# LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (BRADTH00090023) on TOWN HIGHWAY 9, crossing MILL POND BROOK, BRADFORD, VERMONT

Open-File Report 98-195

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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# LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (BRADTH00090023) on TOWN HIGHWAY 9, crossing MILL POND BROOK, BRADFORD, VERMONT

By MICHAEL A. IVANOFF AND TIM SEVERANCE

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**1998**

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BRUCE BABBITT, Secretary

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

For additional information write to:

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

Copies of this report may be purchased from:

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## CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

## OTHER ABBREVIATIONS

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

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

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

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

# LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (BRADTH00090023) ON TOWN HIGHWAY 9, CROSSING MILL POND BROOK, BRADFORD, VERMONT

*By* **Michael A. Ivanoff and Tim Severance**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRADTH00090023 on Town Highway 9 crossing Mill Pond Brook, Bradford, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in east-central Vermont. The 6.06-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of trees, brush, and grassy areas in a suburban setting. The downstream right bank is forested.

In the study area, Mill Pond Brook has an incised, sinuous channel with a slope of approximately 0.02 ft/ft, an average channel top width of 42 ft and an average bank height of 5 ft. The channel bed material ranges from gravel to boulders with a median grain size ($D_{50}$) of 52.4 mm (0.172 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 7, 1995, indicated that the reach was stable.

The Town Highway 9 crossing of Mill Pond Brook is a 33-ft-long, two-lane bridge consisting of one 29-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March 23, 1995). The opening length of the structure parallel to the bridge face is 27.1 ft. The bridge is supported by vertical, “laid-up” stone abutments with concrete caps. The channel is skewed approximately 20 degrees to the opening while the computed opening-skew-to-roadway is 5 degrees.

A scour hole 0.5 ft deeper than the mean thalweg depth was observed in the upstream channel during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) at the upstream ends of the left and right abutments and at the downstream end of the right abutment. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.5 to 1.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 6.2 to 14.8 ft. The worst-case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 5.3 to 8.1 ft. The worst-case right abutment scour occurred at the incipient roadway-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

**Fairlee, VT. Quadrangle, 1:24,000, 1981**

**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*** BRADTH00090023 ***Stream*** Mill Pond Brook

***County*** Orange ***Road*** TH 9 ***District*** 7

## Description of Bridge

***Bridge length*** 33.0 ***ft*** ***Bridge width*** 23.3 ***ft*** ***Max span length*** 29.0 ***ft***

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

***Abutment type*** Vertical, “laid-up” stone ***Embankment type*** Sloping

***Stone fill on abutment?*** Yes ***Date of inspection*** 9/7/95

***Description of stone fill*** Type-2, around the upstream and downstream ends of the right abutment and at the upstream end of the left abutment.

***Brief description of piers/abutments*** Abutments are ”laid-up” stone with concrete caps.

***Is bridge skewed to flood flow according to*** No ***survey?*** Yes ***Angle*** 20

***Is there a channel bend in the bridge reach? If so, describe (mild, moderate, severe)*** There is a mild channel bend in the upstream reach.

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

| | ***Date of inspection*** | ***Percent of channel blocked horizontally*** | ***Percent of channel blocked vertically*** |
|---|---|---|---|
| ***Level I*** | 9/7/95 | 0 | 0 |
| ***Level II*** | 9/7/95 | 0 | 0 |

***Potential for debris*** Moderate. There is some debris along the banks and trees are leaning over the upstream channel.

***Describe any features near or at the bridge that may affect flow (include observation date)*** There is a short wall three feet high in front of the entire base length of the left abutment protruding into the channel as of 9/7/95.

## Description of the Geomorphic Setting

***General topography*** The channel is located within a moderate relief valley with flat to slightly irregular narrow flood plains.

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

***Date of inspection*** 9/7/95

***DS left:*** Steep channel bank to a narrow flood plain.

***DS right:*** Steep channel bank to a narrow flood plain.

***US left:*** Steep channel bank to a moderately sloped overbank.

***US right:*** Steep channel bank to a narrow flood plain.

## Description of the Channel

***Average top width*** 42 ft ***Average depth*** 5 ft

***Predominant bed material*** Gravel/Cobbles ***Bank material*** Silt/Clay/Cobbles

Perennial and sinuous but stable with semi-alluvial channel boundaries and narrow point bars.

9/7/95

***Vegetative co*** Short grass and brush with a few trees.

***DS left:*** Trees and brush.

***DS right:*** Trees and brush with grass on the overbank.

***US left:*** Trees and brush with grass on the flood plain.

***US right:***

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

None, 9/7/95.

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

## Hydrology

***Drainage area*** 6.06 ***mi***$^2$

***Percentage of drainage area in physiographic provinces: (approximate)***

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

***Is drainage area considered rural or urban?*** Rural ***Describe any significant urbanization***: There are a couple of houses on the overbank areas.

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

***USGS gage description*** --

***USGS gage number*** --

***Gage drainage area*** -- ***mi***$^2$

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

### Calculated Discharges

***Q100*** 1,140 ***ft***$^3$***/s*** ***Q500*** 1,830 ***ft***$^3$***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(6.06/6.08)exp 0.67] with flood frequency estimates available for bridge number 4 in Bradford from the VTAOT database (written comm. May 1995). Bridge number 4 crosses Mill Pond Brook downstream of this site and has a drainage area of 6.08 square miles. The drainage area adjusted values were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

***Datum tie between USGS survey and VTAOT plans*** None.

***Description of reference marks used to determine USGS datum.*** RM1 is a chiseled X on top of the DS end of the right abutment (elev. 499.72 ft, arbitrary survey datum). RM2 is a chiseled X on top of the US end of the left abutment (elev. 500.50 ft, arbitrary survey datum). RM3 is a nail 4 ft from the base of a power pole (CVPS 25T, 43-183-41) 44 ft right bankward of the DS end of the RABUT (500.28 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 | -23 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 14 | 1 | Road Grade section |
| APPRO | 56 | 1 | Approach section |

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

### Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.050 to 0.070, and overbank "n" values ranged from 0.035 to 0.065.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0214 ft/ft, which was estimated from surveyed thalweg points downstream of the bridge.

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

For the 100-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

## Bridge Hydraulics Summary

***Average bridge embankment elevation*** 500.4 ***ft***
***Average low steel elevation*** 497.7 ***ft***

***100-year discharge*** 1,140 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 495.3 ***ft***
***Road overtopping?*** No ***Discharge over road*** -- ***$ft^3/s$***
***Area of flow in bridge opening*** 102 ***$ft^2$***
***Average velocity in bridge opening*** 11.2 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 14.4 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 498.0
***Water-surface elevation at Approach section without bridge*** 496.0
***Amount of backwater caused by bridge*** 2.0 ***ft***

***500-year discharge*** 1,830 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 497.7 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 338 ***$ft^3/s$***
***Area of flow in bridge opening*** 164 ***$ft^2$***
***Average velocity in bridge opening*** 9.1 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 13.0 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 500.2
***Water-surface elevation at Approach section without bridge*** 497.4
***Amount of backwater caused by bridge*** 2.8 ***ft***

***Incipient overtopping discharge*** 1,400 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 498.2 ***ft***
***Area of flow in bridge opening*** 167 ***$ft^2$***
***Average velocity in bridge opening*** 8.4 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 10.5 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 499.7
***Water-surface elevation at Approach section without bridge*** 496.6
***Amount of backwater caused by bridge*** 3.1 ***ft***

## Scour Analysis Summary

### Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 500-year and incipient roadway-overtopping discharges 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 these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Furthermore, for those discharges resulting in 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 alternate computations are provided in appendix F.

