# LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (BRAITH00150013) on TOWN HIGHWAY 15, crossing the THIRD BRANCH WHITE RIVER, BRAINTREE, VERMONT

Open-File Report 98-290

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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# LEVEL II SCOUR ANALYSIS FOR BRIDGE 13 (BRAITH00150013) on TOWN HIGHWAY 15, crossing the THIRD BRANCH WHITE RIVER, BRAINTREE, VERMONT

By RONDA L. BURNS and MATTHEW A. WEBER

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**Pembroke, New Hampshire**

**1998**

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

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

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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 (BRAITH00150013) ON TOWN HIGHWAY 15, CROSSING THE THIRD BRANCH WHITE RIVER, BRAINTREE, VERMONT

***By*** **Ronda L. Burns and Matthew A. Weber**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRAITH00150013 on Town Highway 15 crossing the Third Branch White River, Braintree, 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 Green Mountain section of the New England physiographic province in central Vermont. The 28.6-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is shrub and brushland.

In the study area, the Third Branch White River has a sinuous channel with a slope of approximately 0.002 ft/ft, an average channel top width of 60 ft and an average bank height of 6 ft. The channel bed material ranges from sand to boulders with a median grain size ($D_{50}$) of 77.1 mm (0.253 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 20-21, 1994, indicated that the reach was stable.

The Town Highway 15 crossing of the Third Branch White River is a 44-ft-long, one-lane bridge consisting of one 35-foot steel-beam span (Vermont Agency of Transportation, written communication, August 24, 1994). The opening length of the structure parallel to the bridge face is 34.4 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening and the computed opening-skew-to-roadway is 25 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed in the upstream channel and under the bridge during the Level I assessment. Downstream of the bridge, the scour hole was 4.0 ft deeper than the mean thalweg depth. Scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the upstream left and right banks, the upstream left wingwall, the downstream right wingwall, the downstream right bank, and the upstream end of the upstream right wingwall. Type-3 stone fill (less than 48 inches diameter) was observed at the downstream end of the downstream left wingwall. 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 was zero ft. Left abutment scour ranged from 3.1 to 9.4 ft with the worst-case occurring at the incipient roadway-overtopping discharge. Right abutment scour ranged from 5.2 to 8.7 ft with the worst-case occurring 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*** BRAITH00150013 ***Stream*** Third Branch White River

***County*** Orange ***Road*** TH 15 ***District*** 4

## Description of Bridge

***Bridge length*** 44 ***ft*** ***Bridge width*** 14.3 ***ft*** ***Max span length*** 35 ***ft***

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

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

***Stone fill on abutment?*** No ***Date of inspection*** 10/20/94

Type-2, along the upstream left wingwall, the downstream right wingwall, and the upstream end of the upstream right wingwall. Type-3, at the downstream end of the downstream left wingwall.

Abutments and wingwalls are concrete. There is a one foot deep scour hole under the bridge.

Yes 25

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

***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*** | 10/20/94 | 0 | 0 |
| ***Level II*** | 10/20/94 | 0 | 0 |

***Potential for debris*** Moderate. There is some debris in the channel downstream possibly due to beavers in the area.

None, 10/20/94.

***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 within a moderate relief valley with a wide flood plain.

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

***Date of inspection*** 10/20/94

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

***DS right:*** Steep valley wall

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

***US right:*** Steep valley wall

## Description of the Channel

***Average top width*** 60 *ft*

***Average depth*** 6 *ft*

***Predominant bed material*** Cobbles

***Bank material*** Boulders/Sand

Sinuous but stable with semi-alluvial channel boundaries and random width variations of the channel.

10/20/94

***Vegetative co***

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

***DS right:*** Shrubs and brush

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

***US right:*** Shrubs and brush with a few trees

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

None, 10/20/94.

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

## Hydrology

***Drainage area*** 28.6 ***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***: None

***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*** 4,700 ***ft³/s*** ***Q500*** 5,800 ***ft³/s***

The 100- and 500-year discharges were approximated by a drainage area relationship [(28.6/30.0)exp 0.7] with flood frequency estimates available from the VTAOT (written communication, May, 1995) for another site on the Third Branch White River and were approved by the VTAOT (written communication, September 21, 1995). The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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

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

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

***Description of reference marks used to determine USGS datum.*** RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 500.69 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the left abutment (elev. 500.63 ft, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

| [1]*Cross-section* | *Section Reference Distance (SRD) in feet* | [2]*Cross-section development* | *Comments* |
|---|---|---|---|
| EXIT2 | -233 | 1 | Exit section |
| EXITX | -33 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 9 | 1 | Road Grade section |
| APPRO | 50 | 2 | Modelled Approach section (Templated from APTEM) |
| APTEM | 65 | 1 | Approach section as surveyed (Used as a template) |

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

## Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.045, and overbank "n" values ranged from 0.035 to 0.061.

Normal depth at the exit section (EXIT2) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0017 ft/ft, which was estimated from thalweg points surveyed downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.01 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

## Bridge Hydraulics Summary

***Average bridge embankment elevation*** 501.2 ***ft***
***Average low steel elevation*** 499.4 ***ft***

***100-year discharge*** 4,700 ***ft$^3$/s***
***Water-surface elevation in bridge opening*** 499.5 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 4,070 ***ft$^3$/s***
***Area of flow in bridge opening*** 262 ***ft$^2$***
***Average velocity in bridge opening*** 2.5 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 3.0 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 500.3
***Water-surface elevation at Approach section without bridge*** 500.2
***Amount of backwater caused by bridge*** 0.1 ***ft***

***500-year discharge*** 5,800 ***ft$^3$/s***
***Water-surface elevation in bridge opening*** 499.5 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 5,210 ***ft$^3$/s***
***Area of flow in bridge opening*** 262 ***ft$^2$***
***Average velocity in bridge opening*** 2.2 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 2.6 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 500.7
***Water-surface elevation at Approach section without bridge*** 500.6
***Amount of backwater caused by bridge*** 0.1 ***ft***

***Incipient overtopping discharge*** 1,450 ***ft$^3$/s***
***Water-surface elevation in bridge opening*** 497.2 ***ft***
***Area of flow in bridge opening*** 195 ***ft$^2$***
***Average velocity in bridge opening*** 7.4 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 9.3 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 497.7
***Water-surface elevation at Approach section without bridge*** 497.5
***Amount of backwater caused by bridge*** 0.2 ***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.

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

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

Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 1995, p. 48, equation 28) at the right abutment for all modelled flows and at the left abutment for the incipient roadway-overtopping discharge. 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.

Abutment scour was computed by use of the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) at the left abutment for the 100-year and 500-year discharges because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

## 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* | 0.0 | 0.0 | 0.0 |
| *Depth to armoring* | 0.0 | 0.0 | 0.5 |
| ***Left overbank*** | -- | -- | -- |
| ***Right overbank*** | -- | -- | -- |

| Local scour: | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| ***Abutment scour*** | 3.1 | 3.5 | 9.4 |
| *Left abutment* | 8.0 | 8.7 | 5.2 |
| *Right abutment* | | | |
| ***Pier scour*** | -- | -- | -- |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |
| *Pier 3* | | | |

## Riprap Sizing

| | 100-year discharge | 500-year discharge ($D_{50}$ in feet) | Incipient overtopping discharge |
|---|---|---|---|
| ***Abutments:*** | 0.1 | 0.1 | 1.0 |
| *Left abutment* | 0.1 | 0.1 | 1.0 |
| *Right abutment* | -- | -- | -- |
| ***Piers:*** | -- | -- | -- |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | | | |

