# LEVEL II SCOUR ANALYSIS FOR BRIDGE 45 (NFIETH00250045) on TOWN HIGHWAY 25, crossing UNION BROOK, NORTHFIELD, VERMONT

U.S. Geological Survey
Open-File Report 97-407

Prepared in cooperation with
VERMONT AGENCY OF TRANSPORTATION
and
FEDERAL HIGHWAY ADMINISTRATION

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By Ronda L. Burns and Michael A. Ivanoff

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**Pembroke, New Hampshire**

**1997**

U.S. DEPARTMENT OF THE INTERIOR
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## CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

### OTHER ABBREVIATIONS

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

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 45 (NFIETH00250045) ON TOWN HIGHWAY 25, CROSSING UNION BROOK, NORTHFIELD, VERMONT

*By* **Ronda L. Burns and Michael A. Ivanoff**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure NFIETH00250045 on Town Highway 25 crossing Union Brook, Northfield, 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 (U.S. Department of Transportation, 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 4.04-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, surface cover consists of shrubs and brush on all of the banks except the upstream right bank which is forested.

In the study area, Union Brook has an incised, meandering channel with a slope of approximately 0.018 ft/ft, an average channel top width of 41 ft and an average bank height of 2 ft. The channel bed material ranges from sand to cobble with a median grain size ($D_{50}$) of 65.8 mm (0.216 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 24, 1996, indicated that the reach was unstable. The stream meanders and there is a cut bank on the upstream right bank and trees are falling into the channel.

The Town Highway 25 crossing of Union Brook is a 28-ft-long, two-lane bridge consisting of one 26-foot concrete slab span (Vermont Agency of Transportation, written communication, October 13, 1995). The opening length of the structure parallel to the bridge face is 23.8 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 50 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

During the Level I assessment, a scour hole 3.0 ft deeper than the mean thalweg depth was observed at the upstream face of the bridge that extended from the center of the channel to the front of the upstream left wingwall. An additional scour hole 1.5 ft deeper than the mean thalweg depth was observed along the downstream right bank near the bridge. The scour counter measures at the site were a laid-up wall of concrete slabs along the upstream right bank beginning at the end of the upstream right wingwall and type-1 stone fill (less than 12 inches diameter) along the downstream right wingwall and bank, and type-2 stone fill (less than 36 inches diameter) along the downstream left wingwall and bank. 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 others, 1995). 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 0.4 to 0.9 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.5 to 9.1 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 others, 1995, p. 47). 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.

**Northfield, VT. Quadrangle, 1:24,000, 1980**
**Photo inspected 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*** NFIETH00250045 ***Stream*** Union Brook

***County*** Washington ***Road*** TH 25 ***District*** 6

## Description of Bridge

***Bridge length*** 28 ***ft*** ***Bridge width*** 21.4 ***ft*** ***Max span length*** 26 ***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*** 07/24/96

***Description of stone fill*** Type-1, along the downstream right wingwall and bank and type-2 along the downstream left wingwall and bank. A laid-up wall of concrete slabs extends from the upstream end of the upstream right wingwall and along the bank.

***Brief description of piers/abutments*** Abutments and wingwalls are concrete. There is a 0.6 foot scour hole in front of the upstream left wingwall.

***Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)*** Yes

***Is bridge skewed to flood flow according to*** Yes ***survey?*** ***Angle*** 50

There is a moderate channel bend in the upstream reach. The cut bank has developed where the bend impacts the upstream right bank.

***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*** | 07/24/96 | 0 | 0 |
| ***Level II*** | 07/24/96 | 0 | 0 |

***Potential for debris*** High. There is debris in the channel upstream and under the bridge and some trees have fallen down along both banks.

***Describe any features near or at the bridge that may affect flow (include observation date)*** There are piles of debris from a broken beaver dam at the upstream left corner of the left abutment and at the downstream right corner of the right abutment.

