# LEVEL II SCOUR ANALYSIS FOR BRIDGE 25 (JAMATH00010025) on TOWN HIGHWAY 1, crossing BALL MOUNTAIN BROOK, JAMAICA, VERMONT

U.S. Geological Survey
Open-File Report 97-376

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

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By Ronda L. Burns

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**Pembroke, New Hampshire**

**1997**

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## CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

## OTHER ABBREVIATIONS

| | | | |
|---|---|---|---|
| BF | bank full | LWW | left wingwall |
| cfs | cubic feet per second | MC | main channel |
| $D_{50}$ | median diameter of bed material | RAB | right abutment |
| DS | downstream | RABUT | face of right abutment |
| elev. | elevation | RB | right bank |
| f/p | flood plain | ROB | right overbank |
| $ft^2$ | square feet | RWW | right wingwall |
| ft/ft | feet per foot | TH | town highway |
| JCT | junction | UB | under bridge |
| LAB | left abutment | US | upstream |
| LABUT | face of left abutment | USGS | United States Geological Survey |
| LB | left bank | 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 25 (JAMATH00010025) ON TOWN HIGHWAY 1, CROSSING BALL MOUNTAIN BROOK, JAMAICA, VERMONT

***By* Ronda L. Burns**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure JAMATH00010025 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 29.5-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest except on the downstream right bank which is pasture with some trees along the channel.

In the study area, Ball Mountain Brook has an incised, straight channel with a slope of approximately 0.021 ft/ft, an average channel top width of 86 ft and an average bank height of 9 ft. The channel bed material ranges from gravel to bedrock with a median grain size ($D_{50}$) of 222 mm (0.727 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 13, 1996, indicated that the reach was stable.

The Town Highway 1 crossing of Ball Mountain Brook is a 78-ft-long, two-lane bridge consisting of one 75-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 73 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 30 degrees to the opening while the opening-skew-to-roadway is 30 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed at the upstream bridge face. The scour protection measures at the site were type-2 stone fill (less than 36 inches diameter) along the upstream banks and along both abutments, and type-3 stone fill (less than 48 inches diameter) along the downstream banks. 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 only occurred at the 500-year discharge and was 0.1 ft. Abutment scour ranged from 11.2 to 15.7 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 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*** JAMATH00010025 ***Stream*** Ball Mountain Brook

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

## Description of Bridge

***Bridge length*** 78 ***ft*** ***Bridge width*** 24.7 ***ft*** ***Max span length*** 75 ***ft***

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

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

***Stone fill on abutment?*** Y ***Date of inspection*** 08/13/96

***Description of stone fill*** Type-2, along the entire length of the left and right abutments and along all of the wingwalls.

Abutments and wingwalls are concrete.

***Is bridge skewed to flood flow according to*** N ***survey?*** Y ***Angle*** 30

There is a mild channel bend in the upstream reach. A scour hole has developed in the location where the bend impacts the bedrock on the upstream left bank.

***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*** | 08/13/96 | 0 | 0 |
| ***Level II*** | 08/13/96 | 0 | 0 |

***Potential for debris*** Moderate. There is some debris caught on the stone fill in front of the upstream and downstream left wingwalls.

***Describe any features near or at the bridge that may affect flow (include observation date)***

None 08/13/96.

## Description of the Geomorphic Setting

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

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

***Date of inspection*** 08/13/96

***DS left:*** Steep valley wall

***DS right:*** Steep channel bank to a moderately sloped overbank

***US left:*** Steep valley wall

***US right:*** Steep channel bank to a moderately sloped overbank

## Description of the Channel

***Average top width*** 86 ***ft*** ***Average depth*** 9 ***ft***

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

Straight and stable with semi-alluvial channel boundaries.

08/13/96

***Vegetative co*** Trees

***DS left:*** Some trees and brush with short grass on the overbank

***DS right:*** Trees

***US left:*** Trees, brush and grass

***US right:*** Y

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

None 08/13/96.

***Describe any obstructions in channel and date of observation.***

## Hydrology

***Drainage area*** 29.5 ***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***:

***Is there a USGS gage on the stream of interest?*** N

***USGS gage description*** --

***USGS gage number*** --

***Gage drainage area*** -- ***mi²***

***Is there a lake/p*** No

### Calculated Discharges

***Q100*** 8,650 ***ft³/s*** ***Q500*** 12,800 ***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 4.9 ft. from the USGS arbitrary survey datum to obtain the VTAOT plans' datum.

***Description of reference marks used to determine USGS datum.*** RM1 is a VTAOT survey disk on top of the upstream end of the left abutment (elev. 498.66 ft, arbitrary survey datum). RM2 is a chiseled X inside a pre-existing chiseled square on top of the upstream end of the right abutment (elev. 499.52 ft, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

| [1]*Cross-section* | *Section Reference Distance (SRD) in feet* | [2]*Cross-section development* | *Comments* |
|---|---|---|---|
| EXIT1 | -98 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXIT1) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 16 | 1 | Road Grade section |
| APPRO | 95 | 2 | Modelled Approach section (Templated from APTEM) |
| APTEM | 98 | 1 | Approach section as surveyed (Used as a template) |

[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 0.065, and overbank "n" values ranged from 0.060 to 0.080.

Normal depth at the exit section (EXIT1) 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 0.021 ft/ft which was estimated from the streambed slope downstream of the bridge in the Flood Insurance Study for Jamaica, VT (Federal Emergency Management Agency, May 17, 1988).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.048 ft/ft) to establish the modelled approach section (APPRO), 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.

## Bridge Hydraulics Summary

*Average bridge embankment elevation* 499.0 *ft*
*Average low steel elevation* 495.2 *ft*

*100-year discharge* 8,650 *ft³/s*
*Water-surface elevation in bridge opening* 492.1 *ft*
*Road overtopping?* N *Discharge over road* - *ft³/s*
*Area of flow in bridge opening* 675 *ft²*
*Average velocity in bridge opening* 12.8 *ft/s*
*Maximum WSPRO tube velocity at bridge* 15.8 *ft/s*

*Water-surface elevation at Approach section with bridge* 493.9
*Water-surface elevation at Approach section without bridge* 493.7
*Amount of backwater caused by bridge* 0.2 *ft*

*500-year discharge* 12,800 *ft³/s*
*Water-surface elevation in bridge opening* 492.9 *ft*
*Road overtopping?* N *Discharge over road* - *ft³/s*
*Area of flow in bridge opening* 722 *ft²*
*Average velocity in bridge opening* 17.7 *ft/s*
*Maximum WSPRO tube velocity at bridge* 22.0 *ft/s*

*Water-surface elevation at Approach section with bridge* 496.5
*Water-surface elevation at Approach section without bridge* 496.5
*Amount of backwater caused by bridge* 0.0 *ft*

*Incipient overtopping discharge* - *ft³/s*
*Water-surface elevation in bridge opening* - *ft*
*Area of flow in bridge opening* - *ft²*
*Average velocity in bridge opening* - *ft/s*
*Maximum WSPRO tube velocity at bridge* - *ft/s*

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

## Scour Analysis Summary

### Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year and 500-year discharges was computed by use of both the clear-water and live-bed contraction scour equations (Richardson and others, 1995, p. 30, equation 17 and p. 32, equation 20) since the average channel velocity and the incipient-motion velocity of the bed material are nearly the same. Because coarse bed-material is present, the smaller of the computed contraction scour results for each discharge was selected as recommended (Richardson and others, 1995, p. 31). Hence, results from the live-bed contraction scour equation are shown for the 500-year discharge and results from the clear-water contraction scour equation are shown for the 100-year discharge. Results of this analysis are presented in figure 8 and tables 1 and 2. The results of Laursen's live-bed and clear-water contraction scour are also provided in appendix F.