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

## Scour Results

| Contraction scour: | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| | *(Scour depths in feet)* | | |
| ***Main channel*** | | | |
| *Live-bed scour* | -- | -- | -- |
| *Clear-water scour* | 1.0 | 1.1 | 0.5 |
| *Depth to armoring* | 20.8 | 26.4 | 25.8 |
| ***Left overbank*** | -- | -- | -- |
| ***Right overbank*** | -- | -- | -- |
| **Local scour:** | | | |
| ***Abutment scour*** | | | |
| *Left abutment* | 6.2 | 14.8 | 12.2 |
| *Right abutment* | 7.8 | 5.3 | 8.1 |
| ***Pier scour*** | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |
| *Pier 3* | -- | -- | -- |

## Riprap Sizing

| | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| | | ($D_{50}$ in feet) | |
| **Abutments:** | | | |
| *Left abutment* | 1.6 | 1.9 | 1.8 |
| *Right abutment* | 1.6 | 1.9 | 1.8 |
| **Piers:** | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

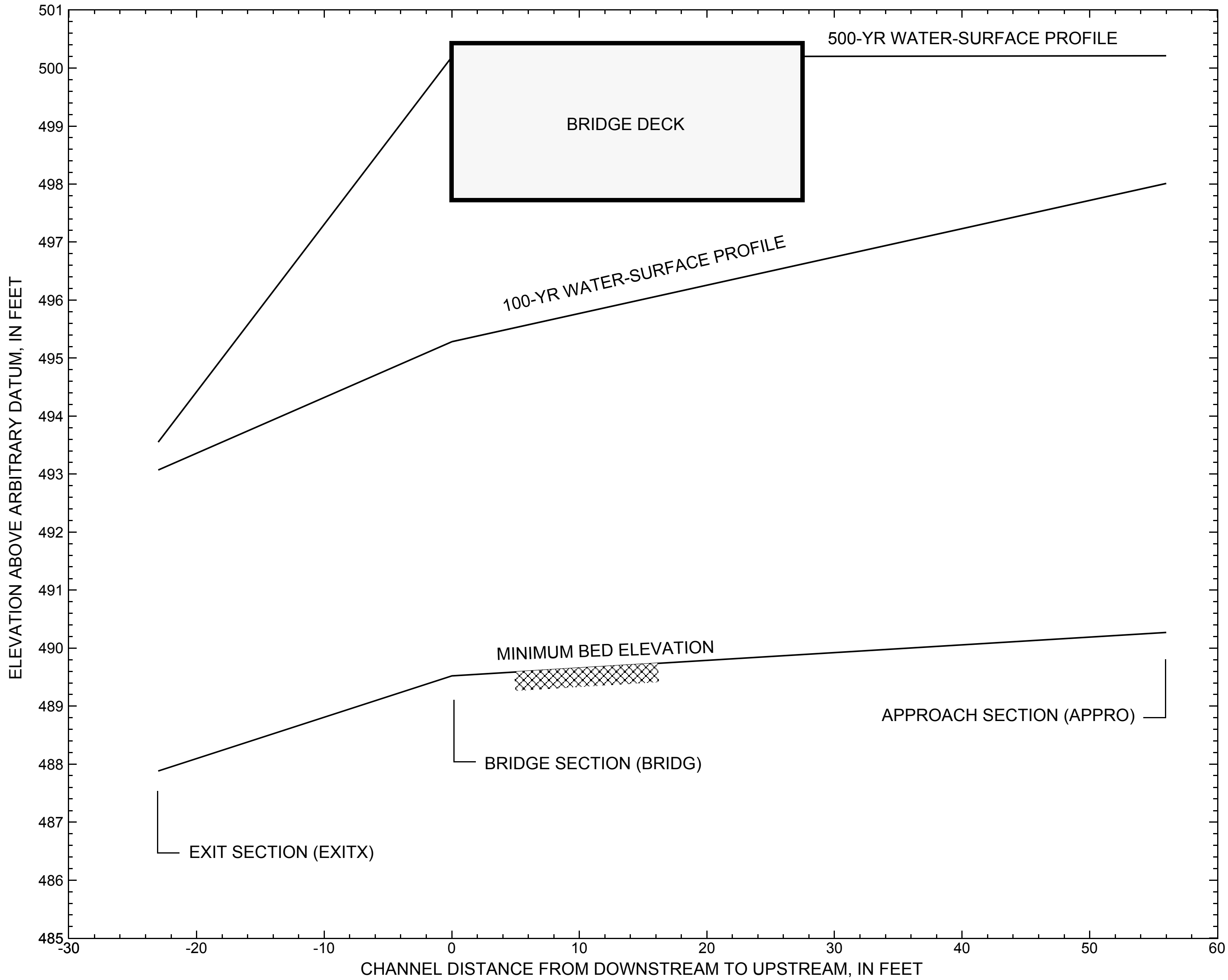


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure BRADTH00090023 on Town Highway 9, crossing Mill Pond Brook, Bradford, Vermont.

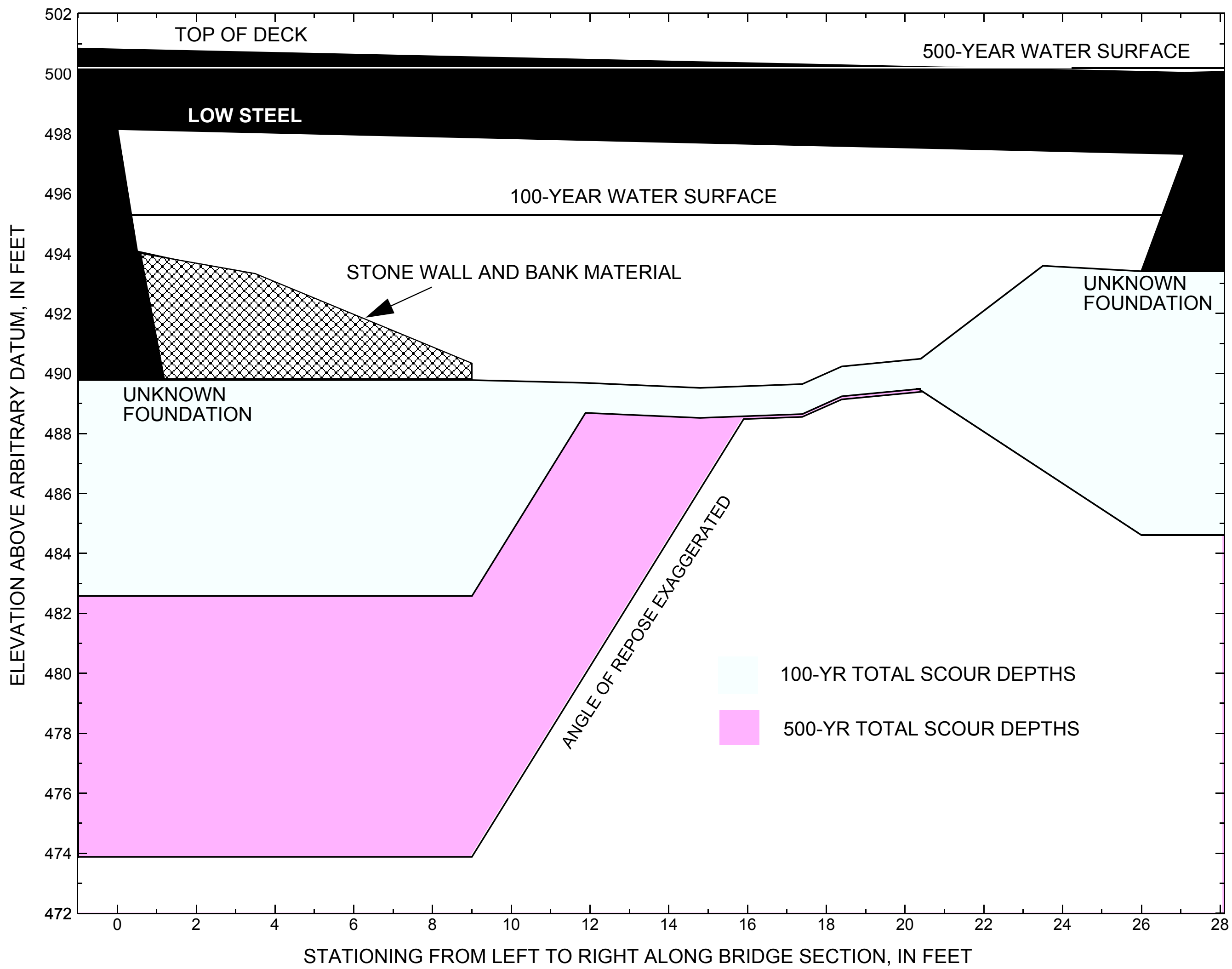


Figure 8. Scour elevations for the 100- and 500-year discharges at structure BRADTH00090023 on Town Highway 9, crossing Mill Pond Brook, Bradford, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure BRADTH00090023 on Town Highway 9, crossing Mill Pond Brook, Bradford, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100-year discharge is 1,140 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 498.2 | -- | 489.8 | 1.0 | 6.2 | -- | 7.2 | 482.6 | -- |
| Right abutment | 27.1 | -- | 497.3 | -- | 493.4 | 1.0 | 7.8 | -- | 8.8 | 484.6 | -- |

