EXITX:XS   ******      1      953  2.95 *****  513.38  510.44   12280  510.44
       -75 ******    167    88853  1.14 ***** *******    1.01   12.89

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.82     512.57     511.20
 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   509.94     530.32    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   509.94     530.32     511.20

FULLV:FV       76      0     1202  1.93  1.11  514.48  511.20   12280  512.55
         0     76    210   116644  1.19  0.00   -0.01    0.82   10.21
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.20     513.00     513.98
 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   512.05     537.41    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   512.05     537.41     513.98
 ===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 “APPRO”
                  WSBEG,WSEND,CRWS =   513.98     537.41     513.98

APPRO:AS      109     -7      795  4.06 *****  518.04  513.98   12280  513.98
       109    109     94    80033  1.09 ***** *******    1.02   15.45
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   516.86       0.00     511.63     514.59
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   524.77         2.     12278.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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       76      0      926  2.06 *****  517.08  510.72   10652  515.02
         0 ******     76    84022  1.00 ***** *******    0.58   11.51

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.450 ******  515.02 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      16.    80.  0.45  1.43  519.24    0.00   1679.  518.26

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    22.    26.    48.   0.9   0.4   5.7  13.3   1.6   3.0
   RT:   1679.    93.    78.   171.   3.7   2.3   8.3   7.9   3.3   3.0

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

APPRO:AS       65    -22     1381  1.43  0.62  519.69  513.98   12280  518.26
       109     66    136   163706  1.16  0.00    0.00    0.57    8.89
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -76.     1.   167.  12280.   88853.     953.   12.89  510.44
   FULLV:FV       0.     0.   210.  12280.  116644.    1202.   10.21  512.55
   BRIDG:BR       0.     0.    76.  10652.   84022.     926.   11.51  515.02
   RDWAY:RG      16.*******     0.   1679.       0.*********    1.00  518.26
   APPRO:AS     109.   -23.   136.  12280.  163706.    1381.    8.89  518.26

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS      FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     510.44     1.01  497.88  529.56************  2.95  513.38  510.44
   FULLV:FV     511.20     0.82  498.64  530.32  1.11  0.00  1.93  514.48  512.55
   BRIDG:BR     510.72     0.58  497.95  516.61************  2.06  517.08  515.02
   RDWAY:RG  ****************  514.59  545.33  0.45******  1.43  519.24  518.26
   APPRO:AS     513.98     0.57  501.43  537.41  0.62  0.00  1.43  519.69  518.26
```

```
        U.S. Geological Survey WSPRO Input File jama026.wsp
        Hydraulic analysis for structure JAMATH00010026   Date: 20-MAR-97
        TH001 crossing Ball Mountain Brook in Jamaica, Vermont             RLB
           *** RUN DATE & TIME: 06-19-97  14:02

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

EXITX:XS   ******      3      707  2.86 *****  511.73  508.09    9250  508.87
       -75 ******    151    62325  1.08 ***** *******    1.08   13.08

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.44

FULLV:FV       76      1      960  1.65  1.16  512.89 *******    9250  511.24
         0     76    168    89651  1.14  0.00   -0.01    0.76    9.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     1.08     511.99     512.23
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   510.74     537.41     0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   510.74     537.41     512.23
 ===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 "APPRO"
                   WSBEG,WSEND,CRWS =   512.23     537.41     512.23

APPRO:AS      109      0      625  3.63 *****  515.86  512.23    9250  512.23
       109    109     91    58226  1.06 ***** *******    1.04   14.81
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =     9250.     509.85

            <<<<<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       76      4      574  4.04 *****  513.89  509.85    9250  509.85
         0     76     76    51326  1.00 ***** *******    1.00   16.11

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  515.02 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.        <<<<<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       65     -9      857  2.00  1.24  516.57  512.23    9250  514.58
       109     66     96    88388  1.10  1.45    0.02    0.70   10.79

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.189  0.012   87079.     6.    77.   513.70

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -76.     3.   151.   9250.   62325.     707.   13.08  508.87
   FULLV:FV       0.     1.   168.   9250.   89651.     960.    9.64  511.24
   BRIDG:BR       0.     4.    76.   9250.   51326.     574.   16.11  509.85
   RDWAY:RG      16.**************      0.******************    1.00********
   APPRO:AS     109.   -10.    96.   9250.   88388.     857.   10.79  514.58

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       6.    77.   87079.

