# LEVEL II SCOUR ANALYSIS FOR BRIDGE 71 (STOWTH0CEM0071) on CEMETARY ROAD, crossing the LITTLE RIVER, STOWE, VERMONT

Open-File Report 98-569

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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By 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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## 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 71 (STOWTH0CEM0071) ON CEMETARY ROAD, CROSSING THE LITTLE RIVER, STOWE, 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 STOWTH0CEM0071 on Cemetary Road crossing the Little River, Stowe, 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 VTAOT files indicate the river at this site is named the Waterbury River. The flood insurance study for the village and town of Stowe (FEMA, 1980) have documented the river at this site as the East Branch Little River.

The site is in the Green Mountain section of the New England physiographic province in north-central Vermont. The 24.4-mi$^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of shrubs and brush on the right bank upstream and the left bank downstream of the bridge. The surface is pasture on the left bank upstream and the right bank downstream.

In the study area, the Little River has a sinuous channel with a slope of approximately 0.001 ft/ft, an average channel top width of 41 ft and an average bank height of 7 ft. The channel bed material ranges from sand to gravel with a median grain size ($D_{50}$) of 0.725 mm (0.00238 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 9, 1996, indicated that the reach was stable.

The Cemetary Road crossing of the Little River is a 44-ft-long, two-lane bridge consisting of one 42-foot prestressed concrete T-beam span (Vermont Agency of Transportation, written communication, October 13, 1995). The opening length of the structure parallel to the bridge face is 43.8 ft. The bridge is supported by vertical abutments faced with galvanized steel “bin-walls”. The channel is skewed approximately 15 degrees to the opening while the opening-skew-to-roadway is zero degrees.

The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the right and left banks upstream and downstream of the bridge. 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 23.0 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 3.9 to 21.4 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results.” Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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.

**Stowe, VT. Quadrangle, 1:24,000, 1968**

**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*** STOWTH0CEM0071 ***Stream*** Little River

***County*** Lamoille ***Road*** Cemetary ***District*** 6

### Description of Bridge

***Bridge length*** 44 ***ft*** ***Bridge width*** 19.6 ***ft*** ***Max span length*** 42 ***ft***

***Alignment of bridge to road (on curve or straight)*** Right is curved and left is straight

***Abutment type*** Vertical, Steel ***Embankment type*** Sloping nearly vertical

***Stone fill on abutment?*** No ***Date of inspection*** 7/9/96

***Description of stone fill*** Only a few stones were evident at each abutment.

***Brief description of piers/abutments*** Abutments are walls faced with corrugated, galvanized, steel “bin-walls”.

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

***Is bridge skewed to flood flow according to Level I survey?*** Yes ***Angle*** 15

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

| | ***Date of inspection*** | ***Percent of channel blocked horizontally*** | ***Percent of channel blocked vertically*** |
|---|---|---|---|
| ***Level I*** | 7/9/96 | 0 | 0 |
| ***Level II*** | 7/9/96 | 0 | 0 |

***Potential for debris*** Moderate. Some minor debris accumulation was observed between the bridge seat and low chord.

***Describe any features near or at the bridge that may affect flow (include observation date)*** None were observed on 7/9/96.

## Description of the Geomorphic Setting

***General topography*** The channel is located in a moderate relief valley setting with a wide, irregular flood plain.

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

***Date of inspection*** 7/9/96

***DS left:*** Moderately sloped channel bank and flood plain.

***DS right:*** Steep channel bank and flood plain.

***US left:*** Steep channel bank and flood plain.

***US right:*** Steep channel bank and flood plain.

## Description of the Channel

***Average top width*** 41 ***ft*** ***Average depth*** 7 ***ft***

***Predominant bed material*** Sand and Gravel ***Bank material*** Sand / Silt & Clay

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

7/9/96

***Vegetative co*** Shrubs and brush with a few small trees

***DS left:*** Shrubs and brush with a few small trees

***DS right:*** Shrubs and brush with a few small trees

***US left:*** Shrubs and brush

***US right:*** Yes

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

None observed on 7/9/96

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

## Hydrology

***Drainage area*** 24.4 ***mi²***

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

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

***Is drainage area considered rural or urban?*** Rural ***Describe any significant urbanization***: -

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

***USGS gage description*** --

***USGS gage number*** --

***Gage drainage area*** -- ***mi²***

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

-

### Calculated Discharges

***Q100*** 4,000 ***ft³/s*** ***Q500*** 5,600 ***ft³/s***

The 100- and 500-year discharges are based on the flood frequency curve derived by use of the New England Hill and Lowland area equation documented by Potter (1957b). The values used were within a range defined by flood frequency curves developed from several other empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a; 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*** Subtract 1.1 feet from the USGS arbitrary survey datum to obtain the VTAOT plans' datum.

***Description of reference marks used to determine USGS datum.*** RM1 is a chiseled "X" on the upstream end of the right abutment (elev. 501.36 ft, arbitrary survey datum). RM2 is the painted downstream corner of the left abutment (elev. 501.92 ft, arbitrary survey datum). RM4 (from FEMA, 1979) is a spike 2 feet above the ground in a white pine, 460 feet right of the right abutment and 20 feet from the cemetary gate on the downstream side of the roadway (elev. 504.81 feet, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

| *[1]Cross-section* | *Section Reference Distance (SRD) in feet* | *[2]Cross-section development* | *Comments* |
|---|---|---|---|
| EXITX | -38 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 10 | 1 | Road Grade section |
| APPRO | 63 | 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 0.032 to 0.045, and overbank "n" values were 0.030.

The water surface elevation downstream of this site is influenced by the confluence of the West Branch Little River and the valley constriction at the State Route 108 crossing of the Little River. Starting water surface elevatons at the exit section (EXITX) were derived from a rating of the discharge and water surface elevations at section "E" from the Flood Insurance Study model of the reach for the village of Stowe (FEMA, 1980).

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.

Culvert routines provided with WSPRO are not fully integrated. Therefore, it was necessary to develop individual ratings for the culverts and bridge to model this multiple-opening situation. The ratings were combined to determine the quantity of the total discharge diverted from the bridge through the culverts. The combined ratings indicate the culverts divert 230 cfs, 40 cfs, and 300 cfs of the total discharge for the 100-year, 500-year, and incipient roadway-overtopping peak discharges respectively. Each discharge modeled at the bridge was reduced by the flow through the culverts for the model provided in appendices A and B.

## Bridge Hydraulics Summary

***Average bridge embankment elevation*** 501.9 ***ft***
***Average low steel elevation*** 498.9 ***ft***

***100-year discharge*** 4,000 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 499.1 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 2,080 ***$ft^3/s$***
***Area of flow in bridge opening*** 241 ***$ft^2$***
***Average velocity in bridge opening*** 7.0 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 9.0 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 502.6
***Water-surface elevation at Approach section without bridge*** 501.3
***Amount of backwater caused by bridge*** 1.3 ***ft***

***500-year discharge*** 5,600 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 499.1 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 5,440 ***$ft^3/s$***
***Area of flow in bridge opening*** 241 ***$ft^2$***
***Average velocity in bridge opening*** 0.5 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 0.7 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 504.3
***Water-surface elevation at Approach section without bridge*** 504.2
***Amount of backwater caused by bridge*** 0.1 ***ft***

***Incipient overtopping discharge*** 2,370 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 499.1 ***ft***
***Area of flow in bridge opening*** 241 ***$ft^2$***
***Average velocity in bridge opening*** 8.6 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 10.9 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 501.1
***Water-surface elevation at Approach section without bridge*** 497.9
***Amount of backwater caused by bridge*** 3.2 ***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. Only scour depths for the 100-year event appear in figure 8 because the scour depths for the 500-year event were less than those for the 100-year event.

At this site, the 100-year, 500-year, and incipient roadway-overtopping discharges resulted in 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 was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison, contraction scour also was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20) 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 was computed for all modeled discharges by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p.30, equation 17). Furthermore, for the incipient-overtopping discharge, which resulted in unsubmerged orifice flow, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these alternative computations are provided in appendix F.