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 BRADTH00090023 on Town Highway 9, crossing Mill Pond Brook, Bradford, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 500-year discharge is 1,830 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 498.2 | -- | 489.8 | 1.1 | 14.8 | -- | 15.9 | 473.9 | -- |
| Right abutment | 27.1 | -- | 497.3 | -- | 493.4 | 1.1 | 5.3 | -- | 6.4 | 487.0 | -- |

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

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APPENDIX A:

# WSPRO INPUT FILE

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File brad023.wsp
T2        Hydraulic analysis for structure BRADTH00090023   Date: 13-AUG-97
T3        Bridge 23 on Town Highway 9 over Mill Pond Brook, Bradford, VT  by MAI
*
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           1140.0   1830.0   1400.0
SK          0.0214   0.0214   0.0214
*
XS   EXITX    -23
GR         -181.7, 509.36   -154.6, 506.55   -128.4, 500.97   -112.0, 499.08
GR          -91.3, 491.28    -52.9, 492.67    -14.7, 492.72      0.0, 492.30
GR            5.3, 489.47     11.7, 488.96     14.0, 488.53     14.3, 487.88
GR           18.2, 488.31     19.8, 488.70     22.6, 489.97     28.4, 490.47
GR           33.0, 492.92     42.4, 492.21     81.3, 491.75     90.7, 493.83
GR          111.5, 494.70    123.5, 497.42    138.0, 497.64    177.4, 497.91
GR          209.0, 497.39    258.3, 497.80    303.0, 497.85    316.3, 502.98
N           0.045       0.070       0.065
SA                   0.0         33.0
*
XS   FULLV      0  * * *   0.0324
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    497.74       5.0
GR            0.0, 498.15      0.5, 494.07      3.5, 493.21      8.9, 490.28
GR            9.0, 489.78     11.9, 489.69     14.8, 489.52     17.4, 489.65
GR           18.4, 490.24     20.4, 490.49     23.5, 493.59     26.0, 493.41
GR           27.1, 497.32      0.0, 498.15
*
*         BRTYPE  BRWDTH
CD            1      27.5
N           0.05
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     14      23.3      1
GR         -268.4, 519.02   -148.9, 506.60   -112.8, 504.20    -45.8, 501.92
GR            0.0, 500.81     28.6, 500.03     45.2, 499.67    107.3, 499.54
GR          146.6, 499.51    237.0, 500.00    287.0, 502.98
*
AS   APPRO     56
GR         -256.9, 518.78   -223.6, 507.51   -145.6, 503.85   -111.5, 501.44
GR          -63.4, 498.76    -20.3, 498.17     -7.8, 497.53
GR            2.8, 494.82      4.7, 490.84      7.5, 490.60     10.2, 490.59
GR           12.2, 490.27     14.8, 490.73     18.4, 491.56     30.9, 495.52
GR           35.8, 497.94     43.5, 499.36     70.3, 499.54    109.6, 499.51
GR          200.0, 500.00    250.0, 502.98
N           0.035      0.065       0.045
SA                  -7.8         43.5
*
HP 1 BRIDG   495.28 1 495.28
HP 2 BRIDG   495.28 * * 1140
HP 1 APPRO   498.01 1 498.01
HP 2 APPRO   498.01 * * 1140
HP 1 BRIDG   497.74 1 497.74
HP 2 BRIDG   497.74 * * 1498
HP 1 BRIDG   496.08 1 496.08
```

# APPENDIX B:

# WSPRO OUTPUT FILE

# WSPRO OUTPUT FILE

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        U.S. Geological Survey WSPRO Input File brad023.wsp
        Hydraulic analysis for structure BRADTH00090023   Date: 13-AUG-97
        Bridge 23 on Town Highway 9 over Mill Pond Brook, Bradford, VT  by MAI
           *** RUN DATE & TIME: 10-15-97  08:31
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     102.    6649.    26.    31.                        1140.
   495.28          102.    6649.    26.    31.  1.00     0.    27.   1140.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.28     0.4    26.5   101.7    6649.    1140.  11.21

X STA.         0.4         5.1         6.9         8.2         9.3        10.1
  A(I)             9.0         6.2         5.4         5.4         4.4
  V(I)            6.32        9.14       10.47       10.50       12.95

X STA.        10.1        10.9        11.6        12.3        13.0        13.7
  A(I)             4.3         4.1         4.0         4.0         4.0
  V(I)           13.39       13.82       14.23       14.29       14.19

X STA.        13.7        14.4        15.1        15.8        16.6        17.3
  A(I)             3.9         4.0         4.0         4.1         4.2
  V(I)           14.44       14.36       14.25       13.87       13.46

X STA.        17.3        18.2        19.1        20.2        21.7        26.5
  A(I)             4.6         4.8         5.1         6.6         9.5
  V(I)           12.49       11.79       11.11        8.69        6.03

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       2.      37.     9.     9.                           6.
             2     191.   10994.    44.    48.                        2264.
   498.01          194.   11031.    53.    58.  1.01   -17.    36.   2077.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.01   -17.2    36.2   193.5   11031.    1140.   5.89

X STA.       -17.2         2.0         5.0         6.3         7.5         8.6
  A(I)            19.1        14.4         9.8         8.8         8.1
  V(I)            2.98        3.96        5.80        6.45        7.00

X STA.         8.6         9.7        10.7        11.7        12.7        13.6
  A(I)             8.0         7.6         7.6         7.3         7.4
  V(I)            7.13        7.55        7.48        7.84        7.73

X STA.        13.6        14.6        15.7        16.8        18.0        19.2
  A(I)             7.3         7.6         7.7         7.9         8.1
  V(I)            7.81        7.54        7.43        7.21        7.05

X STA.        19.2        20.7        22.4        24.5        27.4        36.2
  A(I)             8.7         9.3        10.1        11.8        17.0
  V(I)            6.56        6.11        5.66        4.84        3.35
```

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       U.S. Geological Survey WSPRO Input File brad023.wsp
       Hydraulic analysis for structure BRADTH00090023   Date: 13-AUG-97
       Bridge 23 on Town Highway 9 over Mill Pond Brook, Bradford, VT  by MAI
          *** RUN DATE & TIME: 10-15-97  08:31
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     164.   10871.    13.    50.                        3276.
  497.74          164.   10871.    13.    50.  1.00     0.    27.   3276.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.74     0.1    27.1   164.2   10871.    1498.   9.12

X STA.         0.1        3.3        5.0        6.3        7.4        8.3
  A(I)            12.4        8.0        7.4        6.7        6.3
  V(I)            6.05       9.37      10.12      11.14      11.82

X STA.         8.3        9.2        9.9       10.6       11.4       12.1
  A(I)             6.8        5.8        5.8        5.8        5.8
  V(I)           11.06      12.98      12.84      12.95      12.92

X STA.        12.1       12.8       13.6       14.6       15.6       16.7
  A(I)             6.0        6.4        8.0        8.0        8.3
  V(I)           12.44      11.62       9.31       9.30       9.02

X STA.        16.7       17.8       19.0       20.4       22.4       27.1
  A(I)             8.8        9.4        9.7       12.0       16.6
  V(I)            8.55       7.95       7.73       6.22       4.50

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     123.    8785.    26.    33.                        1501.
  496.08          123.    8785.    26.    33.  1.00     0.    27.   1501.

