# LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (MNTPTH00CU0013) on CUMMINGS STREET, crossing the NORTH BRANCH WINOOSKI RIVER, MONTPELIER, VERMONT

Open-File Report 98-550

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 13 (MNTPTH00CU0013) on CUMMINGS STREET, crossing the NORTH BRANCH WINOOSKI RIVER, MONTPELIER, VERMONT

By RONDA L. BURNS and ROBERT FLYNN

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**Pembroke, New Hampshire**

**1998**

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

U.S. GEOLOGICAL SURVEY
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Denver, CO 80225-0286

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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 13 (MNTPTH00CU0013) ON CUMMINGS STREET, CROSSING THE NORTH BRANCH WINOOSKI RIVER, MONTPELIER, VERMONT

*By* **Ronda L. Burns and Robert Flynn**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MNTPTH00CU0013 on Cummings Street crossing the North Branch Winooski River, Montpelier, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in north-central Vermont. The 76.5-mi$^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream of the bridge and shrub and brushland downstream of the bridge.

In the study area, the North Branch Winooski River has an incised, sinuous channel with a slope of approximately 0.0002 ft/ft, an average channel top width of 114 ft and an average bank height of 5 ft. The channel bed material ranges from organics to silt and clay with a median grain size ($D_{50}$) of 1.28 mm (0.0042 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 15, 1996, indicated that the reach was stable.

The Cummings Street crossing of the North Branch Winooski River is a 64-ft-long, two-lane bridge consisting of one 61-foot steel-beam span (Vermont Agency of Transportation, written communication, October 13, 1995). The opening length of the structure parallel to the bridge face is 59.0 ft. The bridge is supported by vertical, concrete abutments with wingwalls on the upstream right and the downstream left corners of the structure. The channel is not skewed to the opening and the opening-skew-to-roadway is zero degrees.

A scour hole 8 ft deeper than the mean thalweg depth was observed along the right side of the channel under the bridge during the Level I assessment. The scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the upstream left bank, the downstream left wingwall, and the right abutment. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. 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 0.9 to 1.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.1 to 18.3 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results." Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and 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.

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

**NORTH**

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

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

# LEVEL II SUMMARY

***Structure Number*** MNTPTH00CU0013 ***Stream*** North Branch Winooski River

***County*** Washington ***Road*** Cummings St. ***District*** 6

## Description of Bridge

***Bridge length*** 64 ***ft*** ***Bridge width*** 19.1 ***ft*** ***Max span length*** 61 ***ft***

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

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

***Stone fill on abutment?*** Yes ***Date of inspection*** 7/15/96

***Description of stone fill*** Type-2, along the right abutment and downstream left wingwall.

Abutments and wingwalls are concrete.

***Brief description of piers/abutments***

No

***Is bridge skewed to flood flow according to*** The ***survey?*** Yes ***Angle*** 0

channel makes a slight bend 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*** | 7/15/96 | 0 | 0 |
| ***Level II*** | 7/15/96 | 0 | 0 |

***Potential for debris*** Low.

None as of 7/15/96.

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

## Description of the Geomorphic Setting

***General topography*** The channel is located in a low relief valley with a narrow flood plain.

7/15/96

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

***Date of inspection*** Moderately

***DS left:*** sloped channel bank and overbank

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

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

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

## Description of the Channel

***Average top width*** 114 ***ft*** ***Average depth*** 5 ***ft***

***Predominant bed material*** Organics/Silt/Clay ***Bank material*** Organics/Silt/Clay

Sinuous but stable

with semi-alluvial channel boundaries and narrow point bars.

7/15/96

***Vegetative co*** Shrubs and brush

***DS left:*** Shrubs and brush

***DS right:*** Grass

***US left:*** Grass

***US right:*** Yes

***Do banks appear stable?***

***date of observation.***

There is a dam

approximately 2,500 ft downstream, as observed on 7/15/96.

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

## Hydrology

***Drainage area*** 76.5 ***mi²***

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

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

***Is drainage area considered rural or urban?*** Rural ***Describe any significant urbanization***: There are houses on the upstream and downstream right overbanks and on the upstream left overbank.

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

***USGS gage description*** North Branch Winooski River at Wrightsville, VT

***USGS gage number*** 04285500

***Gage drainage area*** 69.2 ***mi²***

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

### Calculated Discharges

***Q100*** 2,000 ***ft³/s*** ***Q500*** 2,830 ***ft³/s***

The 100- and 500-year discharges are flood frequency estimates for the North Branch Winooski River at the confluence with the Winooski River documented in the Flood Insurance Study for the City of Montpelier (FEMA, 1981). These 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). 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 406.3 ft from the USGS arbitrary survey datum to obtain the VTAOT plans' datum. Add 35.5 ft to the USGS arbitrary survey datum to obtain the National Geodetic Vertical Datum of 1929..

***Description of reference marks used to determine USGS datum.*** RM1 is the top of a hydrant on the west side of Elm Street at the corner of Cummings Street and Elm Street (elev. 507.34 ft, arbitrary survey datum). RM2 is a nail, 1.25 ft above the ground, in an utility pole on the upstream left overbank (elev. 500.29 ft, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

[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 0.030 to 0.048, and overbank "n" values ranged from 0.040 to 0.060.

At the exit section (EXITX), the starting water surface was obtained from the flood profiles presented in the Flood Insurance Study for the City of Montpelier (Federal Emergency Management Agency, 1981). Section G in the Flood Insurance Study was assumed to be at the same location as the exit section surveyed for this analysis.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0083 ft/ft) to establish the modelled approach section (APPR1), 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.

## Bridge Hydraulics Summary

*Average bridge embankment elevation* 504.7 *ft*
*Average low steel elevation* 497.7 *ft*

*100-year discharge* 2,000 *ft³/s*
*Water-surface elevation in bridge opening* 493.1 *ft*
*Road overtopping?* No *Discharge over road* -- *ft³/s*
*Area of flow in bridge opening* 473 *ft²*
*Average velocity in bridge opening* 4.2 *ft/s*
*Maximum WSPRO tube velocity at bridge* 5.5 *ft/s*

*Water-surface elevation at Approach section with bridge* 493.4
*Water-surface elevation at Approach section without bridge* 493.3
*Amount of backwater caused by bridge* 0.1 *ft*

*500-year discharge* 2,830 *ft³/s*
*Water-surface elevation in bridge opening* 494.1 *ft*
*Road overtopping?* No *Discharge over road* -- *ft³/s*
*Area of flow in bridge opening* 528 *ft²*
*Average velocity in bridge opening* 5.4 *ft/s*
*Maximum WSPRO tube velocity at bridge* 6.9 *ft/s*

*Water-surface elevation at Approach section with bridge* 494.6
*Water-surface elevation at Approach section without bridge* 494.3
*Amount of backwater caused by bridge* 0.3 *ft*