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS     508.09    1.08  497.88  529.56************  2.86   511.73  508.87
   FULLV:FV   ********    0.76  498.64  530.32  1.16  0.00  1.65   512.89  511.24
   BRIDG:BR     509.85    1.00  497.95  516.61************  4.04   513.89  509.85
   RDWAY:RG   ****************  514.59  545.33**********************************
   APPRO:AS     512.23    0.70  501.43  537.41  1.24  1.45  2.00   516.57  514.58
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure JAMATH00010026, in Jamaica, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number JAMATH00010026

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 29 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 025

Town *(FIPS place code; I - 4; nnnnn)* 36175

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

Waterway *(I - 6)* BALL MOUNTAIN BROOK

Road Name *(I - 7)*: -

Route Number TH001

Vicinity *(I - 9)* AT JCT TH 1 & TH 30

Topographic Map Jamaica

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43053

Longitude *(i - 17; nnnnn.n)* 72489

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10130900261309

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

Maximum span length *(I - 48; nnnn)* 0078

Year built *(I - 27; YYYY)* 1982

Structure length *(I - 49; nnnnnn)* 000080

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

Deck Width *(I - 52; nn.n)* 293

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

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

Opening skew to Roadway *(I - 34; nn)* 08

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

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*) 075.0

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

Vertical clearance from streambed (*nnn.n ft*) 013.0

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

Waterway of full opening (*nnn.n* ft^2) 975.0

Comments:

The structural inspection report of 9/13/93 indicates a single span steel stringer type bridge with a concrete deck. The abutment walls and wingwalls are concrete. On the right abutment there are minor cracks reported in the older concrete of the abutment wall. The upstream end is reported as having an older section of concrete with a newer concrete facing. There is an older concrete footing noted exposed on the right abutment as well. The top of the older footing at the upstream end is about 2 feet higher than the adjacent streambed. The streambed is up to 9 inches below the bottom of this section of the footing just upstream of the newer footing. The top of the footing on the upstream **(Continued, page 33)**

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: 29.0

Terrain character: -

Stream character & type: **Mountainous, steep, and swift moving**

Streambed material: cobbles

Discharge Data *(cfs)*: $Q_{2.33}$ 1900 Q_{10} 4100 Q_{25} 5700

Q_{50} 7150 Q_{100} 8550 Q_{500} -

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

Estimated Discharge *(cfs)*: - Velocity at Q 25 *(ft/s)*: 13.5

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

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

The stream response is (*Flashy, Not flashy*): 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*)	**489.2**	**491.4**	**492.7**	**493.7**	**494.6**
Velocity (*ft / sec*)	-	-	**13.5**	-	-

Long term stream bed changes: -

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

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

Are there other structures nearby? (*Yes, No, Unknown*): Y *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: **Jamaica** Year Built: **1978**

Highway No. : **TH01** Structure No. : **25** Structure Type: **Steel Stringer**

Clear span (*ft*): **62.0** Clear Height (*ft*): **6.0** Full Waterway (ft^2): **372.0**

Comments:

right wingwall is reported exposed but not undermined. There is some cracking reported on the right abutment wall. The left abutment and its wingwalls are reported in "like new" condition. The waterway makes a slight bend into the crossing with all of the flow against the right abutment. The streambed consists of stone and boulders. On older photos, the right abutment had riprap in place along the front of it and the report indicates high water has swept the riprap away.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **29.29** mi^2 Lake and pond area **0.03** mi^2

Watershed storage *(ST)* **0.1** %

Bridge site elevation **1023.6** ft Headwater elevation **3940** ft

Main channel length **9.99** mi

10% channel length elevation **1201** ft 85% channel length elevation **2106** ft

Main channel slope *(S)* **120.88** ft / mi

Watershed Precipitation Data

Average site precipitation __________ in Average headwater precipitation __________ in

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

Average seasonal snowfall *(Sn)* _________ ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY):* ___ / 1982

Project Number BRZ 1442(4) Minimum channel bed elevation: 482.5

Low superstructure elevation: USLAB 499.95 DSLAB 499.81 USRAB 496.78 DSRAB 496.64

Benchmark location description:

TBM#1: spike in root of a 15 inch beech tree elevation 500.0 located on the south edge of a gravel road which is at south side of bridge about 80 feet south of right abutment and 20 feet west of the centerline of the road over bridge. TBM#2: spike in root of an 18 inch pine tree elevation 515.55 about 180 feet north of left abutment along center line of road over bridge and 80 feet west from extended centerline.