## Description of the Geomorphic Setting

***General topography*** The channel is located within a 300 foot-wide, flat to slightly irregular flood plain with steep valley walls on both sides.

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

***Date of inspection*** 07/24/96

***DS left:*** Moderately sloped channel bank to a flood plain

***DS right:*** Flood plain

***US left:*** Moderately sloped channel bank to a flood plain

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

## Description of the Channel

***Average top width*** 41 *ft* ***Average depth*** 2 *ft*

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

Meandering with alluvial channel boundaries and a 300 foot-wide flood plain.

07/24/96

***Vegetative co***

Brush, shrubs and small trees

***DS left:*** Brush, shrubs and small trees

***DS right:*** Brush, shrubs and small trees

***US left:*** Trees

***US right:***

***Do banks appear stable?*** No ***If not, describe location and type of instability and date of observation.***

The stream meanders and there is a cut bank on the upstream right bank and trees are falling into the channel. 07/24/96

None. 07/24/96

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

## Hydrology

***Drainage area*** 4.04 ***mi²***

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

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

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

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

***USGS gage description*** --

***USGS gage number*** --

***Gage drainage area*** -- ***mi²***

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

-

-

### Calculated Discharges

***Q100*** 1,250 ***ft³/s*** ***Q500*** 1,930 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(4.0/5.7)exp 0.67] with the location where the stream intersects the town boundary of Northfield. The drainage area at the town boundary is 5.7 square miles and has flood frequency estimates available in the Flood Insurance Study for the town of Northfield (Federal Emergency Management Agency, November 1977).

## 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 left corner of the bridge deck (elev. 497.39 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the right abutment (elev. 498.15 ft, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

| *[1]Cross-section* | *Section Reference Distance (SRD) in feet* | *[2]Cross-section development* | *Comments* |
|---|---|---|---|
| EXITX | -25 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 13 | 1 | Road Grade section |
| APPRO | 51 | 2 | Modelled Approach section (Templated from APTEM) |
| APTEM | 46 | 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 0.055, and overbank "n" values ranged from 0.055 to 0.085.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.018 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1980).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0082 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 also provides a consistent method for determining scour variables.

For the 100-, 500-year and incipient roadway-overtopping discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

## Bridge Hydraulics Summary

***Average bridge embankment elevation*** 498.6 ***ft***
***Average low steel elevation*** 495.9 ***ft***

***100-year discharge*** 1,250 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 492.8 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 250 ***$ft^3/s$***
***Area of flow in bridge opening*** 90 ***$ft^2$***
***Average velocity in bridge opening*** 11.1 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 13.0 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 495.5
***Water-surface elevation at Approach section without bridge*** 492.8
***Amount of backwater caused by bridge*** 2.7 ***ft***

***500-year discharge*** 1,930 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 493.3 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 754 ***$ft^3/s$***
***Area of flow in bridge opening*** 101 ***$ft^2$***
***Average velocity in bridge opening*** 11.7 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 13.8 ***/s***

***Water-surface elevation at Approach section with bridge*** 496.1
***Water-surface elevation at Approach section without bridge*** 493.3
***Amount of backwater caused by bridge*** 2.8 ***ft***

***Incipient overtopping discharge*** 790 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 492.3 ***ft***
***Area of flow in bridge opening*** 77 ***$ft^2$***
***Average velocity in bridge opening*** 10.2 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 11.8 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 494.6
***Water-surface elevation at Approach section without bridge*** 492.3
***Amount of backwater caused by bridge*** 2.3 ***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 others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the 100-year, 500-year and incipient over-topping discharges were computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For all modeled flows, the right abutment scour was computed by use of the Froehlich equation (Richardson and others, 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 at the left abutment for the 100-year, 500-year and incipient over-topping discharges was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) 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-yr discharge | 500-yr discharge | Incipient overtopping discharge |
| --- | --- | --- | --- |
| | *(Scour depths in feet)* | | |
| ***Main channel*** | | | |
| *Live-bed scour* | -- | -- | -- |
| *Clear-water scour* | 0.7 | 0.9 | 0.4 |
| *Depth to armoring* | N/A | N/A | 26.0 |
| ***Left overbank*** | -- | -- | -- |
| ***Right overbank*** | -- | -- | -- |