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

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

## Scour Analysis Summary

### Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year and 500-year discharges was computed by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p. 30, equation 17). Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

## Scour Results

| Contraction scour: | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| | *(Scour depths in feet)* | | |
| ***Main channel*** | | | |
| *Live-bed scour* | 0.9 | 1.7 | -- |
| *Clear-water scour* | -- | -- | -- |
| *Depth to armoring* | N/A | N/A | -- |
| ***Left overbank*** | -- | -- | -- |
| ***Right overbank*** | -- | -- | -- |

| Local scour: | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| ***Abutment scour*** | | | |
| *Left abutment* | 8.1 | 9.9 | -- |
| *Right abutment* | 15.5 | 18.3 | -- |
| ***Pier scour*** | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |
| *Pier 3* | -- | -- | -- |

## Riprap Sizing

| | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| | | *($D_{50}$ in feet)* | |
| ***Abutments:*** | | | |
| *Left abutment* | 0.5 | 0.7 | -- |
| *Right abutment* | 0.5 | 0.7 | -- |
| ***Piers:*** | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

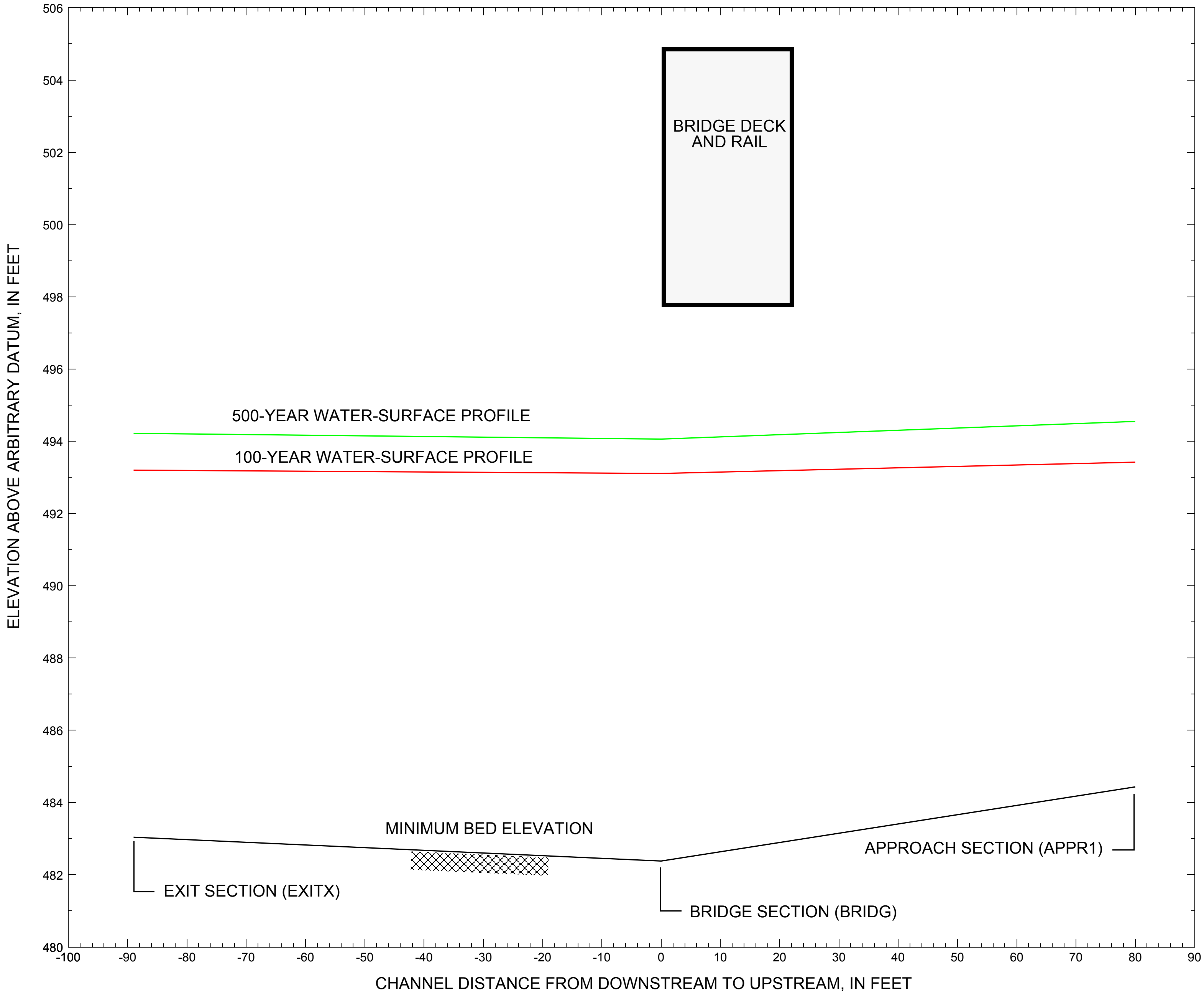



Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure MNTPTH00CU0013 on Cummings Street, crossing the North Branch Winooski River, Montpelier, Vermont.