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      14.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.19    22.7   240.2   108.2    1582.     338.   3.12

X STA.        22.7       46.9       57.0       66.5       75.2       83.4
  A(I)             7.0        5.4        5.3        5.0        4.9
  V(I)            2.41       3.13       3.21       3.38       3.48

X STA.        83.4       91.5       99.2      106.7      113.8      120.9
  A(I)             4.9        4.8        4.8        4.7        4.7
  V(I)            3.45       3.51       3.53       3.63       3.60

X STA.       120.9      128.0      135.1      142.3      149.4      157.2
  A(I)             4.7        4.7        4.8        4.8        5.0
  V(I)            3.60       3.57       3.50       3.51       3.37

X STA.       157.2      166.0      176.4      189.2      205.7      240.2
  A(I)             5.3        5.7        6.2        6.7        8.9
  V(I)            3.21       2.97       2.73       2.52       1.90

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     124.    6933.    82.    82.                         863.
            2     299.   21055.    51.    56.                        4100.
            3      89.    1985.   160.   160.                         375.
  500.21          512.   29973.   293.   297.  1.24   -89.   204.   3452.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.21   -89.4   203.5   511.6   29973.    1830.   3.58

X STA.       -89.4      -51.8      -36.2      -23.3      -13.0       -3.9
  A(I)            36.5       26.9       24.5       22.5       25.6
  V(I)            2.50       3.41       3.73       4.06       3.57

X STA.        -3.9        2.0        5.5        7.3        9.0       10.8
  A(I)            25.9       25.7       17.3       16.7       16.8
  V(I)            3.54       3.56       5.28       5.47       5.46

X STA.        10.8       12.4       14.1       16.0       17.9       20.1
  A(I)            16.3       16.6       17.1       17.5       18.4
  V(I)            5.63       5.51       5.34       5.23       4.96

X STA.        20.1       22.7       26.0       30.9       68.0      203.5
  A(I)            20.1       22.6       26.6       47.9       70.0
  V(I)            4.56       4.06       3.44       1.91       1.31
```

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        U.S. Geological Survey WSPRO Input File brad023.wsp
        Hydraulic analysis for structure BRADTH00090023   Date: 13-AUG-97
        Bridge 23 on Town Highway 9 over Mill Pond Brook, Bradford, VT  by MAI
           *** RUN DATE & TIME: 10-15-97  08:31

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     167.    9490.     0.    63.                          0.
   498.15          167.    9490.     0.    63.  1.00     0.    27.      0.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.15     0.0    27.1   166.9    9490.    1400.   8.39

X STA.         0.0        3.4        5.2        6.7        7.9        9.0
  A(I)            13.7        9.7        9.0        8.2        8.0
  V(I)            5.11       7.21       7.79       8.58       8.71

X STA.         9.0        9.9       10.8       11.6       12.5       13.3
  A(I)             7.3        6.8        6.9        6.9        6.7
  V(I)            9.62      10.29      10.21      10.16      10.46

X STA.        13.3       14.1       15.0       15.8       16.7       17.6
  A(I)             6.8        6.8        6.9        6.9        7.2
  V(I)           10.30      10.27      10.20      10.15       9.74

X STA.        17.6       18.6       19.7       21.0       22.9       27.1
  A(I)             7.8        8.0        8.7       10.4       14.4
  V(I)            8.95       8.80       8.04       6.73       4.87

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     117.    8152.    26.    32.                       1394.
   495.85          117.    8152.    26.    32.  1.00     0.    27.   1394.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      81.    3768.    72.    72.                        492.
             2     271.   17851.    51.    56.                       3534.
             3      13.     115.    94.    94.                         27.
   499.66          365.   21734.   217.   221.  1.11   -80.   137.   2552.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.66   -79.6   137.3   365.4   21734.    1400.   3.83

X STA.       -79.6      -41.3      -24.2      -12.1       -2.7        2.1
  A(I)            30.5       22.7       19.7       22.9       19.5
  V(I)            2.30       3.09       3.56       3.06       3.58

X STA.         2.1        5.3        6.8        8.2        9.6       11.0
  A(I)            21.1       13.7       12.9       12.9       12.6
  V(I)            3.32       5.12       5.44       5.41       5.55

X STA.        11.0       12.4       13.7       15.2       16.7       18.4
  A(I)            12.7       12.6       12.8       13.5       13.9
  V(I)            5.52       5.56       5.45       5.17       5.04

X STA.        18.4       20.3       22.5       25.3       29.3      137.3
  A(I)            14.7       16.1       17.7       20.7       42.3
  V(I)            4.76       4.35       3.94       3.38       1.65
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        U.S. Geological Survey WSPRO Input File brad023.wsp
        Hydraulic analysis for structure BRADTH00090023   Date: 13-AUG-97
        Bridge 23 on Town Highway 9 over Mill Pond Brook, Bradford, VT  by MAI
           *** RUN DATE & TIME: 10-15-97  08:31

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

EXITX:XS   ******   -96.     228.  0.49 *****  493.57  493.06   1140.  493.07
      -23. ******    87.    7792.  1.27 ***** *******    0.89    5.00
 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.28     493.57     493.80
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   492.57     510.11    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   492.57     510.11     493.80
 ===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 =   493.80     510.11     493.80

FULLV:FV      23.   -96.     226.  0.51 *****  494.31  493.80   1140.  493.80
        0.    23.    87.    7688.  1.28 ***** *******    0.91    5.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.35     495.15     495.97
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.30     518.78    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.30     518.78     495.97
 ===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 =   495.97     518.78     495.97

APPRO:AS      56.    -2.     111.  1.64 *****  497.61  495.97   1140.  495.97
       56.    56.    32.    5280.  1.00 ***** *******    1.00   10.28
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1140.      495.28

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

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

BRIDG:BR      23.     0.     102.  1.96 *****  497.23  495.28   1140.  495.28
        0.    23.    27.    6636.  1.00 ***** *******    1.00   11.22

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.74 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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      29.   -17.     194.  0.55  0.51  498.56  495.97   1140.  498.01
       56.    29.    36.   11038.  1.01  0.81   -0.01    0.55    5.89

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.263  0.000   11141.     0.    26.   497.67

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -23.   -96.    87.   1140.    7792.     228.    5.00  493.07
   FULLV:FV       0.   -96.    87.   1140.    7688.     226.    5.05  493.80
   BRIDG:BR       0.     0.    27.   1140.    6636.     102.   11.22  495.28
   RDWAY:RG      14.**************      0.******************    1.00********
   APPRO:AS      56.   -17.    36.   1140.   11038.     194.    5.89  498.01

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       0.    26.   11141.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS      FR#    YMIN    YMAX     HF    HO  VHD      EGL     WSEL
   EXITX:XS     493.06     0.89  487.88  509.36************  0.49  493.57  493.07
   FULLV:FV     493.80     0.91  488.63  510.11************  0.51  494.31  493.80
   BRIDG:BR     495.28     1.00  489.52  498.15************  1.96  497.23  495.28
   RDWAY:RG   ***************    499.51  519.02**********************************
   APPRO:AS     495.97     0.55  490.27  518.78  0.51  0.81  0.55  498.56  498.01
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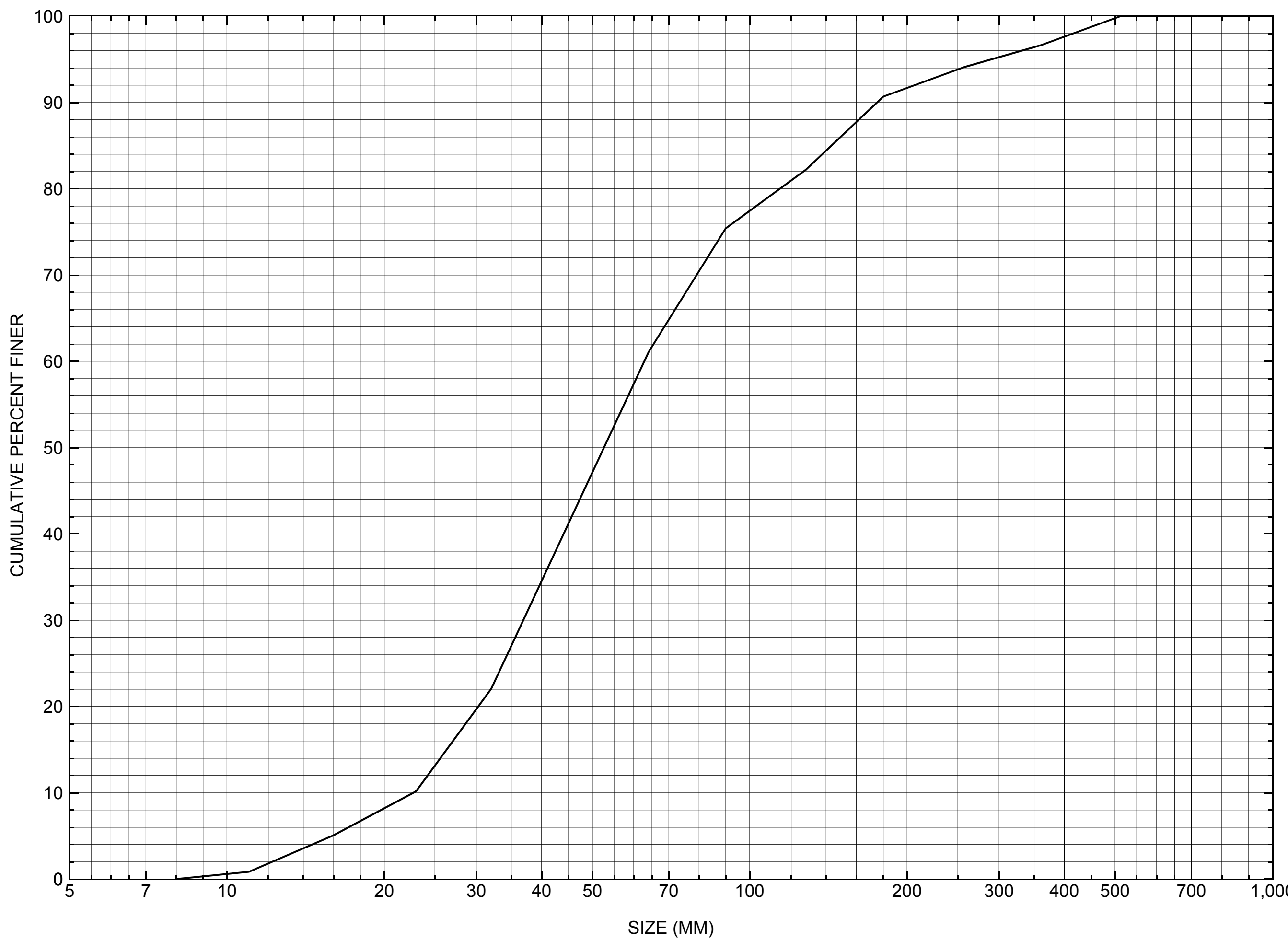
```
        U.S. Geological Survey WSPRO Input File brad023.wsp
        Hydraulic analysis for structure BRADTH00090023   Date: 13-AUG-97
        Bridge 23 on Town Highway 9 over Mill Pond Brook, Bradford, VT  by MAI
           *** RUN DATE & TIME: 10-15-97  08:31