Abutment scour for both abutments 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. The left abutment scour may be limited by the bedrock noted on the left bank.

## Scour Results

| *Contraction scour:* | *100-yr discharge* | *500-yr discharge* | *Incipient overtopping discharge* |
|---|---|---|---|
| | *(Scour depths in feet)* | | |
| *Main channel* | | | |
| *Live-bed scour* | -- | 0.1 | -- |
| *Clear-water scour* | 0.0 | -- | -- |
| *Depth to armoring* | 3.7 | 39.5 | -- |
| *Left overbank* | -- | -- | -- |
| *Right overbank* | -- | -- | -- |

| *Local scour:* | | | |
|---|---|---|---|
| *Abutment scour* | | | |
| *Left abutment* | 11.2 | 14.9 | -- |
| *Right abutment* | 13.5 | 15.7 | -- |
| *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 | 4.7 | -- |
| *Right abutment* | 3.2 | 4.7 | -- |
| *Piers:* | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

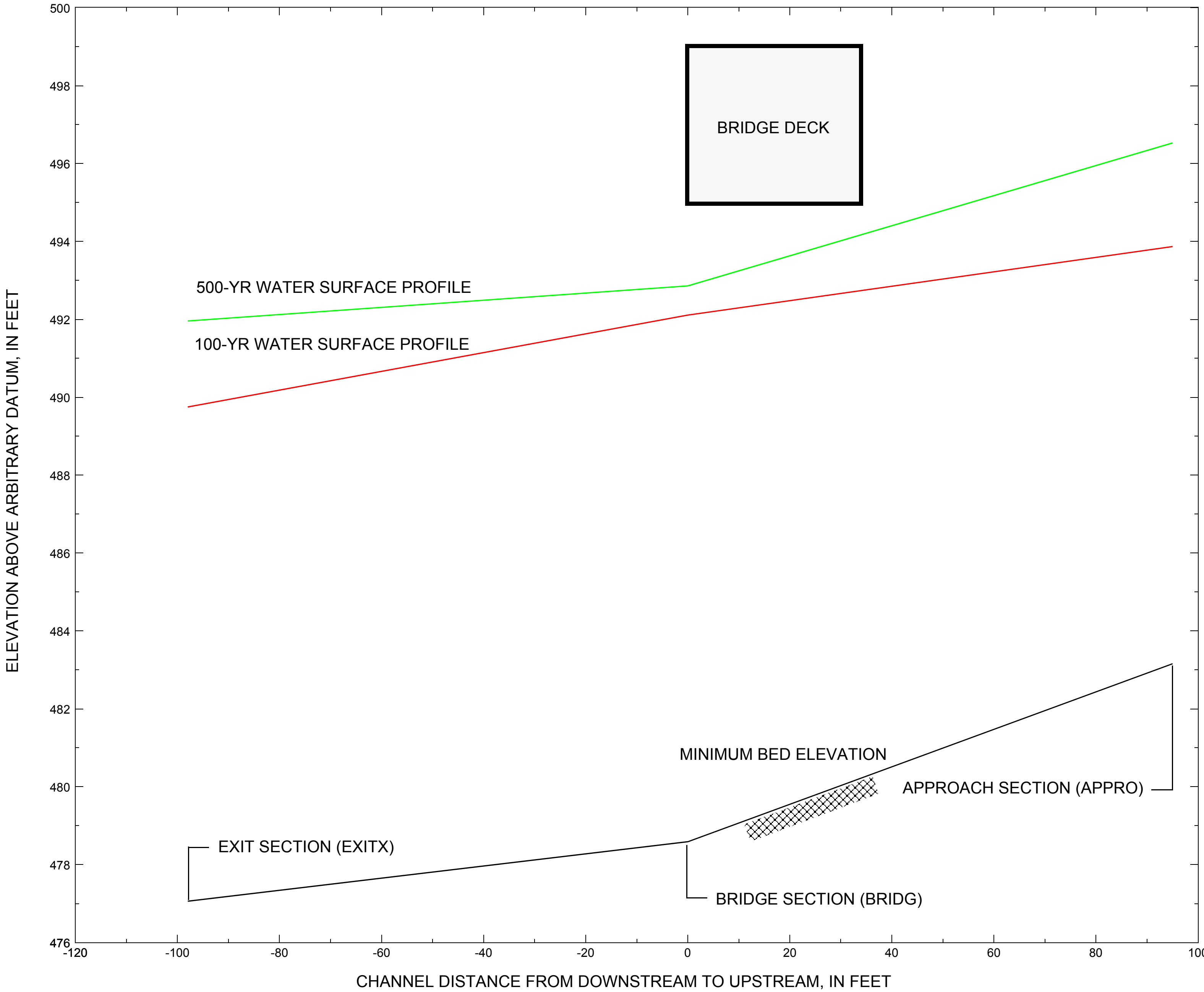


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure JAMATH00010025 on Town Highway 1, crossing Ball Mountain Brook, Jamaica, Vermont.