Abutment scour 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. Variables for the HIRE 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* | 17.6 | 0.0 | 23.0 |
| *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* | 19.1 | 21.4 | 14.1 |
| *Right abutment* | 9.0 | 14.2 | 3.9 |
| *Pier scour* | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |
| *Pier 3* | -- | -- | -- |

## Riprap Sizing

| | 100-year discharge | 500-year discharge ($D_{50}$ in feet) | Incipient overtopping discharge |
|---|---|---|---|
| *Abutments:* | | | |
| *Left abutment* | 1.2 | 0.0 | 1.3 |
| *Right abutment* | 1.2 | 0.0 | 1.3 |
| *Piers:* | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

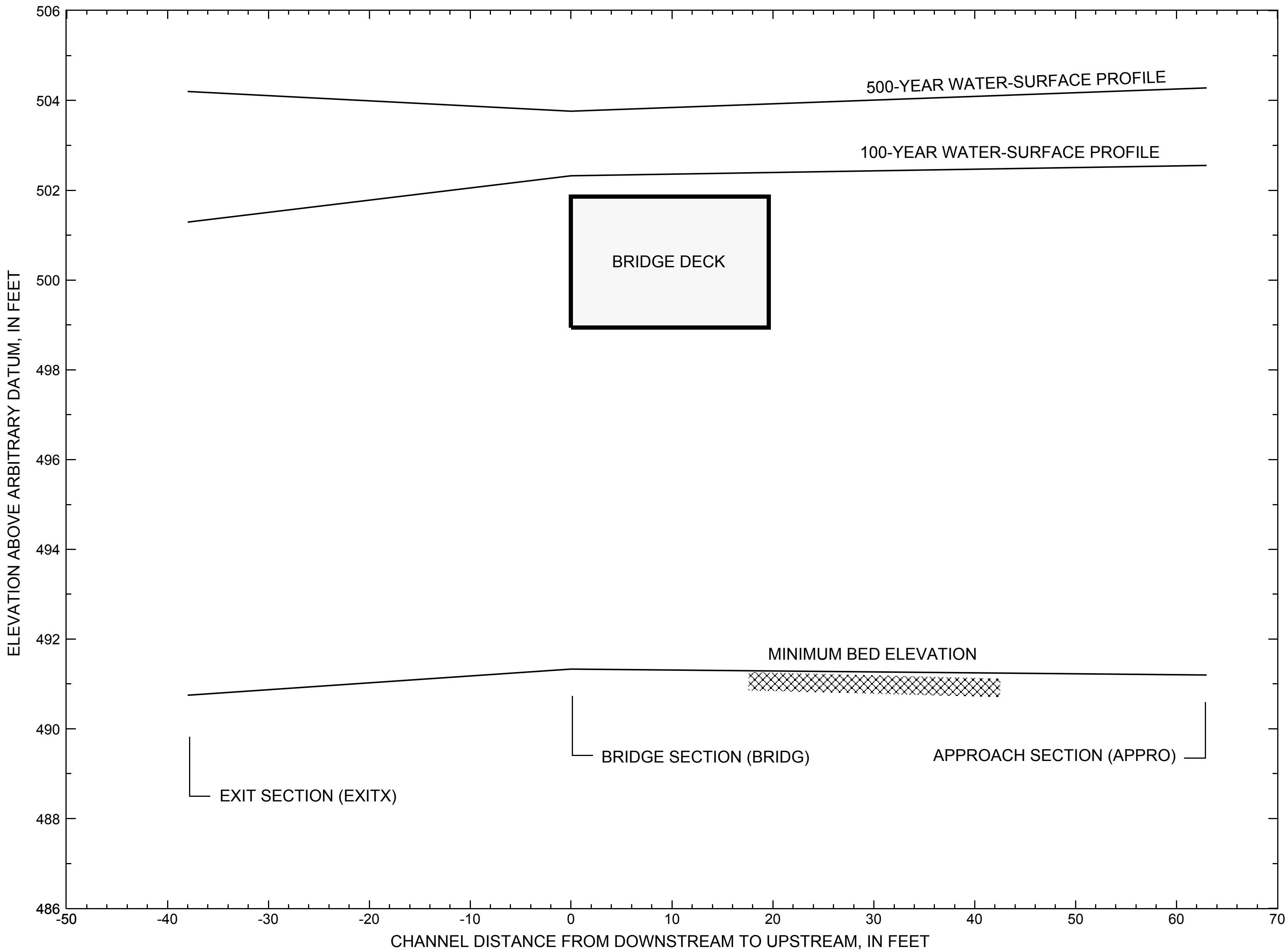


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure STOWTH0CEM0071 on Cemetary Road, crossing the Little River, Stowe, Vermont.

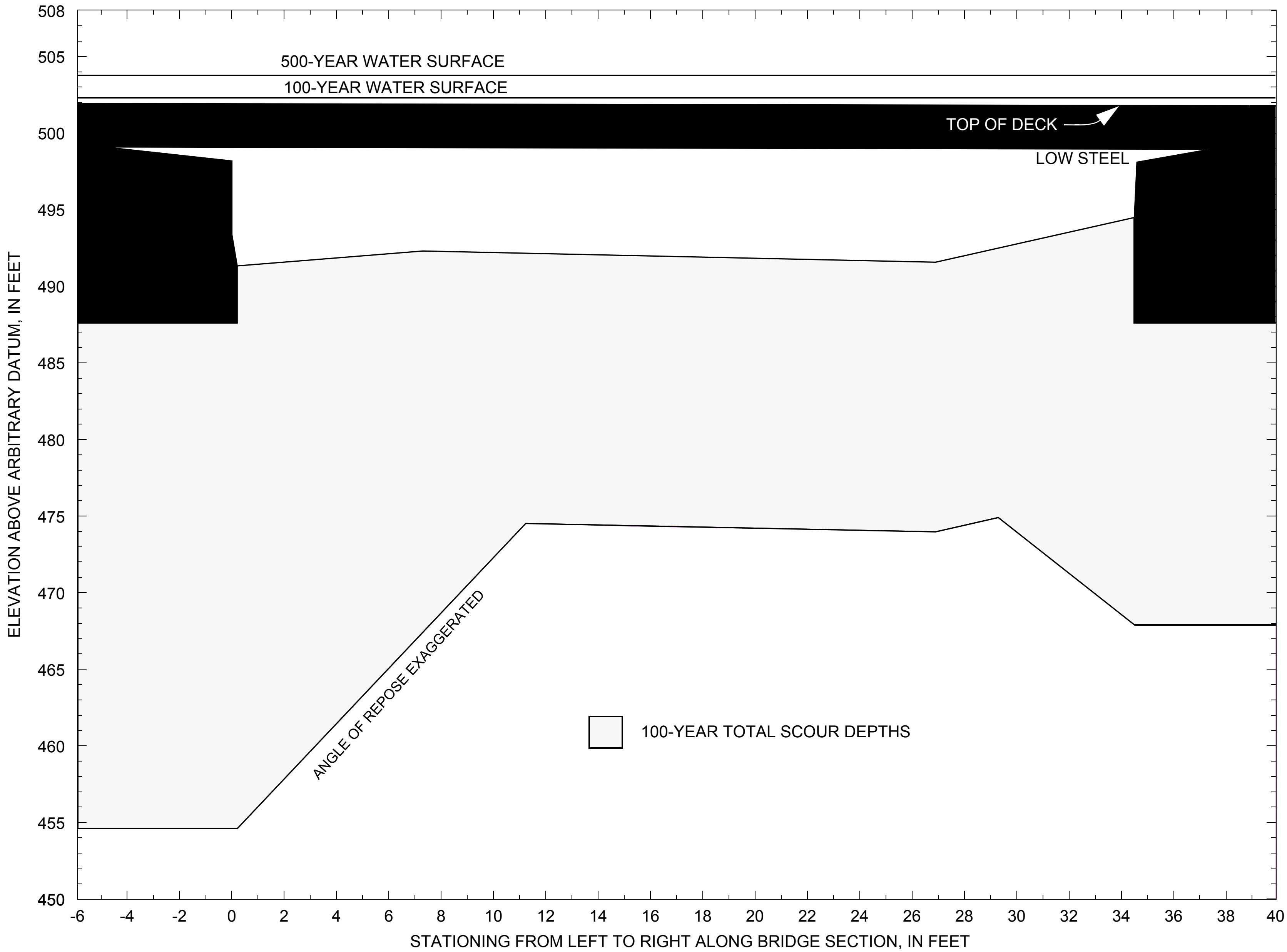


Figure 8. Scour elevations for the 100- and 500-year discharges at structure STOWTH0CEM0071 on Cemetary Road, crossing the Little River, Stowe, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure STOWTH0CEM0071 on Cemetary Road, crossing the Little River, Stowe, Vermont.