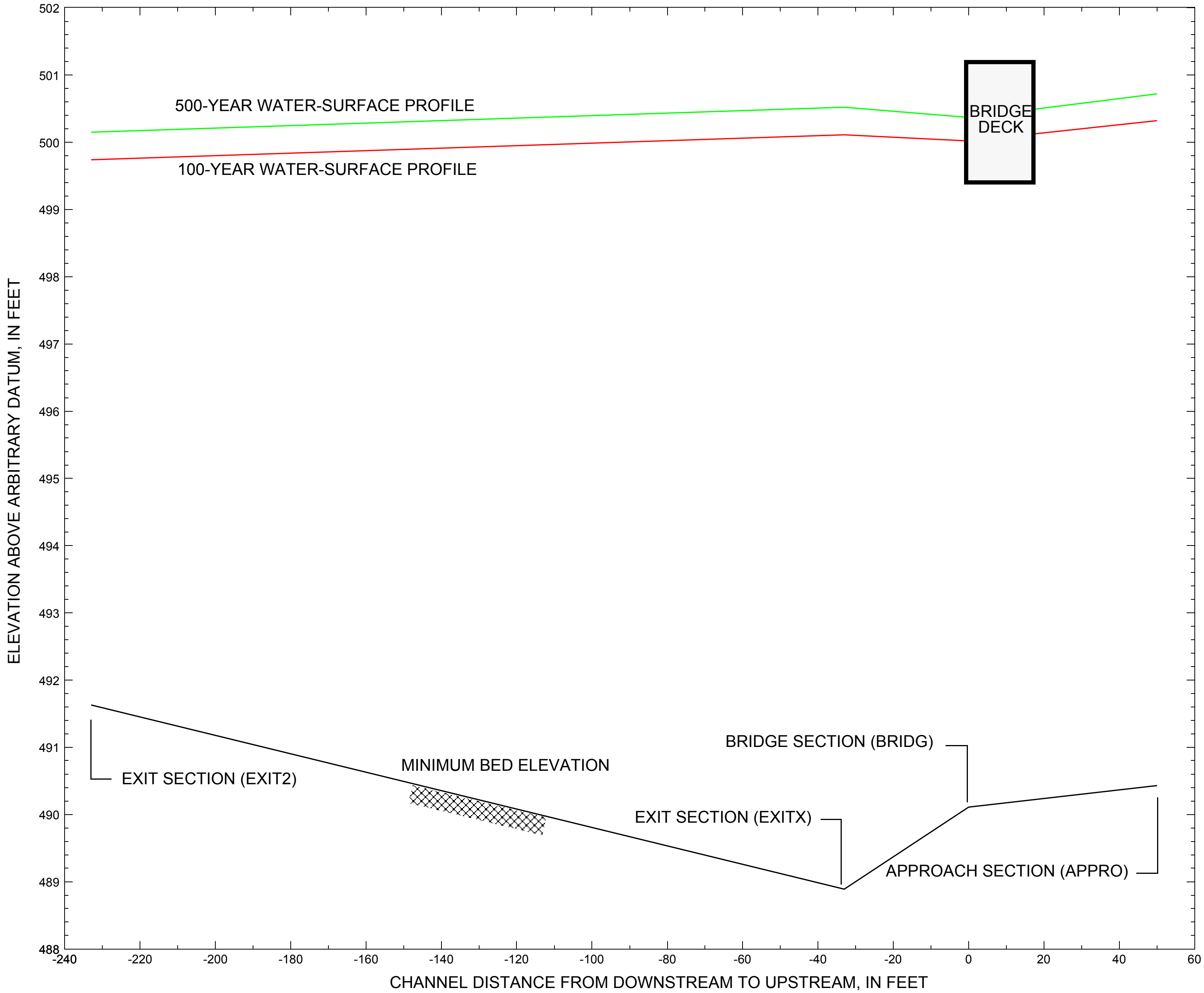


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure BRAITH00150013 on Town Highway 15, crossing the Third Branch White River, Braintree, Vermont.

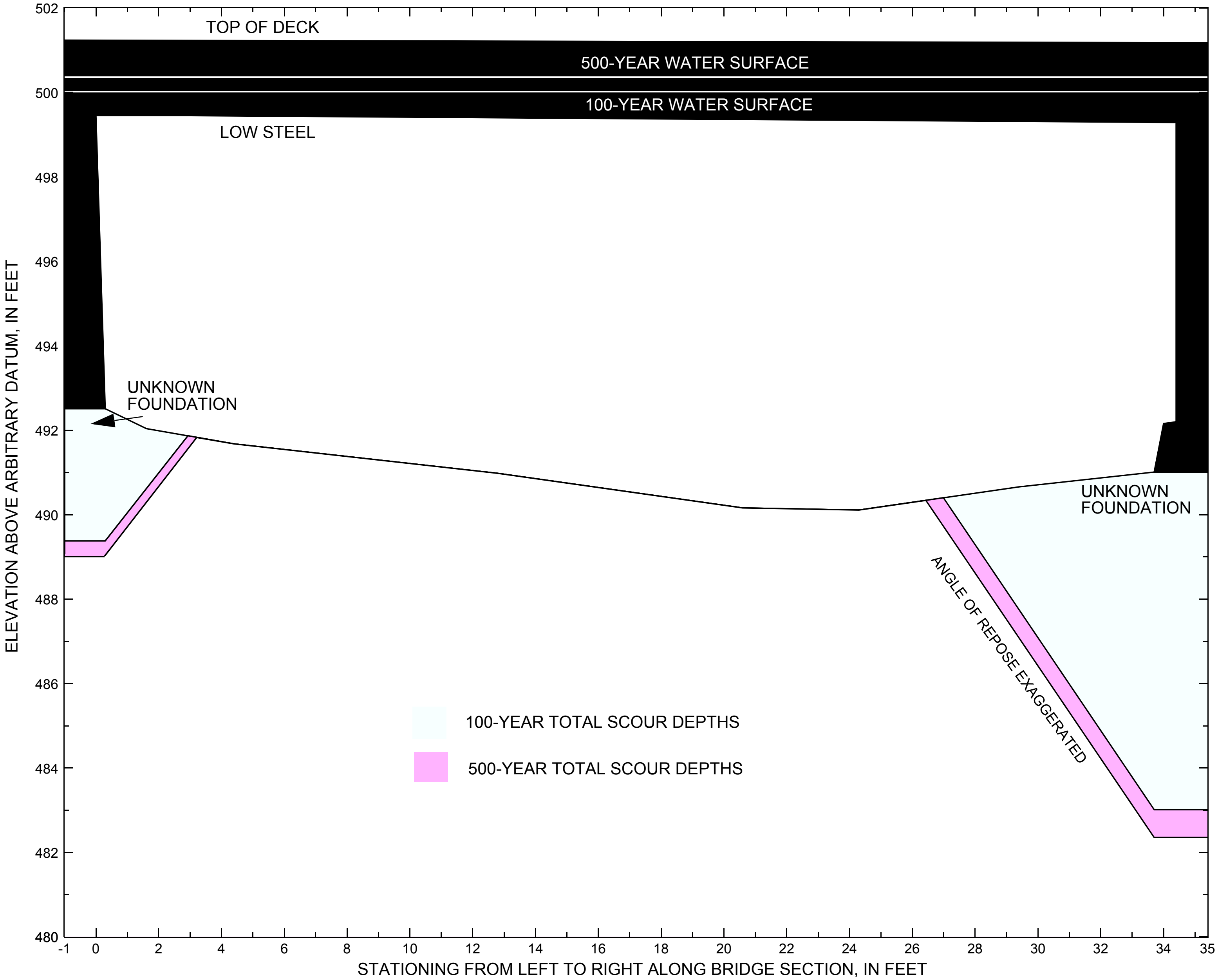


Figure 8. Scour elevations for the 100- and 500-year discharges at structure BRAITH00150013 on Town Highway 15, crossing the Third Branch White River, Braintree, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure BRAITH00150013 on Town Highway 15, crossing the Third Branch White River, Braintree, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100-year discharge is 4,700 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 499.5 | -- | 492.5 | 0.0 | 3.1 | -- | 3.1 | 489.4 | -- |
| Right abutment | 34.4 | -- | 499.3 | -- | 491.0 | 0.0 | 8.0 | -- | 8.0 | 483.0 | -- |