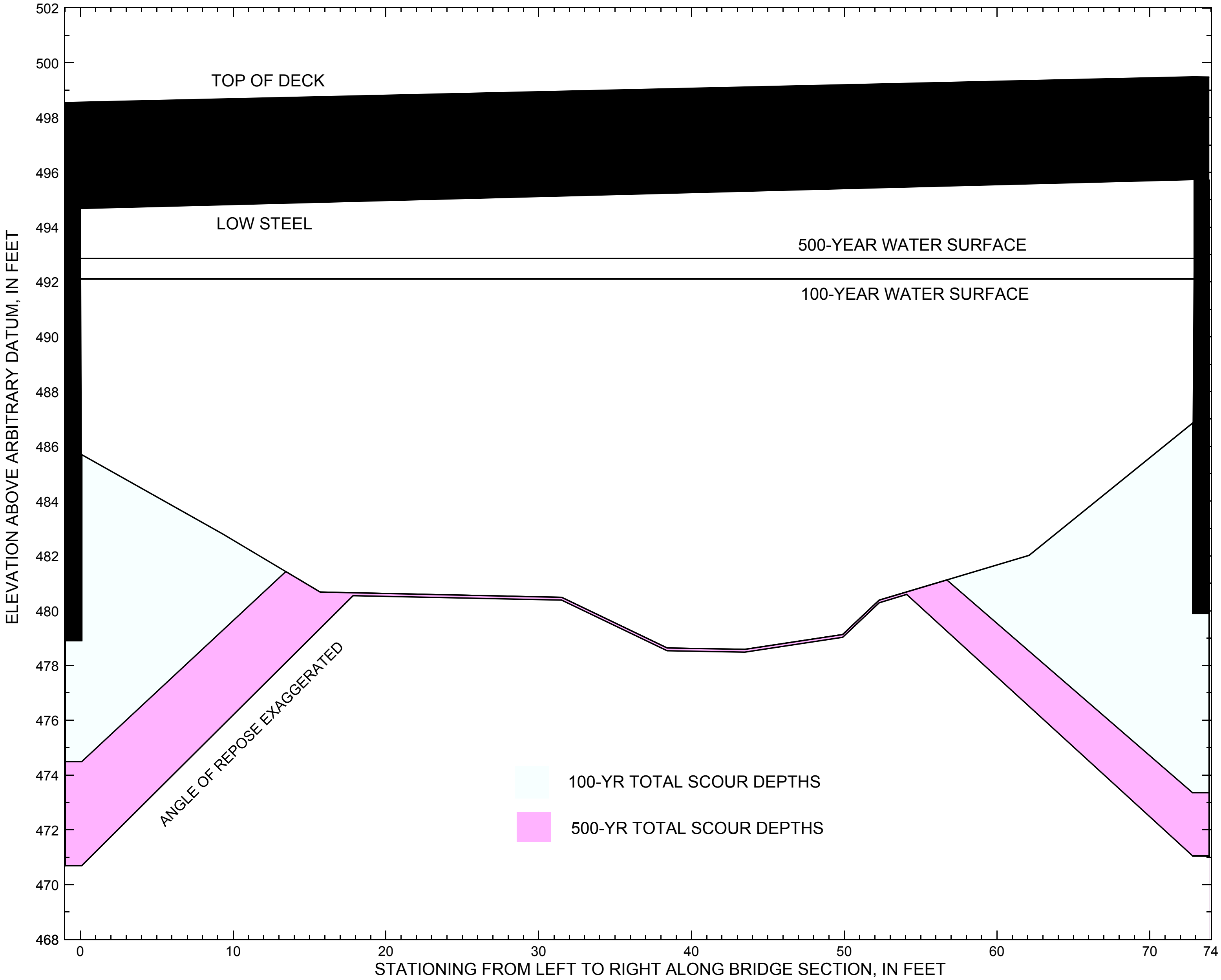


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure JAMATH00010025 on Town Highway 1, crossing Ball Mountain Brook, Jamaica, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure JAMATH00010025 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 8,650 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 489.6 | 494.7 | 478.9 | 485.7 | 0.0 | 11.2 | -- | 11.2 | 474.5 | -4.4 |
| Right abutment | 72.9 | 490.7 | 495.7 | 479.9 | 486.9 | 0.0 | 13.5 | -- | 13.5 | 473.4 | -6.5 |

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 JAMATH00010025 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 12,800 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 489.6 | 494.7 | 478.9 | 485.7 | 0.1 | 14.9 | -- | 15.0 | 470.7 | -8.2 |
| Right abutment | 72.9 | 490.7 | 495.7 | 479.9 | 486.9 | 0.1 | 15.7 | -- | 15.8 | 471.1 | -8.8 |

