# LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (PFRDTH00230033) on TOWN HIGHWAY 23, crossing OTTER CREEK, PITTSFORD, VERMONT

Open-File Report 98-557

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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# LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (PFRDTH00230033) on TOWN HIGHWAY 23, crossing OTTER CREEK, PITTSFORD, VERMONT

By ERICK M. BOEHMLER AND MICHAEL A. IVANOFF

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**Pembroke, New Hampshire**

**1998**

U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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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 33 (PFRDTH00230033) ON TOWN HIGHWAY 23, CROSSING OTTER CREEK, PITTSFORD, VERMONT

*By* **Erick M. Boehmler and Michael A. Ivanoff**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure PFRDTH00230033 on Town Highway 23 crossing Otter Creek, Pittsford, 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 Champlain section of the St. Lawrence Valley physiographic province in west-central Vermont. The 412-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture along the left bank of the bridge and row crops along the right bank while the immediate banks have dense woody vegetation.

In the study area, Otter Creek has an incised, sinuous channel with a slope of approximately 0.00006 ft/ft, an average channel top width of 95 ft and an average bank height of 12 ft. The channel bed material ranges from silt to sand with a median grain size ($D_{50}$) of 0.39 mm (0.001 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 22, 1995, indicated that the reach was laterally unstable with moderate to heavy fluvial erosion upstream and downstream of the bridge.

The Town Highway 23 crossing of Otter Creek is a 135-ft-long, one-lane covered bridge consisting of a maximum 107-foot steel-beam, timber thru-truss span (Vermont Agency of Transportation, written communication, March 14, 1995). The opening length of the structure parallel to the bridge face is 101.8 ft. The bridge is supported by vertical, “laid-up” stone abutments with concrete caps, a concrete pier, and concrete wingwalls. The channel is skewed approximately 25 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 5 ft deeper than the mean thalweg depth was observed along the right bank through the bridge during the Level I assessment. The depth of the hole increases to 8 ft immediately downstream of the bridge. The scour counter-measures at the site included type-1 stone fill (less than 12 inches diameter) along the right abutment, the upstream end of the left bank under the bridge, and the downstream left wingwall and type-2 stone fill (less than 36 inches diameter) at the upstream and downstream right wingwalls. 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 0.0 to 25.4 ft. The worst-case contraction scour occurred at the 500-year discharge. Bank-full flow conditions were modeled at the incipient roadway-overtopping discharge. The width of flow approaching the bridge at this discharge was narrower than the bridge and thus resulted in no computed contraction scour. Abutment scour ranged from 3.6 to 10.9 ft. The worst-case abutment scour occurred at the  incipient roadway-overtopping discharge. Pier scour ranged from 4.9 to 6.9 ft and the worst case occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results.” Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Proctor, VT. Quadrangle, 1:24,000, 1944

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*** PFRDTH00230033 ***Stream*** Otter Creek

***County*** Rutland ***Road*** TH 23 ***District*** 3

## Description of Bridge

***Bridge length*** 135 ***ft*** ***Bridge width*** 17.0 ***ft*** ***Max span length*** 107 ***ft***

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

***Abutment type*** "laid-up" stone ***Embankment type*** Sloping

***Stone fill on abutment?*** Yes ***Date of inspection*** 6/22/95

***Description of stone fill*** Type-1, along the right abutment, the upstream end of the left bank under the bridge, and along the downstream left wingwall. Type-2, at the upstream and downstream right wingwalls.

***Brief description of piers/abutments*** Abutments are "laid-up" stone with concrete caps and concrete wingwalls. There is one pier consisting of 2 concrete columns at the upstream and downstream face of the bridge.

Yes 25

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

There is a moderate channel bend in the upstream reach. A scour hole has developed along the right bank through the bridge.

***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*** | 6/22/95 | 0 | 0 |
| ***Level II*** | 6/22/95 | 0 | 0 |

***Potential for debris*** Moderate. Trees leaning over the channel upstream.

***Describe any features near or at the bridge that may affect flow (include observation date)*** None were observed on 6/22/95.

## Description of the Geomorphic Setting

***General topography*** The channel is located in a moderate relief valley with wide flood plains.

6/22/95

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

***Date of inspection*** Steep channel

***DS left:*** bank to a wide flood plain

***DS right:*** Steep channel bank to a wide flood plain

***US left:*** Steep channel bank to a wide flood plain

***US right:*** Steep channel bank to a wide flood plain

## Description of the Channel

***Average top width*** 95 *ft* ***Average depth*** 12 *ft*

***Predominant bed material*** Sand / Silt ***Bank material*** Silt / Sand

Sinuous with alluvial channel boundaries and narrow point bars.

6/22/95

***Vegetative co*** Trees and brush with pasture on the flood plain

***DS left:*** Trees and brush with row crops on the flood plain

***DS right:*** Trees and brush with pasture on the flood plain

***US left:*** Trees and brush with row crops on the flood plain

***US right:*** No

***Do banks appear stable?*** There is moderate to heavy fluvial erosion along the upstream and ***If not, describe location and type of instability and date of observation.*** downstream banks.

There was a large pile of debris observed downstream of the bridge on 6/22/95.

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

## Hydrology

***Drainage area*** 412.5 ***mi***$^2$

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

| ***Physiographic province/section*** | ***Percent of drainage area*** |
|---|---|
| St. Lawrence Valley/Champlain | 100 |

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

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

***USGS gage description*** Otter Creek at Center Rutland

***USGS gage number*** 04282000

***Gage drainage area*** 307 ***mi***$^2$

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

### Calculated Discharges

***Q100*** 16,400 ***ft***$^3$***/s*** ***Q500*** 20,200 ***ft***$^3$***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(412.5/307)exp 0.67] with flood frequency estimates computed by use of annual peak discharge data obtained from the gage mentioned above. A log-Pearson Type III analysis of the peak discharges recorded at the Center Rutland gage was conducted for the continuous period from 1929 - 1996 in accordance with the guidelines documented by the Interagency Advisory Committee on Water Data (1982). The adjusted discharges 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 141.5 ft from the USGS arbitrary survey datum to obtain VTAOT plans' datum.

***Description of reference marks used to determine USGS datum.*** RM1 is a chiseled X on top of the downstream end of the right wingwall (elev. 506.23 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream left side of the pier (elev. 500.20 ft, arbitrary survey datum). RM3 is a chiseled square on top of the upstream end of the left abutment (elev. 504.35 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 | -112 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| BRTEM | 0 | 4 | Combined bridge and road grade sections (Used as a template) |
| DSBRG | 0 | 4 | Composite section at downstream bridge face (Templated from BRTEM) |
| RDWAY | 11 | 1 | Road Grade section |
| USBRG | 21 | 4 | Composite section at upstream bridge face (Templated from BRTEM) |
| APPRO | 123 | 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 0.035 to 0.040, and overbank "n" values ranged from 0.040 to 0.050.

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 0.00006 ft/ft, which was estimated from the 100-year water surface profile downstream of this site provided in the Flood Insurance Study for the Town of Pittsford (FEMA, 1988).

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- and 500-year discharges, submergence of the roadway (weir) was appreciable. The WSPRO bridge routines failed to provide a solution which balanced the total discharge and energy at the APPRO section with the sum of the discharges and energy over the roadway and through the bridge opening. Therefore, the bridge was ignored, and the channel at the bridge was combined with the roadway cross-section to represent a full valley cross section at the bridge location.

## Bridge Hydraulics Summary

***Average bridge embankment elevation*** 506.3 ***ft***
***Average low steel elevation*** 502.2 ***ft***

***100-year discharge*** 16,400 ***ft³/s***
***Water-surface elevation in bridge opening*** 502.3 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 11,700 ***ft³/s***
***Area of flow in bridge opening*** 1,470 ***ft²***
***Average velocity in bridge opening*** 3.2 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 4.7 ***ft/s***

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

***500-year discharge*** 20,200 ***ft³/s***
***Water-surface elevation in bridge opening*** 502.3 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 15,200 ***ft³/s***
***Area of flow in bridge opening*** 1,470 ***ft²***
***Average velocity in bridge opening*** 3.3 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 5.0 ***ft/s***

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

***Incipient overtopping discharge*** 1,890 ***ft³/s***
***Water-surface elevation in bridge opening*** 497.7 ***ft***
***Area of flow in bridge opening*** 1,060 ***ft²***
***Average velocity in bridge opening*** 1.8 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 2.3 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 497.8
***Water-surface elevation at Approach section without bridge*** 497.8
***Amount of backwater caused by bridge*** 0.0 ***ft***

## Scour Analysis Summary

### Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equations (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100- and 500-year discharges resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison, contraction scour for the 100- and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). In addition, for all modeled discharges, the mean velocity and incipient-motion velocity computed in the main channel were similar. Therefore, contraction scour also was computed for all modeled discharges by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p.30, equation 17). Results with respect to these alternative computations are provided in appendix F.

Abutment scour for the 100- and 500-year discharges was computed by use of the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. For the incipient roadway- overtopping discharge, abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 1995, p. 48, equation 28). The variables used by the HIRE and Froehlich abutment-scour equations 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.

Pier scour was computed by use of an equation developed at Colorado State University (Richardson and others, 1995, p. 36, equation 21) for all discharges modeled. Variables for the pier scour equation include pier length, pier width, average depth and maximum velocity (for the Froude number) immediately upstream of the bridge, and four correction factors for pier shape, flow attack angle, streambed-form, and streambed armoring.