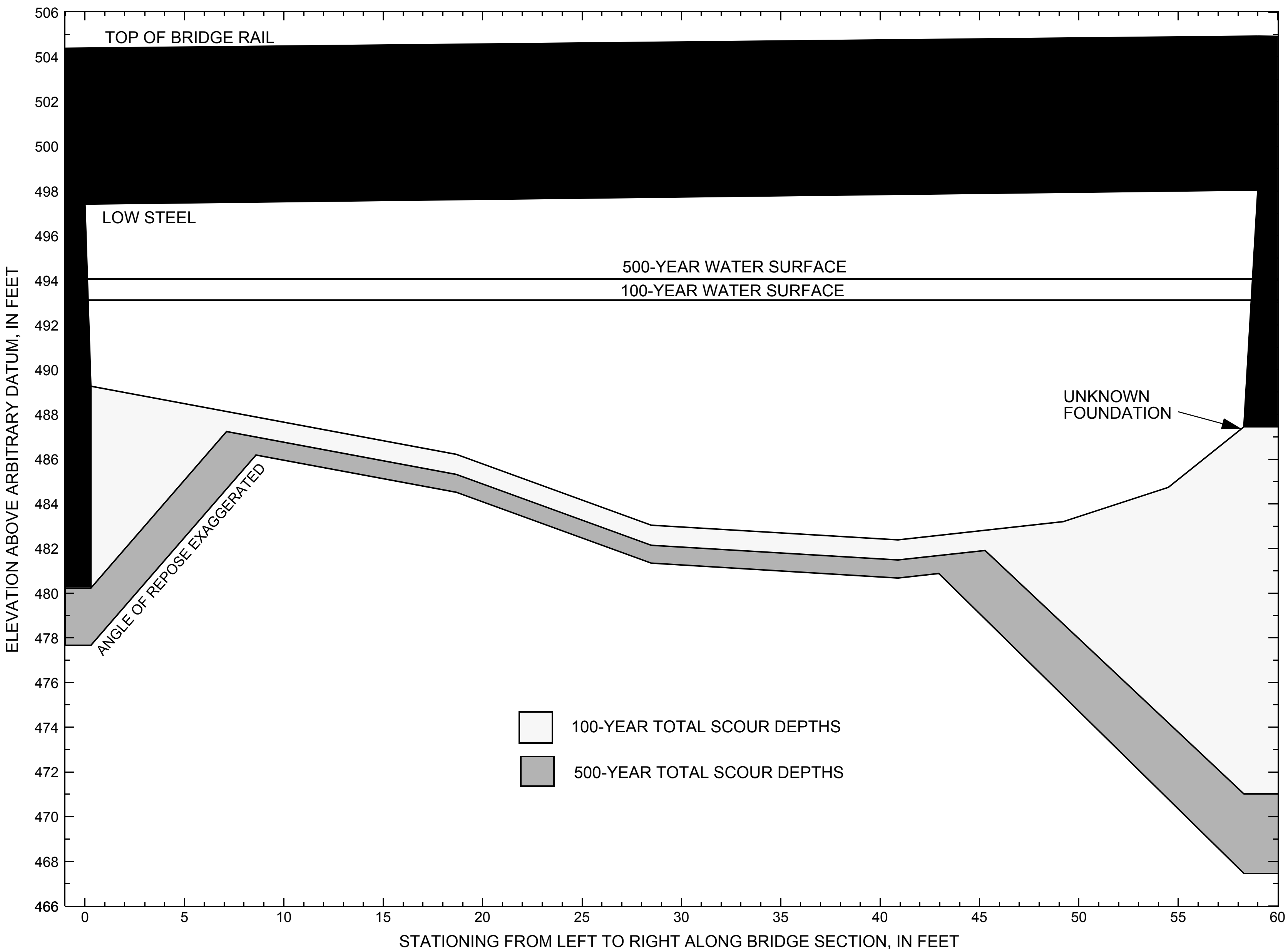



Figure 8. Scour elevations for the 100- and 500-year discharges at structure MNTPTH00CU0013 on Cummings Street, crossing the North Branch Winooski River, Montpelier, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure MNTPTH00CU0013 on Cummings Street, crossing the North Branch Winooski River, Montpelier, 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 2,000 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 91.3 | 497.4 | 480.3 | 489.3 | 0.9 | 8.1 | -- | 9.0 | 480.3 | 0.0 |
| Right abutment | 59.0 | 91.8 | 498.0 | -- | 487.4 | 0.9 | 15.5 | -- | 16.4 | 471.0 | -- |

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 MNTPTH00CU0013 on Cummings Street, crossing the North Branch Winooski River, Montpelier, 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 2,830 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 91.3 | 497.4 | 480.3 | 489.3 | 1.7 | 9.9 | -- | 11.6 | 477.7 | -2.6 |
| Right abutment | 59.0 | 91.8 | 498.0 | -- | 487.4 | 1.7 | 18.3 | -- | 20.0 | 467.4 | -- |

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

# SELECTED REFERENCES


Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Emergency Management Agency, 1981, Flood Insurance Study, City of Montpelier, Washington County, Vermont: Washington, D.C., August 17, 1981.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158.

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Geological Survey, 1968, Montpelier, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

# WSPRO INPUT FILE

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File mntp013.wsp
T2        Hydraulic analysis for structure MNTPTH00CU0013   Date: 10-JUN-98
T3        CUMMINGS ST CROSSING THE N. BR. WINOOSKI RIVER IN MONTPELIER, VT   RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2000.0   2830.0
WS          493.20   494.22
*
XS   EXITX    -89           0.
GR         -320.7, 506.04   -265.8, 501.58   -183.4, 497.36
GR         -165.2, 496.54   -112.0, 493.41    -82.1, 495.26    -61.2, 492.08
GR          -29.6, 491.00     -2.8, 491.90      0.0, 490.49      0.0, 489.64
GR           16.5, 488.82     22.0, 487.01     28.8, 484.61     40.1, 483.07
GR           49.5, 483.04     65.1, 483.23     79.7, 486.08     88.8, 489.87
GR           88.9, 490.63     89.9, 491.93     99.4, 492.28    107.9, 494.05
GR          139.2, 494.00    176.4, 496.49    193.2, 499.45
*
N           0.054         0.040         0.058
SA                  -2.8         107.9
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.73       0.0
GR            0.0, 497.41      0.0, 497.32      0.2, 490.61      0.3, 489.26
GR            4.2, 488.61     18.7, 486.21     28.5, 483.04     40.9, 482.38
GR           49.2, 483.20     54.5, 484.74     58.3, 487.44     58.4, 490.61
GR           58.9, 497.94     59.0, 498.04      0.0, 497.41
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      26.9 * *     14.4     16.1
N           0.030
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      19.1     1
GR         -320.7, 506.04   -265.8, 501.58   -183.4, 497.36   -168.5, 498.00
GR         -126.8, 498.19    -40.6, 499.68     -2.0, 500.60     -1.9, 501.31
GR           -1.4, 501.35     -1.3, 504.33      0.0, 504.39     59.7, 504.93
GR           61.4, 504.86     61.4, 501.96     62.0, 501.96     62.2, 501.73
GR           89.4, 500.40     93.8, 499.57    158.4, 497.86    212.4, 498.77
GR          269.6, 502.70    298.7, 503.52    383.8, 511.02    403.3, 512.51
GR          435.6, 514.10
*
XT   APTEM     93           0.
GR         -309.7, 505.78   -187.2, 498.66   -163.7, 498.28   -148.4, 498.18
GR          -80.8, 499.77    -14.4, 498.47     -8.0, 494.89     -7.0, 490.57
GR            0.0, 488.72     17.7, 488.61     31.9, 486.88     44.9, 485.95
GR           62.5, 484.54     74.2, 485.68     83.6, 488.13     89.4, 490.43
GR          106.5, 490.57    114.0, 494.11    115.7, 496.16    149.9, 498.01
GR          184.8, 497.68    252.2, 497.93    277.6, 502.10    316.4, 504.35
*
AS   APPR1     80  * * *   0.0083
GT
N           0.040         0.048         0.060
SA                  -14.4         149.9
*
HP 1 BRIDG  493.11 1 493.11
HP 2 BRIDG  493.11 * * 2000
HP 1 APPR1  493.42 1 493.42
HP 2 APPR1  493.42 * * 2000
*
```

# APPENDIX B:

# **WSPRO OUTPUT FILE**