| Local scour: | 100-yr discharge | 500-yr discharge | Incipient overtopping discharge |
| --- | --- | --- | --- |
| ***Abutment scour*** | | | |
| *Left abutment* | 8.3 | 9.1 | 7.2 |
| *Right abutment* | 5.6 | 6.9 | 4.5 |
| ***Pier scour*** | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |
| *Pier 3* | -- | -- | -- |

## Riprap Sizing

| | 100-yr discharge | 500-yr discharge | Incipient overtopping discharge |
| --- | --- | --- | --- |
| | | *($D_{50}$ in feet)* | |
| ***Abutments:*** | | | |
| *Left abutment* | 1.6 | 1.8 | 1.4 |
| *Right abutment* | 1.6 | 1.8 | 1.4 |
| ***Piers:*** | -- | -- | -- |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

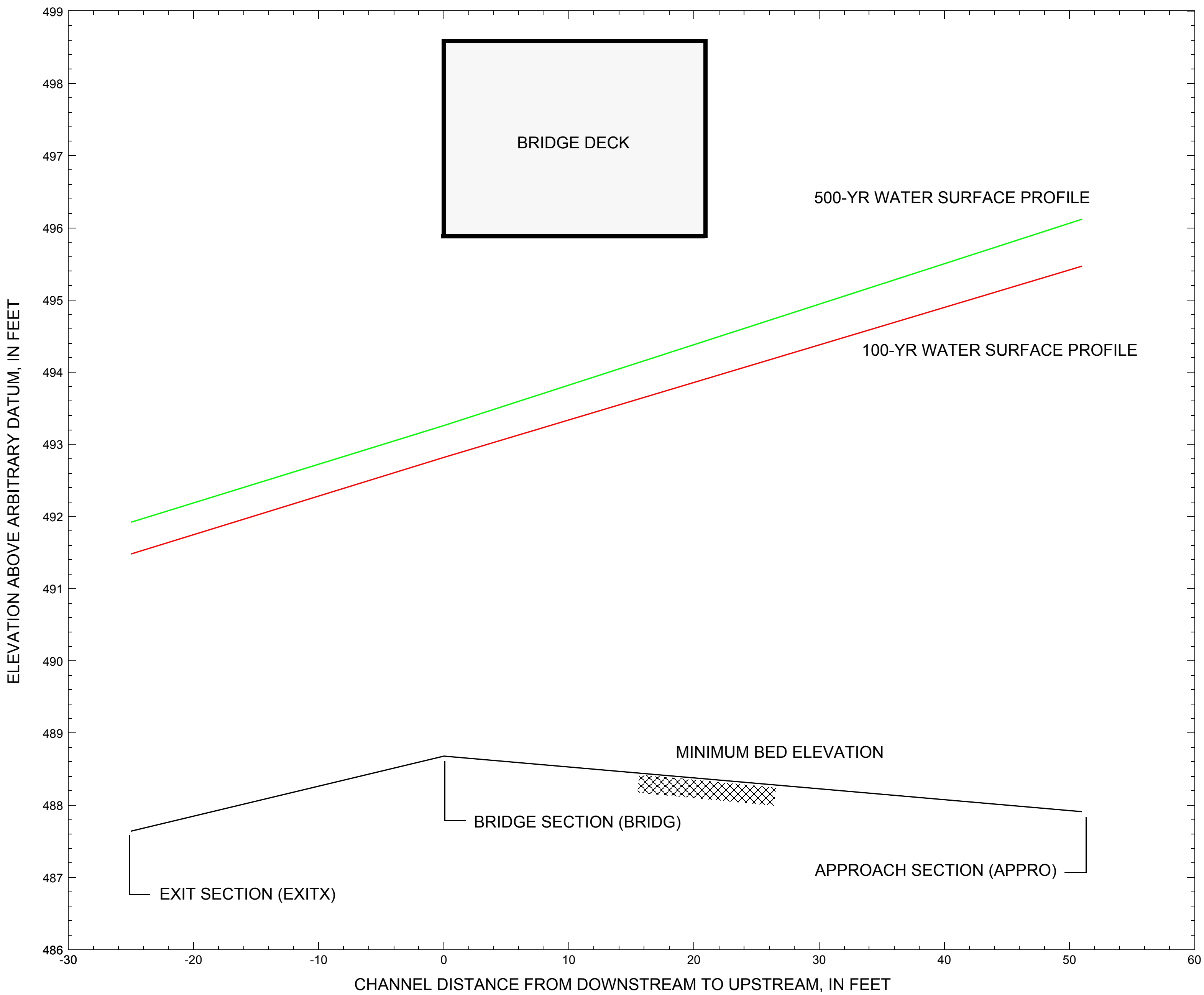


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure NFIETH00250045 on Town Highway 25, crossing Union Brook, Northfield, Vermont.