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 BRAITH00150013 on Town Highway 15, crossing the Third Branch White River, Braintree, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 500-year discharge is 5,800 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 499.5 | -- | 492.5 | 0.0 | 3.5 | -- | 3.5 | 489.0 | -- |
| Right abutment | 34.4 | -- | 499.3 | -- | 491.0 | 0.0 | 8.7 | -- | 8.7 | 482.3 | -- |

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, 1970, Warren, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

# WSPRO INPUT FILE

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File brai013a.wsp
T2        Hydraulic analysis for structure BRAITH00150013   Date: 30-OCT-97
T3        HYDRAULIC ANALYSIS OF BRAINTREE BRIDGE #13 OVER 3RD BRANCH WHITE R.
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4700 5800 1450
SK          0.0017 0.0017 0.0017
*
XS   EXIT2    -233
GR        -500.0, 511.00   -500.0, 498.39   -128.5, 498.39    -94.7, 497.98
GR          -8.9, 495.72     -2.7, 494.45      0.0, 492.55      1.7, 492.21
GR          11.1, 491.80     24.7, 491.85     32.8, 491.63     42.9, 491.65
GR          50.4, 491.74     51.6, 492.42     52.7, 493.29     57.2, 495.27
GR          61.6, 496.43     87.5, 498.96    108.6, 508.60
N           0.035    0.053     0.040     0.060
SA               -94.7    -8.9       61.6
*
XS   EXITX    -33
GR        -500.0, 511.00   -500.0, 498.39   -128.5, 498.39   -117.7, 497.75
GR        -106.6, 494.11    -55.9, 495.14    -53.6, 496.40    -42.8, 499.98
GR         -22.2, 498.85    -14.7, 496.02    -10.7, 493.05     -8.3, 492.07
GR          -4.5, 490.08      0.0, 488.89      8.9, 489.17     14.2, 489.55
GR          27.8, 490.22     33.6, 490.18     39.3, 491.07     39.4, 493.17
GR          47.4, 496.03     54.7, 498.27     87.5, 498.96    108.6, 508.60
N           0.035    0.053     0.040     0.060
SA              -117.7    -14.7      54.7
*
*    For the incipient roadway-overtopping model, the exitx section was cut off
*    at the top of the bank at station -42.8.
*
XS   FULLV     0
*
BR   BRIDG     0 499.36 25
GR           0.0, 499.45      0.1, 493.33      0.3, 492.51      1.6, 492.04
GR           4.4, 491.68     12.8, 490.98     20.6, 490.16     24.3, 490.11
GR          29.4, 490.66     33.7, 491.01     34.0, 492.16     34.4, 493.33
GR          34.4, 492.20     34.4, 499.27      0.0, 499.45
N            0.040
CD          1 21 * * 35 4
*
XR   RDWAY      9 14 2
GR        -500.0, 511.00   -500.0, 498.39   -128.5, 498.39    -94.7, 497.98
GR         -57.5, 497.80    -18.5, 500.66      0.0, 501.24     33.4, 501.18
GR          75.9, 500.00     94.0, 511.05
*
XT   APTEM     65
GR        -500.0, 511.00   -500.0, 498.39   -128.5, 498.39    -94.7, 497.98
GR         -63.9, 497.20    -16.6, 497.96     -9.8, 497.42     -5.6, 495.32
GR          -2.5, 493.25      0.0, 491.76      2.3, 491.34      9.7, 490.58
GR          18.8, 491.04     24.8, 493.17     32.6, 495.91     40.1, 500.07
GR          51.8, 499.42     67.3, 509.75
*
AS   APPRO     50
GT          -0.15
N            0.035      0.055      0.045        0.061
SA               -128.5      -9.8       40.1
*
HP 1 BRIDG     499.45 1 499.45
HP 2 BRIDG     499.45 * * 658
HP 2 RDWAY     500.02 * * 4067
HP 1 APPRO     500.32 1 500.32
HP 2 APPRO     500.32 * * 4700
*
HP 1 BRIDG     499.45 1 499.45
HP 2 BRIDG     499.45 * * 567
HP 2 RDWAY     500.37 * * 5210
HP 1 APPRO     500.72 1 500.72
```

APPENDIX B:

# WSPRO OUTPUT FILE

# WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File brai013a.wsp
      Hydraulic analysis for structure BRAITH00150013   Date: 30-OCT-97
      HYDRAULIC ANALYSIS OF BRAINTREE BRIDGE #13 OVER 3RD BRANCH WHITE R.
         *** RUN DATE & TIME: 10-30-97  12:01

  CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     262.   21690.     0.    79.                           0.
 499.45          262.   21690.     0.    79.  1.00     0.    34.      0.

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

       WSEL     LEW     REW    AREA        K        Q    VEL
     499.45     0.0    34.4   262.2   21690.     658.   2.51

X STA.        0.0        3.3        5.3        7.1        8.8       10.5
  A(I)            21.4       14.0       13.0       12.6       12.0
  V(I)            1.54       2.35       2.52       2.62       2.73

X STA.       10.5       12.1       13.6       15.1       16.5       17.9
  A(I)            12.0       11.5       11.6       11.4       11.2
  V(I)            2.74       2.87       2.85       2.89       2.93

X STA.       17.9       19.3       20.6       22.0       23.3       24.7
  A(I)            11.1       11.3       11.1       11.3       11.6
  V(I)            2.95       2.91       2.95       2.91       2.85

X STA.       24.7       26.1       27.7       29.3       31.2       34.4
  A(I)            11.7       12.3       13.1       14.5       23.6
  V(I)            2.82       2.67       2.52       2.27       1.39

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       9.

       WSEL     LEW     REW    AREA        K        Q    VEL
     500.02  -500.0    75.9   780.4   43046.    4067.   5.21

X STA.     -500.0     -476.3     -454.3     -431.9     -409.2     -387.2
  A(I)            38.7       35.9       36.5       36.9       35.9
  V(I)            5.26       5.67       5.57       5.50       5.67

X STA.     -387.2     -364.4     -342.1     -319.5     -297.3     -275.0
  A(I)            37.1       36.4       36.7       36.3       36.3
  V(I)            5.48       5.58       5.54       5.61       5.61

X STA.     -275.0     -252.5     -230.0     -208.0     -185.6     -162.8
  A(I)            36.7       36.7       35.9       36.4       37.1
  V(I)            5.54       5.54       5.67       5.58       5.47

X STA.     -162.8     -140.8     -118.8      -93.3      -70.1       75.9
  A(I)            35.9       36.4       48.6       48.8       61.1
  V(I)            5.67       5.59       4.18       4.16       3.33

  CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     773.   53402.   372.   374.                        6324.
           2     322.   16923.   119.   119.                        3003.
           3     350.   40599.    50.    53.                        5263.
           4       9.     177.    13.    14.                          44.
 500.32         1454.  111101.   553.   559.  1.31  -500.    53.  11697.

  VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

       WSEL     LEW     REW    AREA        K        Q    VEL
     500.32  -500.0    53.4  1453.7  111101.    4700.   3.23

X STA.     -500.0     -460.0     -421.4     -383.3     -344.4     -306.3
  A(I)            83.1       80.4       79.3       80.9       79.2
  V(I)            2.83       2.92       2.96       2.90       2.97

X STA.     -306.3     -267.3     -229.6     -190.2     -152.3     -106.6
  A(I)            81.1       78.3       82.0       78.8       98.0
  V(I)            2.90       3.00       2.87       2.98       2.40

X STA.     -106.6      -68.0      -36.1       -4.0        1.9        6.2
  A(I)           104.2       98.0       97.0       47.1       40.0
  V(I)            2.26       2.40       2.42       4.99       5.88

X STA.        6.2       10.3       14.5       18.9       24.6       53.4
  A(I)            40.0       40.4       42.1       48.3       75.4
  V(I)            5.87       5.82       5.59       4.86       3.12
```

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     U.S. Geological Survey WSPRO Input File brai013a.wsp
     Hydraulic analysis for structure BRAITH00150013   Date: 30-OCT-97
     HYDRAULIC ANALYSIS OF BRAINTREE BRIDGE #13 OVER 3RD BRANCH WHITE R.
        *** RUN DATE & TIME: 10-30-97  12:01

 CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     262.   21690.     0.    79.                            0.
499.45          262.   21690.     0.    79.  1.00     0.    34.      0.