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

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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 jama025.wsp
T2        Hydraulic analysis for structure JAMATH00010025   Date: 20-FEB-97
T3        TH001 crossing Ball Mountain Brook in Jamaica, VT                  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           8650.0  12800.0
SK          0.021    0.021
*
XS   EXIT1    -98           0.
GR         -116.0, 519.37    -90.5, 496.72    -86.0, 496.54    -63.6, 496.14
GR            0.0, 488.51      3.4, 483.31     22.2, 478.78     25.9, 477.96
GR           28.8, 477.06     32.9, 477.90     39.3, 477.27     48.2, 478.77
GR           58.7, 481.80     74.1, 490.27    231.2, 495.98    345.8, 499.05
GR          604.0, 505.52    824.9, 513.30
*
N           0.080        0.065         0.060
SA                  0.0          74.1
*
*
XS   FULLV      0  * * *   0.024
N           0.080        0.050         0.060
SA                  0.0          74.1
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    495.21      30.0
GR            0.0, 494.68      0.3, 485.69      9.5, 482.74     15.7, 480.68
GR           31.5, 480.49     38.4, 478.64     43.5, 478.59     49.9, 479.13
GR           52.3, 480.39     62.1, 482.02     72.9, 486.85     72.9, 495.74
GR            0.0, 494.68
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      31.5      2.3    499.0     52.2
N           0.050
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     16      24.7     1
GR          -87.9, 516.99    -57.5, 500.10    -48.3, 497.70    -36.0, 497.95
GR           -2.3, 498.54     -2.1, 499.37      0.0, 499.39     73.2, 500.32
GR           75.4, 500.34     75.5, 499.51    164.8, 499.61
GR          428.2, 505.27    669.3, 512.71
*           238.7, 499.61
*
*
*           EXPECTED SRD =   95 AT ONE BR. LENGTH BUT COMPUTED SRD =  101
*
XT   APTEM    98           0.
GR          -48.1, 529.36    -31.7, 511.21    -24.1, 509.33      0.0, 493.81
GR           15.4, 484.25     23.6, 483.30     30.8, 483.33     44.2, 485.15
GR           47.3, 484.26     56.3, 484.10     57.8, 484.98     66.6, 485.11
GR           81.2, 494.74     99.9, 497.57    453.7, 504.78
GR          705.7, 513.30
*           131.2, 499.42
*
AS   APPRO    95 * * * 0.048
GT
N           0.065        0.065
SA                  99.9
*
HP 1 BRIDG  492.11 1 492.11
HP 2 BRIDG  492.11 * * 8650
HP 1 APPRO  493.87 1 493.87
HP 2 APPRO  493.87 * * 8650
*
HP 1 BRIDG  492.86 1 492.86
HP 2 BRIDG  492.86 * * 12800
```

# APPENDIX B:

# **WSPRO OUTPUT FILE**

# WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File jama025.wsp
        Hydraulic analysis for structure JAMATH00010025   Date: 20-FEB-97
        TH001 crossing Ball Mountain Brook in Jamaica, VT                  RLB
           *** RUN DATE & TIME: 04-14-97  13:46

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      675     85194     63     77                        12533
   492.11           675     85194     63     77  1.00      0     73    12533

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.11     0.1    72.9   675.0   85194.    8650.  12.81

X STA.         0.1        8.8       13.4       17.0       20.2       23.3
  A(I)            58.2       39.3       34.6       31.7       30.9
  V(I)            7.43      10.99      12.51      13.63      14.00

X STA.        23.3       26.3       29.2       32.1       34.9       37.5
  A(I)            29.9       29.8       29.1       29.3       28.3
  V(I)           14.49      14.54      14.89      14.74      15.29

X STA.        37.5       39.8       42.2       44.5       46.9       49.5
  A(I)            27.3       27.5       27.8       27.8       28.8
  V(I)           15.83      15.75      15.56      15.55      15.01

X STA.        49.5       52.4       55.7       59.3       63.8       72.9
  A(I)            31.4       32.4       34.6       38.6       57.8
  V(I)           13.78      13.35      12.51      11.20       7.48

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      95.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      639     55646     80     86                        10230
   493.87           639     55646     80     86  1.00      0     80    10230

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      95.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.87    -0.3    80.1   639.4   55646.    8650.  13.53

X STA.        -0.3       13.0       16.8       19.9       22.7       25.3
  A(I)            55.1       35.1       31.6       29.5       27.5
  V(I)            7.85      12.31      13.69      14.68      15.71

X STA.        25.3       27.8       30.4       33.0       35.6       38.4
  A(I)            27.4       27.3       27.1       26.9       27.6
  V(I)           15.78      15.83      15.99      16.09      15.68

X STA.        38.4       41.3       44.6       47.6       50.5       53.3
  A(I)            27.9       29.3       28.4       28.2       28.1
  V(I)           15.52      14.77      15.22      15.35      15.37

X STA.        53.3       56.3       59.7       63.3       67.2       80.1
  A(I)            29.0       31.5       32.3       35.0       54.6
  V(I)           14.91      13.75      13.39      12.34       7.92
```

```
        U.S. Geological Survey WSPRO Input File jama025.wsp
        Hydraulic analysis for structure JAMATH00010025   Date: 20-FEB-97
        TH001 crossing Ball Mountain Brook in Jamaica, VT                  RLB
           *** RUN DATE & TIME: 04-14-97  13:46

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      722     94162     63     79                        13871
   492.86           722     94162     63     79  1.00      0     73    13871

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       492.86     0.1    72.9   722.4   94162.   12800.  17.72

X STA.         0.1        8.8       13.3       16.9       20.1       23.2
  A(I)            63.7       41.1       36.9       34.0       33.0
  V(I)            10.05      15.55      17.33      18.85      19.37

X STA.        23.2       26.2       29.2       32.1       34.8       37.4
  A(I)            31.9       31.8       31.0       30.8       30.5
  V(I)            20.05      20.12      20.62      20.81      20.99

X STA.        37.4       39.8       42.2       44.6       47.0       49.6
  A(I)            29.2       29.3       29.7       29.7       30.8
  V(I)            21.95      21.83      21.57      21.55      20.78

X STA.        49.6       52.5       55.8       59.4       63.9       72.9
  A(I)            33.5       34.9       36.3       41.6       62.6
  V(I)            19.08      18.36      17.65      15.37      10.22

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      95.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      874     81932     98    106                        14770
   496.53           874     81932     98    106  1.00     -3     94    14770

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      95.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.53    -4.4    94.0   873.6   81932.   12800.  14.65

X STA.        -4.4       10.6       15.2       18.4       21.4       24.1
  A(I)            72.1       49.2       40.7       38.7       36.0
  V(I)             8.88      13.02      15.72      16.52      17.77

X STA.        24.1       26.8       29.4       32.0       34.7       37.6
  A(I)            35.8       34.8       34.8       35.5       35.5
  V(I)            17.87      18.38      18.40      18.04      18.01

X STA.        37.6       40.5       43.7       46.9       49.9       53.0
  A(I)            36.3       37.3       38.0       37.9       38.5
  V(I)            17.65      17.16      16.83      16.91      16.64

X STA.        53.0       56.2       59.9       63.8       68.6       94.0
  A(I)            40.2       43.5       45.3       54.8       88.7
  V(I)            15.90      14.70      14.13      11.67       7.21
```

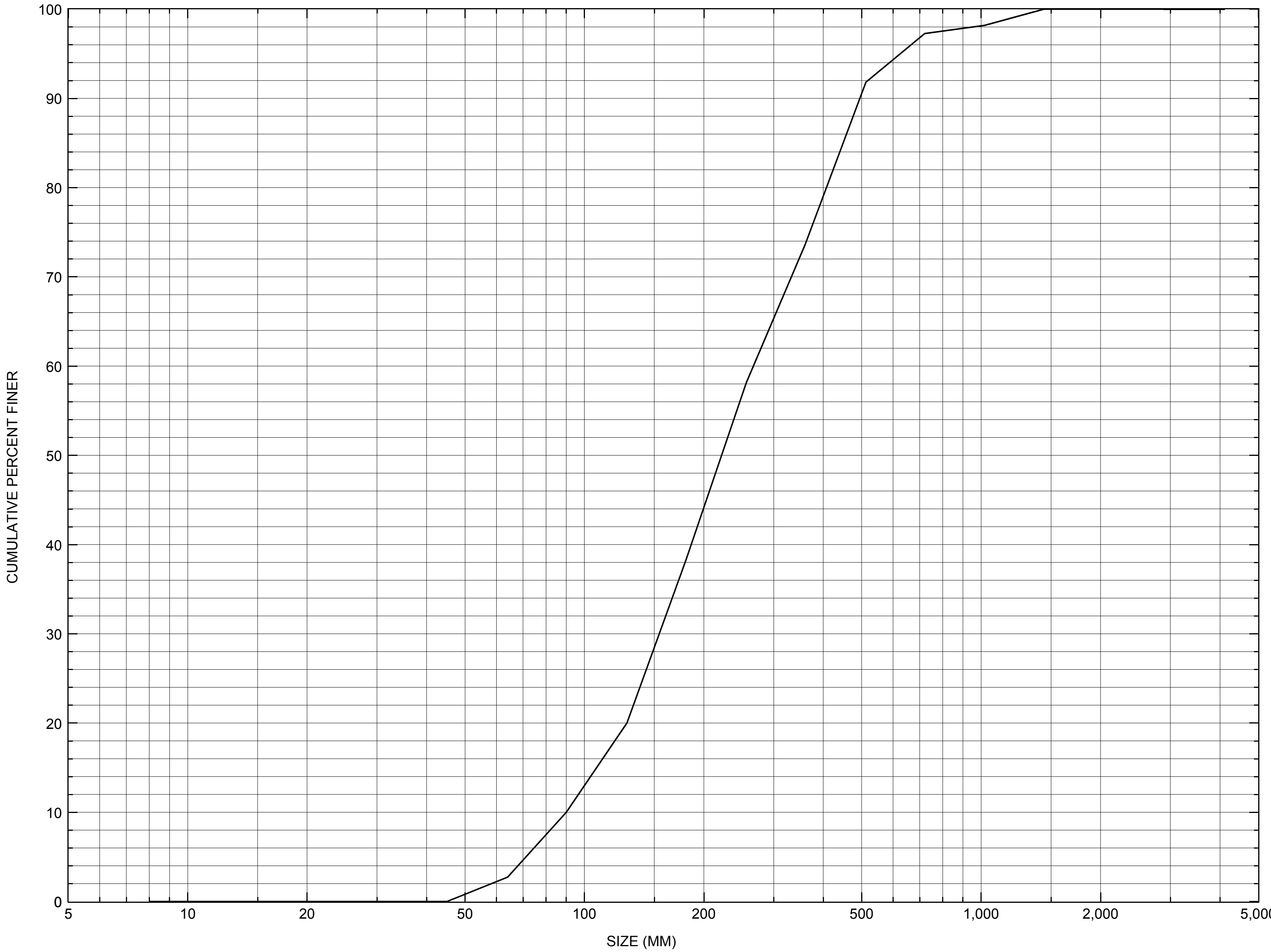
# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File jama025.wsp
        Hydraulic analysis for structure JAMATH00010025   Date: 20-FEB-97
        TH001 crossing Ball Mountain Brook in Jamaica, VT                  RLB
           *** RUN DATE & TIME: 04-14-97  13:46