## 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 | 25.0 | 25.4 | 0.0 |
| Depth to armoring | N/A | N/A | N/A |
| Left overbank | -- | -- | -- |
| Right overbank | -- | -- | -- |

| Local scour: | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
| --- | --- | --- | --- |
| Abutment scour | | | |
| Left abutment | 3.8 | 3.6 | 9.9 |
| Right abutment | 8.7 | 9.2 | 10.9 |
| Pier scour | | | |
| Pier 1 | 6.8 | 6.9 | 4.9 |
| Pier 2 | -- | -- | -- |
| Pier 3 | -- | -- | -- |

## Riprap Sizing

| | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
| --- | --- | --- | --- |
| | ($D_{50}$ in feet) | | |
| Abutments: | | | |
| Left abutment | 0.3 | 0.4 | 0.1 |
| Right abutment | 0.3 | 0.4 | 0.1 |
| Piers: | | | |
| Pier 1 | 0.3 | 0.4 | 0.1 |
| Pier 2 | -- | -- | -- |
| | -- | -- | -- |

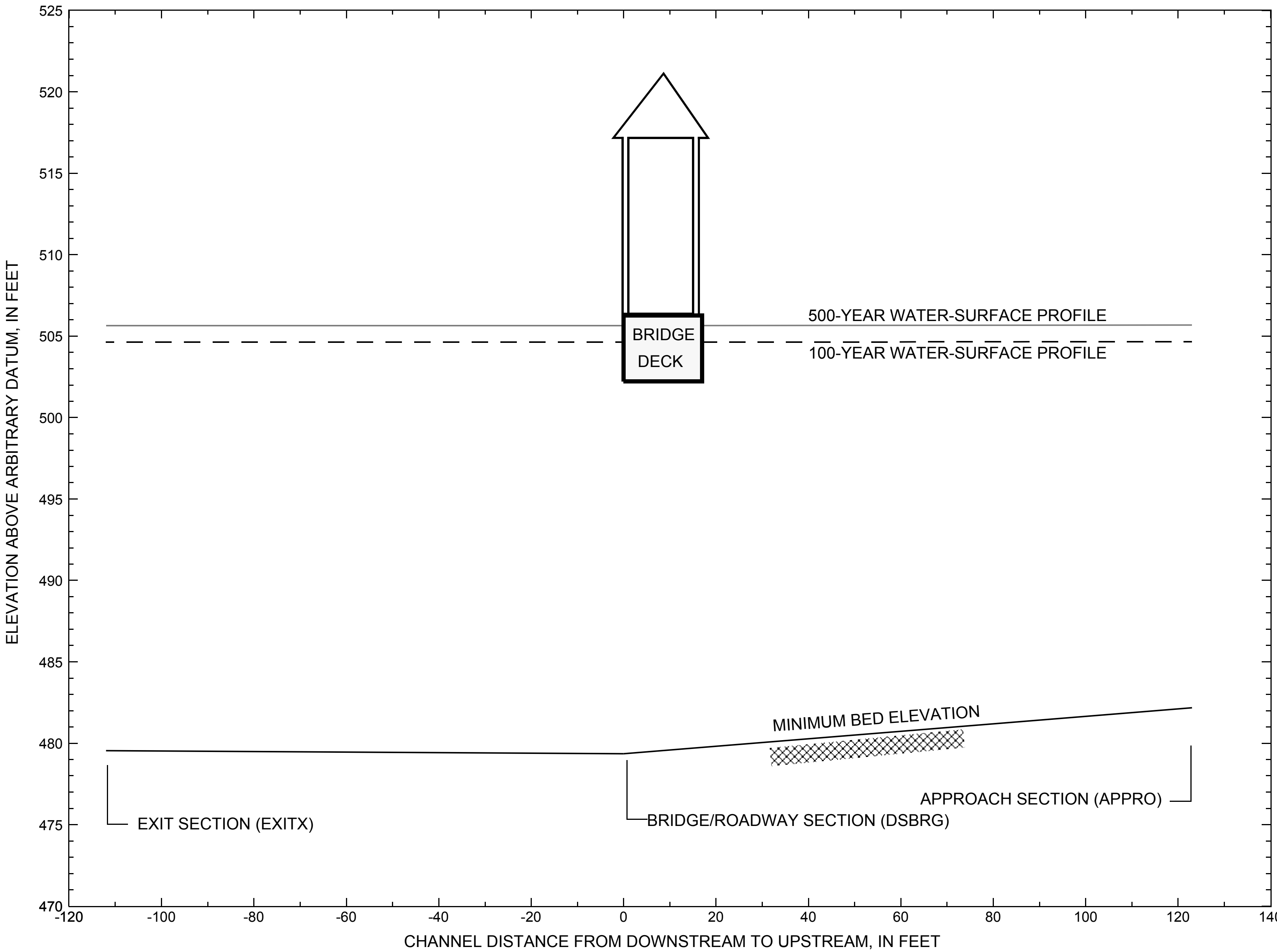


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure PFRDTH00230033 on Town Highway 23, crossing Otter Creek, Pittsford, Vermont.

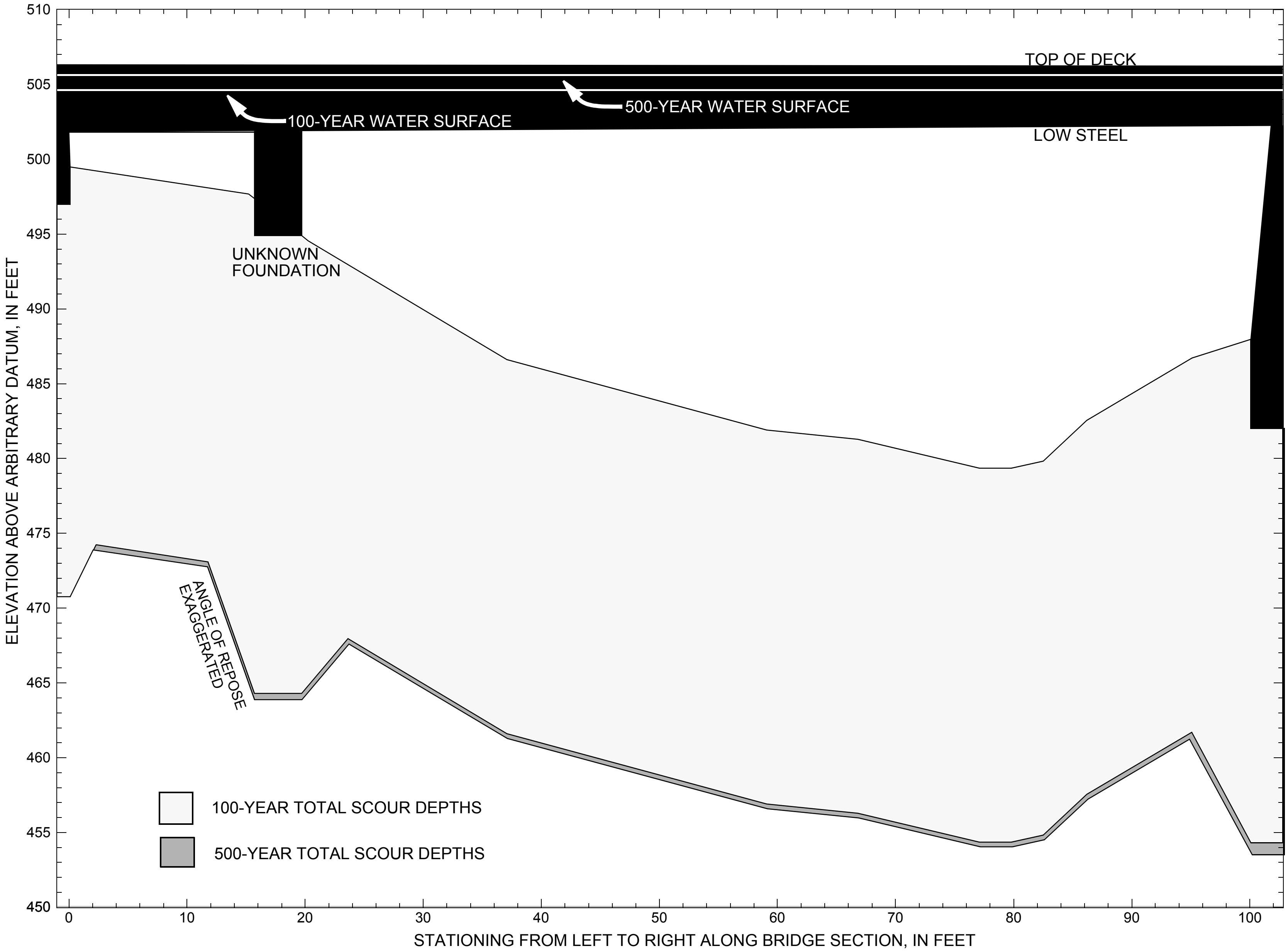


Figure 8. Scour elevations for the 100- and 500-year discharges at structure PFRDTH00230033 on Town Highway 23, crossing Otter Creek, Pittsford, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure PFRDTH00230033 on Town Highway 23, crossing Otter Creek, Pittsford, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

| Description | Station[1] | VTAOT minimum bridge seat 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 16,400 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 360.3 | 501.8 | 497 | 499.5 | 25.0 | 3.8 | -- | 28.8 | 470.7 | -26 |
| Pier | 17.7 | -- | -- | -- | 496.1 | 25.0 | -- | 6.8 | 31.8 | 464.3 | -- |
| Right abutment | 101.8 | 360.8 | 502.3 | 482 | 488.0 | 25.0 | 8.7 | -- | 33.7 | 454.3 | -28 |