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

      WSEL     LEW     REW    AREA        K        Q    VEL
    499.45     0.0    34.4   262.2   21690.     567.   2.16

X STA.        0.0        3.3        5.3        7.1        8.8       10.5
  A(I)           21.4       14.0       13.0       12.6       12.0
  V(I)           1.33       2.03       2.17       2.25       2.35

X STA.       10.5       12.1       13.6       15.1       16.5       17.9
  A(I)           12.0       11.5       11.6       11.4       11.2
  V(I)           2.36       2.47       2.45       2.49       2.53

X STA.       17.9       19.3       20.6       22.0       23.3       24.7
  A(I)           11.1       11.3       11.1       11.3       11.6
  V(I)           2.54       2.51       2.55       2.50       2.45

X STA.       24.7       26.1       27.7       29.3       31.2       34.4
  A(I)           11.7       12.3       13.1       14.5       23.6
  V(I)           2.43       2.30       2.17       1.96       1.20

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       9.

      WSEL     LEW     REW    AREA        K        Q    VEL
    500.37  -500.0    76.5   949.3   59124.    5210.   5.49

X STA.     -500.0     -476.4     -454.5     -432.2     -409.7     -387.8
  A(I)           46.7       43.4       44.1       44.6       43.4
  V(I)           5.57       6.01       5.90       5.84       6.01

X STA.     -387.8     -365.1     -342.9     -321.0     -298.6     -276.2
  A(I)           44.9       44.0       43.3       44.3       44.3
  V(I)           5.81       5.92       6.01       5.87       5.87

X STA.     -276.2     -254.1     -231.9     -209.5     -187.2     -165.1
  A(I)           43.9       43.9       44.4       44.0       43.8
  V(I)           5.94       5.94       5.87       5.91       5.94

X STA.     -165.1     -142.7     -120.8      -94.6      -69.5       76.5
  A(I)           44.4       43.6       58.6       61.3       78.2
  V(I)           5.87       5.97       4.44       4.25       3.33

 CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     921.   71543.   372.   374.                         8233.
          2     369.   21290.   119.   119.                         3692.
          3     370.   44529.    50.    53.                         5720.
          4      15.     367.    14.    14.                           86.
500.72         1675.  137728.   554.   560.  1.23  -500.    54.  14892.

 VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

      WSEL     LEW     REW    AREA        K        Q    VEL
    500.72  -500.0    54.0  1675.2  137728.    5800.   3.46

X STA.     -500.0     -462.3     -427.3     -391.7     -355.7     -320.7
  A(I)           93.5       86.8       88.3       89.4       86.8
  V(I)           3.10       3.34       3.28       3.25       3.34

X STA.     -320.7     -284.5     -248.9     -213.2     -177.8     -142.4
  A(I)           89.8       88.1       88.8       87.7       87.7
  V(I)           3.23       3.29       3.27       3.31       3.31

X STA.     -142.4      -98.0      -62.3      -28.5       -2.2        3.5
  A(I)          115.8      116.2      114.1       98.9       51.5
  V(I)           2.50       2.49       2.54       2.93       5.63

X STA.        3.5        8.3       13.1       18.1       24.3       54.0
  A(I)           48.1       48.0       50.1       55.5       90.0
  V(I)           6.03       6.04       5.79       5.22       3.22
```

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        U.S. Geological Survey WSPRO Input File brai013a.wsp
        Hydraulic analysis for structure BRAITH00150013   Date: 30-OCT-97
        HYDRAULIC ANALYSIS OF BRAINTREE BRIDGE #13 OVER 3RD BRANCH WHITE R.
           *** RUN DATE & TIME: 10-30-97  11:53

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     195.   19659.    31.    44.                         2767.
   497.20          195.   19659.    31.    44.  1.00     0.    34.   2767.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.20     0.0    34.4   194.9   19659.    1450.   7.44

X STA.         0.0         3.7         5.8         7.6         9.4        11.0
  A(I)            16.8        10.7         9.4         9.1         8.9
  V(I)            4.33        6.77        7.71        7.99        8.17

X STA.        11.0        12.5        14.0        15.4        16.7        18.1
  A(I)             8.6         8.2         8.2         8.1         8.0
  V(I)            8.43        8.82        8.89        8.97        9.06

X STA.        18.1        19.3        20.6        21.9        23.1        24.4
  A(I)             7.9         7.8         8.1         8.1         8.3
  V(I)            9.14        9.25        8.90        8.95        8.76

X STA.        24.4        25.8        27.3        28.9        30.8        34.4
  A(I)             8.6         9.4         9.7        11.5        19.6
  V(I)            8.43        7.72        7.45        6.32        3.70

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2       1.      10.     5.     5.                            3.
             3     223.   20319.    46.    49.                         2789.
   497.68          224.   20329.    51.    54.  1.01   -15.    36.   2652.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      50.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.68   -15.0    36.1   224.0   20329.    1450.   6.47

X STA.       -15.0        -2.1         0.3         2.0         3.6         5.0
  A(I)            19.8        13.2        11.0        10.2         9.7
  V(I)            3.66        5.50        6.57        7.12        7.44

X STA.         5.0         6.4         7.7         9.0        10.3        11.5
  A(I)             9.5         9.1         9.2         8.9         8.9
  V(I)            7.62        7.93        7.86        8.11        8.14

X STA.        11.5        12.8        14.1        15.4        16.7        18.2
  A(I)             9.1         9.0         9.4         9.4         9.6
  V(I)            7.95        8.02        7.73        7.73        7.53

X STA.        18.2        19.7        21.5        23.7        26.8        36.1
  A(I)            10.3        11.0        12.2        14.0        20.2
  V(I)            7.04        6.56        5.94        5.18        3.59
```

# WSPRO OUTPUT FILE (continued)

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       U.S. Geological Survey WSPRO Input File brai013a.wsp
       Hydraulic analysis for structure BRAITH00150013   Date: 30-OCT-97
       HYDRAULIC ANALYSIS OF BRAINTREE BRIDGE #13 OVER 3RD BRANCH WHITE R.
          *** RUN DATE & TIME: 10-30-97  12:01

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

EXIT2:XS   ******  -500.    1362.  0.32 *****  500.07  498.96   4700.  499.74
     -233. ******    89.  113895.  1.75 ***** *******    0.53    3.45

EXITX:XS     200.  -500.    1698.  0.20  0.25  500.31 *******   4700.  500.11
      -33.   200.    90.  157380.  1.67  0.00    0.00    0.37    2.77

FULLV:FV      33.  -500.    1722.  0.19  0.03  500.35 *******   4700.  500.15
        0.    33.    90.  160191.  1.66  0.00    0.00    0.36    2.73
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.64

APPRO:AS      50.  -500.    1378.  0.24  0.07  500.43 *******   4700.  500.18
       50.    50.    53.  102605.  1.34  0.03   -0.01    0.44    3.41
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   500.15     499.36

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =    4067.      3790.    1.07

           <<<<<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      33.     0.     262.  0.10 *****  499.55  493.33    658.  499.45
        0. ******    34.   21690.  1.00 ***** *******    0.16    2.51

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  499.36 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    36.  0.06  0.21  500.47    0.01   4067.  500.02

             Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    4067.   473.  -500.   -27.   2.2   1.7   6.1   5.2   2.1   2.8
   RT:       1.     1.    75.    76.   0.0   0.0   2.7  68.6   0.5   2.7

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

APPRO:AS      29.  -500.    1454.  0.21  0.23  500.53  499.39   4700.  500.32
       50.    77.    53.  111159.  1.31  0.00    0.01    0.40    3.23