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

| Description | Station[1] | VTAOT bridge seat elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/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 4,000 cubic-feet per second | | | | | | | | | | | |
| Left abutment | -4.9 | -- | 499.1 | 487.6 | 491.3 | 17.6 | 19.1 | -- | 36.7 | 454.6 | -33 |
| Right abutment | 38.9 | -- | 498.9 | 487.6 | 494.5 | 17.6 | 9.0 | -- | 26.6 | 467.9 | -20 |

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 STOWTH0CEM0071 on Cemetary Road, crossing the Little River, Stowe, Vermont.

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

| Description | Station[1] | VTAOT bridge seat elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/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 5,600 cubic-feet per second | | | | | | | | | | | |
| Left abutment | -4.9 | -- | 499.1 | 487.6 | 491.3 | 0.0 | 21.4 | -- | 21.4 | 469.9 | -18 |
| Right abutment | 38.9 | -- | 498.9 | 487.6 | 494.5 | 0.0 | 14.2 | -- | 14.2 | 480.3 | -7.3 |

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

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U.S. Geological Survey, 1968, Stowe, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Contour interval 20 feet, Scale 1:24,000.

APPENDIX A:

# WSPRO INPUT FILE

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File stow071.wsp
T2        Hydraulic analysis for structure STOWTH0CEM0071   Date: 18-AUG-97
T3        Bridge 71 on Cemetery Rd over East Branch Little R. Stowe, VT  EMB
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
*           4000.0  5600.0   2370.0  <-- Original discharges w/o culvert flow
Q           3770.0  5560.0   2070.0
WS          501.29  504.24   497.34
*
XS   EXITX    -38
GR         -456.9, 505.99   -377.1, 494.54   -136.6, 495.71      0.0, 495.71
GR           16.9, 493.14     20.1, 492.45     30.8, 490.75     39.5, 491.36
GR           42.0, 493.48     46.2, 497.62     80.0, 497.80    157.9, 496.67
GR          347.8, 496.63    513.7, 496.00    597.5, 498.68    639.7, 498.45
GR          732.3, 512.45
N           0.030        0.045       0.030
SA                   0.0         46.2
*
XS   FULLV      0  * * *   0.000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.94       0.0
GR           -4.9, 499.10     -2.7, 498.72      0.0, 498.17      0.0, 493.37
GR            0.2, 491.33      7.3, 492.31     15.3, 491.91     26.9, 491.57
GR           31.3, 493.28     34.5, 494.49     34.6, 498.10     37.1, 498.86
GR           38.9, 498.94     -4.9, 499.10
*
*         BRTYPE  BRWDTH
CD            1      20.2
N           0.032
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      19.6     1
GR         -562.4, 513.08   -402.3, 505.25   -334.6, 504.07   -184.6, 502.86
GR         -157.0, 502.53     -5.9, 501.86      0.0, 501.93     40.0, 501.79
GR          149.6, 501.09    363.2, 501.50    513.2, 501.41    588.0, 505.95
GR          732.3, 512.45
*
AS   APPRO     63
GR         -529.5, 511.68   -465.8, 506.69   -340.4, 496.83   -247.3, 496.63
GR            0.0, 497.90      8.5, 493.23      8.6, 491.50     17.6, 491.20
GR           24.7, 491.50     29.9, 491.45     31.8, 493.33     35.4, 497.42
GR          111.0, 500.01    261.6, 501.03    373.6, 501.21    492.5, 500.91
GR          532.6, 503.76    588.0, 505.95    732.3, 512.45
N           0.030        0.045        0.030
SA                   0.0         35.4
*
HP 1 BRIDG   499.10 1 499.10
HP 2 BRIDG   499.10 * * 1696
HP 2 RDWAY   502.32 * * 2080
HP 1 APPRO   502.55 1 502.55
HP 2 APPRO   502.55 * * 4000
*
HP 1 BRIDG   499.10 1 499.10
HP 2 BRIDG   499.10 * *  125
HP 2 RDWAY   503.76 * * 5436
HP 1 APPRO   504.28 1 504.28
HP 2 APPRO   504.28 * * 5600
*
HP 1 BRIDG   499.10 1 499.10
HP 2 BRIDG   499.10 * * 2070
HP 1 BRIDG   497.36 1 497.36
HP 1 APPRO   501.08 1 501.08
HP 2 APPRO   501.08 * * 2370
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 stow071.wsp
        Hydraulic analysis for structure STOWTH0CEM0071   Date: 18-AUG-97
        Bridge 71 on Cemetery Rd over East Branch Little R. Stowe, VT  EMB
           *** RUN DATE & TIME: 09-29-98  10:11

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     241.  20401.     0.    99.                            0.
   499.10          241.  20401.     0.    99.  1.00    -5.    39.       0.

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       499.10    -4.9    38.9   241.3   20401.    1696.   7.03

X STA.        -4.9        4.2        5.5        6.9        8.4        9.9
  A(I)            33.1        9.5        9.8       10.0        9.9
  V(I)            2.57       8.91       8.64       8.48       8.52

X STA.         9.9       11.3       12.7       14.1       15.5       16.9
  A(I)             9.8        9.9        9.9        9.8        9.9
  V(I)            8.63       8.58       8.61       8.63       8.57

X STA.        16.9       18.3       19.6       21.0       22.3       23.6
  A(I)             9.9       10.0        9.8        9.6        9.7
  V(I)            8.53       8.49       8.65       8.84       8.78

X STA.        23.6       25.0       26.2       27.6       29.0       38.9
  A(I)             9.8        9.5        9.8        9.8       31.9
  V(I)            8.70       8.97       8.63       8.69       2.66

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

         WSEL     LEW     REW    AREA         K        Q    VEL
       502.32  -109.6   528.2   496.7   22179.    2080.   4.19

X STA.      -109.6       54.4       93.4      117.3      137.0      154.1
  A(I)            53.1       29.1       22.6       21.4       20.5
  V(I)            1.96       3.57       4.59       4.87       5.08

X STA.       154.1      170.6      188.4      206.9      226.3      246.3
  A(I)            20.0       20.8       21.1       21.4       21.3
  V(I)            5.20       5.00       4.92       4.87       4.89

X STA.       246.3      266.9      290.2      314.8      342.6      373.4
  A(I)            21.1       22.9       23.0       24.7       25.7
  V(I)            4.94       4.54       4.52       4.22       4.05

X STA.       373.4      404.2      433.4      462.1      488.6      528.2
  A(I)            25.8       24.9       24.9       23.5       29.1
  V(I)            4.04       4.17       4.17       4.42       3.58

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    2057.  297748.   413.   413.                       26043.
             2     343.   47006.    35.    41.                        6070.
             3     952.   74594.   480.   480.                        7605.
   502.55         3352.  419347.   929.   935.  1.15  -413.   516.  33631.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

         WSEL     LEW     REW    AREA         K        Q    VEL
       502.55  -413.1   515.6  3352.2  419347.    4000.   1.19

X STA.      -413.1     -332.7     -309.7     -287.1     -265.3     -243.0
  A(I)           252.4      132.2      131.4      127.7      131.3
  V(I)            0.79       1.51       1.52       1.57       1.52

X STA.      -243.0     -220.5     -197.6     -173.7     -148.7     -122.9
  A(I)           131.5      130.9      134.1      136.9      137.9
  V(I)            1.52       1.53       1.49       1.46       1.45

X STA.      -122.9      -96.0      -67.3      -38.2       -6.3       15.3
  A(I)           140.4      145.3      143.3      151.9      164.4
  V(I)            1.42       1.38       1.40       1.32       1.22

X STA.        15.3       27.0       52.7      100.8      226.3      515.6
  A(I)           131.1      161.1      178.5      275.5      414.2
  V(I)            1.53       1.24       1.12       0.73       0.48
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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 stow071.wsp
        Hydraulic analysis for structure STOWTH0CEM0071   Date: 18-AUG-97
        Bridge 71 on Cemetery Rd over East Branch Little R. Stowe, VT  EMB
           *** RUN DATE & TIME: 09-29-98  10:11

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW     REW     QCR
             1     241.  20401.     0.    99.                             0.
   499.10          241.  20401.     0.    99.  1.00    -5.    39.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.10    -4.9    38.9   241.3   20401.     125.   0.52

X STA.        -4.9        4.2        5.5        6.9        8.4        9.9
  A(I)             33.1        9.5        9.8       10.0        9.9
  V(I)             0.19       0.66       0.64       0.62       0.63

X STA.         9.9       11.3       12.7       14.1       15.5       16.9
  A(I)              9.8        9.9        9.9        9.8        9.9
  V(I)             0.64       0.63       0.63       0.64       0.63