```
       U.S. Geological Survey WSPRO Input File mntp013.wsp
       Hydraulic analysis for structure MNTPTH00CU0013   Date: 10-JUN-98
       CUMMINGS ST CROSSING THE N. BR. WINOOSKI RIVER IN MONTPELIER, VT   RLB
          *** RUN DATE & TIME: 07-02-98  11:34

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

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     473.  84387.    58.    69.                        7632.
  493.11          473.  84387.    58.    69.  1.00     0.    59.   7632.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      493.11     0.1    58.6   472.9   84387.    2000.   4.23

X STA.        0.1       12.8       17.0       20.5       23.3       25.6
  A(I)            61.5       26.1       24.6       22.0       20.9
  V(I)            1.63       3.83       4.07       4.54       4.79

X STA.       25.6       27.7       29.6       31.4       33.2       35.0
  A(I)            19.4       18.9       19.0       18.6       18.2
  V(I)            5.16       5.29       5.27       5.38       5.50

X STA.       35.0       36.8       38.6       40.4       42.2       44.0
  A(I)            18.9       19.1       19.5       18.6       19.2
  V(I)            5.29       5.24       5.13       5.38       5.20

X STA.       44.0       45.8       47.7       49.7       51.8       58.6
  A(I)            18.8       19.2       19.4       19.8       51.4
  V(I)            5.32       5.22       5.16       5.04       1.95

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      80.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            2     681.  65562.   120.   125.                        9190.
  493.42          681.  65562.   120.   125.  1.00    -8.   113.   9190.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      80.

        WSEL     LEW     REW    AREA        K        Q    VEL
      493.42    -7.7   112.8   681.1   65562.    2000.   2.94

X STA.       -7.7        5.7       13.5       20.9       26.8       31.7
  A(I)            55.7       38.2       36.9       33.0       31.0
  V(I)            1.80       2.62       2.71       3.03       3.23

X STA.       31.7       36.1       40.2       44.1       47.8       51.4
  A(I)            30.3       28.7       29.0       28.2       28.4
  V(I)            3.30       3.48       3.44       3.54       3.52

X STA.       51.4       54.7       57.9       60.9       63.9       66.9
  A(I)            27.6       26.8       26.8       26.2       26.4
  V(I)            3.62       3.73       3.73       3.82       3.78

X STA.       66.9       70.1       73.5       77.3       82.1      112.8
  A(I)            27.1       27.3       28.2       30.8       94.3
  V(I)            3.69       3.67       3.55       3.25       1.06
```

```
        U.S. Geological Survey WSPRO Input File mntp013.wsp
        Hydraulic analysis for structure MNTPTH00CU0013   Date: 10-JUN-98
        CUMMINGS ST CROSSING THE N. BR. WINOOSKI RIVER IN MONTPELIER, VT   RLB
           *** RUN DATE & TIME: 07-02-98  11:34

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     528.  99740.    59.    71.                        9009.
   494.06          528.  99740.    59.    71.  1.00     0.    59.   9009.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.06     0.1    58.6   528.4   99740.    2830.   5.36

 X STA.         0.1        11.9        15.9        19.4        22.3        24.7
   A(I)            67.6        28.0        26.8        24.7        23.3
   V(I)            2.09        5.06        5.28        5.73        6.06

 X STA.        24.7        27.0        28.9        30.8        32.7        34.5
   A(I)            22.4        21.0        21.3        20.8        20.4
   V(I)            6.31        6.73        6.64        6.79        6.94

 X STA.        34.5        36.4        38.2        40.1        41.9        43.7
   A(I)            21.4        21.6        21.3        20.8        21.1
   V(I)            6.61        6.55        6.65        6.79        6.70

 X STA.        43.7        45.6        47.5        49.4        51.6        58.6
   A(I)            21.1        21.5        21.1        22.4        59.9
   V(I)            6.72        6.58        6.72        6.32        2.36

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      80.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     818.  87553.   122.   128.                       12010.
   494.55          818.  87553.   122.   128.  1.00    -8.   114.  12010.
1
    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      80.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.55    -7.9   114.5   818.5   87553.    2830.   3.46

 X STA.        -7.9         5.0        12.3        19.3        25.5        30.6
   A(I)            67.0        43.4        42.6        40.7        37.8
   V(I)            2.11        3.26        3.32        3.48        3.75

 X STA.        30.6        35.2        39.5        43.7        47.7        51.4
   A(I)            36.3        35.1        35.3        34.8        33.8
   V(I)            3.90        4.04        4.00        4.07        4.18

 X STA.        51.4        55.0        58.4        61.7        64.9        68.2
   A(I)            33.9        32.8        32.8        31.7        32.6
   V(I)            4.17        4.31        4.31        4.47        4.34