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 PFRDTH00230033 on Town Highway 23, crossing Otter Creek, Pittsford, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

| Description | Station[1] | VTAOT minimum bridge seat 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 20,200 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 360.3 | 501.8 | 497 | 499.5 | 25.4 | 3.6 | -- | 29.0 | 470.5 | -27 |
| Pier | 17.7 | -- | -- | -- | 496.1 | 25.4 | -- | 6.9 | 32.3 | 463.8 | -- |
| Right abutment | 101.8 | 360.8 | 502.3 | 482 | 488.0 | 25.4 | 9.2 | -- | 34.6 | 453.4 | -29 |

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 pfrd033.wsp
T2        Hydraulic analysis for structure PFRDTH00230033   Date: 08-DEC-97
T3        Bridge 33 on Town Highway 23 over Otter Creek Pittsford, VT  by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          16400.0  20200.0
SK         0.00006  0.00006
WS          495.00   498.00
*
XS   EXITX   -112
GR        -1202.9, 508.46   -904.6, 499.59   -112.9, 498.02     -9.7, 499.26
GR            0.0, 497.57      1.8, 492.01      2.5, 488.75      4.9, 486.38
GR           11.6, 482.75     15.5, 481.70     26.0, 479.54     33.5, 479.74
GR           44.6, 479.71     49.2, 479.67     55.2, 479.91     60.6, 481.24
GR           64.5, 483.03     72.2, 486.55     83.1, 492.37     91.6, 498.90
GR          532.7, 497.69    761.0, 495.48    943.3, 495.59   1098.2, 498.35
GR         1396.6, 507.22
*
N           0.045        0.040        0.040
SA                  -9.7          91.6
*
XT   BRTEM     0
GR        -1202.9, 508.46   -904.6, 499.59   -792.7, 500.06   -463.5, 500.51
GR         -221.6, 501.80    -56.2, 504.98      0.0, 506.32      0.0, 499.49
GR           15.2, 497.68     15.7, 500.13     19.7, 500.19     20.2, 494.58
GR           37.1, 486.60     59.1, 481.90     66.8, 481.28     77.1, 479.35
GR           79.8, 479.35     82.5, 479.82     86.2, 482.55     95.1, 486.71
GR          100.1, 487.96    101.8, 502.26    101.8, 506.23
GR          162.5, 504.39    210.8, 503.25    310.1, 500.51    425.2, 499.58
GR          590.9, 499.09    668.5, 498.13    801.7, 497.78    968.8, 497.85
GR         1098.2, 498.35   1223.4, 500.25   1250.9, 500.07   1324.3, 508.73
*         -221.6, 501.80    -56.2, 504.98    161.0, 505.02
XS   DSBRG     0 * * * 0.0
GT
N           0.035      0.035      0.035
SA                 0.0     101.8
*
XS   USBRG    21 * * * 0.0
GT
N           0.045      0.035      0.035
SA                 0.0     101.8
*
XS   APPRO    123
GR        -1202.9, 508.46   -904.6, 499.59   -208.5, 499.50   -117.7, 499.25
GR          -63.0, 496.32    -38.0, 498.09      0.0, 499.66     10.9, 489.32
GR           19.2, 486.69     25.3, 485.18     34.4, 484.46     40.6, 484.25
GR           43.7, 484.23     64.6, 483.43     71.2, 482.79     81.2, 482.17
GR           87.9, 484.13     94.5, 486.84     96.7, 497.92    114.2, 499.24
GR          132.7, 498.45    290.9, 496.12    345.1, 495.28    617.5, 496.45
GR          712.3, 493.98    775.1, 492.54    858.3, 494.55    986.0, 494.30
GR         1250.9, 500.07   1324.3, 508.73
*
N            0.050        0.040         0.040
SA                  0.0          114.2
*
HP 1 USBRG 504.62 1 504.62
HP 2 USBRG 504.62 * * 16400
HP 1 APPRO 504.66 1 504.66
HP 2 APPRO 504.66 * * 16400
*
HP 1 USBRG 505.64 1 505.64
HP 2 USBRG 505.64 * * 20200
HP 1 APPRO 505.68 1 505.68
HP 2 APPRO 505.68 * * 20200
EX
ER
```

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T1        U.S. Geological Survey WSPRO Input File pfrd033.io.wsp
T2        Hydraulic analysis for structure PFRDTH00230033   Date: 08-DEC-97
T3        Bridge 33 on Town Highway 23 over Otter Creek Pittsford, VT  EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1890.0    2000.0
SK         0.00006   0.00006
WS          499.00    499.00
*
*        Overbank points for EXITX and APPRO sections were removed for this model to prevent
*        WSPRO from modeling flow on the overbanks divided from flow in the main channel.
*
XS   EXITX   -112
GR          -9.8, 500.00     -9.7, 499.26      0.0, 497.57      1.8, 492.01
GR           2.5, 488.75      4.9, 486.38     11.6, 482.75     15.5, 481.70
GR          26.0, 479.54     33.5, 479.74     44.6, 479.71     49.2, 479.67
GR          55.2, 479.91     60.6, 481.24     64.5, 483.03     72.2, 486.55
GR          83.1, 492.37     91.6, 498.90     92.0, 500.00
N          0.045       0.040       0.040
SA                 -9.7         91.6
*
XS   FULLV      0  * * *  0.0000
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    502.22      0.0
GR           0.0, 501.82      0.0, 499.49     15.2, 497.68
GR          20.2, 494.58     37.1, 486.60     59.1, 481.90
GR          66.8, 481.28     77.1, 479.35     79.8, 479.35     82.5, 479.82
GR          86.2, 482.55     95.1, 486.71    100.1, 487.96    101.8, 502.26
GR           0.0, 501.82
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      26.1 * *     64.6      2.5
PW         496.13,2.2  497.68,4.5  500.19,4.5  500.19,2  502.00,2
N           0.035
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     11      17.0     1
GR        -1202.9, 508.46   -904.6, 499.59   -792.7, 500.06   -463.5, 500.51
GR         -221.6, 501.80    -56.2, 504.98      0.0, 506.32    108.2, 506.23
GR          161.0, 505.02    162.5, 504.39    210.8, 503.25    310.1, 500.51
GR          425.2, 499.58    590.9, 499.09    668.5, 498.13    801.7, 497.78
GR          968.8, 497.85   1098.2, 498.35   1223.4, 500.25   1250.9, 500.07
GR         1324.3, 508.73
*
AS   APPRO    123
GR          -1.0, 508.46      0.0, 499.66     10.9, 489.32     19.2, 486.69
GR          25.3, 485.18     34.4, 484.46     40.6, 484.25     43.7, 484.23
GR          64.6, 483.43     71.2, 482.79     81.2, 482.17     87.9, 484.13
GR          94.5, 486.84     96.7, 497.92    114.2, 499.24    115.0, 508.73
N          0.050       0.040       0.040
SA                  0.0         114.2
*
HP 1 BRIDG 502.26 1 502.26
HP 2 BRIDG 502.26 * * 4724
HP 2 RDWAY 504.62 * * 11676
*
HP 1 BRIDG 502.26 1 502.26
HP 2 BRIDG 502.26 * * 4961
HP 2 RDWAY 505.64 * * 15239
*
HP 1 BRIDG 497.74 1 497.74
HP 2 BRIDG 497.74 * * 1890
HP 1 APPRO 497.76 1 497.76
HP 2 APPRO 497.76 * * 1890
EX
ER
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APPENDIX B:

# WSPRO OUTPUT FILE

# WSPRO OUTPUT FILE

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File pfrd033.wsp
        Hydraulic analysis for structure PFRDTH00230033   Date: 08-DEC-97
        Bridge 33 on Town Highway 23 over Otter Creek Pittsford, VT  by MAI
           *** RUN DATE & TIME: 07-10-98  13:24

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = USBRG;  SRD =      21.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     3434.  258998.   999.   999.                      36132.
             2     1732.  411483.   102.   131.                      40539.
             3     5925.  758105.  1135.  1137.                      76839.
   504.62         11091. 1428585.  2235.  2268.  1.57 -1074.  1289. 112044.

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     1487.  223638.     0.   224.                          0.
   502.26          1487.  223638.     0.   224.  1.00     0.   102.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.26     0.0   101.8  1487.5  223638.    4724.   3.18

X STA.          0.0        37.7        41.9        45.8        49.2        52.5
  A(I)             280.3        66.7        65.1        60.4        61.3
  V(I)              0.84        3.54        3.63        3.91        3.85

X STA.         52.5        55.6        58.6        61.4        64.2        66.6
  A(I)              58.8        58.6        57.3        57.6        49.8
  V(I)              4.01        4.03        4.13        4.10        4.74

X STA.         66.6        69.3        72.1        74.8        77.4        80.0
  A(I)              55.3        60.3        60.6        59.0        58.2
  V(I)              4.27        3.92        3.90        4.00        4.06

X STA.         80.0        82.5        85.4        88.7        92.3       101.8
  A(I)              57.3        62.5        63.1        63.7       131.6
  V(I)              4.12        3.78        3.74        3.71        1.79

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

         WSEL     LEW     REW    AREA        K        Q    VEL
       504.62 -1073.8  1289.5  9358.6  925851.   11676.   1.25

X STA.     -1073.8      -856.9      -741.3      -618.0      -483.1      -322.2
  A(I)             660.6       534.1       543.0       570.5       608.4
  V(I)              0.88        1.09        1.08        1.02        0.96

X STA.      -322.2       363.5       454.2       533.4       606.3       661.2
  A(I)            1059.1       443.0       415.4       399.5       332.6
  V(I)              0.55        1.32        1.41        1.46        1.76

X STA.       661.2       713.5       769.3       822.1       875.7       929.1
  A(I)             342.2       372.5       359.7       365.8       362.9
  V(I)              1.71        1.57        1.62        1.60        1.61

X STA.       929.1       981.7      1035.8      1093.2      1159.4      1289.5
  A(I)             356.0       358.2       367.3       386.5       521.2
  V(I)              1.64        1.63        1.59        1.51        1.12

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = APPRO;  SRD =     123.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     5255.  450950.  1075.  1075.                      65926.
             2     1937.  439028.   114.   129.                      45251.
             3    10068. 1569499.  1176.  1176.                     167196.
   504.66         17260. 2459478.  2365.  2380.  1.28 -1075.  1290. 233681.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = APPRO;  SRD =     123.

         WSEL     LEW     REW    AREA        K        Q    VEL
       504.66 -1075.1  1289.8 17259.7 2459478.   16400.   0.95

X STA.     -1075.1      -659.4      -385.5      -114.5        19.9        43.1
  A(I)            1679.3      1402.2      1409.0      1027.0       459.0
  V(I)              0.49        0.58        0.58        0.80        1.79

X STA.        43.1        65.6        89.3       224.1       321.9       403.0
  A(I)             468.7       515.6       967.5       809.9       748.9
  V(I)              1.75        1.59        0.85        1.01        1.09

X STA.       403.0       488.9       580.5       670.3       738.4       795.1
  A(I)             769.2       784.0       776.5       712.5       666.6
  V(I)              1.07        1.05        1.06        1.15        1.23

X STA.       795.1       857.2       926.7       996.3      1075.0      1289.8
  A(I)             676.1       707.9       715.7       730.8      1233.5
  V(I)              1.21        1.16        1.15        1.12        0.66
```