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

EXITX:XS   ******   -97.     316.  0.59 *****  494.14  493.44   1830.  493.55
      -23. ******    89.   12501.  1.13 ***** *******    0.84    5.79
 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.08     494.05     494.19
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.05     510.11    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.05     510.11     494.19
 ===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 =   494.19     510.11     494.19

FULLV:FV      23.   -97.     296.  0.68 *****  494.87  494.19   1830.  494.19
        0.    23.    89.   11362.  1.15 ***** *******    0.93    6.17
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    3.40     494.12     497.36
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.69     518.78    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.69     518.78     497.36
 ===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 =   497.36     518.78     497.36

APPRO:AS      56.    -7.     163.  1.95 *****  499.31  497.36   1830.  497.36
       56.    56.    35.    8741.  1.00 ***** *******    1.00   11.20
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   500.25       0.00     496.75     499.51
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   501.52         0.      1830.
 ===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      23.     0.     164.  1.29 *****  499.03  496.08   1498.  497.74
        0. ******    27.   10871.  1.00 ***** *******    0.65    9.12

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.485 ******  497.74 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.    33.  0.12  0.25  500.33    0.00    338.  500.19

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    75.   -61.    14.   2.0   1.0   6.0   6.3   1.6   3.1
   RT:    338.   208.    29.   237.   0.7   0.5   3.7   3.1   0.7   3.1

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

APPRO:AS      29.   -89.     510.  0.25  0.25  500.45  497.36   1830.  500.21
       56.    29.   203.   29892.  1.23  0.00    0.00    0.53    3.59

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q         K      AREA     VEL    WSEL
   EXITX:XS      -23.   -97.    89.   1830.   12501.     316.    5.79  493.55
   FULLV:FV        0.   -97.    89.   1830.   11362.     296.    6.17  494.19
   BRIDG:BR        0.     0.    27.   1498.   10871.     164.    9.12  497.74
   RDWAY:RG       14.*******     0.    338.       0.        0.    1.00  500.19
   APPRO:AS       56.   -89.   203.   1830.   29892.     510.    3.59  500.21

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO   VHD     EGL    WSEL
   EXITX:XS     493.44    0.84  487.88  509.36************  0.59  494.14  493.55
   FULLV:FV     494.19    0.93  488.63  510.11************  0.68  494.87  494.19
   BRIDG:BR     496.08    0.65  489.52  498.15************  1.29  499.03  497.74
   RDWAY:RG   ****************  499.51  519.02   0.12******  0.25  500.33  500.19
   APPRO:AS     497.36    0.53  490.27  518.78   0.25  0.00  0.25  500.45  500.21
```

# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File brad023.wsp
        Hydraulic analysis for structure BRADTH00090023   Date: 13-AUG-97
        Bridge 23 on Town Highway 9 over Mill Pond Brook, Bradford, VT  by MAI
           *** RUN DATE & TIME: 10-15-97  08:31

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

EXITX:XS   ******   -97.     264.  0.53 *****  493.79  493.21   1400.  493.27
      -23. ******    88.    9569.  1.20 ***** *******    0.86    5.31
 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.18     493.77     493.95
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   492.77     510.11    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   492.77     510.11     493.95
 ===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 =   493.95     510.11     493.95

FULLV:FV      23.   -96.     253.  0.58 *****  494.53  493.95   1400.  493.95
        0.    23.    88.    9010.  1.22 ***** *******    0.92    5.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.54     495.35     496.55
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.45     518.78    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.45     518.78     496.55
 ===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 =   496.55     518.78     496.55

APPRO:AS      56.    -4.     131.  1.77 *****  498.31  496.55   1400.  496.55
       56.    56.    33.    6579.  1.00 ***** *******    1.00   10.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.87     498.41     498.87     497.74
 ===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      23.     0.     167.  1.09 *****  499.24  495.85   1394.  498.15
        0. ******    27.    9490.  1.00 ***** *******    0.59    8.35

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.467 ******  497.74 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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      29.   -79.     365.  0.25  0.28  499.91  496.55   1400.  499.66
       56.    29.   137.   21687.  1.11  0.80    0.00    0.55    3.84

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -23.   -97.    88.   1400.    9569.     264.    5.31  493.27
   FULLV:FV       0.   -96.    88.   1400.    9010.     253.    5.54  493.95
   BRIDG:BR       0.     0.    27.   1394.    9490.     167.    8.35  498.15
   RDWAY:RG      14.**************      0.       0.       0.    1.00********
   APPRO:AS      56.   -79.   137.   1400.   21687.     365.    3.84  499.66

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO  VHD      EGL    WSEL
   EXITX:XS    493.21    0.86  487.88  509.36************  0.53  493.79  493.27
   FULLV:FV    493.95    0.92  488.63  510.11************  0.58  494.53  493.95
   BRIDG:BR    495.85    0.59  489.52  498.15************  1.09  499.24  498.15
   RDWAY:RG  ****************  499.51  519.02************  0.25  499.77********
   APPRO:AS    496.55    0.55  490.27  518.78  0.28  0.80  0.25  499.91  499.66
```

# APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BRADTH00090023, in Bradford, Vermont.

APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **BRADTH00090023**

## General Location Descriptive

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

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

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

County *(FIPS county code; I - 3; nnn)* **017**

Town *(FIPS place code; I - 4; nnnnn)* **07375**

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

Waterway *(I - 6)* **Mill Pond Brook**

Road Name *(I - 7):* **-**

Route Number **TH009**

Vicinity *(I - 9)* **0.05 MI JCT TH 9 + TH 2**

Topographic Map **Fairlee**

Hydrologic Unit Code: **01080103**

Latitude *(I - 16; nnnn.n)* **43592**

Longitude *(i - 17; nnnnn.n)* **72086**

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10090100230901**

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

Maximum span length *(I - 48; nnnn)* **0029**

Year built *(I - 27; YYYY)* **1934**

Structure length *(I - 49; nnnnnn)* **000033**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000400**

Deck Width *(I - 52; nn.n)* **233**

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

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

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

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

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

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

Structure type *(I - 43; nnn)* **104**

Year Reconstructed *(I - 106)* **0000**

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

Clear span (*nnn.n ft*) **-**

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

Vertical clearance from streambed (*nnn.n ft*) **007.9**

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

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

Comments:

**The structural inspection report of 6/29/93 indicates the structure is a concrete T-beam type bridge. The abutment walls are noted as partially grouted and stone chinked "laid-up" stone blocks with concrete caps. Some of the grouting and stone chinking is reported missing overall. The concrete caps have some minor cracks and spalls reported. There are no wingwalls. The footings are reported as not seen with no undermining or settling indicated as well. Some scour is reported as possible along the right abutment as a log, which may have been used to form the streamward extent of the stone blocks at the base of the wall, is reported visible at the surface along the bottom of the abutment.** **(Continued, page 33)**

## Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: Gravel and stone

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

$Q_{50}$ - $Q_{100}$ - $Q_{500}$ -

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

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

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

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

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

Watershed storage area (*in percent*): - %

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

| Peak discharge frequency | $Q_{2.33}$ | $Q_{10}$ | $Q_{25}$ | $Q_{50}$ | $Q_{100}$ |
|---|---|---|---|---|---|
| Water surface elevation (*ft*) | - | - | - | - | - |
| Velocity (*ft / sec*) | - | - | - | - | - |

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

**The log is noted as deteriorated with rotten sections. There is stone and boulder fill protection noted along the front of each abutment wall and around the ends. Further there is some of the same stone fill noted on the banks US and DS of the bridge. The stone fill is noted as washed away from the upstream half of the right abutment.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **6.06** mi$^2$ Lake/pond/swamp area **0.03** mi$^2$

Watershed storage *(ST)* **0.5** %

Bridge site elevation **510** ft Headwater elevation **1670** ft

Main channel length **5.19** mi

10% channel length elevation **600** ft 85% channel length elevation **1260** ft

Main channel slope *(S)* **170** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

## Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

**NO BENCHMARK INFORMATION**

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

**NO FOUNDATION MATERIAL INFORMATION**

Comments:

**NO PLANS.**

## Cross-sectional Data

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

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

Comments: **This cross section is of the upstream face. The low chord elevation is from the survey log done for this report on 09/07/95. The low chord to bed length data are from the sketch attached to a bridge inspection report dated 06/29/93.**

| Station | 0 | 10 | 16 | 20 | 27 | - | - | - | - | - | - |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Feature | LAB | - | - | - | RAB | - | - | - | - | - | - |
| Low chord elevation | 498.2 | 497.9 | 497.7 | 497.6 | 497.3 | - | - | - | - | - | - |
| Bed elevation | 493.1 | 490.0 | 489.5 | 490.1 | 491.7 | - | - | - | - | - | - |
| Low chord to bed | 5.1 | 7.9 | 8.2 | 7.5 | 5.6 | - | - | - | - | - | - |

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

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

Comments: -

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

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

APPENDIX E:

# LEVEL I DATA FORM

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

Qa/Qc Check by: CG Date: 02/23/96
Computerized by: CG Date: 02/23/96
Reviewd by: MAI Date: 01/27/98

# Structure Number BRADTH00090023

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. Severance Date *(MM/DD/YY)* 09 / 07 / 1995

2. Highway District Number 07 Mile marker 0

County Orange (017) Town Bradford (07375)

Waterway *(I - 6)* Mill Pond Brook Road Name -

Route Number TH 009 Hydrologic Unit Code: 01080103

3. Descriptive comments:

**The site is located 0.05 miles to the junction with Town Highway 2.**

## B. Bridge Deck Observations

4. Surface cover... LBUS 2 RBUS 2 LBDS 2 RBDS 6 Overall 2
*(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 33.0 *(feet)* Span length 29.0 *(feet)* Bridge width 23.3 *(feet)*

### Road approach to bridge:

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

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

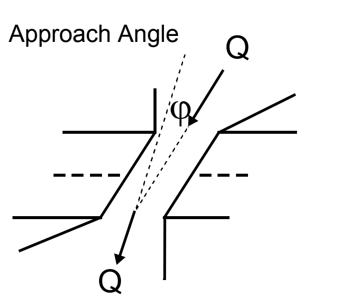
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

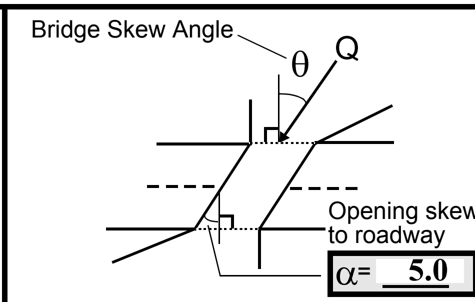
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 0 | - | 3 | 1 |
| RBUS | 0 | - | 2 | 1 |
| RBDS | 0 | - | 0 | - |
| LBDS | 0 | - | 0 | - |

*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: 50 16. Bridge skew: 20




17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 0 feet DS *(US, UB, DS)* to 45 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 0
Range? 0 feet DS *(US, UB, DS)* to 50 feet DS

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

18. Bridge Type: **1b**

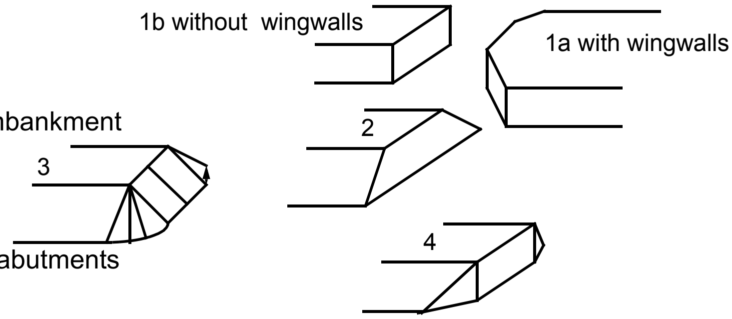
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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




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

**4. There is a “laid-up” stone retaining wall on the left bank DS. The DS right bank is forested, but all other immediate overbanks have dwellings and roads.**

**7. The bridge dimension values are from the VTAOT database. The measured bridge length is 33 ft, span length is 30 ft, and bridge width is 23.2 ft.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| **36.5** | **6.5** | | | **8.0** | **1** | **2** | **134** | **14** | **2** | **0** |

23. Bank width **25.0**   24. Channel width **15.0**   25. Thalweg depth **51.5**   29. Bed Material **4**

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

*SRD - Section ref. dist. to US face*   *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*

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

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

*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

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

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

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **42** 35. Mid-bar width: **71**

36. Point bar extent: **70** feet **US** (US, UB) to **20** feet **US** (US, UB, DS) positioned **65** %LB to **100** %RB

37. Material: **314**

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

**The point bar material is primarily gravel and silt/sand, but there is some cobble.**

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

41. Mid-bank distance: **40** 42. Cut bank extent: **65** feet **US** (US, UB) to **33** feet **US** (US, UB, DS)

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

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

**Tree roots are exposed. Cobbles are falling out of the base of the bank. The grass is slumped at the top edge of the bank.**