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

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

If 1: Footing Thickness 2.0 Footing bottom elevation: 484.0*

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:

Other elevation points: 1) the point at the downstream right wingwall where it intersects the right abutment, elevation 500.8 and 2) at the downstream left wingwall where it intersects left abutment, elevation 504.04.

*** Elevation is for the left abutment. The right abutment footing bottom elevation is unknown.**

Cross-sectional Data

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

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

Comments: -

Station	176	177	192	210	227	245	251	-	-	-	-
Feature	LAB	-	-	-	-	-	RAB	-	-	-	-
Low cord elevation	1018.2	1018.2	1017.5	1016.7	1016.0	1015.2	1014.9	-	-	-	-
Bed elevation	-	1012.3	1004.4	1000.9	999.7	1000.8	1003.8	-	-	-	-
Low cord to bed length	-	5.9	13.1	15.8	16.3	14.4	11.1	-	-	-	-

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

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

Comments: -

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **11/06/96**
Computerized by: **RB** Date: **11/07/96**
Reviewd by: **RB** Date: **05/05/97**

Structure Number **JAMATH00010026**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. MEDALIE** Date *(MM/DD/YY)* **08** / **12** / 19**96**
2. Highway District Number **02** Mile marker **0000**
   County **WINDHAM (025)** Town **JAMAICA (36175)**
   Waterway *(I - 6)* **BALL MOUNTAIN BROOK** Road Name **-**
   Route Number **TH01** Hydrologic Unit Code: **01080107**
3. Descriptive comments:
Located at the junction of TH 1 and TH 30.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **6** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US **2** UB **1** DS **2** *(**1**- pool; **2**- riffle)*
6. Bridge structure type **1** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length **80** *(feet)* Span length **78** *(feet)* Bridge width **29.3** *(feet)*

Road approach to bridge:

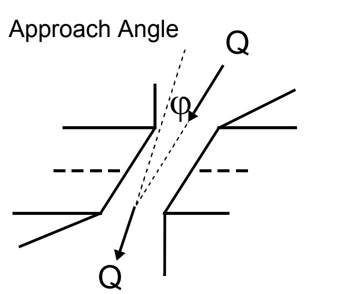
8. LB **2** RB **1** *(**0** even, **1**- lower, **2**- higher)*
9. LB **2** RB **1** *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **16:7:1** US right **11:8:1**

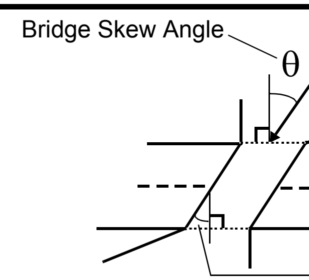
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	**0**	**-**	**0**	**-**
RBUS	**0**	**-**	**0**	**-**
RBDS	**0**	**-**	**2**	**2**
LBDS	**2**	**1**	**2**	**1**

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

Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **10**





Opening skew to roadway
α= **8.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **198** feet **US** *(US, UB, DS)* to **0** feet **US**
Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **180** feet **DS** *(US, UB, DS)* to **400** feet **DS**

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

18. Bridge Type: 1a/3

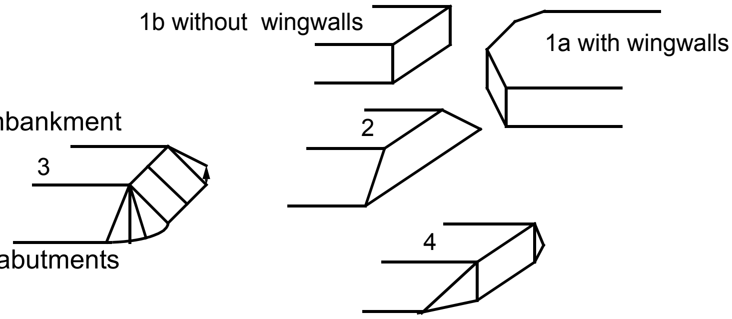
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

5. The DS water surface is pooled to 25 ft. DS then it is riffled.

7. Values are from the VT AOT files. Measured bridge length is 79.5 ft., span length is 75.4 ft., and the bridge width is 29.6 ft.

14. The right bank DS road wash erosion is moderately severe because of the steep slope and loose material. The left bank DS road approach protection is an extension of the DS left wingwall protection around the end of the wingwall.

18. The wingwalls are all type 1a except the DS right wingwall which is type 4. There is protection around the left abutment that creates a spill through slope.