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File pfrd033.wsp
        Hydraulic analysis for structure PFRDTH00230033   Date: 08-DEC-97
        Bridge 33 on Town Highway 23 over Otter Creek Pittsford, VT  by MAI
           *** RUN DATE & TIME: 07-10-98  13:24

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = USBRG;  SRD =      21.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     4495.  385214.  1080.  1080.                      52052.
             2     1836.  451083.   102.   132.                      44239.
             3     7104. 1000513.  1177.  1181.                      99046.
   505.64         13435. 1836810.  2358.  2393.  1.45 -1108.  1298. 150931.

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     1487.  223638.     0.   224.                          0.
   502.26          1487.  223638.     0.   224.  1.00     0.   102.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.26     0.0   101.8  1487.5  223638.    4961.   3.34

X STA.         0.0       37.7       41.9       45.8       49.2       52.5
  A(I)            280.3       66.7       65.1       60.4       61.3
  V(I)             0.88       3.72       3.81       4.11       4.04

X STA.        52.5       55.6       58.6       61.4       64.2       66.6
  A(I)             58.8       58.6       57.3       57.6       49.8
  V(I)             4.22       4.23       4.33       4.31       4.98

X STA.        66.6       69.3       72.1       74.8       77.4       80.0
  A(I)             55.3       60.3       60.6       59.0       58.2
  V(I)             4.49       4.11       4.09       4.21       4.26

X STA.        80.0       82.5       85.4       88.7       92.3      101.8
  A(I)             57.3       62.5       63.1       63.7      131.6
  V(I)             4.33       3.97       3.93       3.89       1.88

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

         WSEL     LEW     REW    AREA        K        Q    VEL
       505.64 -1108.1  1298.1 11583.4 1265326.   15239.   1.32

X STA.     -1108.1     -864.5     -754.1     -635.7     -512.7     -370.6
  A(I)            854.5      626.2      644.9      649.5      707.4
  V(I)             0.89       1.22       1.18       1.17       1.08

X STA.      -370.6     -153.1      396.1      481.5      559.3      623.7
  A(I)            849.4     1105.7      518.5      493.3      427.4
  V(I)             0.90       0.69       1.47       1.54       1.78

X STA.       623.7      681.9      743.7      802.4      859.4      916.7
  A(I)            424.4      472.0      456.3      448.0      447.6
  V(I)             1.80       1.61       1.67       1.70       1.70

X STA.       916.7      974.2     1031.5     1093.9     1161.1     1298.1
  A(I)            448.4      439.2      463.8      459.7      647.3
  V(I)             1.70       1.74       1.64       1.66       1.18

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = APPRO;  SRD =     123.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     6369.  608428.  1109.  1110.                      86595.
             2     2053.  483918.   114.   129.                      49394.
             3    11272. 1885193.  1184.  1185.                     197329.
   505.68         19694. 2977539.  2408.  2423.  1.25 -1109.  1298. 285701.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = APPRO;  SRD =     123.

         WSEL     LEW     REW    AREA        K        Q    VEL
       505.68 -1109.4  1298.4 19693.7 2977539.   20200.   1.03

X STA.     -1109.4     -698.9     -451.7     -207.8      -20.4       35.2
  A(I)           1879.2     1515.6     1503.4     1339.4      726.8
  V(I)             0.54       0.67       0.67       0.75       1.39

X STA.        35.2       60.3       86.2      208.0      308.6      392.0
  A(I)            542.7      590.5     1037.2      913.6      851.9
  V(I)             1.86       1.71       0.97       1.11       1.19

X STA.       392.0      477.7      568.9      661.6      733.7      793.3
  A(I)            858.4      879.1      886.0      815.2      759.1
  V(I)             1.18       1.15       1.14       1.24       1.33

X STA.       793.3      859.0      930.5     1002.0     1086.0     1298.4
  A(I)            782.0      801.1      807.7      850.3     1354.7
  V(I)             1.29       1.26       1.25       1.19       0.75
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File pfrd033.wsp
        Hydraulic analysis for structure PFRDTH00230033  Date: 08-DEC-97
        Bridge 33 on Town Highway 23 over Otter Creek Pittsford, VT  by MAI
           *** RUN DATE & TIME: 07-10-98  13:24

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

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1    1064.  218125.   87.   101.                       21162.
   497.74         1064.  218125.   87.   101.  1.00    15.   101.  21162.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.74    14.7   101.3  1063.8  218125.    1890.   1.78

X STA.        14.7       39.4       43.5       47.2       50.5       53.6
  A(I)            155.5       49.5       47.4       45.5       44.4
  V(I)             0.61       1.91       1.99       2.08       2.13

X STA.        53.6       56.6       59.3       61.9       64.5       67.0
  A(I)             44.0       42.1       42.7       41.9       41.1
  V(I)             2.15       2.24       2.22       2.26       2.30

X STA.        67.0       69.6       72.1       74.5       76.7       79.0
  A(I)             42.2       43.4       42.0       41.1       41.1
  V(I)             2.24       2.18       2.25       2.30       2.30

X STA.        79.0       81.2       83.6       86.5       89.6      101.3
  A(I)             40.5       42.5       46.3       45.5      125.0
  V(I)             2.34       2.22       2.04       2.08       0.76

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     123.

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             2    1165.  211147.   95.   109.                       23185.
   497.76         1165.  211147.   95.   109.  1.00     2.    97.  23185.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     123.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.76     2.0    96.7  1164.8  211147.    1890.   1.62

X STA.         2.0       20.7       25.4       29.4       33.4       37.2
  A(I)            135.8       55.6       51.1       52.1       50.9
  V(I)             0.70       1.70       1.85       1.81       1.86

X STA.        37.2       40.9       44.7       48.4       52.0       55.6
  A(I)             50.3       51.1       49.8       49.8       50.3
  V(I)             1.88       1.85       1.90       1.90       1.88

X STA.        55.6       59.1       62.7       66.2       69.5       72.8
  A(I)             49.9       50.4       49.8       49.5       48.2
  V(I)             1.89       1.87       1.90       1.91       1.96

X STA.        72.8       75.9       79.1       82.0       85.4       96.7
  A(I)             48.2       47.9       46.5       50.2      127.4
  V(I)             1.96       1.97       2.03       1.88       0.74
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# WSPRO OUTPUT FILE (continued)

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WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188              MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File pfrd033.wsp
        Hydraulic analysis for structure PFRDTH00230033   Date: 08-DEC-97
        Bridge 33 on Town Highway 23 over Otter Creek Pittsford, VT  by MAI
           *** RUN DATE & TIME: 07-10-98  13:24

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

EXITX:XS   ****** -1074.   15712.  0.02 *****  504.64  493.50  16400.  504.62
     -112. ******  1309. 2116345.  1.38 ***** *******    0.08    1.04

DSBRG:XS     112. -1074.   11081.  0.05  0.01  504.66 *******  16400.  504.62
        0.   112.  1289. 1500688.  1.41  0.01    0.00    0.14    1.48