       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
   EXIT2:XS    -233.  -500.    89.   4700.  113895.    1362.    3.45  499.74
   EXITX:XS     -33.  -500.    90.   4700.  157380.    1698.    2.77  500.11
   FULLV:FV       0.  -500.    90.   4700.  160191.    1722.    2.73  500.15
   BRIDG:BR       0.     0.    34.    658.   21690.     262.    2.51  499.45
   RDWAY:RG       9.******* 4067.   4067.*****************    2.00  500.02
   APPRO:AS      50.  -500.    53.   4700.  111159.    1454.    3.23  500.32

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT2:XS    498.96    0.53  491.63  511.00************  0.32  500.07  499.74
   EXITX:XS  ********    0.37  488.89  511.00  0.25  0.00  0.20  500.31  500.11
   FULLV:FV  ********    0.36  488.89  511.00  0.03  0.00  0.19  500.35  500.15
   BRIDG:BR    493.33    0.16  490.11  499.45************  0.10  499.55  499.45
   RDWAY:RG  ****************  497.80  511.05  0.06******  0.21  500.47  500.02
   APPRO:AS    499.39    0.40  490.43  510.85  0.23  0.00  0.21  500.53  500.32
```

```
        U.S. Geological Survey WSPRO Input File brai013a.wsp
        Hydraulic analysis for structure BRAITH00150013   Date: 30-OCT-97
        HYDRAULIC ANALYSIS OF BRAINTREE BRIDGE #13 OVER 3RD BRANCH WHITE R.
           *** RUN DATE & TIME: 10-30-97  12:01

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

EXIT2:XS   ****** -500.    1603.  0.33 *****  500.48  499.29   5800.  500.15
     -233. ******    90.  140628.  1.61 ***** *******    0.49    3.62

EXITX:XS     200.  -500.    1937.  0.22  0.26  500.74 *******   5800.  500.52
      -33.   200.    91.  187004.  1.57  0.00    0.00    0.36    2.99

FULLV:FV      33.  -500.    1962.  0.21  0.03  500.77 *******   5800.  500.56
        0.    33.    91.  190271.  1.55  0.00    0.00    0.36    2.96
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

APPRO:AS      50.  -500.    1610.  0.25  0.07  500.85 *******   5800.  500.60
       50.    50.    54.  129559.  1.25  0.02   -0.01    0.42    3.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   500.56     499.36

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =    5210.      4894.    1.06

            <<<<<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      33.     0.     262.  0.07 *****  499.52  493.10     567.  499.45
        0. ******    34.   21690.  1.00 ***** *******    0.14    2.16

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  499.36 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    36.  0.06  0.23  500.89    0.00   5210.  500.37

               Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   5187.   478.  -500.   -22.   2.6   2.0   6.5   5.5   2.5   2.8
   RT:     22.    14.    63.    77.   0.4   0.2   3.4   8.6   0.7   2.7

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

APPRO:AS      29.  -500.    1675.  0.23  0.28  500.95  499.61   5800.  500.72
       50.    81.    54.  137764.  1.23  0.00    0.00    0.39    3.46

       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
   EXIT2:XS    -233.  -500.    90.   5800.  140628.    1603.    3.62  500.15
   EXITX:XS     -33.  -500.    91.   5800.  187004.    1937.    2.99  500.52
   FULLV:FV       0.  -500.    91.   5800.  190271.    1962.    2.96  500.56
   BRIDG:BR       0.     0.    34.    567.   21690.     262.    2.16  499.45
   RDWAY:RG       9.******* 5187.   5210.*****************    2.00  500.37
   APPRO:AS      50.  -500.    54.   5800.  137764.    1675.    3.46  500.72

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT2:XS    499.29    0.49  491.63  511.00************  0.33  500.48  500.15
   EXITX:XS  ********    0.36  488.89  511.00  0.26  0.00  0.22  500.74  500.52
   FULLV:FV  ********    0.36  488.89  511.00  0.03  0.00  0.21  500.77  500.56
   BRIDG:BR    493.10    0.14  490.11  499.45************  0.07  499.52  499.45
   RDWAY:RG  ****************  497.80  511.05  0.06******  0.23  500.89  500.37
   APPRO:AS    499.61    0.39  490.43  510.85  0.28  0.00  0.23  500.95  500.72
```

```
        U.S. Geological Survey WSPRO Input File brai013a.wsp
        Hydraulic analysis for structure BRAITH00150013   Date: 30-OCT-97
        HYDRAULIC ANALYSIS OF BRAINTREE BRIDGE #13 OVER 3RD BRANCH WHITE R.
           *** RUN DATE & TIME: 10-30-97  11:53

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

EXIT2:XS   ******   -68.     381.  0.27 *****  497.56  494.73   1450.  497.29
     -233. ******    70.   35135.  1.20 ***** *******    0.44    3.80

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "EXITX"     KRATIO =  1.46

EXITX:XS     200.   -19.     426.  0.18  0.23  497.79 *******   1450.  497.61
      -33.   200.    53.   51264.  1.01  0.00    0.00    0.25    3.41

FULLV:FV      33.   -19.     428.  0.18  0.03  497.82 *******   1450.  497.64
        0.    33.    53.   51665.  1.01  0.00    0.00    0.25    3.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.37

APPRO:AS      50.   -12.     214.  0.72  0.11  498.19 *******   1450.  497.47
       50.    50.    36.   18998.  1.00  0.27   -0.01    0.57    6.79
         <<<<<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      33.     0.     195.  0.86  0.07  498.06  495.00   1450.  497.20
        0.    33.    34.   19655.  1.00  0.20    0.01    0.52    7.44

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  499.36 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      29.   -15.     224.  0.66  0.16  498.34  495.65   1450.  497.68
       50.    31.    36.   20324.  1.01  0.11    0.00    0.55    6.47

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.284  0.000   21152.    -6.    28.   497.50

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT2:XS    -233.   -68.    70.   1450.   35135.     381.    3.80  497.29
   EXITX:XS     -33.   -19.    53.   1450.   51264.     426.    3.41  497.61
   FULLV:FV       0.   -19.    53.   1450.   51665.     428.    3.39  497.64
   BRIDG:BR       0.     0.    34.   1450.   19655.     195.    7.44  497.20
   RDWAY:RG       9.**************      0.****************    2.00********
   APPRO:AS      50.   -15.    36.   1450.   20324.     224.    6.47  497.68