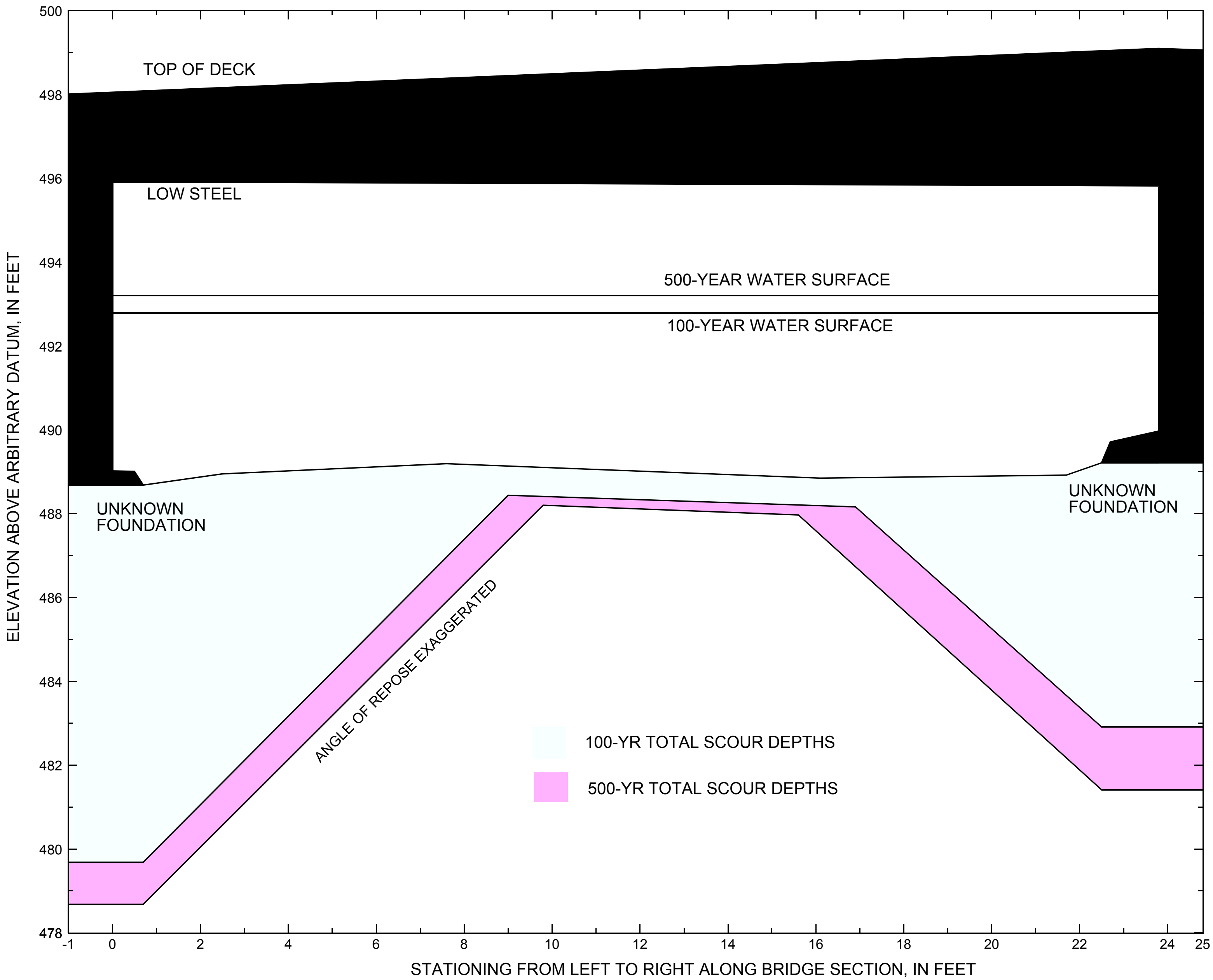


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure NFIETH00250045 on Town Highway 25, crossing Union Brook, Northfield, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure NFIETH00250045 on Town Highway 25, crossing Union Brook, Northfield, 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 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-yr. discharge is 1,250 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 495.9 | -- | 488.7 | 0.7 | 8.3 | -- | 9.0 | 479.7 | -- |
| Right abutment | 23.8 | -- | 495.8 | -- | 489.2 | 0.7 | 5.6 | -- | 6.3 | 482.9 | -- |

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 NFIETH00250045 on Town Highway 25, crossing Union Brook, Northfield, 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 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-yr. discharge is 1,930 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 495.9 | -- | 488.7 | 0.9 | 9.1 | -- | 10.0 | 478.7 | -- |
| Right abutment | 23.8 | -- | 495.8 | -- | 489.2 | 0.9 | 6.9 | -- | 7.8 | 481.4 | -- |