X STA.        16.9       18.3       19.6       21.0       22.3       23.6
  A(I)              9.9       10.0        9.8        9.6        9.7
  V(I)             0.63       0.63       0.64       0.65       0.65

X STA.        23.6       25.0       26.2       27.6       29.0       38.9
  A(I)              9.8        9.5        9.8        9.8       31.9
  V(I)             0.64       0.66       0.64       0.64       0.20

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

         WSEL     LEW     REW    AREA        K        Q    VEL
       503.76  -296.2   551.9  1575.1  122015.    5436.   3.45

X STA.      -296.2      -91.1      -36.9        9.9       61.7       94.6
  A(I)            170.4       88.9       86.1      101.9       72.9
  V(I)             1.60       3.06       3.16       2.67       3.73

X STA.        94.6      122.9      148.1      172.9      198.3      223.7
  A(I)             68.0       65.1       65.8       66.1       64.9
  V(I)             3.99       4.18       4.13       4.11       4.19

X STA.       223.7      250.0      277.9      306.3      336.2      367.0
  A(I)             65.7       68.5       68.0       69.9       70.2
  V(I)             4.14       3.97       4.00       3.89       3.87

X STA.       367.0      398.3      429.7      460.2      490.4      551.9
  A(I)             71.3       71.9       70.4       70.3       99.0
  V(I)             3.81       3.78       3.86       3.87       2.75

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW     REW     QCR
             1    2791.  478211.   435.   435.                        40102.
             2     405.   61791.    35.    41.                         7764.
             3    1805.  208090.   510.   511.                        19265.
   504.28         5000.  748092.   981.   987.  1.09  -435.   546.  61368.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

         WSEL     LEW     REW    AREA        K        Q    VEL
       504.28  -435.1   545.8  5000.5  748092.    5600.   1.12

X STA.      -435.1     -334.1     -307.5     -282.0     -255.8     -230.6
  A(I)            399.8      199.8      192.1      199.3      192.1
  V(I)             0.70       1.40       1.46       1.41       1.46

X STA.      -230.6     -204.3     -176.7     -149.0     -120.1      -90.3
  A(I)            197.2      203.1      199.7      204.3      206.3
  V(I)             1.42       1.38       1.40       1.37       1.36

X STA.       -90.3      -59.1      -26.8        7.6       25.2       54.3
  A(I)            211.3      212.8      237.3      225.4      238.3
  V(I)             1.32       1.32       1.18       1.24       1.17

X STA.        54.3       98.5      172.4      267.5      386.7      545.8
  A(I)            241.4      305.4      335.8      375.4      423.7
  V(I)             1.16       0.92       0.83       0.75       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 stow071.wsp
        Hydraulic analysis for structure STOWTH0CEM0071   Date: 18-AUG-97
        Bridge 71 on Cemetery Rd over East Branch Little R. Stowe, VT  EMB
           *** RUN DATE & TIME: 09-29-98  10:11

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     241.   20401.     0.    99.                          0.
   499.10          241.   20401.     0.    99.  1.00    -5.    39.      0.

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       499.10    -4.9    38.9   241.3   20401.    2070.   8.58

X STA.        -4.9        4.2        5.5        6.9        8.4        9.9
  A(I)            33.1        9.5        9.8       10.0        9.9
  V(I)            3.13      10.88      10.55      10.35      10.40

X STA.         9.9       11.3       12.7       14.1       15.5       16.9
  A(I)             9.8        9.9        9.9        9.8        9.9
  V(I)           10.53      10.47      10.51      10.53      10.47

X STA.        16.9       18.3       19.6       21.0       22.3       23.6
  A(I)             9.9       10.0        9.8        9.6        9.7
  V(I)           10.41      10.36      10.56      10.79      10.71

X STA.        23.6       25.0       26.2       27.6       29.0       38.9
  A(I)             9.8        9.5        9.8        9.8       31.9
  V(I)           10.61      10.94      10.53      10.60       3.25

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     180.   21587.    35.    44.                       2340.
   497.36          180.   21587.    35.    44.  1.00     0.    35.   2340.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1463.  174111.   394.   395.                      15993.
             2     291.   35745.    35.    41.                       4744.
             3     270.   11787.   327.   327.                       1391.
   501.08         2025.  221644.   757.   763.  1.14  -394.   495.  17606.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      63.

         WSEL     LEW     REW    AREA         K        Q    VEL
       501.08  -394.5   494.9  2024.5  221644.    2370.   1.17

X STA.      -394.5     -332.1     -312.5     -292.6     -273.5     -254.6
  A(I)           150.0       84.1       86.5       83.6       83.2
  V(I)            0.79       1.41       1.37       1.42       1.42

X STA.      -254.6     -235.5     -216.1     -195.8     -175.0     -152.8
  A(I)            84.5       84.1       86.0       86.2       89.3
  V(I)            1.40       1.41       1.38       1.38       1.33

X STA.      -152.8     -129.9     -105.4      -79.8      -52.3      -22.8
  A(I)            89.6       92.4       93.8       96.7       99.3
  V(I)            1.32       1.28       1.26       1.23       1.19

X STA.       -22.8        7.1       16.4       24.4       37.0      494.9
  A(I)           110.7       86.7       77.6       95.9      264.2
  V(I)            1.07       1.37       1.53       1.24       0.45
```

# 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 stow071.wsp
        Hydraulic analysis for structure STOWTH0CEM0071   Date: 18-AUG-97
        Bridge 71 on Cemetery Rd over East Branch Little R. Stowe, VT  EMB
           *** RUN DATE & TIME: 09-29-98  10:11

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

EXITX:XS   ******  -424.    5402.  0.01 *****  501.30  496.54   3770.  501.29
      -38. ******   658.  770916.  1.03 ***** *******    0.06    0.70

FULLV:FV      38.  -424.    5403.  0.01  0.00  501.30 *******   3770.  501.29
        0.    38.   658.  771204.  1.03  0.00    0.00    0.06    0.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.31

APPRO:AS      63.  -397.    2188.  0.05  0.00  501.33 *******   3770.  501.27
       63.    63.   498.  240274.  1.19  0.02    0.00    0.21    1.72
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   501.29     498.94

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =    2080.      1770.    1.18

            <<<<<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      38.     -5.     241.  0.77 *****  499.87  496.34   1696.  499.10
        0. ******    39.   20401.  1.00 ***** *******    0.53    7.03

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.94 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    43.  0.00  0.02  502.57    0.00   2080.  502.32

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    142.   127.  -110.    17.   0.5   0.3   3.3   4.2   0.5   3.0
   RT:   1939.   511.    17.   528.   1.2   0.9   4.9   4.2   1.2   3.1

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

APPRO:AS      43.  -413.    3352.  0.02  0.08  502.57  498.37   3770.  502.55
       63.    95.   516.  419317.  1.15  0.00    0.00    0.11    1.12

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -38.  -424.   658.   3770.  770916.    5402.    0.70  501.29
   FULLV:FV       0.  -424.   658.   3770.  771204.    5403.    0.70  501.29
   BRIDG:BR       0.     -5.    39.   1696.   20401.     241.    7.03  499.10
   RDWAY:RG      10.*******   142.   2080.******************    1.00  502.32
   APPRO:AS      63.  -413.   516.   3770.  419317.    3352.    1.12  502.55

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXITX:XS    496.54    0.06  490.75  512.45************  0.01  501.30  501.29
   FULLV:FV  ********    0.06  490.75  512.45  0.00  0.00  0.01  501.30  501.29
   BRIDG:BR    496.34    0.53  491.33  499.10************  0.77  499.87  499.10
   RDWAY:RG  ****************  501.09  513.08  0.00******  0.02  502.57  502.32
   APPRO:AS    498.37    0.11  491.20  512.45  0.08  0.00  0.02  502.57  502.55
```

# 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 stow071.wsp
        Hydraulic analysis for structure STOWTH0CEM0071   Date: 18-AUG-97
        Bridge 71 on Cemetery Rd over East Branch Little R. Stowe, VT  EMB
           *** RUN DATE & TIME: 09-29-98  10:11

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

EXITX:XS   ****** -445.    8655.  0.01 *****  504.25  496.95   5560.  504.24
      -38. ******   678. 1643407.  1.01 ***** *******    0.04    0.64

FULLV:FV      38.  -445.    8655.  0.01  0.00  504.25 *******   5560.  504.24
        0.    38.   678. 1643604.  1.01  0.00    0.00    0.04    0.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.45