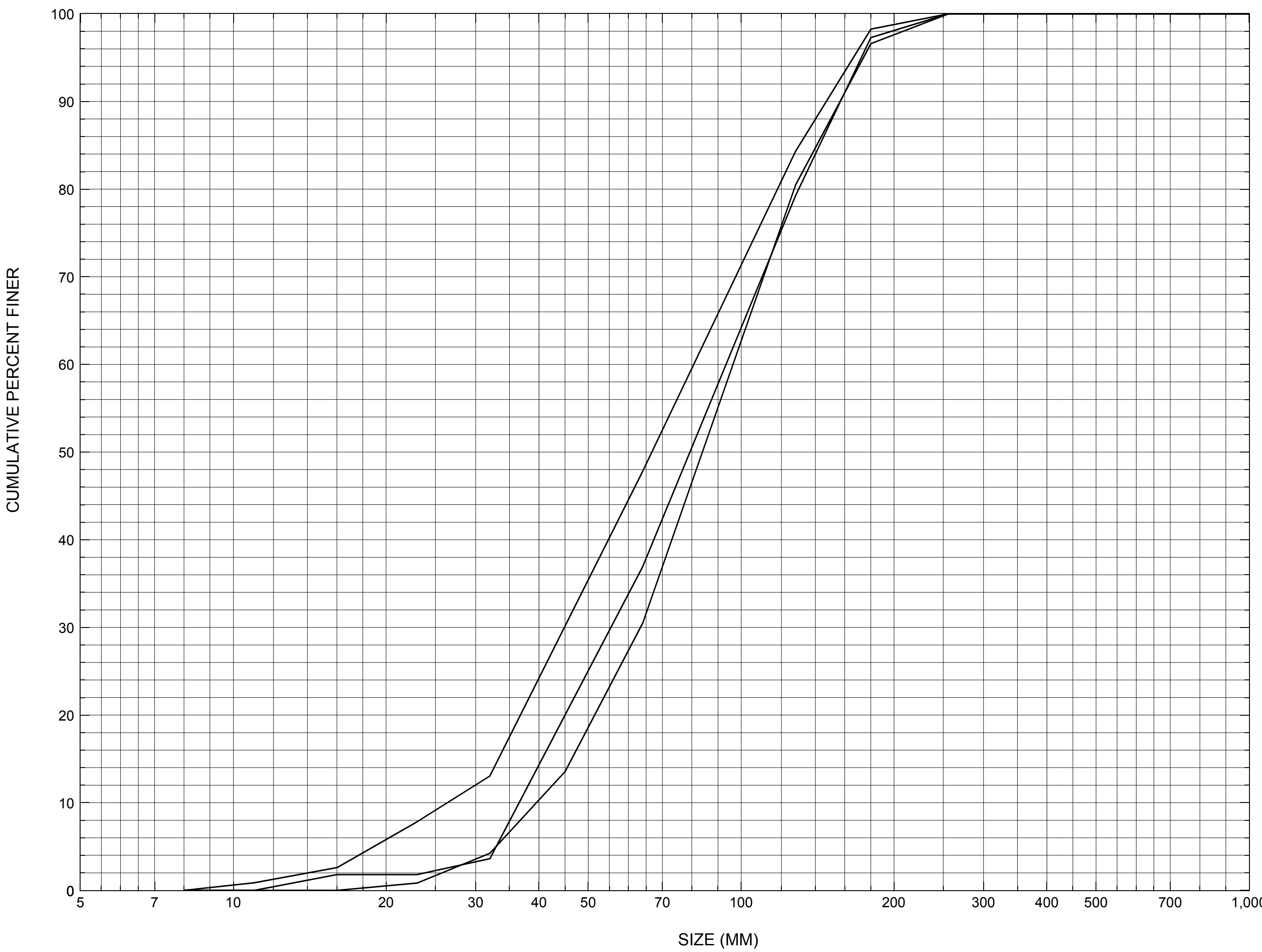
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -6.    28.   21152.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT2:XS    494.73    0.44  491.63  511.00************  0.27  497.56  497.29
   EXITX:XS  ********    0.25  488.89  511.00  0.23  0.00  0.18  497.79  497.61
   FULLV:FV  ********    0.25  488.89  511.00  0.03  0.00  0.18  497.82  497.64
   BRIDG:BR    495.00    0.52  490.11  499.45  0.07  0.20  0.86  498.06  497.20
   RDWAY:RG  ****************  497.80  511.05**********************************
   APPRO:AS    495.65    0.55  490.43  510.85  0.16  0.11  0.66  498.34  497.68
```

APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for three pebble counts in the channel approach of structure BRAITH00150013, in Braintree, Vermont.

# APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

# Structure Number BRAITH00150013

## General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 24 / 94

Highway District Number *(I - 2; nn)* 04

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

Town *(FIPS place code; I - 4; nnnnn)* 07600

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

Waterway *(I - 6)* 3RD BRANCH WHITE RIVER

Road Name *(I - 7):* -

Route Number TH015

Vicinity *(I - 9)* 0.2 MI JCT TH 15 + VT12A

Topographic Map Warren

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 44003

Longitude *(i - 17; nnnnn.n)* 72499

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10090200130902

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

Maximum span length *(I - 48; nnnn)* 0035

Year built *(I - 27; YYYY)* 1971

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

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

Deck Width *(I - 52; nn.n)* 143

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

Channel & Protection *(I - 61; n)* 7

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 008.5

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

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

Comments:

**The structural inspection report of 4/27/93 indicates the structure is a steel I-beam bridge with a timber deck and a narrow gravel road approach surface. The report indicates the abutment and wingwall concrete is in "like new" condition. Both abutment footings are reported as exposed. The exposure ranges from the top of the footing flush with the streambed at the upstream end of the left abutment to 1 foot exposure at the downstream end. For the right abutment, the footing top is exposed at the downstream end and there is 1 foot of exposure at the upstream end. The report indicates no change in channel scour from prior inspections and no embankment erosion. There is no vegetation buildup near the bridge. Channel alignment is noted as straight into the bridge crossing. Stone fill is reported as boulders in good condition.**

## 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: Sand and gravel and some larger stones

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:
-

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **28.58** $mi^2$  Lake/pond/swamp area **0.03** $mi^2$
Watershed storage *(ST)* **0.1** %
Bridge site elevation **810** ft  Headwater elevation **2823** ft
Main channel length **9.3** mi
10% channel length elevation **830** ft  85% channel length elevation **1600** ft
Main channel slope *(S)* **110.4** ft / mi

Watershed Precipitation Data

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

## Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

**NO BENCHMARK INFORMATION**

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

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

**NO FOUNDATION MATERIAL INFORMATION**

Comments:

**NO PLANS**

## Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

# LEVEL I DATA FORM

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

Qa/Qc Check by: **EMB** Date: **02/06/95**

Computerized by: **MAW** Date: **03/09/95**

Reviewd by: **RLB** Date: **05/08/98**

Structure Number **BRAITH00150013**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. WEBER** Date *(MM/DD/YY)* **10** / **20** / 19**94**

2. Highway District Number **04** Mile marker **000000**

County **ORANGE (017)** Town **BRAINTREE (07600)**

Waterway *(I - 6)* **THIRD BRANCH WHITE RIVER** Road Name **-**

Route Number **TH15** Hydrologic Unit Code: **01080105**

3. Descriptive comments:

**The bridge is 0.2 miles from the junction of TH 15 and VT12A. Railroad tracks are parallel to the stream on the right bank.**

## B. Bridge Deck Observations

4. Surface cover... LBUS **5** RBUS **5** 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 **44** *(feet)* Span length **35** *(feet)* Bridge width **14.3** *(feet)*

### Road approach to bridge:

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

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

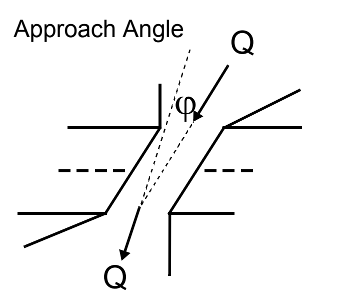
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

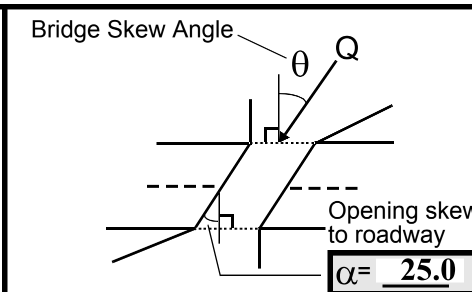
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 1 | 1 | 0 | - |
| RBUS | 1 | 1 | 2 | 1 |
| RBDS | 2 | 1 | 0 | - |
| LBDS | 2 | 1 | 0 | - |

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

### Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **25**




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

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

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

18. Bridge Type: 1a

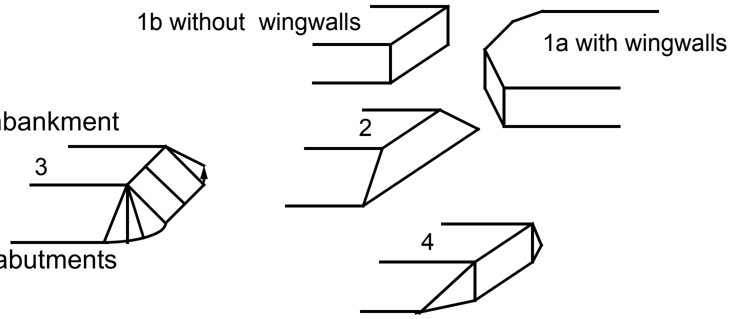
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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




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

**There are some trees on the right bank upstream but it is not heavily forested. The roadway width is approximately equal to the deck width, however, there are no true embankments, so road overflow will not act as weir flow. The upstream road approach protection is light. The road wash erosion at the right bank upstream road approach is probably off the embankment of nearby VT12A and the railroad embankment.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 44.5 | 4.0 | | | 7.0 | 1 | 3 | 7 | 7 | 0 | 0 |

23. Bank width **30.0** 24. Channel width **25.0** 25. Thalweg depth **50.0** 29. Bed Material **4**

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.):