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

EXIT1:XS   ******     -9      650  2.79 *****  492.55  488.41    8650  489.75
       -97 ******     73    59657  1.02 ***** *******    0.85   13.30

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.93     491.29     490.76

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   489.25     521.72    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   489.25     521.72     490.76

FULLV:FV       98     -3      585  3.40  1.84  494.69  490.76    8650  491.29
         0     98     72    66882  1.00  0.30    0.00    0.93   14.78
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.87     493.70     492.92

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   490.79     529.22    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   490.79     529.22     492.92

APPRO:AS       95      0      623  2.99  1.98  496.67  492.92    8650  493.67
        95     95     80    53663  1.00  0.00   -0.01    0.88   13.87
         <<<<<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       98      0      675  2.55  2.13  494.67  489.76    8650  492.11
         0     98     73    85234  1.00  0.00    0.02    0.69   12.81

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  495.21 ****** ****** ******

    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       64      0      639  2.85  1.59  496.72  492.92    8650  493.87
        95     68     80    55637  1.00  0.45   -0.01    0.85   13.53

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.088  0.000   57830.     1.    74.   492.17

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -98.   -10.    73.   8650.   59657.     650.   13.30  489.75
   FULLV:FV       0.    -4.    72.   8650.   66882.     585.   14.78  491.29
   BRIDG:BR       0.     0.    73.   8650.   85234.     675.   12.81  492.11
   RDWAY:RG      16.**************       0.******************     1.00********
   APPRO:AS      95.     0.    80.   8650.   55637.     639.   13.53  493.87

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    74.   57830.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS     488.41    0.85  477.06  519.37************  2.79  492.55  489.75
   FULLV:FV     490.76    0.93  479.41  521.72  1.84  0.30  3.40  494.69  491.29
   BRIDG:BR     489.76    0.69  478.59  495.74  2.13  0.00  2.55  494.67  492.11
   RDWAY:RG   ****************  497.70  516.99**********************************
   APPRO:AS     492.92    0.85  483.16  529.22  1.59  0.45  2.85  496.72  493.87
```

```
        U.S. Geological Survey WSPRO Input File jama025.wsp
        Hydraulic analysis for structure JAMATH00010025   Date: 20-FEB-97
        TH001 crossing Ball Mountain Brook in Jamaica, VT                  RLB
           *** RUN DATE & TIME: 04-14-97  13:46

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

EXIT1:XS   ******    -28      897  3.63 *****  495.59  491.42   12800  491.96
       -97 ******    121    88273  1.14 ***** *******    1.10   14.28

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.17     493.35     493.59

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.46     521.72    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.46     521.72     493.59

 ===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 "FULLV"
                  WSBEG,WSEND,CRWS =   493.59     521.72     493.59

FULLV:FV       98    -22      797  4.37 *****  497.96  493.59   12800  493.59
         0     98    101   100637  1.09 ***** *******    1.16   16.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.88     496.44     495.42

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.09     529.22    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.09     529.22     495.42

APPRO:AS       95     -3      868  3.38  1.90  499.86  495.42   12800  496.48
        95     95     94    81352  1.00  0.00    0.00    0.87   14.74
         <<<<<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       98      0      722  4.89  2.02  497.74  492.26   12800  492.86
         0     98     73    94105  1.00  0.12   -0.02    0.92   17.73

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  495.21 ****** ****** ******

    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       64     -3      874  3.34  1.46  499.87  495.42   12800  496.53
        95     66     94    81979  1.00  0.68    0.01    0.87   14.64

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.256  0.000   90080.     0.    73.   494.82

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -98.   -29.   121.  12800.   88273.     897.   14.28  491.96
   FULLV:FV       0.   -23.   101.  12800.  100637.     797.   16.05  493.59
   BRIDG:BR       0.     0.    73.  12800.   94105.     722.   17.73  492.86
   RDWAY:RG      16.**************       0.******************     1.00********
   APPRO:AS      95.    -4.    94.  12800.   81979.     874.   14.64  496.53