APPRO:AS      63.  -435.    4956.  0.02  0.00  504.26 *******   5560.  504.23
       63.    63.   545.  738322.  1.09  0.01    0.00    0.09    1.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   504.24     498.94

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =    5436.      3905.    1.39

            <<<<<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      38.     -5.     241.  0.00 *****  499.10  492.71    125.  499.10
        0. ******    39.   20401.  1.00 ***** *******    0.04    0.52

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.94 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    43.  0.00  0.02  504.29    0.00   5436.  503.76

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1343.   313.  -296.    17.   1.9   1.1   3.8   3.7   1.7   2.0
   RT:   4093.   535.    17.   552.   2.7   2.3   4.1   3.4   2.8   1.6

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

APPRO:AS      43.  -435.    4996.  0.02  0.05  504.30  498.75   5560.  504.28
       63.    93.   546.  747153.  1.09  0.00    0.00    0.09    1.11

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -38.  -445.   678.   5560. 1643407.    8655.    0.64  504.24
   FULLV:FV       0.  -445.   678.   5560. 1643604.    8655.    0.64  504.24
   BRIDG:BR       0.    -5.    39.    125.   20401.     241.    0.52  499.10
   RDWAY:RG      10.******* 1343.   5436.******************    1.00  503.76
   APPRO:AS      63.  -435.   546.   5560.  747153.    4996.    1.11  504.28

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    496.95    0.04  490.75  512.45************  0.01  504.25  504.24
   FULLV:FV  ********    0.04  490.75  512.45  0.00  0.00  0.01  504.25  504.24
   BRIDG:BR    492.71    0.04  491.33  499.10************  0.00  499.10  499.10
   RDWAY:RG  ***************  501.09  513.08  0.00******  0.02  504.29  503.76
   APPRO:AS    498.75    0.09  491.20  512.45  0.05  0.00  0.02  504.30  504.28
```

# 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 stow071.wsp
        Hydraulic analysis for structure STOWTH0CEM0071   Date: 18-AUG-97
        Bridge 71 on Cemetery Rd over East Branch Little R. Stowe, VT  EMB
           *** RUN DATE & TIME: 09-29-98  10:11

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

EXITX:XS   ******  -397.    1327.  0.04 *****  497.38  496.11   2070.  497.34
      -38. ******   556.   92545.  1.16 ***** *******    0.24    1.56

FULLV:FV      38.  -397.    1344.  0.04  0.02  497.40 *******   2070.  497.36
        0.    38.   556.   94195.  1.15  0.00    0.00    0.24    1.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.86     512.45    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.86     512.45     497.86

 ===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 =   497.86     512.45     497.86

APPRO:AS      63.  -354.     440.  0.51 *****  498.37  497.86   2070.  497.86
       63.    63.    48.   26368.  1.48 ***** *******    0.95    4.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   496.95     500.38     500.48     498.94

 ===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      38.    -5.     241.  1.14 *****  500.24  496.95   2068.  499.10
        0. ******    39.   20401.  1.00 ***** *******    0.64    8.57

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.486  0.000  498.94 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      43.  -394.    2023.  0.02  0.07  501.10  497.86   2070.  501.08
       63.    79.   495.  221430.  1.14  0.24    0.00    0.12    1.02

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   501.07

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -38.  -397.   556.   2070.   92545.    1327.    1.56  497.34
   FULLV:FV       0.  -397.   556.   2070.   94195.    1344.    1.54  497.36
   BRIDG:BR       0.    -5.    39.   2068.   20401.     241.    8.57  499.10
   RDWAY:RG      10.**************      0.       0.*********    1.00********
   APPRO:AS      63.  -394.   495.   2070.  221430.    2023.    1.02  501.08

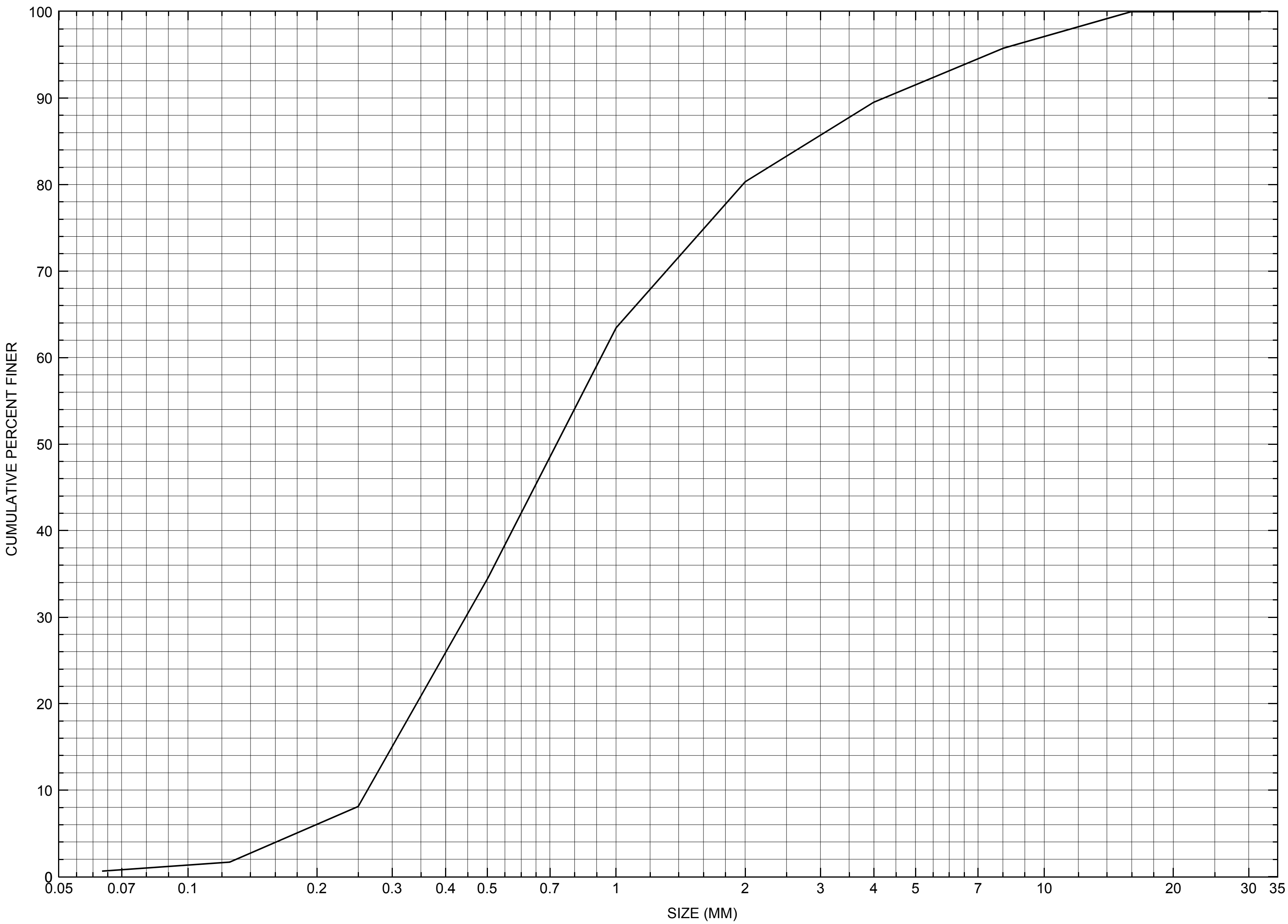
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    496.11    0.24  490.75  512.45************  0.04  497.38  497.34
   FULLV:FV  ********    0.24  490.75  512.45  0.02  0.00  0.04  497.40  497.36
   BRIDG:BR    496.95    0.64  491.33  499.10************  1.14  500.24  499.10
   RDWAY:RG  ****************  501.09  513.08************  0.02  501.12********
   APPRO:AS    497.86    0.12  491.20  512.45  0.07  0.24  0.02  501.10  501.08
  ER
```

APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for three composite sediment samples from the channel approach of structure STOWTH0CEM0071, in Stowe, Vermont.

APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number STOWTH0CEM0071

## General Location Descriptive

Data collected by *(First Initial, Full last name)* L. Medalie

Date *(MM/DD/YY)* 10 / 13 / 95

Highway District Number *(I - 2; nn)* 06

County *(FIPS county code; I - 3; nnn)* 015

Town *(FIPS place code; I - 4; nnnnn)* 70450

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

Waterway *(I - 6)* WATERBURY RIVER

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

Route Number C3CEM

Vicinity *(I - 9)* 0.18 MI TO JCT W VT100

Topographic Map Stowe

Hydrologic Unit Code: 2010003

Latitude *(I - 16; nnnn.n)* 44281

Longitude *(i - 17; nnnnn.n)* 72409

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10080800710808

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

Maximum span length *(I - 48; nnnn)* 0042

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

Structure length *(I - 49; nnnnnn)* 000044

Average daily traffic, ADT *(I - 29; nnnnnn)* 000020

Deck Width *(I - 52; nn.n)* 196

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

Channel & Protection *(I - 61; n)* 6

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

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

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

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

Structure type *(I - 43; nnn)* 504

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 43

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

Vertical clearance from streambed (*nnn.n ft*) 6.5

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

Waterway of full opening (*nnn.n ft$^2$*) 279.5

Comments:

**According to structural inspection report dated 6/7/95, the deck surface is recently paved and the superstructure consists of 3 pre-stressed channel/tee beam sections. Both "stub" abutments are protected by metal bin-walls. There are retaining walls at the wings. No undermining is noted and footings are not visible at the surface. Channel scour problems were noted in the past, but are corrected at present. Gravel bars reportedly are "normal" and debris is minor. Riprap is possibly buried or washed away.**

## Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *($mi^2$)*: 24

Terrain character: -

Stream character & type: -

Streambed material: sand

Discharge Data *(cfs)*: $Q_{2.33}$ - $Q_{10}$ 2000 $Q_{25}$ 2700

$Q_{50}$ 3300 $Q_{100}$ 3900 $Q_{500}$ -

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

Estimated Discharge *(cfs)*: - Velocity at Q 25 *(ft/s)*: 11

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*) | - | 500 | 500.7 | 501 | 501.3 |
| Velocity (*ft / sec*) | | | | | |

Long term stream bed changes:

Is the roadway overtopped below the $Q_{100}$? (*Yes, No, Unknown*): y Frequency: Q10

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

Are there other structures nearby? (*Yes, No, Unknown*): *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:
-

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 24.4 $mi^2$ Lake/pond/swamp area 0.09 $mi^2$
Watershed storage *(ST)* 0.4 %
Bridge site elevation 700 ft Headwater elevation 3620 ft
Main channel length 10.55 mi
10% channel length elevation 710 ft 85% channel length elevation 2205 ft
Main channel slope *(S)* 188.94 ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* 2.3 in
Average seasonal snowfall *(Sn)* 8.3 ft

## Bridge Plan Data

Are plans available? Y *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:

**BM#1, S.I.T. 8” W.B. (tree?), assumed el=500’ in wooded brush approx. 100’ left of bridge, 30’ DS of road**
**BM#2 S.I.P. #6/5 (power pole?), assumed el=500.17 in lawn upstream (120’) of road, 100’ from right bank**

Reference Point (*MSL, Arbitrary, Other*): **Arbitrary**    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? ____ *If no, type ctrl-n bi*    Number of borings taken: ____

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

Briefly describe material at foundation bottom elevation or around piles:

**There are bonded metal Bin type retaining walls at both abutments. See photocopy of plans.**

Comments:

-

## Cross-sectional Data

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

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

Comments: **The following are data for the bridge section at this site in the Flood Insurance Study for the Town of Stowe, VT. The elevations are based on the NGVD of 1929.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | **0** | **12** | **25** | | | | | | | | |
| Feature | **LAB** | **-** | **RAB** | | | | | | | | |
| Low chord elevation | **702.3** | **-** | **702.3** | | | | | | | | |
| Bed elevation | **693.0** | **690.9** | **690.4** | | | | | | | | |
| Low chord to bed | **9.3** | **-** | **11.9** | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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: EW Date: 10/28/96
Computerized by: EW Date: 10/28/96
Reviewd by: EMB Date: 7/9/98

# Structure Number STOWTH0CEM0071

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 07 / 09 / 1996

2. Highway District Number 06 Mile marker 000000

County LAMOILLE (015) Town STOWE (70450)

Waterway *(I - 6)* Little River (Waterbury River) Road Name Cemetary Road

Route Number -- Hydrologic Unit Code: 02010003

3. Descriptive comments:

**This bridge is located 0.18 mile from the intersection with VT 100. The deck is paved and the abutments are protected by a metal-bin wall.**

## B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 5 LBDS 5 RBDS 4 Overall 4

*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US 1 UB 1 DS 1 *(**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 44 *(feet)* Span length 42 *(feet)* Bridge width 19.6 *(feet)*

### Road approach to bridge:

8. LB 0 RB 0 *( **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 --:1 US right --:1

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

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

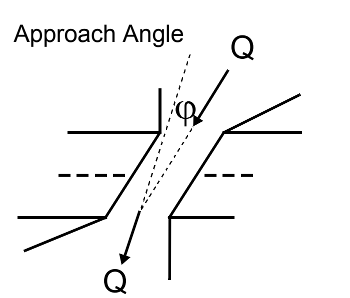
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

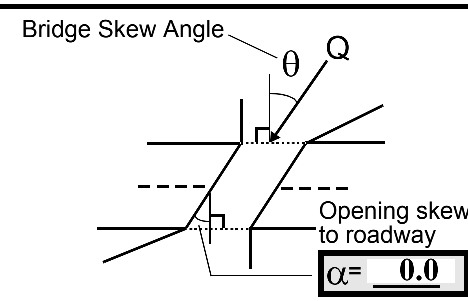
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

### Channel approach to bridge (BF):

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




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

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

Range? 5 feet DS *(US, UB, DS)* to 90 feet DS

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

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

Range? 170 feet US *(US, UB, DS)* to 70 feet US

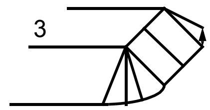
*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: 1b

1a- Vertical abutments with wingwalls

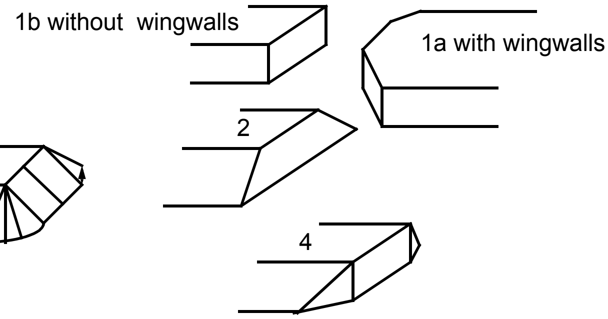
1b- Vertical abutments without wingwalls

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: RBUS - There is also lawn and trees on the overbank (refer to sketch).**

**7: The measured values of the bridge dimensions at the time of the site visit were: 1) bridge width = 19.5 feet; 2) span length = 35.4 feet; and 3) bridge length = 46 feet.**

**11: There is no protection for the road embankment along the downstream right edge with the exception of 4 square feet of dumped concrete 3 feet from the road and 15 feet from the stream.**
**The downstream left bank road protection is 2 large stones (12 inches each) set within gravel.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 44.0 | 6.5 | | | 6.0 | 3 | 3 | 2 | 2 | 1 | 1 |

23. Bank width 35.0 24. Channel width 40.0 25. Thalweg depth 35.5 29. Bed Material 2

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

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

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

**Right bank protection extends from 45 feet upstream to 0 feet upstream.**

**Left bank protection extends from 150 feet upstream to 0 feet upstream. Left bank protection is larger material (3 feet) from 10 feet upstream to 0 feet upstream. The other protection material present along the left bank is smaller (1-2 feet).**

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 110 35. Mid-bar width: 6

36. Point bar extent: 125 feet US (US, UB) to 85 feet US (US, UB, DS) positioned 75 %LB to 95 %RB

37. Material: 23

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

**Point bar is entirely submerged and fairly indistinct.**

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: 150 42. Cut bank extent: 170 feet US (US, UB) to 70 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.):

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 135

47. Scour dimensions: Length 30 Width 8 Depth : 1 Position 10 %LB to 45 %RB

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

**Higher water velocities are present along the left side.**

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

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

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

54. Confluence comments (eg. confluence name):

**NO MAJOR CONFLUENCES**

## D. Under Bridge Channel Assessment

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

| 56. Height (BF) LB | 56. Height (BF) RB | 57 Angle (BF) LB | 57 Angle (BF) RB | 61. Material (BF) LB | 61. Material (BF) RB | 62. Erosion (BF) LB | 62. Erosion (BF) RB |
|---|---|---|---|---|---|---|---|
| 22.0 | | 2.0 | | 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.):