USBRG:XS      21. -1074.   11082.  0.05  0.00  504.67 *******  16400.  504.62
       21.    21.  1289. 1426951.  1.57  0.00    0.00    0.15    1.48

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.72

APPRO:XS     102. -1075.   17256.  0.02  0.01  504.68 *******  16400.  504.66
      123.   102.  1290. 2458767.  1.28  0.00    0.00    0.07    0.95

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD     LEW     REW       Q        K      AREA      VEL    WSEL
   EXITX:XS    -112. -1074.  1309.  16400. 2116345.   15712.     1.04  504.62
   DSBRG:XS       0. -1074.  1289.  16400. 1500688.   11081.     1.48  504.62
   USBRG:XS      21. -1074.  1289.  16400. 1426951.   11082.     1.48  504.62
   APPRO:XS     123. -1075.  1290.  16400. 2458767.   17256.     0.95  504.66

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS      FR#    YMIN     YMAX    HF     HO   VHD      EGL    WSEL
   EXITX:XS    493.50     0.08  479.54  508.46************  0.02  504.64  504.62
   DSBRG:XS  ********     0.14  479.35  508.73  0.01  0.01  0.05  504.66  504.62
   USBRG:XS  ********     0.15  479.35  508.73  0.00  0.00  0.05  504.67  504.62
   APPRO:XS  ********     0.07  482.17  508.73  0.01  0.00  0.02  504.68  504.66
```
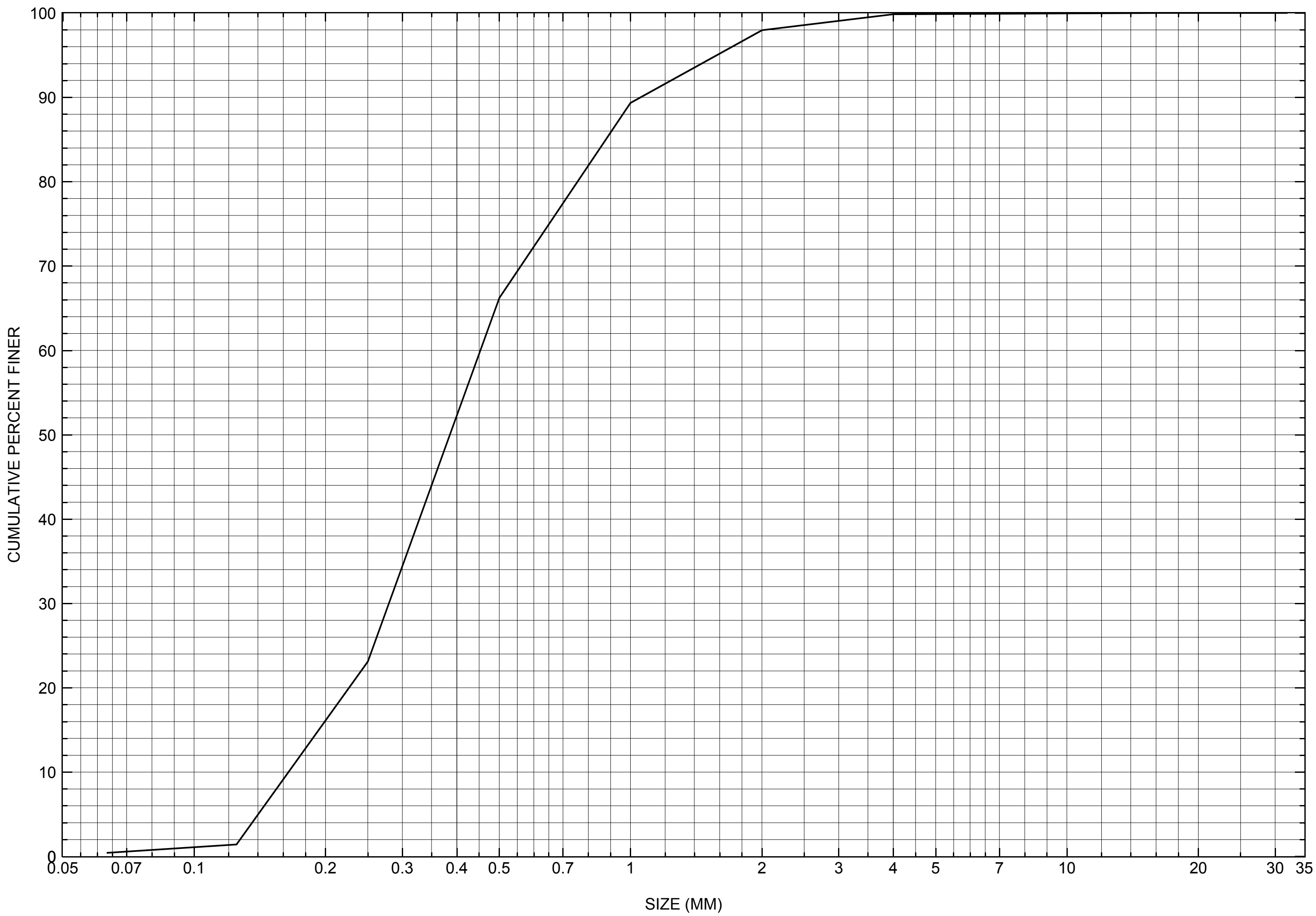

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188              MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File pfrd033.wsp
        Hydraulic analysis for structure PFRDTH00230033   Date: 08-DEC-97
        Bridge 33 on Town Highway 23 over Otter Creek Pittsford, VT  by MAI
           *** RUN DATE & TIME: 07-10-98  13:24

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

EXITX:XS   ****** -1108.   18183.  0.02 *****  505.67  499.17  20200.  505.64
     -112. ******  1343. 2607387.  1.30 ***** *******    0.08    1.11

DSBRG:XS     112. -1108.   13433.  0.05  0.01  505.68 *******  20200.  505.64
        0.   112.  1298. 1946501.  1.30  0.01    0.00    0.13    1.50

USBRG:XS      21. -1108.   13433.  0.05  0.00  505.69 *******  20200.  505.64
       21.    21.  1298. 1836418.  1.45  0.00    0.00    0.13    1.50

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.62

APPRO:XS     102. -1109.   19687.  0.02  0.01  505.70 *******  20200.  505.68
      123.   102.  1298. 2976019.  1.25  0.00    0.00    0.07    1.03

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD     LEW     REW       Q        K      AREA      VEL    WSEL
   EXITX:XS    -112. -1108.  1343.  20200. 2607387.   18183.     1.11  505.64
   DSBRG:XS       0. -1108.  1298.  20200. 1946501.   13433.     1.50  505.64
   USBRG:XS      21. -1108.  1298.  20200. 1836418.   13433.     1.50  505.64
   APPRO:XS     123. -1109.  1298.  20200. 2976019.   19687.     1.03  505.68

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS      FR#    YMIN     YMAX    HF     HO   VHD      EGL    WSEL
   EXITX:XS    499.17     0.08  479.54  508.46************  0.02  505.67  505.64
   DSBRG:XS  ********     0.13  479.35  508.73  0.01  0.01  0.05  505.68  505.64
   USBRG:XS  ********     0.13  479.35  508.73  0.00  0.00  0.05  505.69  505.64
   APPRO:XS  ********     0.07  482.17  508.73  0.01  0.00  0.02  505.70  505.68
```

# WSPRO OUTPUT FILE (continued)

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File pfrd033.io.wsp
        Hydraulic analysis for structure PFRDTH00230033   Date: 08-DEC-97
        Bridge 33 on Town Highway 23 over Otter Creek Pittsford, VT  EMB
           *** RUN DATE & TIME: 07-13-98  07:52

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

EXITX:XS   ******    -1.    1253.  0.04 *****  497.78  483.79   1890.  497.74
     -112. ******    90.  244169.  1.00 ***** *******    0.07    1.51

FULLV:FV     112.    -1.    1253.  0.04  0.01  497.79 *******   1890.  497.75
        0.   112.    90.  244301.  1.00  0.00    0.00    0.07    1.51
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     123.     2.    1165.  0.04  0.01  497.80 *******   1890.  497.76
      123.   123.    97.  211097.  1.00  0.00    0.00    0.08    1.62
          <<<<<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     112.    15.    1064.  0.05  0.01  497.79  485.65   1890.  497.74
        0.   112.   101.  218066.  1.09  0.00   -0.02    0.09    1.78

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
      1.   0.   1.  0.956  0.005  502.22 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<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      97.     2.    1165.  0.04  0.01  497.80  486.71   1890.  497.76
      123.   106.    97.  211125.  1.00  0.00    0.00    0.08    1.62

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.084  0.000  215000.     3.    90.  497.75

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -112.    -1.     90.   1890.  244169.    1253.    1.51  497.74
   FULLV:FV       0.    -1.     90.   1890.  244301.    1253.    1.51  497.75
   BRIDG:BR       0.    15.    101.   1890.  218066.    1064.    1.78  497.74
   RDWAY:RG      11.**************       0.******************    1.00********
   APPRO:AS     123.     2.     97.   1890.  211125.    1165.    1.62  497.76