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, 1980, Northfield, 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 nfie045.wsp
T2        Hydraulic analysis for structure NFIETH00250045   Date: 18-APR-97
T3        TH 25 CROSSING UNION BROOK IN NORTHFIELD, VT                       RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1250.0   1930.0  790.0
SK          0.018    0.018   0.018
*
XS   EXIT1    -25           0.
GR         -277.0, 508.83   -262.4, 500.51   -187.1, 494.46    -92.2, 491.81
GR          -15.0, 491.16     -6.8, 490.55      0.0, 489.06      3.4, 488.49
GR            8.3, 487.97     12.2, 487.64     15.9, 488.42     17.9, 489.10
GR           24.6, 490.23    205.0, 490.23    250.7, 493.47    293.3, 506.55
* GR          110.5, 488.94    171.9, 488.00    -45.4, 495.69    -26.5, 495.84
*
N           0.055        0.050       0.085
SA                  -6.8        24.6
*
XS   FULLV      0  * * *   0.0071
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    495.85       0.0
GR            0.0, 495.90      0.0, 489.02      0.5, 489.01
GR            0.7, 488.68      2.5, 488.95      7.6, 489.19     12.0, 489.02
GR           16.1, 488.85     21.7, 488.92     22.5, 489.21     22.7, 489.71
GR           23.8, 489.97     23.8, 495.80      0.0, 495.90
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      31.5 * *     38.6      6.4
N           0.040
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     13      21.4     1
GR         -352.6, 506.28   -292.5, 500.60   -218.4, 494.98   -144.1, 494.64
GR          -67.1, 495.05      0.0, 498.05     23.9, 499.10    114.2, 505.30
GR          198.6, 514.87
*
XT   APTEM     46           0.
GR         -277.0, 508.83   -262.4, 500.51   -187.1, 494.46    -92.2, 491.81
GR          -16.7, 491.11      0.0, 489.68      7.9, 488.59
GR           13.3, 488.23     16.1, 487.87     17.7, 488.18     18.5, 488.47
GR           20.5, 491.41     35.9, 494.38     41.1, 498.69     47.7, 499.73
GR          210.0, 514.75
*
AS   APPRO     51  * * *   0.0082
GT
N           0.065        0.055
SA                   0.0
*
HP 1 BRIDG 492.82 1 492.82
HP 2 BRIDG 492.82 * * 1000
HP 2 RDWAY 495.34 * * 250
HP 1 APPRO 495.47 1 495.47
HP 2 APPRO 495.47 * * 1250
*
HP 1 BRIDG 493.26 1 493.26
HP 2 BRIDG 493.26 * * 1176
HP 2 RDWAY 495.90 * * 754
HP 1 APPRO 496.12 1 496.12
HP 2 APPRO 496.12 * * 1930
*
HP 1 BRIDG 492.28 1 492.28
HP 2 BRIDG 492.28 * * 790
HP 1 APPRO 494.63 1 494.63
HP 2 APPRO 494.63 * * 790
*
EX
ER
```

# APPENDIX B:

# **WSPRO OUTPUT FILE**

# WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File nfie045.wsp
     Hydraulic analysis for structure NFIETH00250045   Date: 18-APR-97
     TH 25 CROSSING UNION BROOK IN NORTHFIELD, VT                      RLB
        *** RUN DATE & TIME: 05-23-97  13:40

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

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1       90      6847     24     31                          998
 492.82            90      6847     24     31  1.00      0     24      998

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     492.82     0.0    23.8    90.3    6847.    1000.  11.07

X STA.         0.0        2.0        3.3        4.5        5.6        6.7
  A(I)            7.9        4.9        4.6        4.3        4.1
  V(I)           6.32      10.19      10.84      11.73      12.07

X STA.         6.7        7.8        8.9       10.0       11.1       12.1