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
77.5	4.5			8.0	2	1	345	5	1	1

23. Bank width 30.0 24. Channel width 30.0 25. Thalweg depth 69.0 29. Bed Material 453

30 .Bank protection type: LB 4 RB 4 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.):

26. The right bank has minimal vegetation cover from the bridge till 154 ft. US, then it is type 4. On the left bank, there is minimal vegetation cover from the bridge to 62 ft. US, then it is type 4.

28. The right bank is an almost vertical wall of boulders built from the stream to be the road embankment for TH30.

30. The left bank protection extends from under the bridge to 29 ft. US. It is the same as the wingwall protection. The right bank protection extends from the end of the wingwall to 154 ft. US, though there is still mostly boulders in the bank beyond at least 100 ft. There is also type-3 and type-2 protection along the banks.

33. Point/Side bar present? **Y** (*Y or N. if N type ctrl-n pb*) 34. Mid-bar distance: **133** 35. Mid-bar width: **34**

36. Point bar extent: **172** feet **US** (*US, UB*) to **74** feet **DS** (*US, UB, DS*) positioned **0** %LB to **75** %RB

37. Material: **543**

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

-

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

41. Mid-bank distance: **172** 42. Cut bank extent: **200** feet **US** (*US, UB*) to **18** feet **US** (*US, UB, DS*)

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

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

The cut bank begins at the end of the US right wingwall.

45. Is channel scour present? **Y** (*Y or if N type ctrl-n cs*) 46. Mid-scour distance: **0**

47. Scour dimensions: Length **25** Width **6** Depth : **1** Position **95** %LB to **100** %RB

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

There are also some minor local pockets of scour around large boulders.

49. Are there major confluences? **Y** (*Y or if N type ctrl-n mc*) 50. How many? **1**

51. Confluence 1: Distance **375** 52. Enters on **RB** (*LB or RB*) 53. Type **2** (***1****- perennial;* ***2****- ephemeral*)

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

54. Confluence comments (eg. confluence name):

-

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
47.5		1.0		2	7	7	-

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

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

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

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

453

-

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

-

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		0	90	0	0	-	-	90.0
RABUT	1	5	90			2	3	74.5

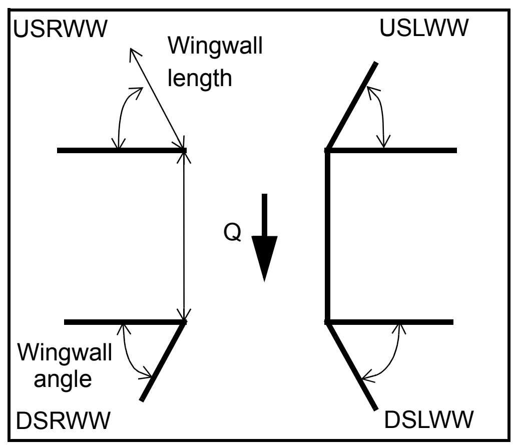
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1*- Concrete; *2*- Stone masonry or drywall; *3*- steel or metal; *4*- wood

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

2
2
1
72. The concrete part of the left abutment is at 90 degrees, and the stone fill is at a 45 degree angle.
71. The attack angle on the right abutment is 30 degrees if considering the bend of the channel beyond 150 ft. US. For the closest 150 ft. of the channel, the attack angle is 5 degrees.
On the right abutment, beginning at 11 ft. under the bridge from the DS bridge face and continuing around the DS right wingwall, the top of a concrete footing is flush with the channel bottom and extends 6.5 ft. into the channel. The scour depth and exposure depth given in #75 and #76 represent what is occurring at the US most 20 ft. of the right abutment. The exposure depth is measured from the top of the footing. Average thal-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	weg		dept		h is 1	74.5	
USRWW:	ft.		Ther		e is a	2.0	
DSLWW:	smal		l		spot	34.0	
DSRWW:	of		unde		rmin	30.5	



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	ing	mid	und	brid	re it	sible	etra	in.
Condition	abo	-	er	ge	is	to	te	
Extent	ut	way	the	whe	pos-	pen-	10	Y

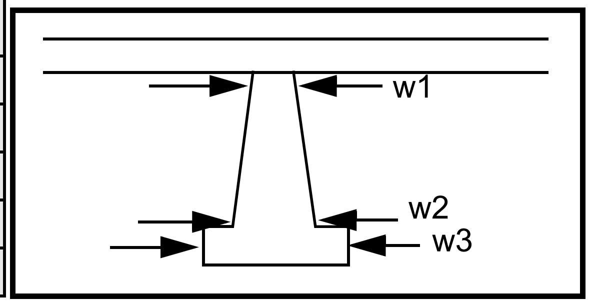
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
1
0
-
-
Y
1
1
1
0
Y
1