**Unprotected banks further upstream indicate the bank material is fine sand and silt. Both banks have light fluvial erosion. On the streambed, sand is visible between cobbles. The cobbles are of a fairly uniform size and many are flat. There is local anabranching and gravel bars in the streambed several hundred feet upstream, which may have been caused by a 3 ft high beaver dam at about 900 ft upstream. The streambed material under the bridge and in the pooled area upstream is much larger than at the riffle far upstream. The banks near the bridge are well protected with stone fill. There is a small tributary about 500-600 ft upstream entering on the left bank, which is approximately 5% of the flow in the Third Branch White River.**

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

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

37. Material: -

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

**NO POINT BARS**

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

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

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

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

**NO CUT-BANKS**

45. Is channel scour present? Y *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: 50

47. Scour dimensions: Length 265 Width 15 Depth : 1 Position 10 %LB to 90 %RB

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

**Upstream scour starts at about 100 ft upstream and is about 1 ft deeper than in other pools upstream. More comments are in the downstream channel scour section. The channel scour deepens downstream.**

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 |
|---|---|---|---|---|---|---|---|
| 27.5 | | 2.5 | | 2 | 7 | 7 | 0 |

58. Bank width (BF) - 59. Channel width - 60. Thalweg depth 90.0 63. Bed Material 0

*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.):

**4**

**The bed material ranges from sand to boulders, with the median size being large cobble. Some material appears to be stone fill. Low flow is constricted by the abutments.**

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

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

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

70. Debris and Ice Comments:

**2**

**There is some debris in the channel downstream possibly due to beavers in the area.**

| Abutments | 71. Attack ∠(BF) | 72. Slope ∠ (Qmax) | 73. Toe loc. (BF) | 74. Scour Condition | 75. Scour depth | 76. Exposure depth | 77. Material | 78. Length |
|---|---|---|---|---|---|---|---|---|
| LABUT | | - | 90 | 2 | 2 | 0 | 1 | 90.0 |
| RABUT | 1 | - | 90 | | | 2 | 2 | 31.0 |

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

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

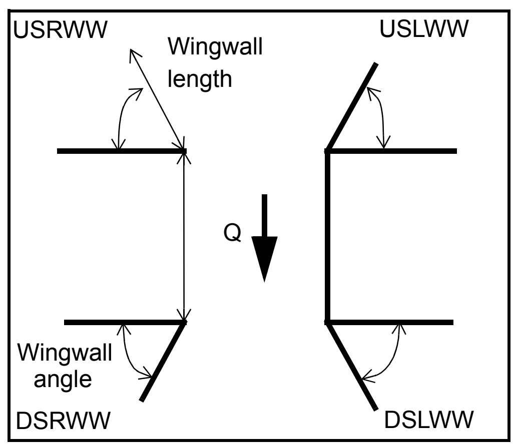
**0**
**1**
**1**

**The footing exposure of the left abutment is on the downstream end. The right abutment footing is exposed on the upstream end.**

80. Wingwalls:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 31.0 | |
| USRWW: | Y | | 1 | | 0 | 3.0 | |
| DSLWW: | 0 | | - | | Y | 17.5 | |
| DSRWW: | 1 | | 2 | | 0 | 19.0 | |

*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 | 0.5 | 2 | Y | 0 | 1 | 1 | - | - |
| Condition | Y | 0 | 1 | - | 1 | 2 | - | - |
| Extent | 1 | 1 | 0 | 2 | 2 | 0 | 0 | - |

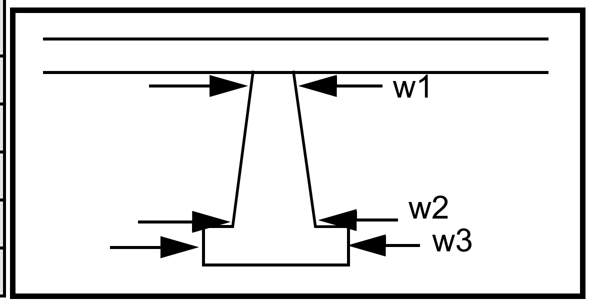
*Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee*
*Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed*
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
3
1
3
2
1
1

## Piers:

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

| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | | 5.0 | 4.5 | 10.0 | 60.0 | 65.0 |
| Pier 2 | 6.0 | 5.5 | - | 20.0 | - | - |
| Pier 3 | - | - | - | - | - | - |
| Pier 4 | - | - | - | - | - | - |




| Level 1 Pier Descr. | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| 86. Location (BF) | e type- | left | the up- | d as | *LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP* |
| 87. Type | 3 | wing | strea | well | ***1**- Solid pier, **2**- column, **3**- bent* |
| 88. Material | boul- | wall, | m | as | ***1**- Wood; **2**- concrete; **3**- metal; **4**- stone* |
| 89. Shape | der | cov- | junc- | the | ***1**- Round; **2**- Square; **3**- Pointed* |
| 90. Inclined? | is at | er- | tion | foot- | *Y- yes; N- no* |
| 91. Attack ∠ (BF) | the | ing | with | ing. | |
| 92. Pushed | base | most | the | Ther | *LB or RB* |
| 93. Length (feet) | - | - | - | - | |
| 94. # of piles | of | of its | left | e is | |
| 95. Cross-members | the | base | abut | type- | ***0**- none; **1**- laterals; **2**- diagonals; **3**- both* |
| 96. Scour Condition | dow | lengt | ment | 2 | ***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed* |
| 97. Scour depth | nstre | h, | is ex- | pro- | |
| 98. Exposure depth | am | but | pose | tec- | |

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

**tion on the left bank downstream.**

**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: 1______

Scour dimensions: Length 1_____ Width 2_____ Depth: 7_____ Positioned 0____ %LB to 0____ %RB

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

**4**
**0**
**2**
**-**

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

Confluence 1: Distance ma-____ Enters on teri-____ *(LB or RB)* Type al is____ *( **1**- perennial; **2**- ephemeral)*

Confluence 2: Distance large____ Enters on cob-____ *(LB or RB)* Type bles,____ *( **1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

**small boulders, and sand until 100 ft downstream where it is a sand channel over coarser material until the debris dam. Estimated maximum depth of the pool downstream is 6 ft. In the shallow areas, the sand layer is**

## F. Geomorphic Channel Assessment

107. Stage of reach evolution onl____

*__1__- Constructed*
*__2__- Stable*
*__3__- Aggraded*
*__4__- Degraded*
*__5__- Laterally unstable*
*__6__- Vertically and laterally unstable*

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

**y a few inches deep. Sand bank material is exposed at a large cut-bank 700 ft downstream on the left bank. There is also a large point bar at about 700 ft downstream on the right bank. There is no bank erosion within 2 bridge lengths, but where the left bank and right bank are unprotected, the banks are slightly cut. The right bank within 2 bridge lengths is protected with stone fill. The channel width at the exit section is about twice as wide as in the approach or bridge sections. The channel is very deep in areas upstream, under the bridge, and especially downstream. Local anabranching was seen in unprotected reaches far 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: BRAITH00150013　　Town: BRAINTREE
Road Number: TH 15　　County: ORANGE