  A(I)            4.1        4.0        4.0        3.9        3.9
  V(I)          12.27      12.38      12.37      12.81      12.68

X STA.        12.1       13.1       14.1       15.1       16.1       17.1
  A(I)            3.9        3.9        3.9        3.9        3.9
  V(I)          12.93      12.79      12.95      12.89      12.70

X STA.        17.1       18.1       19.2       20.3       21.5       23.8
  A(I)            4.0        4.2        4.2        4.9        7.7
  V(I)          12.58      11.79      11.77      10.24       6.53

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

       WSEL     LEW     REW    AREA        K        Q    VEL
     495.34  -223.1   -60.6    79.3    1331.     250.   3.15

X STA.      -223.1     -206.9     -196.9     -188.2     -180.7     -173.8
  A(I)            5.3        4.3        4.2        3.9        3.8
  V(I)           2.36       2.88       3.00       3.21       3.32

X STA.      -173.8     -167.5     -161.7     -156.2     -151.0     -146.2
  A(I)            3.6        3.5        3.4        3.4        3.3
  V(I)           3.45       3.53       3.62       3.67       3.77

X STA.      -146.2     -141.4     -136.4     -130.9     -125.2     -118.7
  A(I)            3.3        3.3        3.5        3.5        3.7
  V(I)           3.75       3.75       3.54       3.54       3.34

X STA.      -118.7     -111.6     -103.6      -94.0      -82.0      -60.6
  A(I)            3.9        4.0        4.4        4.8        5.9
  V(I)           3.20       3.10       2.85       2.59       2.14

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      607     29258    199    199                         6017
           2      176     12953     37     40                         2182
 495.47           784     42211    236    239  1.12   -198     37     7637

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

       WSEL     LEW     REW    AREA        K        Q    VEL
     495.47  -199.2    37.2   783.8   42211.    1250.   1.59

X STA.      -199.2     -141.7     -119.5     -103.0      -89.6      -78.0
  A(I)           78.7       56.5       50.7       47.2       42.7
  V(I)           0.79       1.11       1.23       1.32       1.47

X STA.       -78.0      -66.9      -56.6      -46.5      -37.0      -28.0
  A(I)           42.3       40.3       40.1       39.0       37.4
  V(I)           1.48       1.55       1.56       1.60       1.67

X STA.       -28.0      -19.4      -11.3       -4.8        0.6        4.5
  A(I)           36.7       36.2       33.1       29.9       24.1
  V(I)           1.70       1.73       1.89       2.09       2.60

X STA.         4.5        8.2       11.6       15.2       19.3       37.2
  A(I)           24.4       23.8       25.6       29.8       45.3
  V(I)           2.56       2.63       2.44       2.10       1.38
```

```
     U.S. Geological Survey WSPRO Input File nfie045.wsp
     Hydraulic analysis for structure NFIETH00250045   Date: 18-APR-97
     TH 25 CROSSING UNION BROOK IN NORTHFIELD, VT                       RLB
        *** RUN DATE & TIME: 05-23-97  13:40

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      101      8070     24     32                         1177
493.26           101      8070     24     32  1.00      0     24     1177

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    493.26     0.0    23.8   100.8    8070.    1176.  11.67

X STA.         0.0        2.0        3.4        4.5        5.7        6.8