 X STA.        68.2        71.7        75.5        79.8        86.4       114.5
   A(I)            32.8        33.9        35.0        43.1       103.2
   V(I)            4.31        4.18        4.05        3.28        1.37
```

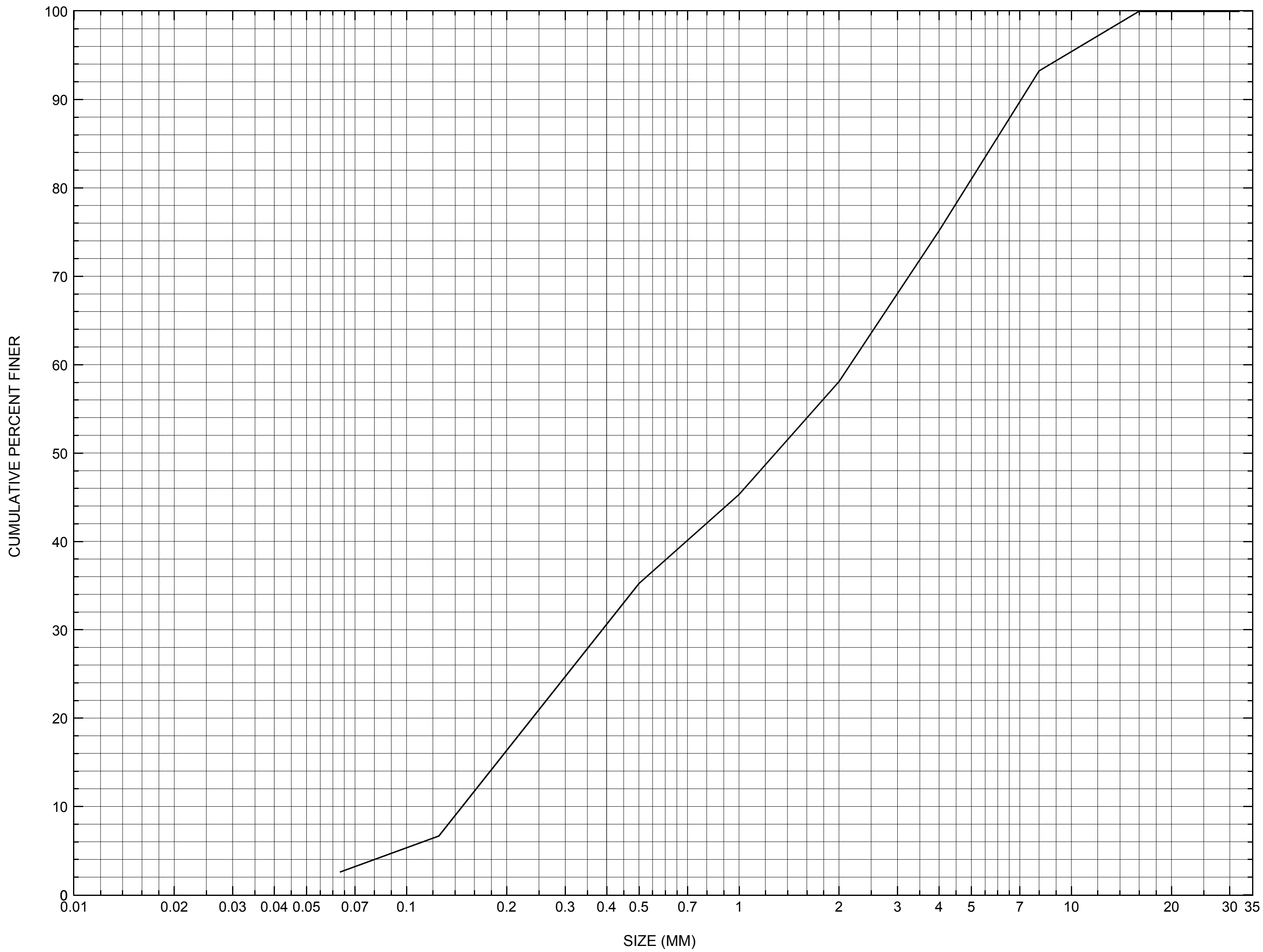
# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File mntp013.wsp
        Hydraulic analysis for structure MNTPTH00CU0013   Date: 10-JUN-98
        CUMMINGS ST CROSSING THE N. BR. WINOOSKI RIVER IN MONTPELIER, VT   RLB
           *** RUN DATE & TIME: 07-02-98  11:34

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

EXITX:XS   ******   -69.     799.  0.11 *****  493.31  487.34   2000.  493.20
      -89. ******   104.   91881.  1.16 ***** *******    0.22    2.50

FULLV:FV      89.   -69.     807.  0.11  0.04  493.36 *******   2000.  493.25
        0.    89.   104.   92998.  1.17  0.00    0.00    0.22    2.48
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPR1"     KRATIO =  0.68

APPR1:AS      80.    -8.     665.  0.14  0.05  493.43 *******   2000.  493.29
       80.    80.   112.   63148.  1.00  0.01    0.00    0.23    3.01
         <<<<<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      89.     0.     473.  0.36  0.08  493.47  488.10   2000.  493.11
        0.    89.    59.   84432.  1.28  0.08   -0.01    0.30    4.23

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.884 ******  497.73 ****** ****** ******

    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

APPR1:AS      53.    -8.     681.  0.13  0.07  493.55  489.28   2000.  493.42
       80.    59.   113.   65560.  1.00  0.02    0.01    0.22    2.94

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.513  0.230   50413.    17.    75.   493.36

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -89.   -69.   104.   2000.   91881.     799.    2.50  493.20
   FULLV:FV       0.   -69.   104.   2000.   92998.     807.    2.48  493.25
   BRIDG:BR       0.     0.    59.   2000.   84432.     473.    4.23  493.11
   RDWAY:RG      11.**************      0.*****************    1.00********
   APPR1:AS      80.    -8.   113.   2000.   65560.     681.    2.94  493.42

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS      17.    75.   50413.
1
 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO  VHD      EGL    WSEL
   EXITX:XS    487.34    0.22  483.04  506.04************  0.11  493.31  493.20
   FULLV:FV  ********    0.22  483.04  506.04  0.04  0.00  0.11  493.36  493.25
   BRIDG:BR    488.10    0.30  482.38  498.04  0.08  0.08  0.36  493.47  493.11
   RDWAY:RG ***************  497.36  514.10**********************************
   APPR1:AS    489.28    0.22  484.43  505.67  0.07  0.02  0.13  493.55  493.42
```

```
        U.S. Geological Survey WSPRO Input File mntp013.wsp
        Hydraulic analysis for structure MNTPTH00CU0013   Date: 10-JUN-98
        CUMMINGS ST CROSSING THE N. BR. WINOOSKI RIVER IN MONTPELIER, VT   RLB
           *** RUN DATE & TIME: 07-02-98  11:34

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

EXITX:XS   ****** -126.     998.  0.16 *****  494.38  488.22   2830.  494.22
      -89. ******  142.  117725.  1.26 ***** *******    0.28    2.84

FULLV:FV      89.  -127.    1013.  0.15  0.05  494.43 *******   2830.  494.28
        0.    89.   143.  119530.  1.27  0.00    0.00    0.27    2.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPR1"     KRATIO =  0.69

APPR1:AS      80.    -8.     790.  0.20  0.06  494.52 *******   2830.  494.32
       80.    80.   114.   82822.  1.00  0.02    0.00    0.25    3.58
         <<<<<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      89.     0.     528.  0.57  0.09  494.63  489.17   2830.  494.06
        0.    89.    59.   99671.  1.28  0.16   -0.02    0.36    5.36

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.883 ******  497.73 ****** ****** ******

    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

APPR1:AS      53.    -8.     818.  0.19  0.08  494.73  489.95   2830.  494.55
       80.    59.   114.   87464.  1.00  0.02    0.02    0.24    3.46

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.521  0.264   64173.    17.    76.   494.48

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -89.  -126.   142.   2830.  117725.     998.    2.84  494.22
   FULLV:FV       0.  -127.   143.   2830.  119530.    1013.    2.79  494.28
   BRIDG:BR       0.     0.    59.   2830.   99671.     528.    5.36  494.06
   RDWAY:RG      11.**************      0.******************    1.00********
   APPR1:AS      80.    -8.   114.   2830.   87464.     818.    3.46  494.55

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS      17.    76.   64173.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO  VHD     EGL    WSEL
   EXITX:XS    488.22    0.28  483.04  506.04************  0.16  494.38  494.22
   FULLV:FV  ********    0.27  483.04  506.04  0.05  0.00  0.15  494.43  494.28
   BRIDG:BR    489.17    0.36  482.38  498.04  0.09  0.16  0.57  494.63  494.06
   RDWAY:RG ****************  497.36  514.10**********************************
   APPR1:AS    489.95    0.24  484.43  505.67  0.08  0.02  0.19  494.73  494.55
```

# APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a sieve analysis of a sample from the channel approach of structure MNTPTH00CU0013, in Montpelier, Vermont.

# APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

## Structure Number MNTPTH00CU0013

## 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)* 023

Town *(FIPS place code; I - 4; nnnnn)* 46000

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

Waterway *(I - 6)* NORTH BRANCH WINOOSKI RIVER

Road Name *(I - 7):* -

Route Number C30CU

Vicinity *(I - 9)* 0.1 MI TO JCT W CL1 TH5

Topographic Map Montpelier

Hydrologic Unit Code: 2010003

Latitude *(I - 16; nnnn.n)* 44163

Longitude *(i - 17; nnnnn.n)* 72342

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10121100131211

Maintenance responsibility *(I - 21; nn)* 04

Maximum span length *(I - 48; nnnn)* 0061

Year built *(I - 27; YYYY)* 1929

Structure length *(I - 49; nnnnnn)* 000064

Average daily traffic, ADT *(I - 29; nnnnnn)* 000300

Deck Width *(I - 52; nn.n)* 191

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

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

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

Waterway adequacy *(I - 71; n)* 6

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

Underwater Inspection Frequency *(I - 92B; XYY)* Y48

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 53

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

Vertical clearance from streambed (*nnn.n ft*) 14

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

Waterway of full opening (*nnn.n ft*$^2$) 742

Comments:

**According to the structural inspection report dated 10/19/93, the bridge deck is concrete with an asphalt overlay. The RABUT and its wingwalls have a few fine cracks and small leaks overall, with minor spalling along their bottoms at the water line. The LABUT and its wingwalls have alligator cracks and leaks overall, with some surface spalling along the wingwalls at the water line. Some stone fill is present around the end of the wingwalls on each abutment, with a small pile of laid up granite blocks at the left end of the LABUT. Channel scour is approximately 8 ft deep at the RABUT and 2 ft deep at the LABUT. The US and DS channel embankments show signs of erosion from past flooding.** **(Continued, page 31)**

## Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): -    Discharge over roadway at $Q_{100}$ (*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 are branches along the channel bottom from beaver activity.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 76.51 $mi^2$  Lake/pond/swamp area 1.12 $mi^2$
Watershed storage *(ST)* 1.5 %
Bridge site elevation 520 ft  Headwater elevation 1800 ft
Main channel length 19.47 mi
10% channel length elevation 540 ft  85% channel length elevation 1220 ft
Main channel slope *(S)* 46.56 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):* - / 1930

Project Number - Minimum channel bed elevation: 75

Low superstructure elevation: USLAB 91.31 DSLAB 91.31 USRAB 91.77 DSRAB 91.77

Benchmark location description:

**BM #1: Hydrant at elevation 100 ft on west side of Elm Street approximately 250 ft west of the right bank**

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

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

If 1: Footing Thickness 2 Footing bottom elevation: 74

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:

**There is ledge at the bottom of the right abutment.**
**There is unknown material at the bottom of the left abutment.**

Comments:

**Footing bottom elevation at the LABUT = 74 ft. Footing bottom elevation at the downstream end of the RABUT is 82.91 ft, upstream end top of footing=85 ft (see copy of plans).**
**The low superstructure elevations are the bridge seat elevations from the bridge plans.**
**From plans, normal high water elevation = 90.4 ft; streambed at the LABUT is 78 ft.**

## Cross-sectional Data

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

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

Comments: **This cross section is the upstream face. The low chord elevations are from the survey log done for this report on 7/15/96. The low chord to bed length data are from the sketch attached to a bridge inspection report dated 10/18/93.**

| Station | 0 | 22 | 30 | 41 | 49 | 53 | - | - | - | - | - |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Feature | LAB | | | | | RAB | - | - | - | - | - |
| Low chord elevation | 497.4 | 497.6 | 497.7 | 497.8 | 497.9 | 498.0 | - | - | - | - | - |
| Bed elevation | 489.2 | 487.8 | 485.0 | 481.5 | 483.7 | 485.3 | - | - | - | - | - |
| Low chord to bed | 8.2 | 9.9 | 12.7 | 16.3 | 14.2 | 12.7 | - | - | - | - | - |

| 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: **RB** Date: **10/17/96**
Computerized by: **RB** Date: **10/31/96**
Reviewd by: **RB** Date: **7/15/98**

# Structure Number **MNTPTH00CU0013**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. FLYNN** Date *(MM/DD/YY)* **07** / **15** / 19**96**
2. Highway District Number **06** Mile marker **00000**
   County **023** Town **46000**
   Waterway *(I - 6)* **N. BRANCH WINOOSKI RIVER** Road Name **CUMMINGS STREET**
   Route Number **C30CU** Hydrologic Unit Code: **2010003**
3. Descriptive comments:

**Located 0.1 miles to the junction with CL1 TH5.**

## B. Bridge Deck Observations

4. Surface cover... LBUS **2** RBUS **2** LBDS **5** RBDS **5** Overall **5**
*(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 **64** *(feet)* Span length **61** *(feet)* Bridge width **19.1** *(feet)*

### Road approach to bridge:

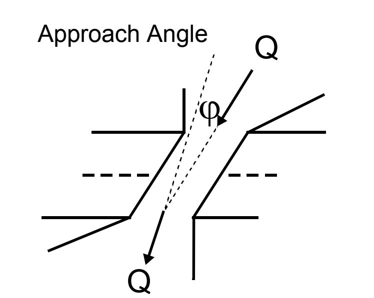
8. LB **1** RB **1** *( **0** even, **1**- lower, **2**- higher)*
9. LB **1** RB **1** *( **1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
    US left **--** US right **--**

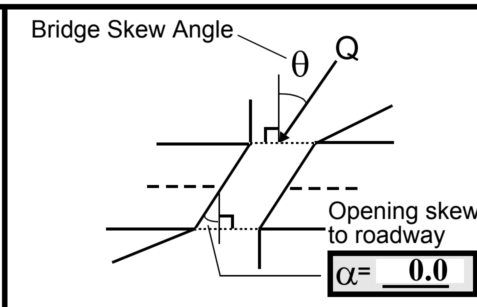
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 2 | 2 | 1 | 1 |
| RBUS | 0 | - | 1 | 1 |
| RBDS | 0 | - | 3 | 1 |
| LBDS | 1 | 3 | 3 | 3 |

*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: **10** 16. Bridge skew: **0**



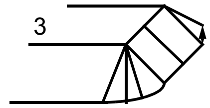



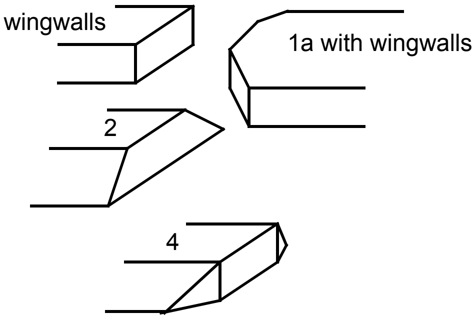

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
    Where? **RB** *(LB, RB)* Severity **1**
    Range? **10** feet **US** *(US, UB, DS)* to **100** feet **US**
    Channel impact zone 2: Exist? **Y** *(Y or N)*
    Where? **RB** *(LB, RB)* Severity **1**
    Range? **20** feet **DS** *(US, UB, DS)* to **130** feet **DS**

*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.)