Piers:

84. Are there piers? 0 (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		9.5		35.0	65.0	22.0
Pier 2		9.0		45.0	40.0	17.0
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	-	2	-	placed	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	-	4	4	to	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	Y	1	1	pro-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	1	1	1	tect	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	1	0	0	the	*Y- yes; N- no*
91. Attack ∠ (BF)	1	-	-	US	
92. Pushed	0	-	-	end	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	4	-	82.	of	
95. Cross-members	1	-	Ther	the	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	1	-	e are	US	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	3	-	stone	right	
98. Exposure depth	1	-	s	wing	

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

wall. The protection on the left abutment creates a spill through slope. There is also type-3 and type-2 protection in front of the US left wingwall.

80. Along the DS 12 ft. of the base of the US right wingwall there is a squared wooden horizontal beam, from which the top of the concrete footing extends 5 ft. into the channel and is flush with the channel bottom. The DS right wingwall footing is also flush with the channel bottom and only extends 4 ft. into the channel.

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
-	-			-			N	-	-	-

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

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

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: -

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

-
-
-
-

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

Cut bank extent: NO feet PI (US, UB, DS) to ERS 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 4 Depth: 1 Positioned 54 %LB to 54 %RB

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

1
1
54
4

Are there major confluences? 0 (Y or if N type ctrl-n mc) How many? 1

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

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

Confluence comments (eg. confluence name):

r on the right bank is minimal until 73 ft. DS and then it is type 4. The left bank protection extends to 10 ft. DS. It is the same as the DS left wingwall protection.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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)*:

N

109. G. Plan View Sketch

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: JAMATH00010026 Town: JAMAICA
Road Number: TH 1 County: WINDHAM
Stream: BALL MOUNTAIN BROOK

Initials RLB Date: 04/06/97 Checked: MAI

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	8550	12280	9250
Main Channel Area, ft2	710	1057	767
Left overbank area, ft2	70	222	90
Right overbank area, ft2	0	103	0
Top width main channel, ft	76	79	77
Top width L overbank, ft	26	41	29
Top width R overbank, ft	0	39	0
D50 of channel, ft	0.271	0.271	0.271
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.3	13.4	10.0
y1, average depth, LOB, ft	2.7	5.4	3.1
y1, average depth, ROB, ft	ERR	2.6	ERR
Total conveyance, approach	78038	163811	88425
Conveyance, main channel	75377	142242	84622
Conveyance, LOB	2661	13229	3804
Conveyance, ROB	0	8340	0
Percent discrepancy, conveyance	0.0000	0.0000	-0.0011
Qm, discharge, MC, cfs	8258.5	10663.1	8852.2
Ql, discharge, LOB, cfs	291.5	991.7	397.9
Qr, discharge, ROB, cfs	0.0	625.2	0.0
Vm, mean velocity MC, ft/s	11.6	10.1	11.5
Vl, mean velocity, LOB, ft/s	4.2	4.5	4.4
Vr, mean velocity, ROB, ft/s	ERR	6.1	ERR
Vc-m, crit. velocity, MC, ft/s	10.5	11.2	10.6
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour

y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)

ys=y2-y_bridge

(Richardson and others, 1995, p. 30, eq. 17 and 18)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	8550	12280	9250	8550	10652	9250
Total conveyance	78038	163811	88425	49128	84022	51293
Main channel conveyance	75377	142242	84622	49128	84022	51293
Main channel discharge	8258	10663	8852	8550	10652	9250
Area - main channel, ft2	710	1057	767	557	926	574
(W1) channel width, ft	76	79	77	63.9	66.1	64.2
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	76	79	77	63.9	66.1	64.2
D50, ft	0.271	0.271	0.271			
w, fall velocity, ft/s (p. 32)	4.26	4.26	4.26			
y, ave. depth flow, ft	9.34	13.38	9.96	8.72	14.01	8.94
S1, slope EGL	0.026	0.033	0.027			
P, wetted perimeter, MC, ft	80	84	82			
R, hydraulic Radius, ft	8.875	12.583	9.354			
V*, shear velocity, ft/s	2.726	3.657	2.852			
V*/w	0.640	0.858	0.669			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.64	0.64	0.64			
y2,depth in contraction, ft	10.75	14.98	11.62			
ys, scour depth, ft (y2-y_bridge)	2.04	0.97	2.68			