  A(I)             9.0        5.8        4.9        4.7        4.7
  V(I)            6.55      10.20      11.95      12.48      12.54

X STA.         6.8        7.9        9.0       10.1       11.1       12.1
  A(I)             4.5        4.5        4.5        4.3        4.3
  V(I)           13.07      13.18      13.19      13.68      13.55

X STA.        12.1       13.1       14.1       15.1       16.1       17.1
  A(I)             4.3        4.3        4.3        4.3        4.3
  V(I)           13.75      13.62      13.81      13.75      13.55

X STA.        17.1       18.1       19.1       20.3       21.5       23.8
  A(I)             4.5        4.6        5.0        5.4        8.7
  V(I)           13.05      12.90      11.74      10.82       6.78

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.

      WSEL     LEW     REW    AREA        K        Q    VEL
    495.90  -230.5   -48.1   175.9    4649.     754.   4.29

X STA.      -230.5     -211.7     -202.3     -193.5     -185.5     -177.8
  A(I)            11.8        9.2        8.9        8.4        8.3
  V(I)            3.19       4.11       4.23       4.47       4.52

X STA.      -177.8     -170.6     -163.7     -157.2     -150.8     -144.7
  A(I)             8.1        8.0        7.8        7.7        7.6
  V(I)            4.63       4.74       4.86       4.89       4.93

X STA.      -144.7     -138.5     -132.1     -125.3     -118.2     -110.7
  A(I)             7.7        7.7        8.0        8.1        8.3
  V(I)            4.91       4.89       4.71       4.64       4.52

X STA.      -110.7     -102.4      -93.6      -84.2      -73.0      -48.1
  A(I)             8.7        8.9        9.1       10.2       13.2
  V(I)            4.31       4.24       4.13       3.69       2.86

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      739     39549    207    207                         7924
          2      201     15805     38     41                         2623
496.12           940     55355    245    248  1.10   -206     38     9963

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.12  -207.3    37.9   940.3   55355.    1930.   2.05

X STA.      -207.3     -151.6     -128.6     -111.5      -97.5      -85.3
  A(I)            91.3       67.5       59.6       54.9       52.0
  V(I)            1.06       1.43       1.62       1.76       1.85

X STA.       -85.3      -74.0      -63.3      -52.9      -43.1      -33.6
  A(I)            49.6       48.1       47.8       45.7       45.1
  V(I)            1.95       2.01       2.02       2.11       2.14

X STA.       -33.6      -24.5      -15.7       -8.1       -1.7        3.2
  A(I)            44.3       43.8       40.9       38.1       31.9
  V(I)            2.18       2.21       2.36       2.53       3.03

X STA.         3.2        7.4       11.2       15.2       20.1       37.9
  A(I)            29.7       29.2       31.6       36.2       53.0
  V(I)            3.25       3.30       3.06       2.66       1.82
```

```
       U.S. Geological Survey WSPRO Input File nfie045.wsp
       Hydraulic analysis for structure NFIETH00250045   Date: 18-APR-97
       TH 25 CROSSING UNION BROOK IN NORTHFIELD, VT                       RLB
          *** RUN DATE & TIME: 05-23-97  13:40

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       77      5428     24     30                          793
  492.28            77      5428     24     30  1.00      0     24      793