**7. Values are from the VTAOT files. Measured bridge length is 64 ft, bridge span is 59.5 ft, and the bridge width is 19.1 ft.**
**13. The severe designation of the DS left bank road approach erosion has occurred above the protection and is caused mostly by road wash and eddy currents.**
**18. The wingwalls are present on the US right and on the DS left corners of the structure. The wingwalls are at 90 degrees (parallel to the roadway) to the abutments on the US left and the DS right corners of the structure.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| **78.0** | **8.0** | | | **5.5** | **1** | **1** | **01** | **01** | **1** | **1** |

23. Bank width **45.0** 24. Channel width **10.0** 25. Thalweg depth **117.0** 29. Bed Material **01**

30 .Bank protection type: LB **2** RB **0** 31. Bank protection condition: LB **1** 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.):

**28. The banks are scalloped and some tree roots are exposed along the banks.**
**30. The left bank protection US is type-2 from 0 ft US to 30 ft US and type-1 from 30 ft US to 70 ft US.**

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 65 35. Mid-bar width: 20

36. Point bar extent: 20 feet US (US, UB) to 100 feet US (US, UB, DS) positioned 0 %LB to 30 %RB

37. Material: 321

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

-

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

41. Mid-bank distance: 80 42. Cut bank extent: 30 feet US (US, UB) to 150 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.):

**There is no protection on this part of the bank, which is mostly organics. Tree roots are exposed.**

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

47. Scour dimensions: Length 140 Width 40 Depth : 8 Position 50 %LB to 80 %RB

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

**The US scour extends under the bridge and DS along the right side of the channel. Scour is from 50 ft US to 70 ft DS with mid-scour at the DS bridge face.**

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 |
|---|---|---|---|---|---|---|---|
| 96.5 | | 6.0 | | 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.):

**01**

-

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 1____ ( 1- Low; 2- Moderate; 3- High)

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

70. Debris and Ice Comments:

**2**

**Local residents commented that ice jams are common in the winter.**

| 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 | 1 | 0 | 90 | | | 2 | 1 | 59.0 |

*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.):

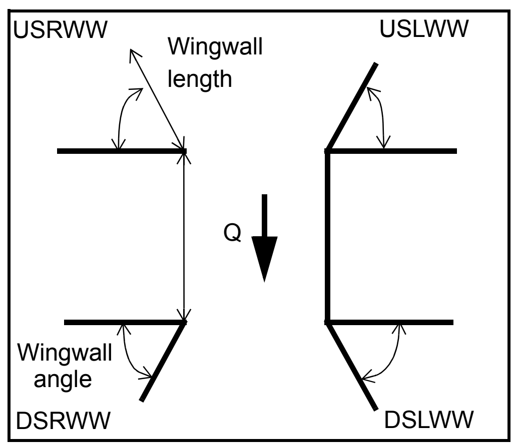
**8**
**-**
**1**

**73. There is deep sediment along the left abutment. Either the footing or rock protection is located under 1 ft of sediment, 2 ft below the present water surface.**

**74. There is protection at the base of the right abutment which extends 3 ft into the channel and slopes into the scour hole.**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 59.0 | |
| USRWW: | N | | - | | - | 8.0 | |
| DSLWW: | - | | - | | Y | 21.0 | |
| DSRWW: | 1 | | 1 | | 7 | 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 | 0 | N | - | - | - | - | 1 |
| Condition | Y | - | - | - | - | - | - | 1 |
| Extent | 1 | - | - | - | 0 | 0 | 2 | - |

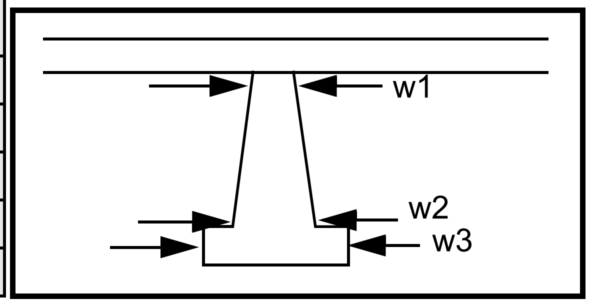
*Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee*
*Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed*
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

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

## Piers:

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

| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | **0.0** | | | **11.0** | **30.0** | **24.0** |
| Pier 2 | | | | **35.0** | **14.0** | **180.0** |
| Pier 3 | | - | - | **14.5** | - | - |
| Pier 4 | - | - | - | - | - | - |




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

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

## E. Downstream Channel Assessment

100.

| SRD | Bank height (BF) LB | Bank height (BF) RB | Bank angle (BF) LB | Bank angle (BF) RB | % Veg. cover (BF) LB | % Veg. cover (BF) RB | Bank material (BF) LB | Bank material (BF) RB | Bank erosion (BF) LB | Bank erosion (BF) RB |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | - | NO | PIE | RS | | |

Bank width (BF) - Channel width - 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.):

**2**
**1**
**01**
**01**
**2**
**2**
**01**
**0**
**0**
**-**
**-**
**Protection on left bank is described as the DS left wingwall protection in question 82.**

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

Material: **OP**

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

**STRUCTURE**

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

Cut bank extent: **100** feet **25** *(US, UB, DS)* to **70** feet **DS** *(US, UB, DS)*

Bank damage: **120** *( **1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

**DS**
**0**
**50**
**3210**

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

Scour dimensions: Length ______ Width ______ Depth: **Y** Positioned **RB** %LB to **40** %RB

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

**10**
**DS**
**65**
**DS**

Are there major confluences? **1** *(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 **N** 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)*:

**-**

**NO CHANNEL SCOUR**

**Channel scour continues from US.  See US channel assessment.**

**N**

**-**

**-**

**-**

**-**

**-**

**-**

**-**

## 109. G. Plan View Sketch

- N

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

# APPENDIX F:

# SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: MNTPTH00CU0013 Town: MONTPELIER
Road Number: CUMMINGS STREET County: WASHINGTON
Stream: NORTH BRANCH WINOOSKI RIVER