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    90.  215000.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    483.79    0.07  479.54  500.00************  0.04  497.78  497.74
   FULLV:FV  ********    0.07  479.54  500.00  0.01  0.00  0.04  497.79  497.75
   BRIDG:BR    485.65    0.09  479.35  502.26  0.01  0.00  0.05  497.79  497.74
   RDWAY:RG  ****************  497.78  508.73**********************************
   APPRO:AS    486.71    0.08  482.17  508.73  0.01  0.00  0.04  497.80  497.76
```

# APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a sieve analysis in the channel approach of structure PFRDTH00230033, in Pittsford, Vermont.

# APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number PFRDTH00230033

## General Location Descriptive

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

Date (MM/DD/YY) 03 / 14 / 95

Highway District Number (I - 2; nn) 03

County (FIPS county code; I - 3; nnn) 021

Town (FIPS place code; I - 4; nnnnn) 55600

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

Waterway (I - 6) Otter Creek

Road Name (I - 7): -

Route Number TH023

Vicinity (I - 9) 0.4 miles to jct. with TH 1

Topographic Map Proctor

Hydrologic Unit Code: 02010002

Latitude (I - 16; nnnn.n) 43426

Longitude (i - 17; nnnnn.n) 73026

## Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10111600331116

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0107

Year built (I - 27; YYYY) 1840

Structure length (I - 49; nnnnnn) 000135

Average daily traffic, ADT (I - 29; nnnnnn) 001000

Deck Width (I - 52; nn.n) 170

Year of ADT (I - 30; YY) 92

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) 302

Year Reconstructed (I - 106) 1985

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

Clear span (nnn.n ft) 098.7

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 018.0

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

Waterway of full opening (nnn.n $ft^2$) 1421.

Comments:

**The structural inspection report of 10/3/94 indicates the structure is a steel beam, timber thru-truss type covered bridge. The abutment walls are "laid up" stone walls with concrete caps. The right abutment is reported as having a few small voids where stones have fallen out. Many of the stone blocks in the lower half of the wall have broken in half or several pieces. A few of the small pieces have broken off the larger blocks and have slipped out from the wall creating the larger voids. The piers are solid concrete columns. The upstream and downstream channel embankments are reported as eroded from previous flooding. The footings are noted as not in view.**

## Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: 410.0

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ 6300 $Q_{10}$ 10700 $Q_{25}$ 14500

$Q_{50}$ 16700 $Q_{100}$ 20100 $Q_{500}$ -

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

Estimated Discharge *(cfs)*: - Velocity at Q 25 *(ft/s)*: 1.5

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

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

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

Describe any significant site conditions upstream or downstream that may influence the stream's stage: **High storage and wide flood plain both upstream and downstream.**

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*) | 360.1 | 362.0 | 363.7 | 364.5 | 366.1 |
| Velocity (*ft / sec*) | 1.2 | 1.5 | 1.5 | 1.6 | 1.6 |

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 $Q_{100}$ (*ft³/ sec*): -

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

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

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

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

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

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

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

Comments:

**There is no full hydrologic report compiled. The information given above is from office memorandums mainly. The bridge was designed for the Q25.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **412.48** $mi^2$

Lake/pond/swamp area **4.99** $mi^2$

Watershed storage *(ST)* **1.2** %

Bridge site elevation **360** ft

Headwater elevation **3051** ft

Main channel length **48.69** mi

10% channel length elevation **360** ft

85% channel length elevation **679** ft

Main channel slope *(S)* **8.74** 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)*: 08 / 1984

Project Number TH 3409 Minimum channel bed elevation: 340.0

Low superstructure elevation: USLAB 360.3 DSLAB 360.3 USRAB 360.75 DSRAB 360.75

Benchmark location description:

**Original project benchmark was not shown on the plans. The bridge seat and top of the abutments are shown level. Therefore, use any corner . The elevation shown at the corners between the abutment concrete extending parallel with the deck and the wingwall concrete which extends at an angle to the deck is shown as 364.83 feet.**

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

Foundation Type: 3 (*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:

-

Comments:

***Footing bottom elevation left: 355 and right 340. The footings of the abutment walls are indicated as unknown on the structural reports. The only copy of the plans appears to be in the structures folder. These plans were devised under the project number COV.BR. TH3409.**

## Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

# APPENDIX E:

# LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 2/13/96

Computerized by: RB Date: 2/20/96

Reviewd by: MAL Date: 6/4/98

Structure Number PFRDTH00230033

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. Degnan Date *(MM/DD/YY)* 06 / 22 / 1995

2. Highway District Number 03 Mile marker 0000

County Rutland (021) Town Pittsford (55600)

Waterway *(I - 6)* Otter Creek Road Name -

Route Number TH 23 Hydrologic Unit Code: 02010002

3. Descriptive comments:

**The bridge has a covered bridge shell, but the deck has been replaced with steel I beams and is not structurally dependent on the walls or roof.**
**This site is located 0.4 miles to the junction with Town Highway 1.**

## B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 3 LBDS 4 RBDS 3 Overall 3
*(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 1 UB 1 DS 1 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 135 *(feet)* Span length 107 *(feet)* Bridge width 17 *(feet)*

### Road approach to bridge:

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

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

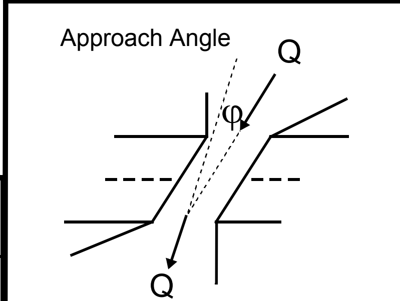
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right 3.0:1

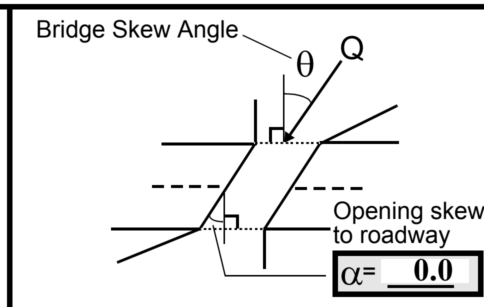
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 0 | 0 | 0 | 0 |
| RBUS | 1 | 2 | 2 | 1 |
| RBDS | 2 | 1 | 2 | 2 |
| LBDS | 2 | 1 | 0 | 0 |

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

### Channel approach to bridge (BF):

15. Angle of approach: 35 16. Bridge skew: 25




17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 5 feet DS *(US, UB, DS)* to 137 feet US

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

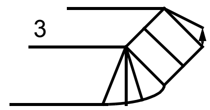
*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: 1a

1a- Vertical abutments with wingwalls

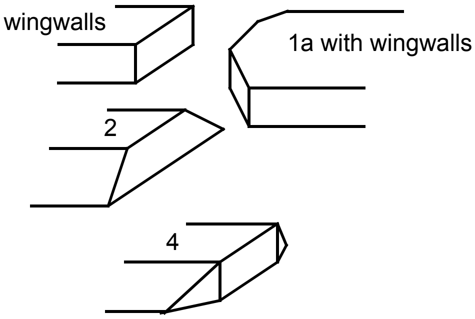
1b- Vertical abutments without wingwalls

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




3- Spill through abutments

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




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

**4. The US left bank surface cover is row crops above the inflow. The immediate banks have trees and shrubs.**
**7. The bridge dimension values are from the VTAOT files. The measured bridge length is 108 ft, span length is 103 ft, and bridge width is 17 ft.**
**18. The wingwalls on the left bank slope downward from the abutment.**

## C. Upstream Channel Assessment

| 20. SRD | 21. Bank height (BF) LB | 21. Bank height (BF) RB | 22. Bank angle (BF) LB | 22. Bank angle (BF) RB | 26. % Veg. cover (BF) LB | 26. % Veg. cover (BF) RB | 27. Bank material (BF) LB | 27. Bank material (BF) RB | 28. Bank erosion (BF) LB | 28. Bank erosion (BF) RB |
|---|---|---|---|---|---|---|---|---|---|---|
| 90.5 | 13.0 | | | 11.0 | 2 | 1 | 12 | 12 | 2 | 3 |