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **4**

47. Scour dimensions: Length **10** Width **5** Depth : **0.5** Position **0** %LB to **80** %RB

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

**There is some localized scour upstream of the bridge (beyond 2 bridge lengths).**

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

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

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

54. Confluence comments (eg. confluence name):

**NO MAJOR CONFLUENCES**

## D. Under Bridge Channel Assessment

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

| 56. Height (BF) | | 57 Angle (BF) | | 61. Material (BF) | | 62. Erosion (BF) | |
|---|---|---|---|---|---|---|---|
| LB | RB | LB | RB | LB | RB | LB | RB |
| **14.0** | | **0.5** | | **2** | **7** | **7** | **-** |

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

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

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

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

**34**

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

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

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

70. Debris and Ice Comments:

**1**

**There is greater than 8 ft of vertical distance between the channel and the deck. The bridge is not particularly constrictive. There is some debris in the channel. Trees are leaning into the channel upstream.**

| Abutments | 71. Attack ∠(BF) | 72. Slope ∠ (Qmax) | 73. Toe loc. (BF) | 74. Scour Condition | 75. Scour depth | 76. Exposure depth | 77. Material | 78. Length |
|---|---|---|---|---|---|---|---|---|
| LABUT | | **-** | **90** | **2** | **0** | **-** | **-** | **90.0** |
| RABUT | **2** | **20** | **90** | | | **2** | **2** | **27.0** |

*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.):

**0**

**0.5**

**2**

**77. The abutments are "laid-up" granite blocks with concrete caps.**

**75 & 76. The footing is exposed along the right abutment in places, but there is no water along the right abutment at this time.**

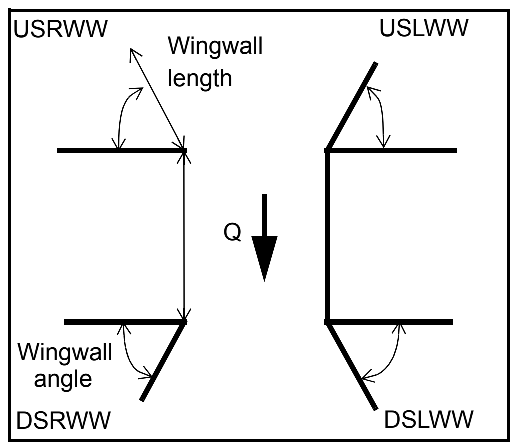
**The bridge appears to have been widened. There are remains of what appears to be the base of the old left abutment.**

**There is some localized scour beneath the bridge. One hole is by the upstream bridge face with dimensions of 2 ft long by 2 ft wide by 0.25 ft deep. The other hole is to the left of the bridge center point and has dimensions**

80. Wingwalls:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | **of 3** | | **ft** | | **long** | **27.0** | |
| USRWW: | **by 1** | | **ft** | | **wide** | **0.5** | |
| DSLWW: | **by** | | **0.25** | | **ft** | **27.5** | |
| DSRWW: | **deep.** | | | | | **27.5** | |

*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 | **N** | **-** | **-** | **-** | **-** | **N** | **-** | **1** |
| Condition | **-** | **-** | **-** | **N** | **-** | **-** | **-** | **4** |
| Extent | **-** | **N** | **-** | **-** | **-** | **-** | **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*

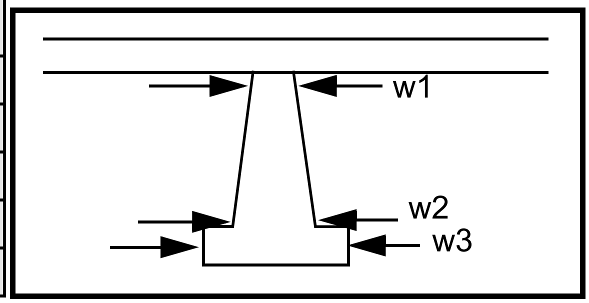
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

**1**
**4**
**2**
**1**
**2**
**2**
**2**
**2**
**-**
**-**
**-**

## Piers:

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

| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | - | - | - | - | - | - |
| Pier 2 | - | - | - | - | - | - |
| Pier 3 | - | - | - | - | - | - |
| Pier 4 | - | - | - | - | - | - |




| Level 1 Pier Descr. | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| 86. Location (BF) | **-** | **walls,** | **abut-** | **left** | *LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP* |
| 87. Type | **-** | **but** | **ment** | **abut** | ***1**- Solid pier, **2**- column, **3**- bent* |
| 88. Material | **0** | **stone** | **s.** | **ment** | ***1**- Wood; **2**- concrete; **3**- metal; **4**- stone* |
| 89. Shape | **-** | **is** | **(This** | **, but** | ***1**- Round; **2**- Square; **3**- Pointed* |
| 90. Inclined? | **-** | **stack** | **is** | **a** | *Y- yes; N- no* |
| 91. Attack ∠ (BF) | **2** | **ed at** | **not** | **laid-** | |
| 92. Pushed | **1** | **the** | **true** | **up** | *LB or RB* |
| 93. Length (feet) | - | - | - | - | |
| 94. # of piles | **4** | **end** | **at** | **wall** | |
| 95. Cross-members | **Ther** | **cor-** | **the** | **meet** | ***0**- none; **1**- laterals; **2**- diagonals; **3**- both* |
| 96. Scour Condition | **e are** | **ners** | **dow** | **s the** | ***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed* |
| 97. Scour depth | **no** | **of** | **nstre** | **left** | |
| 98. Exposure depth | **wing** | **the** | **am** | **abut** | |

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

**ment at a 90 degree angle.)**
**Remains of the old left abutment exist. The space between the old and current abutment is filled in with gravel, some boulders and silt. The old abutment base is about 2 ft high.**

## 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 -  Thalweg depth -  Bed Material -

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

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

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

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

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

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

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

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

Material: -

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

-
-
-
-

Is a cut-bank present? - (Y or if N type ctrl-n cb) Where? NO (LB or RB) Mid-bank distance: PIE

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

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

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

Is channel scour present? ____ (Y or if N type ctrl-n cs) Mid-scour distance: 1

Scour dimensions: Length 4 Width 14 Depth: 14 Positioned 1 %LB to 1 %RB

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

453
0
0
-

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

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

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

Confluence comments (eg. confluence name):

similar to the upstream channel in that cobbles are falling out of the base of the banks, but the banks downstream are not as high as upstream. There are some exposed roots.

## F. Geomorphic Channel Assessment

107. Stage of reach evolution Th

**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)*:

**e stream varies with riffles and pools.**

## 109. G. Plan View Sketch

N

| | | | |
|---|---|---|---|
| point bar (pb) | debris | flow (Q) | stone wall |
| cut-bank (cb) | rip rap or stone fill | cross-section | other wall |
| scour hole | | ambient channel | |

# APPENDIX F:

# SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: BRADTH00090023 Town: Bradford
Road Number: TH 9 County: Orange
Stream: Mill Pond Brook

Initials MAI Date: 09/09/97 Checked: RHF

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 | 1140 | 1830 | 1400 |
| Main Channel Area, ft2 | 191 | 299 | 271 |
| Left overbank area, ft2 | 2 | 124 | 81 |
| Right overbank area, ft2 | 0 | 89 | 13 |
| Top width main channel, ft | 44 | 51 | 51 |
| Top width L overbank, ft | 8 | 82 | 72 |
| Top width R overbank, ft | 0 | 160 | 94 |
| D50 of channel, ft | 0.17207 | 0.17207 | 0.17207 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 4.3 | 5.9 | 5.3 |
| y1, average depth, LOB, ft | 0.3 | 1.5 | 1.1 |
| y1, average depth, ROB, ft | ERR | 0.6 | 0.1 |
| Total conveyance, approach | 11031 | 29973 | 21734 |
| Conveyance, main channel | 10994 | 21055 | 17851 |
| Conveyance, LOB | 37 | 6933 | 3768 |
| Conveyance, ROB | 0 | 1985 | 115 |
| Percent discrepancy, conveyance | 0.0000 | 0.0000 | 0.0000 |
| Qm, discharge, MC, cfs | 1136.2 | 1285.5 | 1149.9 |
| Ql, discharge, LOB, cfs | 3.8 | 423.3 | 242.7 |
| Qr, discharge, ROB, cfs | 0.0 | 121.2 | 7.4 |
| Vm, mean velocity MC, ft/s | 5.9 | 4.3 | 4.2 |
| Vl, mean velocity, LOB, ft/s | 1.9 | 3.4 | 3.0 |
| Vr, mean velocity, ROB, ft/s | ERR | 1.4 | 0.6 |
| Vc-m, crit. velocity, MC, ft/s | 8.0 | 8.4 | 8.2 |
| Vc-l, crit. velocity, LOB, ft/s | ERR | ERR | ERR |
| Vc-r, crit. velocity, ROB, ft/s | ERR | ERR | ERR |