Initials RLB Date: 7/2/98 Checked: EMB

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 | 2000 | 2830 | 0 |
| Main Channel Area, ft2 | 681 | 818 | 0 |
| Left overbank area, ft2 | 0 | 0 | 0 |
| Right overbank area, ft2 | 0 | 0 | 0 |
| Top width main channel, ft | 120 | 122 | 0 |
| Top width L overbank, ft | 0 | 0 | 0 |
| Top width R overbank, ft | 0 | 0 | 0 |
| D50 of channel, ft | 0.0042 | 0.0042 | 0 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 5.7 | 6.7 | ERR |
| y1, average depth, LOB, ft | ERR | ERR | ERR |
| y1, average depth, ROB, ft | ERR | ERR | ERR |
| Total conveyance, approach | 65562 | 87553 | 0 |
| Conveyance, main channel | 65562 | 87553 | 0 |
| Conveyance, LOB | 0 | 0 | 0 |
| Conveyance, ROB | 0 | 0 | 0 |
| Percent discrepancy, conveyance | 0.0000 | 0.0000 | ERR |
| Qm, discharge, MC, cfs | 2000.0 | 2830.0 | ERR |
| Ql, discharge, LOB, cfs | 0.0 | 0.0 | ERR |
| Qr, discharge, ROB, cfs | 0.0 | 0.0 | ERR |
| Vm, mean velocity MC, ft/s | 2.9 | 3.5 | ERR |
| Vl, mean velocity, LOB, ft/s | ERR | ERR | ERR |
| Vr, mean velocity, ROB, ft/s | ERR | ERR | ERR |
| Vc-m, crit. velocity, MC, ft/s | 2.4 | 2.5 | N/A |
| Vc-l, crit. velocity, LOB, ft/s | ERR | ERR | ERR |
| Vc-r, crit. velocity, ROB, ft/s | ERR | ERR | ERR |

Results

| Live-bed(1) or Clear-Water(0) Contraction Scour? | 100 yr | 500 yr | other Q |
|---|---|---|---|
| Main Channel | 1 | 1 | N/A |
| Left Overbank | N/A | N/A | N/A |
| Right Overbank | N/A | N/A | N/A |

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour

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

ys=y2-y_bridge

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

| Characteristic | Approach 100 yr | Approach 500 yr | Approach Other Q | Bridge 100 yr | Bridge 500 yr | Bridge Other Q |
|---|---|---|---|---|---|---|
| Q1, discharge, cfs | 2000 | 2830 | 0 | 2000 | 2830 | 0 |
| Total conveyance | 65562 | 87553 | 0 | 84387 | 99740 | 0 |
| Main channel conveyance | 65562 | 87553 | 0 | 84387 | 99740 | 0 |
| Main channel discharge | 2000 | 2830 | ERR | 2000 | 2830 | ERR |
| Area - main channel, ft2 | 681 | 818 | 0 | 472.9 | 528.4 | 0 |
| (W1) channel width, ft | 120 | 122 | 0 | 58.5 | 58.5 | 0 |
| (Wp) cumulative pier width, ft | 0 | 0 | 0 | 0 | 0 | 0 |
| W1, adjusted bottom width(ft) | 120 | 122 | 0 | 58.5 | 58.5 | 0 |
| D50, ft | 0.0042 | 0.0042 | 0 | | | |
| w, fall velocity, ft/s (p. 32) | 0.5122 | 0.5122 | 0 | | | |
| y, ave. depth flow, ft | 5.68 | 6.70 | N/A | 8.08 | 9.03 | ERR |
| S1, slope EGL | 0.0009 | 0.0011 | 0 | | | |
| P, wetted perimeter, MC, ft | 125 | 128 | 0 | | | |
| R, hydraulic Radius, ft | 5.448 | 6.391 | ERR | | | |
| V*, shear velocity, ft/s | 0.397 | 0.476 | N/A | | | |
| V*/w | 0.776 | 0.929 | ERR | | | |
| Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33) | | | | | | |
| k1 | 0.64 | 0.64 | 0 | | | |
| y2,depth in contraction, ft | 8.99 | 10.73 | ERR | | | |
| ys, scour depth, ft (y2-y_bridge) | 0.90 | 1.70 | N/A | | | |

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 | 2000 | 2830 | N/A |
| Main channel area (DS), ft2 | 472.9 | 528.4 | 0 |
| Main channel width (normal), ft | 58.5 | 58.5 | 0.0 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 58.5 | 58.5 | 0.0 |
| D90, ft | 0.0232 | 0.0232 | 0.0000 |
| D95, ft | 0.0314 | 0.0314 | 0.0000 |
| Dc, critical grain size, ft | 0.0259 | 0.0404 | ERR |
| Pc, Decimal percent coarser than Dc | 0.000 | 0.000 | 0.000 |

| | | | |
|---|---|---|---|
| Depth to armoring, ft | N/A | N/A | ERR |

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)

| | Left Abutment | | | Right Abutment | | |
|---|---|---|---|---|---|---|
| Characteristic | 100 yr Q | 500 yr Q | Other Q | 100 yr Q | 500 yr Q | Other Q |
| (Qt), total discharge, cfs | 2000 | 2830 | 0 | 2000 | 2830 | 0 |
| a', abut.length blocking flow, ft | 7.8 | 8 | 0 | 54.2 | 55.9 | 0 |
| Ae, area of blocked flow ft2 | 32.42 | 41.55 | 0 | 280.85 | 343.11 | 0 |
| Qe, discharge blocked abut.,cfs | 58.21 | 87.75 | 0 | 776.67 | 1123.42 | 0 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 1.80 | 2.11 | ERR | 2.77 | 3.27 | ERR |
| ya, depth of f/p flow, ft | 4.16 | 5.19 | ERR | 5.18 | 6.14 | ERR |
| --Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru) | | | | | | |
| K1 | 1.00 | 1.00 | 1.00 | 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 | 0.155 | 0.163 | ERR | 0.214 | 0.233 | ERR |
| ys, scour depth, ft | 8.13 | 9.89 | N/A | 15.52 | 18.28 | N/A |

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) | 7.8 | 8 | 0 | 54.2 | 55.9 | 0 |
| y1 (depth f/p flow, ft) | 4.16 | 5.19 | ERR | 5.18 | 6.14 | ERR |
| a'/y1 | 1.88 | 1.54 | ERR | 10.46 | 9.11 | ERR |
| Skew correction (p. 49, fig. 16) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Froude no. f/p flow | 0.16 | 0.16 | N/A | 0.21 | 0.23 | N/A |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | ERR | ERR | ERR | ERR | ERR | ERR |
| vertical w/ ww's | ERR | ERR | ERR | ERR | ERR | ERR |
| spill-through | ERR | ERR | ERR | ERR | ERR | ERR |

Abutment riprap Sizing

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

| Characteristic | Q100 | Q500 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 0.3 | 0.36 | 0 | 0.3 | 0.36 | 0 |
| y, depth of flow in bridge, ft | 8.08 | 9.03 | 0.00 | 8.08 | 9.03 | 0.00 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | 0.45 | 0.72 | 0.00 | 0.45 | 0.72 | 0.00 |
| Fr>0.8 (vertical abut.) | ERR | ERR | ERR | ERR | ERR | ERR |