**2**

**Abutment protection consists of four, 18 inch rocks on the right abutment near the midpoint of the wall.**

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

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

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

70. Debris and Ice Comments:

**2**

**66: Minor debris is present between the bridge seat and abutments upstream.**

**68/69: Low gradient channel and low clearance from streambed.**

| Abutments | 71. Attack ∠(BF) | 72. Slope ∠ (Qmax) | 73. Toe loc. (BF) | 74. Scour Condition | 75. Scour depth | 76. Exposure depth | 77. Material | 78. Length |
|---|---|---|---|---|---|---|---|---|
| LABUT | | 0 | 90 | 2 | 0 | - | - | 90.0 |
| RABUT | 3 | 10 | 90 | | | 2 | 0 | 41.5 |

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

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

**-**

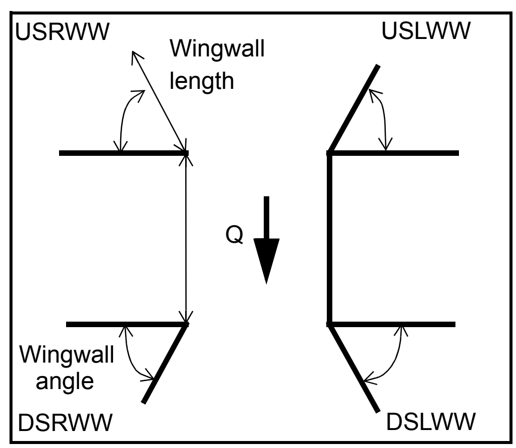
**-**

**3**

**Silt and sand from the streambed has accumulated in front of both abutment faces. Range pole could penetrate into this sand at 45 degrees before hitting footings.**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 41.5 | |
| USRWW: | N | | - | | - | 1.5 | |
| DSLWW: | - | | - | | N | 20.0 | |
| DSRWW: | - | | - | | - | 20.5 | |




*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 | - | - | - | 1 | 1 |
| Condition | N | - | - | - | - | - | 4 | 4 |
| Extent | - | - | - | - | - | 2 | 2 | - |

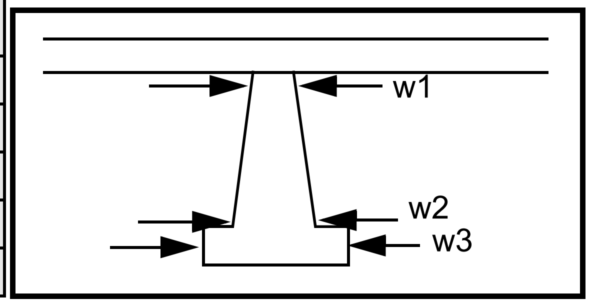
*Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee*
*Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed*
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

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

## Piers:

84. Are there piers? His (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) | torical | e are | h | plate | LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP |
| 87. Type | form | meta | exte | exte | 1- Solid pier, 2- column, 3- bent |
| 88. Material | notes | l cor- | nd | nds 5 | 1- Wood; 2- concrete; 3- metal; 4- stone |
| 89. Shape | retai | ruga | 90 | feet | 1- Round; 2- Square; 3- Pointed |
| 90. Inclined? | ner | ted | degr | back | Y- yes; N- no |
| 91. Attack ∠ (BF) | walls | plate | ees | from | |
| 92. Pushed | at | s like | from | abut | LB or RB |
| 93. Length (feet) | - | - | - | - | |
| 94. # of piles | the | the | abut | ment | |
| 95. Cross-members | wing | abut | ment | faces | 0- none; 1- laterals; 2- diagonals; 3- both |
| 96. Scour Condition | walls | ment | faces | , | 0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed |
| 97. Scour depth | . | faces | . | exce | |
| 98. Exposure depth | Thes | whic | Each | pt | |

99. Pier comments (eg. undermined penetration, protection and protection extent, unusual scour processes, etc.):
**for the downstream left plate which is 6 feet long.**

**LABUT protection consists of a rock at the upstream end.**
**RABUT protection consists of only 4 stones in the center of the abutment.**

**N**

## E. Downstream Channel Assessment

100.

| SRD | Bank height (BF) LB | Bank height (BF) RB | Bank angle (BF) LB | Bank angle (BF) RB | % Veg. cover (BF) LB | % Veg. cover (BF) RB | Bank material (BF) LB | Bank material (BF) RB | Bank erosion (BF) LB | Bank erosion (BF) RB |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | - | - | - | - | - | - |

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

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

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

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

101. Is a drop structure present? - *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet
103. Drop: - feet 104. Structure material: - *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*
105. Drop structure comments (eg. downstream scour depth):
-
-
-
-
-
-

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

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

Material: -

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

-
-
-
-

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

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

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

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

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

Scour dimensions: Length 2 Width 21 Depth: 21 Positioned 1 %LB to 1 %RB

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

**23**
**2**
**2**
**1**

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

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

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

Confluence comments (eg. confluence name):

**extends from 0 feet downstream to 100 feet downstream.**
**Left bank protection extends from 0 feet downstream to 50 feet downstream.**

## 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)*:

**The bed material is mostly sand. Some gravel is present along the thalweg, beginning 60 feet downstream and extending further downstream.**

**N**

## 109. G. Plan View Sketch

-

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

APPENDIX F:

# SCOUR COMPUTATIONS

# SCOUR COMPUTATIONS

| | | | |
|---|---|---|---|
| Structure Number: | STOWTH0CEM0071 | Town: | Stowe |
| Road Number: | Cemetary Road | County: | Lamoille |
| Stream: | East Branch Little River | | |

Initials EMB      Date:    8/20/98  Checked: RF

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 Davis, 1995, p. 28, eq. 16)

Approach Section

| Characteristic | 100 yr | 500 yr | other Q |
|---|---|---|---|
| Total discharge, cfs | 4000 | 5600 | 2370 |
| Main Channel Area, ft2 | 343 | 405 | 291 |
| Left overbank area, ft2 | 2057 | 2791 | 1463 |
| Right overbank area, ft2 | 952 | 1805 | 270 |
| Top width main channel, ft | 35 | 35 | 35 |
| Top width L overbank, ft | 413 | 435 | 394 |
| Top width R overbank, ft | 480 | 510 | 327 |
| D50 of channel, ft | 0.00238 | 0.00238 | 0.00238 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 9.8 | 11.6 | 8.3 |
| y1, average depth, LOB, ft | 5.0 | 6.4 | 3.7 |
| y1, average depth, ROB, ft | 2.0 | 3.5 | 0.8 |
| Total conveyance, approach | 419347 | 748092 | 221644 |
| Conveyance, main channel | 47006 | 61791 | 35745 |
| Conveyance, LOB | 297748 | 478211 | 174111 |
| Conveyance, ROB | 74594 | 208090 | 11787 |
| Percent discrepancy, conveyance | -0.0002 | 0.0000 | 0.0005 |
| Qm, discharge, MC, cfs | 448.4 | 462.5 | 382.2 |
| Ql, discharge, LOB, cfs | 2840.1 | 3579.7 | 1861.7 |
| Qr, discharge, ROB, cfs | 711.5 | 1557.7 | 126.0 |
| Vm, mean velocity MC, ft/s | 1.3 | 1.1 | 1.3 |
| Vl, mean velocity, LOB, ft/s | 1.4 | 1.3 | 1.3 |
| Vr, mean velocity, ROB, ft/s | 0.7 | 0.9 | 0.5 |
| Vc-m, crit. velocity, MC, ft/s | 2.2 | 2.3 | 2.1 |
| 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 |

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 | 1696 | 125 | 2070 |
| Main channel area (DS), ft2 | 241.3 | 241.3 | 180 |
| Main channel width (normal), ft | 34.6 | 34.6 | 34.6 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 34.6 | 34.6 | 34.6 |
| D90, ft | 0.0145 | 0.0145 | 0.0145 |
| D95, ft | 0.0247 | 0.0247 | 0.0247 |
| Dc, critical grain size, ft | 0.0662 | 0.0004 | 0.1899 |
| Pc, Decimal percent coarser than Dc | 0.000 | 0.000 | 0.000 |
| Depth to armoring, ft | N/A | N/A | N/A |