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       0.    73.   90080.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS    491.42    1.10  477.06  519.37************  3.63  495.59  491.96
   FULLV:FV    493.59    1.16  479.41  521.72************  4.37  497.96  493.59
   BRIDG:BR    492.26    0.92  478.59  495.74  2.02  0.12  4.89  497.74  492.86
   RDWAY:RG  ****************  497.70  516.99**********************************
   APPRO:AS    495.42    0.87  483.16  529.22  1.46  0.68  3.34  499.87  496.53
```

# APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure JAMATH00010025, in Jamaica, Vermont.

APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number JAMATH00010025

## 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)* 2.0 MI TO JCT W VT30

Topographic Map Jamaica

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43054

Longitude *(i - 17; nnnnn.n)* 72484

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10130900251309

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

Maximum span length *(I - 48; nnnn)* 0075

Year built *(I - 27; YYYY)* 1978

Structure length *(I - 49; nnnnnn)* 000078

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

Deck Width *(I - 52; nn.n)* 247

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

Channel & Protection *(I - 61; n)* 8

Opening skew to Roadway *(I - 34; nn)* 30

Waterway adequacy *(I - 71; n)* 7

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*) 078.0

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

Vertical clearance from streambed (*nnn.n ft*) 010.0

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

Waterway of full opening (*nnn.n ft²*) 780.0

Comments:

**The structural inspection report of 9/13/93 indicates the structure is a single span steel stringer type bridge with a concrete deck and an asphalt roadway surface. The right abutment wall and the wingwalls are concrete. The left abutment wall is "laid-up" stone with a concrete cap and concrete facing at the upstream end on top of a massive bedrock outcrop. The right abutment reportedly has a few randomly distributed minor cracks. The footing is noted as "not in view" at the surface and there is boulder riprap placed in front of the wall. The left abutment is reported as "quite" stable. The waterway is noted as proceeding nearly straight through the structure. The streambed consists of stone** **(Continued, page 31)**

## Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area (*$mi^2$*): **29.2**

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data (*cfs*): $Q_{2.33}$ - $Q_{10}$ **4125** $Q_{25}$ **5750**

$Q_{50}$ **7200** $Q_{100}$ **8650** $Q_{500}$ -

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

Estimated Discharge (*cfs*): - Velocity at Q **25** (*ft/s*): **16.6**

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*) | - | **6.1** | **7.5** | **8.6** | **9.6** |
| Velocity (*ft / sec*) | - | - | **16.6** | - | - |

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

**and boulders on the right half under the bridge and is bedrock on the left half. A full hydraulic report was not generated. The hydraulic report recommended using class IV type stone fill.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **29.48** $mi^2$  Lake and pond area **0.03** $mi^2$

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

Bridge site elevation **970** ft  Headwater elevation **3940** ft

Main channel length **10.33** mi

10% channel length elevation **1201** ft  85% channel length elevation **2067** ft

Main channel slope *(S)* **111.83** 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)*: **02** / **1977**

Project Number **DSR0032 & TH2801 (1977)** Minimum channel bed elevation: **479.5**

Low superstructure elevation: USLAB **489.86** DSLAB **489.62** USRAB **490.75** DSRAB **490.65**

Benchmark location description:

**BM#1: spike in root of a 36 inch maple, elevation 500.0; 350 feet right bankward from the right abutment on the downstream side of the road about 40 feet from the roadway. BM#2: spike in root of 24 inch maple, assumed elevation 492.27; 60 feet from left abutment downstream side of road about 15 feet from the roadway.**

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: **474.***

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:

***Footing bottom elevations are left: 474.0 and right: 475.0. Downstream left wingwall has a cut away section at the end 7 feet below top most point (492.5) down to 485.5 then declining under the wall to 482.0 to the footing base at 474.0.**

## Cross-sectional Data

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

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

Comments: **Several channel cross sections are also available from VT AOT.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | **159** | **189** | **226** | **231** | - | - | - | - | - | - | - |
| Feature | **LAB** | - | - | **RAB** | - | - | - | - | - | - | - |
| Low cord elevation | **965.3** | **965.8** | **966.5** | **966.6** | - | - | - | - | - | - | - |
| Bed elevation | **956.5** | **955.8** | **956.8** | **959.7** | - | - | - | - | - | - | - |
| Low cord to bed length | **8.8** | **10.0** | **9.7** | **6.9** | - | - | - | - | - | - | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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: **EW** Date: **10/22/96**

Computerized by: **EW** Date: **10/24/96**

Reviewd by: **RB** Date: **05/07/97**

Structure Number **JAMATH00010025**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. BURNS** Date *(MM/DD/YY)* **08** / **13** / 19**96**

2. Highway District Number **02** Mile marker **000000**

County **WINDHAM (025)** Town **JAMAICA (36175)**

Waterway *(I - 6)* **BALL MOUNTAIN BROOK** Road Name **-**

Route Number **TH001** Hydrologic Unit Code: **01080107**

3. Descriptive comments:

**Located 2.0 miles to junction with Vermont 30. This is a steel stringer type bridge with a concrete deck. Bridge plaque states bridge number DSR0032 and TH 2801, 1977.**

## B. Bridge Deck Observations

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

5. Ambient water surface... US **2** UB **2** DS **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 **78** *(feet)* Span length **75** *(feet)* Bridge width **24.7** *(feet)*

### Road approach to bridge:

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

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

10. Embankment slope (*run / rise in feet / foot*):
US left **2.1:1** US right **2.5:1**

| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 0 | - | 0 | - |
| RBUS | 2 | 1 | 0 | - |
| RBDS | 5 | 1 | 0 | - |