23. Bank width 35.0 24. Channel width 80.0 25. Thalweg depth 96.5 29. Bed Material 21

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.):

**There is a minor inflow 275 ft US of the bridge on the left bank. It has incised through the flood plain down to the water surface. There is a small amount of water presently flowing. At the mouth it is 8 ft deep and 18 ft wide, bank to bank top.**
**26. Both banks are lined with large trees but the overbank area is not wooded.**

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

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

37. Material: **-**

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

**NO POINT BARS**

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

41. Mid-bank distance: **90** 42. Cut bank extent: **40** feet **US** *(US, UB)* to **140** feet **US** *(US, UB, DS)*

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

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

**Trees are being undermined on the cutbank. There are fallen stumps which are evidence of block failure.**

45. Is channel scour present? **Y** *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: **57**

47. Scour dimensions: Length **115** Width **15** Depth : **5** Position **65** %LB to **5** %RB

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

**The channel scour extends to the DS cross section and beyond along the right bank. The scour depth is 5 ft below the 3 ft thalweg depth, this is only representative of the US portion. The dimensions include only the US portion.**

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**

**The confluence has a deep channel but little flow.**

## D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB **1** 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 |
|---|---|---|---|---|---|---|---|
| 75.5 | | 4.5 | | 2 | 12 | 7 | 1 |

58. Bank width (BF) **-** 59. Channel width **-** 60. Thalweg depth **90.0** 63. Bed Material **1**

*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.):

**21**

**62. The left bank erosion is due to roof run off on each side.**

**The right bank has dumped stone below the abutment. The left bank has some dumped stone just US of the US pier.**

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

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

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

70. Debris and Ice Comments:

**1**

**Just US of the bridge are trees rooted in the cutbank that could contribute to debris problems. The trees have bark ripped off at 4 ft above the present surface which could be a result of ice.**

| 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 | | - | - | 1 | 0 | - | - | 90.0 |
| RABUT | 2 | 35 | 90 | | | 0 | 0 | 102.0 |

*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.):

**-**

**-**

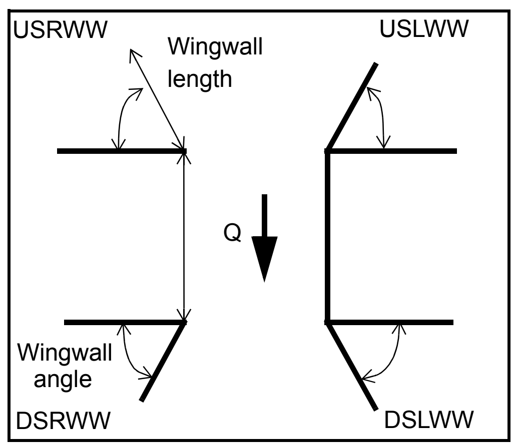
**2**

**The abutments are high on each bank. The protection below the right abutment seems to constrict the channel. The right abutment has a concrete cap. The left abutment is also capped with concrete with an old stone abutment on the overbank.**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 102.0 | |
| USRWW: | Y | | 1 | | 0 | 7.5 | |
| DSLWW: | - | | - | | Y | 21.0 | |
| DSRWW: | 1 | | 0 | | - | 21.0 | |

*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 | - | - | 2 | - | 2 |
| Condition | Y | - | 1 | - | - | 4 | - | 1 |
| Extent | 1 | - | 0 | 0 | 2 | 0 | 1 | 1 |

*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*

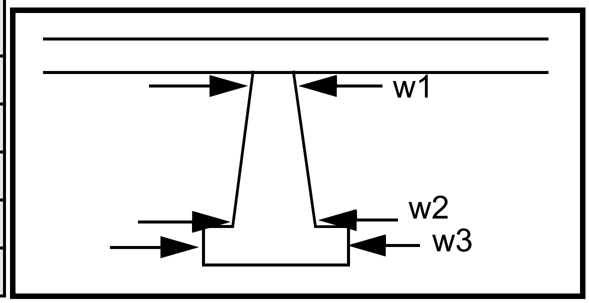
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

**2**
**2**
**1**
**2**
**1**
**1**
**1**
**1**
**2**
**1**
**1**

## Piers:

84. Are there piers? **Th** *(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 | | **5.5** | **6.5** | **90.0** | **40.0** | **90.0** |
| Pier 2 | **5.5** | **7.0** | | **30.0** | **2.0** | **502.0** |
| Pier 3 | **4.0** | **-** | **2.0** | **500.2** | **-** | **502.0** |
| Pier 4 | **4.0** | **-** | **-** | **500.2** | **-** | **-** |




| Level 1 Pier Descr. | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| 86. Location (BF) | **e US** | **bank** | **The** | **d in** | *LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP* |
| 87. Type | **right** | **from** | **scou** | **the** | ***1**- Solid pier, **2**- column, **3**- bent* |
| 88. Material | **wing** | **the** | **r in** | **DS** | ***1**- Wood; **2**- concrete; **3**- metal; **4**- stone* |
| 89. Shape | **wall** | **wing** | **the** | **chan** | ***1**- Round; **2**- Square; **3**- Pointed* |
| 90. Inclined? | **pro-** | **wall** | **chan** | **nel** | *Y- yes; N- no* |
| 91. Attack ∠ (BF) | **tec-** | **hold-** | **nel** | **asses** | |
| 92. Pushed | **tion** | **ing** | **unde** | **smen** | *LB or RB* |
| 93. Length (feet) | **-** | **-** | **-** | **-** | |
| 94. # of piles | **is** | **back** | **r the** | **t.** | |
| 95. Cross-members | **abou** | **the** | **brid** | | ***0**- none; **1**- laterals; **2**- diagonals; **3**- both* |
| 96. Scour Condition | **t 6 ft** | **grav** | **ge is** | | ***0**- not evident; **1**- evident (comment);<br>**2**- footing exposed; **3**- piling exposed;<br>**4**- undermined footing; **5**- settled; **6**- failed* |
| 97. Scour depth | **dow** | **el** | **desc** | | |
| 98. Exposure depth | **n the** | **fill.** | **ribe** | | |

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

**Y**
**LTB**
**1**
**2**
**3**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | Y | - | LB | - | - | - |

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

Bank protection type (Qmax): LB -  RB LT     Bank protection condition: LB B  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*

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
**2**
**3**
**Y**
**-**
**LB**
**-**
**-**
**-**
**-**
**-**
**-**
**-**
**-**
**-**
**-**

101. Is a drop structure present? - (Y or N, if N type ctrl-n ds)     102. Distance: 6.0 feet

103. Drop: 6.0 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.):

-

**The piers are on the same bank parallel to each other.**

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

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

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

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

**1**

**12**

**12**

**2**

Is channel scour present? 2 (Y or if N type ctrl-n cs) Mid-scour distance: 21

Scour dimensions: Length 0 Width 0 Depth: - Positioned - %LB to The %RB

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

**re are trees on the banks, more on the left bank and roots are exposed.**

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

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

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

Confluence comments (eg. confluence name):

## F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

*1- Constructed*
*2- Stable*
*3- Aggraded*
*4- Degraded*
*5- Laterally unstable*
*6- Vertically and laterally unstable*

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

**N**

**-**

**NO DROP STRUCTURE**

**Y**

**330**

**25**

**300**

**DS**

## 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: PFRDTH00230033 Town: Pittsford
Road Number: TH 23 County: Rutland
Stream: Otter Creek

Initials EMB Date: 05/27/98 Checked: RLB

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

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

| Approach Section Characteristic | 100 yr | 500 yr | other Q |
|---|---|---|---|
| Total discharge, cfs | 16400 | 20200 | 1890 |
| Main Channel Area, ft2 | 1937 | 2053 | 1165 |
| Left overbank area, ft2 | 5255 | 6369 | 0 |
| Right overbank area, ft2 | 10068 | 11272 | 0 |
| Top width main channel, ft | 114 | 114 | 95 |
| Top width L overbank, ft | 1075 | 1109 | 0 |
| Top width R overbank, ft | 1176 | 1184 | 0 |
| D50 of channel, ft | 0.001264 | 0.001264 | 0.001264 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 17.0 | 18.0 | 12.3 |
| y1, average depth, LOB, ft | 4.9 | 5.7 | ERR |
| y1, average depth, ROB, ft | 8.6 | 9.5 | ERR |
| Total conveyance, approach | 2459478 | 2977539 | 211147 |
| Conveyance, main channel | 439028 | 483918 | 211147 |
| Conveyance, LOB | 450950 | 608428 | 0 |
| Conveyance, ROB | 1569499 | 1885193 | 0 |
| Percent discrepancy, conveyance | 0.0000 | 0.0000 | 0.0000 |