Stream: 3RD BRANCH WHITE RIVER

Initials RLB　Date: 4/17/98　Checked: ECW

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 | 4700 | 5800 | 1450 |
| Main Channel Area, ft2 | 350 | 370 | 223 |
| Left overbank area, ft2 | 1095 | 1290 | 1 |
| Right overbank area, ft2 | 9 | 15 | 0 |
| Top width main channel, ft | 50 | 50 | 46 |
| Top width L overbank, ft | 491 | 491 | 5 |
| Top width R overbank, ft | 13 | 14 | 0 |
| D50 of channel, ft | 0.2531 | 0.2531 | 0.2531 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 7.0 | 7.4 | 4.8 |
| y1, average depth, LOB, ft | 2.2 | 2.6 | 0.2 |
| y1, average depth, ROB, ft | 0.7 | 1.1 | ERR |
| Total conveyance, approach | 111101 | 137728 | 20329 |
| Conveyance, main channel | 40599 | 44529 | 20319 |
| Conveyance, LOB | 70325 | 92833 | 10 |
| Conveyance, ROB | 177 | 367 | 0 |
| Percent discrepancy, conveyance | 0.0000 | -0.0007 | 0.0000 |
| Qm, discharge, MC, cfs | 1717.5 | 1875.2 | 1449.3 |
| Ql, discharge, LOB, cfs | 2975.0 | 3909.4 | 0.7 |
| Qr, discharge, ROB, cfs | 7.5 | 15.5 | 0.0 |
| Vm, mean velocity MC, ft/s | 4.9 | 5.1 | 6.5 |
| Vl, mean velocity, LOB, ft/s | 2.7 | 3.0 | 0.7 |
| Vr, mean velocity, ROB, ft/s | 0.8 | 1.0 | ERR |
| Vc-m, crit. velocity, MC, ft/s | 9.8 | 9.9 | 9.2 |
| Vc-l, crit. velocity, LOB, ft/s | ERR | ERR | ERR |
| Vc-r, crit. velocity, ROB, ft/s | ERR | ERR | ERR |

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

| Bridge Section | Q100 | Q500 | Other Q |
|---|---|---|---|
| (Q) total discharge, cfs | 4700 | 5800 | 1450 |
| (Q) discharge thru bridge, cfs | 658 | 567 | 1450 |
| Main channel conveyance | 21690 | 21690 | 19659 |
| Total conveyance | 21690 | 21690 | 19659 |
| Q2, bridge MC discharge,cfs | 658 | 567 | 1450 |
| Main channel area, ft2 | 262 | 262 | 195 |
| Main channel width (normal), ft | 31.2 | 31.2 | 31.2 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 31.2 | 31.2 | 31.2 |
| y_bridge (avg. depth at br.), ft | 8.40 | 8.40 | 6.25 |
| Dm, median (1.25*D50), ft | 0.316375 | 0.316375 | 0.316375 |
| y2, depth in contraction,ft | 2.35 | 2.06 | 4.62 |
| ys, scour depth (y2-ybridge), ft | -6.06 | -6.34 | -1.63 |

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 | 4700 | 5800 | 1450 |
| Q, thru bridge MC, cfs | 658 | 567 | 1450 |
| Vc, critical velocity, ft/s | 9.81 | 9.90 | 9.22 |
| Va, velocity MC approach, ft/s | 4.91 | 5.07 | 6.50 |
| Main channel width (normal), ft | 31.2 | 31.2 | 31.2 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 31.2 | 31.2 | 31.2 |
| qbr, unit discharge, ft2/s | 21.1 | 18.2 | 46.5 |
| Area of full opening, ft2 | 262.2 | 262.2 | 194.9 |
| Hb, depth of full opening, ft | 8.40 | 8.40 | 6.25 |
| Fr, Froude number, bridge MC | 0.16 | 0.14 | 0 |
| Cf, Fr correction factor (<=1.0) | 0.68 | 0.64 | 0.00 |
| **Area at downstream face, ft2 | N/A | N/A | N/A |
| **Hb, depth at downstream face, ft | N/A | N/A | N/A |
| **Fr, Froude number at DS face | ERR | ERR | ERR |
| **Cf, for downstream face (<=1.0) | N/A | N/A | N/A |
| Elevation of Low Steel, ft | 499.36 | 499.36 | 0 |

| | | | |
|---|---|---|---|
| Elevation of Bed, ft | 490.96 | 490.96 | -6.25 |
| Elevation of Approach, ft | 500.32 | 500.72 | 0 |
| Friction loss, approach, ft | 0.23 | 0.28 | 0 |
| Elevation of WS immediately US, ft | 500.09 | 500.44 | 0.00 |
| ya, depth immediately US, ft | 9.13 | 9.48 | 6.25 |
| Mean elevation of deck, ft | 501.21 | 501.21 | 0 |
| w, depth of overflow, ft (>=0) | 0.00 | 0.00 | 0.00 |
| Cc, vert contrac correction (<=1.0) | 0.98 | 0.97 | 1.00 |
| **Cc, for downstream face (<=1.0) | ERR | ERR | ERR |
| | | | |
| Ys, scour w/Chang equation, ft | -5.19 | -5.47 | N/A |
| Ys, scour w/Umbrell equation, ft | -1.77 | -1.42 | 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 | 658 | 567 | 1450 |
| Main channel area (DS), ft2 | 262.2 | 262.2 | 194.9 |
| Main channel width (normal), ft | 31.2 | 31.2 | 31.2 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 31.2 | 31.2 | 31.2 |
| D90, ft | 0.5045 | 0.5045 | 0.5045 |
| D95, ft | 0.5613 | 0.5613 | 0.5613 |
| Dc, critical grain size, ft | 0.0225 | 0.0167 | 0.2217 |
| Pc, Decimal percent coarser than Dc | 1.000 | 1.000 | 0.582 |
| | | | |
| Depth to armoring, ft | 0.00 | 0.00 | 0.48 |

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 | 4700 | 5800 | 1450 | 4700 | 5800 | 1450 |
| a’, abut.length blocking flow, ft | 501.6 | 501.6 | 16.6 | 20.6 | 21.2 | 3.3 |
| Ae, area of blocked flow ft2 | 416.47 | 458.1 | 41.41 | 45.98 | 53.74 | 7.17 |
| Qe, discharge blocked abut.,cfs | -- | -- | 200.44 | -- | -- | 25.73 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 2.81 | 3.11 | 4.84 | 3.12 | 3.22 | 3.59 |
| ya, depth of f/p flow, ft | 0.83 | 0.91 | 2.49 | 2.23 | 2.53 | 2.17 |
| | | | | | | |
| --Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru) | | | | | | |
| K1 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 |

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

| | | | | | | |
|---|---|---|---|---|---|---|
| theta | 65 | 65 | 65 | 115 | 115 | 115 |
| K2 | 0.96 | 0.96 | 0.96 | 1.03 | 1.03 | 1.03 |
| Fr, froude number f/p flow | 0.325 | 0.332 | 0.540 | 0.339 | 0.326 | 0.429 |
| ys, scour depth, ft | 12.55 | 13.45 | 9.40 | 8.00 | 8.66 | 5.16 |

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) | 501.6 | 501.6 | 16.6 | 20.6 | 21.2 | 3.3 |
| y1 (depth f/p flow, ft) | 0.83 | 0.91 | 2.49 | 2.23 | 2.53 | 2.17 |
| a'/y1 | 604.13 | 549.23 | 6.65 | 9.23 | 8.36 | 1.52 |
| Skew correction (p. 49, fig. 16) | 0.92 | 0.92 | 0.92 | 1.06 | 1.06 | 1.06 |
| Froude no. f/p flow | 0.33 | 0.33 | 0.54 | 0.34 | 0.33 | 0.43 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | 3.82 | 4.23 | ERR | ERR | ERR | ERR |
| vertical w/ ww's | 3.13 | 3.47 | ERR | ERR | ERR | ERR |
| spill-through | 2.10 | 2.33 | 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 | 0.16 | 0.14 | 0.52 | 0.16 | 0.14 | 0.52 |
| y, depth of flow in bridge, ft | 8.40 | 8.40 | 6.25 | 8.40 | 8.40 | 6.25 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | 0.13 | 0.10 | 1.04 | 0.13 | 0.10 | 1.04 |
| Fr>0.8 (vertical abut.) | ERR | ERR | ERR | ERR | ERR | ERR |