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	8550	12280	9250
(Q) discharge thru bridge, cfs	8550	10652	9250
Main channel conveyance	49128	84022	51293
Total conveyance	49128	84022	51293
Q2, bridge MC discharge,cfs	8550	10652	9250
Main channel area, ft2	557	926	574
Main channel width (normal), ft	63.9	66.1	64.2
Cum. width of piers in MC, ft	0.0	0.0	0.0

W, adjusted width, ft	63.9	66.1	64.2
y_bridge (avg. depth at br.), ft	8.72	14.01	8.94
Dm, median (1.25*D50), ft	0.33875	0.33875	0.33875
y2, depth in contraction,ft	11.21	13.15	11.94
ys, scour depth (y2-ybridge), ft	2.49	-0.86	3.00

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	8550	12280	9250
Q, thru bridge MC, cfs	8550	10652	9250
Vc, critical velocity, ft/s	10.53	11.18	10.64
Va, velocity MC approach, ft/s	11.63	10.09	11.54
Main channel width (normal), ft	63.9	66.1	64.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	63.9	66.1	64.2
qbr, unit discharge, ft2/s	133.8	161.1	144.1
Area of full opening, ft2	557.0	926.0	574.0
Hb, depth of full opening, ft	8.72	14.01	8.94
Fr, Froude number, bridge MC	0	0.58	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	772	N/A
**Hb, depth at downstream face, ft	N/A	11.68	N/A
**Fr, Froude number at DS face	ERR	0.71	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	515.02	0
Elevation of Bed, ft	-8.72	501.01	-8.94
Elevation of Approach, ft	0	518.26	0
Friction loss, approach, ft	0	0.62	0
Elevation of WS immediately US, ft	0.00	517.64	0.00
ya, depth immediately US, ft	8.72	16.63	8.94
Mean elevation of deck, ft	0	519.67	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.96	1.00
**Cc, for downstream face (<=1.0)	ERR	0.909307	ERR
Ys, scour w/Chang equation, ft	N/A	1.04	N/A
Ys, scour w/Umbrell equation, ft	N/A	3.22	N/A

**=for UNsubmerged orifice flow only.

**Ys, scour w/Chang equation, ft	N/A	4.18	N/A

**Ys, scour w/Umbrell equation, ft	ERR	5.55	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	N/A	14.01	N/A
WSEL at downstream face, ft	--	512.55	--
Depth at downstream face, ft	ERR	11.54	ERR
Ys, depth of scour (Laursen), ft	ERR	2.47	ERR

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	8550	10652	9250
Main channel area (DS), ft2	557	772	574
Main channel width (normal), ft	63.9	66.1	64.2
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	63.9	66.1	64.2
D90, ft	1.0572	1.0572	1.0572
D95, ft	1.4285	1.4285	1.4285
Dc, critical grain size, ft	1.1173	0.7984	1.2180
Pc, Decimal percent coarser than Dc	0.088	0.166	0.071
Depth to armoring, ft	34.87	12.03	47.81

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	8550	12280	9250	8550	12280	9250
a', abut.length blocking flow, ft	19	32.3	21.5	18.7	60.7	20.2
Ae, area of blocked flow ft2	57.4	148.4	70.8	94.1	183.85	109
Qe, discharge blocked abut.,cfs	280.1	590.2	329.3	665	--	764.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.88	3.98	4.65	7.07	6.57	7.01
ya, depth of f/p flow, ft	3.02	4.59	3.29	5.03	3.03	5.40
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	80	80	80	100	100	100
K2	0.98	0.98	0.98	1.01	1.01	1.01
Fr, froude number f/p flow	0.495	0.327	0.452	0.555	0.528	0.532
ys, scour depth, ft	8.35	11.20	8.88	16.69	17.08	17.62

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)	19	32.3	21.5	18.7	60.7	20.2
y1 (depth f/p flow, ft)	3.02	4.59	3.29	5.03	3.03	5.40
a'/y1	6.29	7.03	6.53	3.72	20.04	3.74
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.49	0.33	0.45	0.56	0.53	0.53
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 others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.96	0.71	1	0.96	0.71	1
y, depth of flow in bridge, ft	8.72	11.68	8.94	8.72	11.68	8.94
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	3.64	ERR	ERR	3.64	ERR
Fr>0.8 (vertical abut.)	3.61	ERR	3.74	3.61	ERR	3.74
Fr<=0.8 (spillthrough abut.)	ERR	3.18	ERR	ERR	3.18	ERR
Fr>0.8 (spillthrough abut.)	3.19	ERR	3.31	3.19	ERR	3.31