| LBDS | 0 | - | 0 | - |

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

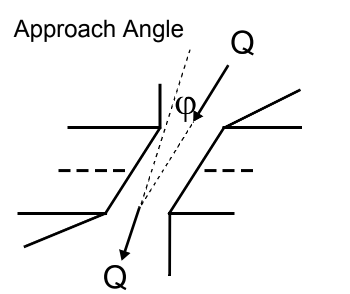
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

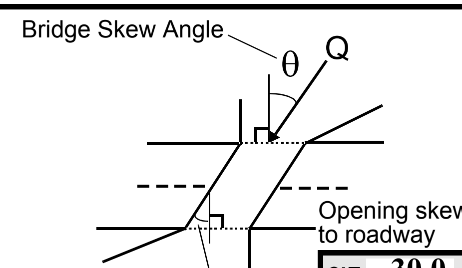
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

### Channel approach to bridge (BF):

15. Angle of approach: **5** 16. Bridge skew: **30**




α= **30.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*

Where? **LB** *(LB, RB)* Severity **1**

Range? **300** feet **US** *(US, UB, DS)* to **250** feet **US**

Channel impact zone 2: Exist? **N** *(Y or N)*

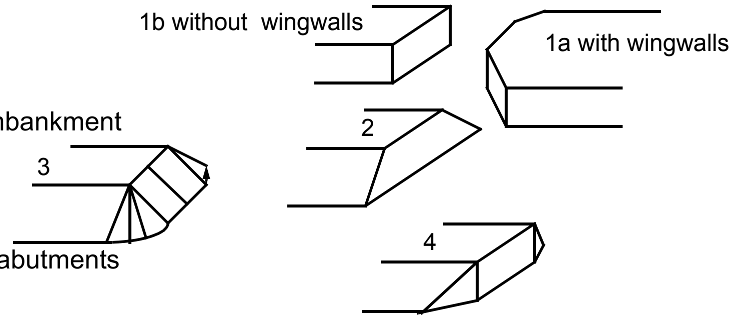
Where? **-** *(LB, RB)* Severity **-**

Range? **-** feet **-** *(US, UB, DS)* to **-** feet **-**

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

18. Bridge Type: 4

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.




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

**#4: On the right bank downstream, there is a house with a large lawn and gravel driveway, forest is beyond.**

**#7: Measured values during site visit: bridge length = 77.5 feet; span length = 73 feet; and bridge width = 26 feet between inside of curb edges, the curb is 1 foot wide.**

**#11: On the right bank downstream, there is a small stone wall along the road embankment. It is acting like a retaining wall for the flower garden which exists along the road.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 73.0 | 9.5 | | | 12.5 | 4 | 2 | 546 | 543 | 0 | 1 |

23. Bank width 30.0 24. Channel width 20.0 25. Thalweg depth 100.0 29. Bed Material 5436

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

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

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

**#27: There is a bedrock outcrop on the left bank that protrudes into the stream from 300 feet upstream to 150 feet upstream.**

**#30: The left bank protection extends from 80 feet upstream to 0 feet upstream. The old laid-up stone abutment wall is on the left bank from 45 feet upstream to 30 feet upstream.**

**The right bank protection extends from 80 feet upstream to the upstream end of the wingwall.**

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 0 US 35. Mid-bar width: 15

36. Point bar extent: 40 feet US (US, UB) to 25 feet DS (US, UB, DS) positioned 0 %LB to 40 %RB

37. Material: 3245

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

**Side bar goes under the bridge along the bottom of the left abutment protection. Mid-bar distance is at the upstream bridge face.**

**Another point bar exists from 220 feet upstream to 165 feet upstream on the right bank. It is composed of cobbles, boulders and gravel. At 185 feet upstream it is 20 feet wide.**

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

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

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

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

**NO CUT BANKS**

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

47. Scour dimensions: Length 15 Width 10 Depth : 1 Position 60 %LB to 80 %RB

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

**This scour hole extends from 10 ft. upstream to 5 ft. under the bridge, measured from the upstream bridge face. An additional scour hole is along the bedrock outcrop on the left bank upstream. It is 30 ft. long, 5 ft. wide and 1.5 ft. deep. The mid-scour distance is at 200 ft. upstream and it is positioned from 40% left bank to 60% right bank.**

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 |
|---|---|---|---|---|---|---|---|
| 51.0 | | 1.5 | | 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.):

**5**

**-**

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

67. Debris Potential 2 ____ *( 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**

**There is debris caught in the stone fill protection at the upstream and downstream faces of the bridge on the left bank.**

| 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 | | 5 | 90 | 2 | 0 | - | - | 90.0 |
| RABUT | 1 | - | 90 | | | 2 | 0 | 63.0 |

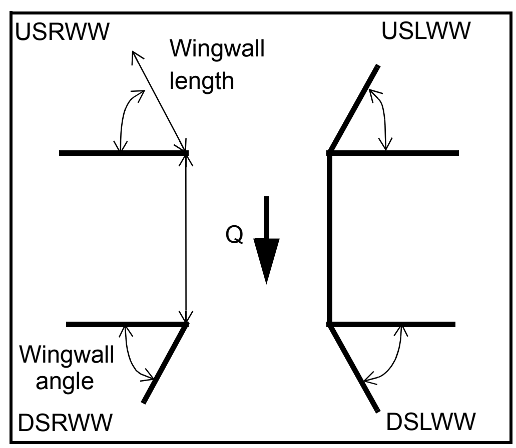
*Pushed: LB or RB* *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
*Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed*
Materials: *1-* Concrete; *2-* Stone masonry or drywall; *3-* steel or metal; *4-* wood

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

**-**
**-**
**1**
**-**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 63.0 | |
| USRWW: | Y | | 1 | | 0 | 2.0 | |
| DSLWW: | - | | - | | Y | 32.0 | |
| DSRWW: | 1 | | 0 | | - | 31.0 | |




*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 | - | 0 | Y | - | 1 | 1 | 1 | 1 |
| Condition | Y | - | 1 | - | 1 | 1 | 1 | 1 |
| Extent | 1 | - | 0 | 2 | 2 | 2 | 2 | - |

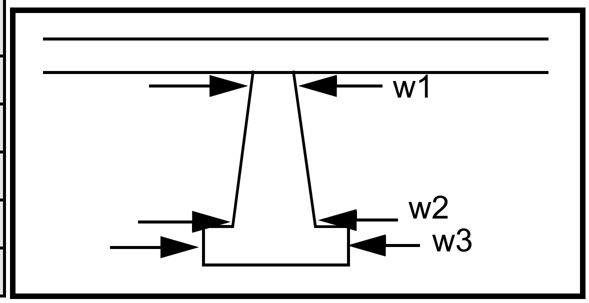
*Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee*
*Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed*
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

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

## Piers:

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

| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | | | | **60.0** | **10.0** | **45.0** |
| Pier 2 | | **0.0** | | **23.0** | **21.0** | **65.0** |
| Pier 3 | | - | - | **12.0** | - | - |
| Pier 4 | - | - | - | - | - | - |




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

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

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | - | NO | PIE | RS | | |

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.):

**4**
**1**
**543**
**54**
**1**
**0**
**5**
**3**
**3**
**1**
**1**
**Right bank protection extends from 0 feet downstream to 200 feet downstream. At 70 feet downstream, the right bank protection changes from type 3 stone fill to type 2 native stone fill.**

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

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

105. Drop structure comments (eg. downstream scour depth):
**t bank protection extends from 0 feet downstream to 70 feet downstream.**

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 **N** *(US, UB, DS)* positioned **-** %LB to **NO** %RB

Material: **DR**

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

**OP STRUCTURE**

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

Cut bank extent: **0 DS** feet **7** *(US, UB, DS)* to **15** feet **UB** *(US, UB, DS)*

Bank damage: **10** *( **1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

**DS**
**90**
**100**
**342**

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