| Qm, discharge, MC, cfs | 2927.5 | 3283.0 | 1890.0 |
| Ql, discharge, LOB, cfs | 3007.0 | 4127.7 | 0.0 |
| Qr, discharge, ROB, cfs | 10465.5 | 12789.4 | 0.0 |
| Vm, mean velocity MC, ft/s | 1.5 | 1.6 | 1.6 |
| Vl, mean velocity, LOB, ft/s | 0.6 | 0.6 | ERR |
| Vr, mean velocity, ROB, ft/s | 1.0 | 1.1 | ERR |
| Vc-m, crit. velocity, MC, ft/s | 1.9 | 2.0 | 1.8 |
| 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 |

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)

| Characteristic | Approach 100 yr | 500 yr | Other Q | Bridge 100 yr | 500 yr | Other Q |
|---|---|---|---|---|---|---|
| Q1, discharge, cfs | 16400 | 20200 | 1890 | 4724 | 4961 | 1890 |
| Total conveyance | 2459478 | 2977539 | 211147 | 223638 | 223638 | 218125 |
| Main channel conveyance | 439028 | 483918 | 211147 | 223638 | 223638 | 218125 |
| Main channel discharge | 2927 | 3283 | 1890 | 4724 | 4961 | 1890 |
| Area - main channel, ft2 | 1937 | 2053 | 1165 | 1469.2 | 1469.2 | 1058.6 |
| (W1) channel width, ft | 114 | 114 | 95 | 101.8 | 101.8 | 86.6 |
| (Wp) cumulative pier width, ft | 0 | 0 | 0 | 4 | 4 | 4 |
| W1, adjusted bottom width(ft) | 114 | 114 | 95 | 97.8 | 97.8 | 82.6 |
| D50, ft | 0.001264 | 0.001264 | 0.001264 | | | |
| w, fall velocity, ft/s (p. 32) | 0.164 | 0.164 | 0.164 | | | |
| y, ave. depth flow, ft | 16.99 | 18.01 | 12.26 | 15.02 | 15.02 | 12.82 |
| S1, slope EGL | 0.00016 | 0.00016 | 0.00008 | | | |
| P, wetted perimeter, MC, ft | 129 | 129 | 109 | Pier area | | |
| R, hydraulic Radius, ft | 15.016 | 15.915 | 10.688 | 18.3 | 18.3 | 5.2 |
| V*, shear velocity, ft/s | 0.278 | 0.286 | 0.166 | | | |
| V*/w | 1.696 | 1.746 | 1.012 | | | |
| Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33) | | | | | | |
| k1 | 0.64 | 0.64 | 0.64 | | | |
| y2,depth in contraction, ft | 28.25 | 28.30 | 13.41 | | | |
| ys, scour depth, ft (y2-y_bridge) | 13.22 | 13.28 | 0.60 | | | |

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 | 16400 | 20200 | 1890 |
| (Q) discharge thru bridge, cfs | 4724 | 4961 | 1890 |
| Main channel conveyance | 223638 | 223638 | 218125 |
| Total conveyance | 223638 | 223638 | 218125 |
| Q2, bridge MC discharge,cfs | 4724 | 4961 | 1890 |
| Main channel area, ft2 | 1469.2 | 1469.2 | 1058.6 |
| Main channel width (normal), ft | 101.8 | 101.8 | 86.6 |
| Cum. width of piers in MC, ft | 4.0 | 4.0 | 4.0 |
| W, adjusted width, ft | 97.8 | 97.8 | 82.6 |
| y_bridge (avg. depth at br.), ft | 15.02 | 15.02 | 12.82 |
| Dm, median (1.25*D50), ft | 0.00158 | 0.00158 | 0.00158 |
| y2, depth in contraction,ft | 21.70 | 22.63 | 11.44 |
| ys, scour depth (y2-ybridge), ft | 6.67 | 7.60 | -1.38 |

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 | 16400 | 20200 | 1890 |
| Q, thru bridge MC, cfs | 4724 | 4961 | 1890 |
| Vc, critical velocity, ft/s | 1.94 | 1.96 | 1.84 |
| Va, velocity MC approach, ft/s | 1.51 | 1.60 | 1.62 |
| Main channel width (normal), ft | 101.8 | 101.8 | 86.6 |
| Cum. width of piers in MC, ft | 4.0 | 4.0 | 4.0 |
| W, adjusted width, ft | 97.8 | 97.8 | 82.6 |
| qbr, unit discharge, ft2/s | 48.3 | 50.7 | 22.9 |
| Area of full opening, ft2 | 1469.2 | 1469.2 | 1058.6 |
| Hb, depth of full opening, ft | 15.02 | 15.02 | 12.82 |
| Fr, Froude number, bridge MC | 0.14 | 0.15 | 0 |
| Cf, Fr correction factor (<=1.0) | 0.64 | 0.66 | 0.00 |
| **Area at downstream face, ft2 | N/A | N/A | N/A |
| **Hb, depth at downstream face, ft | N/A | N/A | N/A |
| **Fr, Froude number at DS face | ERR | ERR | ERR |
| **Cf, for downstream face (<=1.0) | N/A | N/A | N/A |
| Elevation of Low Steel, ft | 502.22 | 502.22 | 0 |
| Elevation of Bed, ft | 487.20 | 487.20 | -12.82 |
| Elevation of Approach, ft | 504.66 | 504.66 | 0 |
| Friction loss, approach, ft | 0.01 | 0.01 | 0 |
| Elevation of WS immediately US, ft | 504.65 | 504.65 | 0.00 |
| ya, depth immediately US, ft | 17.45 | 17.45 | 12.82 |
| Mean elevation of deck, ft | 506.28 | 506.28 | 0 |
| w, depth of overflow, ft (>=0) | 0.00 | 0.00 | 0.00 |
| Cc, vert contrac correction (<=1.0) | 0.96 | 0.96 | 1.00 |
| **Cc, for downstream face (<=1.0) | ERR | ERR | ERR |
| | | | |
| Ys, scour w/Chang equation, ft | 25.03 | 25.42 | N/A |
| Ys, scour w/Umbrell equation, ft | 1.51 | 1.98 | N/A |

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

| | | | |
|---|---|---|---|
| **Ys, scour w/Chang equation, ft | N/A | N/A | N/A |
| **Ys, scour w/Umbrell equation, ft | N/A | N/A | ERR |

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

| | | | |
|---|---|---|---|
| y2, from Laursen's equation, ft | N/A | N/A | N/A |
| WSEL at downstream face, ft | -- | -- | -- |
| Depth at downstream face, ft | N/A | N/A | N/A |
| Ys, depth of scour (Laursen), ft | N/A | N/A | 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)

| Characteristic | Left Abutment 100 yr Q | 500 yr Q | Other Q | Right Abutment 100 yr Q | 500 yr Q | Other Q |
|---|---|---|---|---|---|---|
| (Qt), total discharge, cfs | 16400 | 20200 | 1890 | 16400 | 20200 | 1890 |
| a', abut.length blocking flow, ft | 1075.1 | 1109.4 | 12.7 | 1188 | 1196.6 | 0 |
| Ae, area of blocked flow ft2 | 1874.3 | 1827.4 | 92.23 | 4342 | 4556.8 | -- |
| Qe, discharge blocked abut.,cfs | -- | -- | 64.18 | -- | -- | -- |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 0.59 | 0.68 | 0.70 | 1.04 | 1.13 | 0.76 |
| ya, depth of f/p flow, ft | 1.74 | 1.65 | 7.26 | 3.65 | 3.81 | 10.86 |
| --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 | 90 | 90 | 90 | 90 | 90 | 90 |
| K2 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Fr, froude number f/p flow | 0.046 | 0.049 | 0.046 | 0.062 | 0.065 | 0.041 |
| ys, scour depth, ft | 9.60 | 9.66 | 9.87 | 18.66 | 19.67 | 10.86 |

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) | 1075.1 | 1109.4 | 12.7 | 1188 | 1196.6 | 0 |
| y1 (depth f/p flow, ft) | 1.74 | 1.65 | 7.26 | 3.65 | 3.81 | ERR |
| a'/y1 | 616.68 | 673.51 | 1.75 | 325.04 | 314.22 | ERR |
| Skew correction (p. 49, fig. 16) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Froude no. f/p flow | 0.05 | 0.05 | 0.05 | 0.06 | 0.07 | 0.04 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | 4.59 | 4.43 | ERR | 10.62 | 11.24 | ERR |
| vertical w/ ww's | 3.76 | 3.63 | ERR | 8.71 | 9.21 | ERR |
| spill-through | 2.52 | 2.44 | ERR | 5.84 | 6.18 | ERR |

Abutment riprap Sizing

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

| Characteristic | Q100 | Q500 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 0.19 | 0.2 | 0.09 | 0.19 | 0.2 | 0.09 |
| y, depth of flow in bridge, ft | 15.02 | 15.02 | 12.82 | 15.02 | 15.02 | 12.82 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | 0.34 | 0.37 | 0.06 | 0.34 | 0.37 | 0.06 |
| Fr>0.8 (vertical abut.) | ERR | ERR | ERR | ERR | ERR | ERR |

Pier Scour

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)

V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

| Pier 1 | Q100 | Q500 | Qother |
|---|---|---|---|
| Pier stationing, ft | 17.7 | 17.7 | 17.7 |
| Area of WSPRO flow tube, ft2 | 49.8 | 49.8 | 41.1 |
| Skewed width of flow tube, ft | 2.4 | 2.4 | 2.2 |
| y1, pier approach depth, ft | 20.75 | 20.75 | 18.68 |
| y1 in meters | 6.324 | 6.324 | 5.694 |
| V1, pier approach velocity, ft/s | 4.74 | 4.98 | 2.3 |
| a, pier width, ft | 4 | 4 | 4 |
| L, pier length, ft | 12 | 12 | 12 |
| Fr1, Froude number at pier | 0.183 | 0.193 | 0.094 |
| Pier attack angle, degrees | 0 | 0 | 0 |
| K1, shape factor | 0.9 | 0.9 | 0.9 |
| K2, attack factor | 1.00 | 1.00 | 1.00 |
| K3, bed condition factor | 1.1 | 1.1 | 1.1 |
| D50, ft | 0.001264 | 0.001264 | 0.001264 |
| D50, m | 0.000385 | 0.000385 | 0.000385 |
| D90, ft | 0.003456 | 0.0035 | 0.0035 |
| D90, m | 0.001053 | 0.001067 | 0.001067 |
| Vc50,critical velocity(D50),m/s | 0.613 | 0.613 | 0.602 |
| Vc90,critical velocity(D90),m/s | 0.856 | 0.860 | 0.845 |
| Vi,incipient velocity,m/s | 0.258 | 0.258 | 0.253 |
| Vr, velocity ratio | 1.982 | 2.092 | 0.756 |
| K4, armor factor | 0.00 | ERR | 0.00 |
| ys, scour depth (K4 applicable) ft | ERR | ERR | ERR |
| ys, scour depth (K4 not applied)ft | 6.80 | 6.94 | 4.91 |

Pier rip-rap sizing
D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

| Pier 1 | Q100 | Q500 | Qother |
|---|---|---|---|
| K, pier shape coeff. | 1.5 | 1.5 | 1.5 |
| V, velocity on pier, ft/s | 4.74 | 4.98 | 2.3 |
| Used velocity correction factor = 1.0 | | | |
| D50, median stone diameter, ft | 0.33 | 0.36 | 0.08 |