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and Davis, 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 | 4000 | 5600 | 2370 | 1696 | 125 | 2070 |
| Total conveyance | 419347 | 748092 | 221644 | 20401 | 20401 | 20401 |
| Main channel conveyance | 47006 | 61791 | 35745 | 20401 | 20401 | 20401 |
| Main channel discharge | 448 | 463 | 382 | 1696 | 125 | 2070 |
| Area - main channel, ft2 | 343 | 405 | 291 | 241.3 | 241.3 | 241.3 |
| (W1) channel width, ft | 35 | 35 | 35 | 34.6 | 34.6 | 34.6 |
| (Wp) cumulative pier width, ft | 0 | 0 | 0 | 0 | 0 | 0 |
| W1, adjusted bottom width(ft) | 35 | 35 | 35 | 34.6 | 34.6 | 34.6 |
| D50, ft | 0.00238 | 0.00238 | 0.00238 | | | |
| w, fall velocity, ft/s (p. 32) | 0.364 | 0.364 | 0.364 | | | |
| y, ave. depth flow, ft | 9.80 | 11.57 | 8.31 | 6.97 | 6.97 | 6.97 |
| S1, slope EGL | 0.00048 | 0.00016 | 0.0154 | | | |
| P, wetted perimeter, MC, ft | 41 | 41 | 41 | | | |
| R, hydraulic Radius, ft | 8.366 | 9.878 | 7.098 | | | |
| V*, shear velocity, ft/s | 0.360 | 0.226 | 1.876 | | | |
| V*/w | 0.988 | 0.620 | 5.154 | | | |
| 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 | 0.69 | | | |
| y2,depth in contraction, ft | 30.88 | 3.80 | 35.66 | | | |
| ys, scour depth, ft (y2-y_bridge) | 23.91 | -3.18 | 28.68 | | | |

Clear Water Contraction Scour in MAIN CHANNEL

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

| Bridge Section | Q100 | Q500 | Other Q |
|---|---|---|---|
| (Q) total discharge, cfs | 4000 | 5600 | 2370 |
| (Q) discharge thru bridge, cfs | 1696 | 125 | 2070 |
| Main channel conveyance | 20401 | 20401 | 20401 |
| Total conveyance | 20401 | 20401 | 20401 |
| Q2, bridge MC discharge,cfs | 1696 | 125 | 2070 |
| Main channel area, ft2 | 241 | 241 | 241 |
| Main channel width (normal), ft | 34.6 | 34.6 | 34.6 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 34.6 | 34.6 | 34.6 |
| y_bridge (avg. depth at br.), ft | 6.97 | 6.97 | 6.97 |
| Dm, median (1.25*D50), ft | 0.002975 | 0.002975 | 0.002975 |
| y2, depth in contraction,ft | 18.34 | 1.96 | 21.75 |
| ys, scour depth (y2-ybridge), ft | 11.36 | -5.01 | 14.78 |

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 Davis, 1995, p. 144-146)
```

| | Q100 | Q500 | OtherQ |
|---|---|---|---|
| Q, total, cfs | 4000 | 5600 | 2370 |
| Q, thru bridge MC, cfs | 1696 | 125 | 2070 |
| Vc, critical velocity, ft/s | 2.19 | 2.25 | 2.13 |
| Va, velocity MC approach, ft/s | 1.31 | 1.14 | 1.31 |
| Main channel width (normal), ft | 34.6 | 34.6 | 34.6 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 34.6 | 34.6 | 34.6 |
| qbr, unit discharge, ft2/s | 49.0 | 3.6 | 59.8 |
| Area of full opening, ft2 | 241.3 | 241.3 | 241.3 |
| Hb, depth of full opening, ft | 6.97 | 6.97 | 6.97 |
| Fr, Froude number, bridge MC | 0.53 | 0.04 | 0.64 |
| Cf, Fr correction factor (<=1.0) | 1.00 | 0.38 | 1.00 |
| **Area at downstream face, ft2 | N/A | N/A | 180 |
| **Hb, depth at downstream face, ft | N/A | N/A | 5.20 |
| **Fr, Froude number at DS face | ERR | ERR | 0.89 |
| **Cf, for downstream face (<=1.0) | N/A | N/A | 1.00 |
| Elevation of Low Steel, ft | 498.94 | 498.94 | 498.94 |
| Elevation of Bed, ft | 491.97 | 491.97 | 491.97 |
| Elevation of Approach, ft | 502.55 | 504.28 | 501.08 |
| Friction loss, approach, ft | 0.08 | 0.05 | 0.07 |
| Elevation of WS immediately US, ft | 502.47 | 504.23 | 501.01 |
| ya, depth immediately US, ft | 10.50 | 12.26 | 9.04 |
| Mean elevation of deck, ft | 501.86 | 501.86 | 501.86 |
| w, depth of overflow, ft (>=0) | 0.61 | 2.37 | 0.00 |
| Cc, vert contrac correction (<=1.0) | 0.91 | 0.91 | 0.94 |
| **Cc, for downstream face (<=1.0) | ERR | ERR | 0.829017 |
| | | | |
| Ys, scour w/Chang equation, ft | 17.62 | -2.28 | 23.05 |
| Ys, scour w/Umbrell equation, ft | 1.21 | 0.91 | 0.47 |

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

| | | | |
|---|---|---|---|
| **Ys, scour w/Chang equation, ft | N/A | N/A | 28.67 |
| **Ys, scour w/Umbrell equation, ft | N/A | N/A | 2.24 |

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 | 21.75 |
| WSEL at downstream face, ft | -- | -- | 497.36 |
| Depth at downstream face, ft | N/A | N/A | 5.20 |
| Ys, depth of scour (Laursen), ft | N/A | ERR | 16.55 |

## Abutment Scour

### Froehlich's Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1

(Richardson and Davis, 1995, p. 48, eq. 28)

| Characteristic | Left Abutment 100 yr Q | Left Abutment 500 yr Q | Left Abutment Other Q | Right Abutment 100 yr Q | Right Abutment 500 yr Q | Right Abutment Other Q |
|---|---|---|---|---|---|---|
| (Qt), total discharge, cfs | 4000 | 5600 | 2370 | 4000 | 5600 | 2370 |
| a', abut.length blocking flow, ft | 329.2 | 420.7 | 301.9 | 227 | 227 | 227 |
| Ae, area of blocked flow ft2 | 1802.63 | 2745.67 | 1193.53 | 618 | 1023.09 | 282.5 |
| Qe, discharge blocked abut.,cfs | -- | -- | -- | -- | -- | 141.1 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 1.38 | 1.28 | 1.27 | 0.75 | 0.86 | 0.50 |
| ya, depth of f/p flow, ft | 5.48 | 6.53 | 3.95 | 2.72 | 4.51 | 1.24 |
| --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 | 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 | 0.108 | 0.089 | 0.116 | 0.093 | 0.080 | 0.079 |
| ys, scour depth, ft | 24.09 | 26.84 | 19.51 | 12.45 | 16.33 | 6.87 |

### HIRE equation (a'/ya > 25)

ys = 4*Fr^0.33*y1*K/0.55

(Richardson and Davis, 1995, p. 49, eq. 29)

| | | | | | | |
|---|---|---|---|---|---|---|
| a'(abut length blocked, ft) | 329.2 | 420.7 | 301.9 | 227 | 227 | 227 |
| y1 (depth f/p flow, ft) | 5.48 | 6.53 | 3.95 | 2.72 | 4.51 | 1.24 |
| a'/y1 | 60.12 | 64.46 | 76.36 | 83.38 | 50.37 | 182.40 |
| Skew correction (p. 49, fig. 16) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Froude no. f/p flow | 0.11 | 0.09 | 0.12 | 0.09 | 0.08 | 0.08 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | 19.11 | 21.36 | 14.12 | 9.04 | 14.24 | 3.91 |
| vertical w/ ww's | 15.67 | 17.52 | 11.58 | 7.41 | 11.68 | 3.21 |
| spill-through | 10.51 | 11.75 | 7.77 | 4.97 | 7.83 | 2.15 |

## Abutment riprap Sizing

### Isbash Relationship

D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)

(Richardson and Davis, 1995, p112, eq. 81,82)

| Characteristic | Q100 | Q500 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 0.53 | 0.04 | 0.64 | 0.53 | 0.04 | 0.64 |
| y, depth of flow in bridge, ft | 6.97 | 6.97 | 5.20 | 6.97 | 6.97 | 5.20 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | 1.21 | 0.01 | 1.32 | 1.21 | 0.01 | 1.32 |
| Fr>0.8 (vertical abut.) | ERR | ERR | ERR | ERR | ERR | ERR |