Results

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

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 | 1140 | 1830 | 1400 |
| (Q) discharge thru bridge, cfs | 1140 | 1498 | 1400 |
| Main channel conveyance | 6649 | 10871 | 9490 |
| Total conveyance | 6649 | 10871 | 9490 |
| Q2, bridge MC discharge,cfs | 1140 | 1498 | 1400 |
| Main channel area, ft2 | 102 | 164 | 167 |
| Main channel width (normal), ft | 26.0 | 26.9 | 27.0 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 26 | 26.9 | 27 |
| y_bridge (avg. depth at br.), ft | 3.91 | 6.10 | 6.18 |
| Dm, median (1.25*D50), ft | 0.215088 | 0.215088 | 0.215088 |
| y2, depth in contraction,ft | 4.91 | 6.02 | 5.66 |
| ys, scour depth (y2-ybridge), ft | **0.99** | -0.08 | -0.52 |

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 | 1140 | 1830 | 1400 |
| Q, thru bridge MC, cfs | 1140 | 1498 | 1400 |
| Vc, critical velocity, ft/s | 7.96 | 8.37 | 8.24 |
| Va, velocity MC approach, ft/s | 5.95 | 4.30 | 4.24 |
| Main channel width (normal), ft | 26.0 | 26.9 | 27.0 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 26.0 | 26.9 | 27.0 |
| qbr, unit discharge, ft2/s | 43.8 | 55.7 | 51.9 |
| Area of full opening, ft2 | 0.0 | 164.2 | 166.9 |
| Hb, depth of full opening, ft | 0.00 | 6.10 | 6.18 |
| Fr, Froude number, bridge MC | 0 | 0.65 | 0.59 |
| Cf, Fr correction factor (<=1.0) | 0.00 | 1.00 | 1.00 |
| **Area at downstream face, ft2 | N/A | 123 | 117 |
| **Hb, depth at downstream face, ft | N/A | 4.57 | 4.33 |
| **Fr, Froude number at DS face | ERR | 1.00 | 1.01 |
| **Cf, for downstream face (<=1.0) | N/A | 1.00 | 1.00 |
| Elevation of Low Steel, ft | 0 | 497.74 | 497.74 |

| | | | |
|---|---|---|---|
| Elevation of Bed, ft | 0.00 | 491.64 | 491.56 |
| Elevation of Approach, ft | 0 | 500.21 | 499.66 |
| Friction loss, approach, ft | 0 | 0.25 | 0.28 |
| Elevation of WS immediately US, ft | 0.00 | 499.96 | 499.38 |
| ya, depth immediately US, ft | 0.00 | 8.32 | 7.82 |
| Mean elevation of deck, ft | 0 | 500.42 | 500.42 |
| w, depth of overflow, ft (>=0) | 0.00 | 0.00 | 0.00 |
| Cc, vert contrac correction (<=1.0) | ERR | 0.92 | 0.94 |
| **Cc, for downstream face (<=1.0) | ERR | 0.79 | 0.79 |
| | | | |
| Ys, scour w/Chang equation, ft | N/A | **1.11** | **0.50** |
| Ys, scour w/Umbrell equation, ft | N/A | 0.03 | -0.40 |

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

| | | | |
|---|---|---|---|
| **Ys, scour w/Chang equation, ft | N/A | 3.85 | 3.64 |
| **Ys, scour w/Umbrell equation, ft | ERR | 1.56 | 1.44 |

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 | 4.91 | 6.02 | 5.66 |
| WSEL at downstream face, ft | -- | 496.08 | 495.85 |
| Depth at downstream face, ft | N/A | 4.57 | 4.33 |
| Ys, depth of scour (Laursen), ft | N/A | 1.45 | 1.33 |

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 | 1140 | 1498 | 1400 |
| Main channel area (DS), ft2 | 102 | 123 | 117 |
| Main channel width (normal), ft | 26.0 | 26.9 | 27.0 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 26.0 | 26.9 | 27.0 |
| D90, ft | 0.5747 | 0.5747 | 0.5747 |
| D95, ft | 0.9517 | 0.9517 | 0.9517 |
| Dc, critical grain size, ft | 0.6439 | 0.7143 | 0.7060 |
| Pc, Decimal percent coarser than Dc | 0.085 | 0.075 | 0.076 |
| | | | |
| Depth to armoring, ft | **20.82** | **26.43** | **25.75** |

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 | 1140 | 1830 | 1400 | 1140 | 1830 | 1400 |
| a', abut.length blocking flow, ft | 17.7 | 89.5 | 79.6 | 9.7 | 176.5 | 110.3 |
| Ae, area of blocked flow ft2 | 17.61 | 153.56 | 106.77 | 20.66 | 41.8 | 54.2 |
| Qe, discharge blocked abut.,cfs | 52.55 | 519.53 | 319.38 | 74.69 | -- | 110.25 |

(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)

| | | | | | | |
|---|---|---|---|---|---|---|
| Ve, (Qe/Ae), ft/s | 2.98 | 3.38 | 2.99 | 3.62 | 1.84 | 2.03 |
| ya, depth of f/p flow, ft | 0.99 | 1.72 | 1.34 | 2.13 | 0.24 | 0.49 |

--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)

| | | | | | | |
|---|---|---|---|---|---|---|
| K1 | 1 | 1 | 1 | 1 | 1 | 1 |

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

| | | | | | | |
|---|---|---|---|---|---|---|
| theta | 85 | 85 | 85 | 95 | 95 | 95 |
| K2 | 0.99 | 0.99 | 0.99 | 1.01 | 1.01 | 1.01 |
| Fr, froude number f/p flow | 0.527 | 0.455 | 0.455 | 0.437 | 0.365 | 0.511 |
| ys, scour depth, ft | **6.23** | **14.81** | **12.16** | **7.77** | **5.27** | **8.14** |

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) | 17.7 | 89.5 | 79.6 | 9.7 | 176.5 | 110.3 |
| y1 (depth f/p flow, ft) | 0.99 | 1.72 | 1.34 | 2.13 | 0.24 | 0.49 |
| a'/y1 | 17.79 | 52.16 | 59.34 | 4.55 | 745.27 | 224.47 |
| Skew correction (p. 49, fig. 16) | 0.98 | 0.98 | 0.98 | 1.01 | 1.01 | 1.01 |
| Froude no. f/p flow | 0.53 | 0.46 | 0.46 | 0.44 | 0.37 | 0.51 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | ERR | 9.46 | 7.40 | ERR | 1.25 | 2.90 |
| vertical w/ ww's | ERR | 7.76 | 6.06 | ERR | 1.02 | 2.37 |
| spill-through | ERR | 5.20 | 4.07 | ERR | 0.69 | 1.59 |

Abutment riprap Sizing

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

| Characteristic | Q100 | Q500 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 1 | 1 | 1.01 | 1 | 1 | 1.01 |
| y, depth of flow in bridge, ft | 3.91 | 4.57 | 4.33 | 3.91 | 4.57 | 4.33 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | ERR | ERR | ERR | ERR | ERR | ERR |
| Fr>0.8 (vertical abut.) | **1.64** | **1.91** | **1.82** | **1.64** | **1.91** | **1.82** |