Scour dimensions: Length **is** Width **alon** Depth: **g** Positioned **the** %LB to **rig** %RB

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

**ht abutment.**

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

Confluence 1: Distance **190** Enters on **170** *(LB or RB)* Type **DS** *( **1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **200** Enters on **DS** *(LB or RB)* Type **1** *( **1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

**Bank is eroded on top of natural protection and some tree roots are exposed.**

## 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)*:

**Y**
**80**
**20**
**15**
**1.5**
**10**
**60**
**This scour hole exists downstream of large boulders across the channel at 70 feet downstream. The scour depth is based on a thalweg of 2.5 feet.**

**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: JAMATH00010025 Town: JAMAICA
Road Number: TH 1 County: WINDHAM
Stream: BALL MOUNTAIN BROOK

Initials RLB Date: 04/14/97 Checked: EB

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 | 8650 | 12800 | 0 |
| Main Channel Area, ft2 | 639 | 874 | 0 |
| Left overbank area, ft2 | 0 | 0 | 0 |
| Right overbank area, ft2 | 0 | 0 | 0 |
| Top width main channel, ft | 80 | 98 | 0 |
| Top width L overbank, ft | 0 | 0 | 0 |
| Top width R overbank, ft | 0 | 0 | 0 |
| D50 of channel, ft | 0.727 | 0.727 | 0 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 8.0 | 8.9 | ERR |
| y1, average depth, LOB, ft | ERR | ERR | ERR |
| y1, average depth, ROB, ft | ERR | ERR | ERR |
| Total conveyance, approach | 55646 | 81932 | 0 |
| Conveyance, main channel | 55646 | 81932 | 0 |
| Conveyance, LOB | 0 | 0 | 0 |
| Conveyance, ROB | 0 | 0 | 0 |
| Percent discrepancy, conveyance | 0.0000 | 0.0000 | ERR |
| Qm, discharge, MC, cfs | 8650.0 | 12800.0 | ERR |
| Ql, discharge, LOB, cfs | 0.0 | 0.0 | ERR |
| Qr, discharge, ROB, cfs | 0.0 | 0.0 | ERR |
| Vm, mean velocity MC, ft/s | 13.5 | 14.6 | ERR |
| Vl, mean velocity, LOB, ft/s | ERR | ERR | ERR |
| Vr, mean velocity, ROB, ft/s | ERR | ERR | ERR |
| Vc-m, crit. velocity, MC, ft/s | 14.3 | 14.5 | N/A |
| Vc-l, crit. velocity, LOB, ft/s | ERR | ERR | ERR |
| Vc-r, crit. velocity, ROB, ft/s | ERR | ERR | ERR |

Results

| Live-bed(1) or Clear-Water(0) Contraction Scour? | | | |
|---|---|---|---|
| Main Channel | 0 | 1 | N/A |
| 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 | 8650 | 12800 | 0 | 8650 | 12800 | 0 |
| Total conveyance | 55646 | 81932 | 0 | 85194 | 94162 | 0 |
| Main channel conveyance | 55646 | 81932 | 0 | 85194 | 94162 | 0 |
| Main channel discharge | 8650 | 12800 | ERR | 8650 | 12800 | ERR |
| Area - main channel, ft2 | 639 | 874 | 0 | 675 | 722 | 0 |
| (W1) channel width, ft | 80 | 98 | 0 | 63 | 63 | 0 |
| (Wp) cumulative pier width, ft | 0 | 0 | 0 | 0 | 0 | 0 |
| W1, adjusted bottom width(ft) | 80 | 98 | 0 | 63 | 63 | 0 |
| D50, ft | 0.727 | 0.727 | 0.727 | | | |
| w, fall velocity, ft/s (p. 32) | 6.977 | 6.977 | 0 | | | |
| y, ave. depth flow, ft | 7.99 | 8.92 | N/A | 10.71 | 11.46 | ERR |
| S1, slope EGL | 0.021 | 0.02 | 0 | | | |
| P, wetted perimeter, MC, ft | 86 | 106 | 0 | | | |
| R, hydraulic Radius, ft | 7.430 | 8.245 | ERR | | | |
| V*, shear velocity, ft/s | 2.242 | 2.304 | N/A | | | |
| V*/w | 0.321 | 0.330 | ERR | | | |
| 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 | 0.59 | 0.59 | 0 | | | |
| y2,depth in contraction, ft | 9.20 | 11.57 | ERR | | | |
| ys, scour depth, ft (y2-y_bridge) | -1.52 | 0.11 | N/A | | | |
| ARMORING | | | | | | |
| D90 | 1.622 | 1.622 | 0 | | | |
| D95 | 2.049 | 2.049 | 0 | | | |
| Critical grain size,Dc, ft | 0.8593 | 1.5953 | ERR | | | |
| Decimal-percent coarser than Dc | 0.408 | 0.108 | 0 | | | |
| depth to armoring, ft | 3.74 | 39.53 | ERR | | | |

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)

| Approach Section | Q100 | Q500 | Qother |
|---|---|---|---|
| Main channel Area, ft2 | 639 | 874 | 0 |
| Main channel width, ft | 80 | 98 | 0 |
| y1, main channel depth, ft | 7.99 | 8.92 | ERR |

Bridge Section

| | | | |
|---|---|---|---|
| (Q) total discharge, cfs | 8650 | 12800 | 0 |
| (Q) discharge thru bridge, cfs | 8650 | 12800 | 0 |
| Main channel conveyance | 85194 | 94162 | 0 |
| Total conveyance | 85194 | 94162 | 0 |
| Q2, bridge MC discharge,cfs | 8650 | 12800 | ERR |
| Main channel area, ft2 | 675 | 722 | 0 |
| Main channel width (skewed), ft | 63.0 | 63.0 | 0.0 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 63 | 63 | 0 |
| y_bridge (avg. depth at br.), ft | 10.71 | 11.46 | ERR |
| Dm, median (1.25*D50), ft | 0.90875 | 0.90875 | 0 |
| y2, depth in contraction,ft | 8.64 | 12.10 | ERR |
| ys, scour depth (y2-ybridge), ft | -2.07 | 0.64 | N/A |

Abutment Scour

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

| | 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 | 8650 | 12800 | 0 | 8650 | 12800 | 0 |
| a', abut.length blocking flow, ft | 5.3 | 9.4 | 0 | 12.1 | 26 | 0 |
| Ae, area of blocked flow ft2 | 22 | 45.2 | 0 | 51.2 | 95.6 | 0 |
| Qe, discharge blocked abut.,cfs | 172.4 | 401.1 | 0 | 405.7 | 720 | 0 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 7.84 | 8.87 | ERR | 7.92 | 7.53 | ERR |
| ya, depth of f/p flow, ft | 4.15 | 4.81 | ERR | 4.23 | 3.68 | ERR |
| --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 | 120 | 120 | 120 | 60 | 60 | 60 |
| K2 | 1.04 | 1.04 | 1.04 | 0.95 | 0.95 | 0.95 |
| Fr, froude number f/p flow | 0.680 | 0.713 | ERR | 0.679 | 0.692 | ERR |
| ys, scour depth, ft | 11.19 | 14.89 | N/A | 13.50 | 15.71 | N/A |

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

| | | | | | | |
|---|---|---|---|---|---|---|
| a'(abut length blocked, ft) | 5.3 | 9.4 | 0 | 12.1 | 26 | 0 |
| y1 (depth f/p flow, ft) | 4.15 | 4.81 | ERR | 4.23 | 3.68 | ERR |
| a'/y1 | 1.28 | 1.95 | ERR | 2.86 | 7.07 | ERR |
| Skew correction (p. 49, fig. 16) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Froude no. f/p flow | 0.68 | 0.71 | N/A | 0.68 | 0.69 | N/A |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | ERR | ERR | ERR | ERR | ERR | ERR |
| vertical w/ ww's | ERR | ERR | ERR | ERR | ERR | ERR |
| spill-through | ERR | ERR | ERR | ERR | ERR | ERR |

Abutment riprap Sizing

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

| Characteristic | Q100 | Q500 | Qother | | | |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 0.69 | 0.92 | 0 | 0.69 | 0.92 | 0 |
| (Fr from the characteristic V and y in contracted section--mc, bridge section) | | | | | | |
| y, depth of flow in bridge, ft | 10.70 | 11.44 | 0.00 | 10.70 | 11.44 | 0.00 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | 3.15 | ERR | 0.00 | 3.15 | ERR | 0.00 |
| Fr>0.8 (vertical abut.) | ERR | 4.67 | ERR | ERR | 4.67 | ERR |