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

        WSEL     LEW     REW    AREA       K        Q    VEL
      492.28     0.0    23.8    77.4    5428.     790.  10.20

X STA.         0.0        1.9        3.2        4.3        5.5        6.6
  A(I)             6.5        4.3        3.8        3.7        3.6
  V(I)            6.06       9.23      10.46      10.60      10.94

X STA.         6.6        7.8        8.9       10.0       11.1       12.1
  A(I)             3.6        3.5        3.5        3.4        3.4
  V(I)           10.94      11.31      11.28      11.48      11.70

X STA.        12.1       13.2       14.2       15.2       16.2       17.2
  A(I)             3.4        3.4        3.4        3.4        3.4
  V(I)           11.55      11.77      11.71      11.63      11.76

X STA.        17.2       18.2       19.2       20.3       21.5       23.8
  A(I)             3.5        3.6        3.7        4.1        6.4
  V(I)           11.42      11.04      10.75       9.69       6.15

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      444     18023    189    189                         3870
            2      146      9625     36     38                         1660
  494.63           590     27648    225    227  1.18   -188     36     4992

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      51.

        WSEL     LEW     REW    AREA       K        Q    VEL
      494.63  -188.7    36.2   590.1   27648.     790.   1.34

X STA.      -188.7     -123.6     -103.0      -88.8      -76.5      -65.2
  A(I)            64.7       44.9       37.9       35.4       33.7
  V(I)            0.61       0.88       1.04       1.11       1.17

X STA.       -65.2      -54.6      -45.0      -35.7      -26.8      -18.5
  A(I)            32.5       30.4       30.4       29.6       28.5
  V(I)            1.21       1.30       1.30       1.33       1.39

X STA.       -18.5      -10.9       -5.0       -0.2        3.3        6.4
  A(I)            27.8       24.9       22.8       17.9       17.1
  V(I)            1.42       1.59       1.73       2.20       2.31

X STA.         6.4        9.3       12.2       15.1       18.4       36.2
  A(I)            17.5       17.8       18.5       21.7       35.9
  V(I)            2.25       2.21       2.13       1.82       1.10
```

# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File nfie045.wsp
        Hydraulic analysis for structure NFIETH00250045   Date: 18-APR-97
        TH 25 CROSSING UNION BROOK IN NORTHFIELD, VT                       RLB
           *** RUN DATE & TIME: 05-23-97  13:40

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

EXIT1:XS   ******    -52      330  0.47 *****  491.96  491.43    1250  491.48
       -24 ******    223     9315  2.12 ***** *******    0.89    3.79

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.42

FULLV:FV       25    -92      436  0.26  0.32  492.27 *******    1250  492.01
         0     25    228    13242  1.99  0.00    0.00    0.61    2.87
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.18     492.51     492.75
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   491.51     514.79    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   491.51     514.79     492.75
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   492.75     514.79     492.75

APPRO:AS       51   -124      233  0.67 *****  493.42  492.75    1250  492.75
        51     51     27     8548  1.50 ***** *******    0.93    5.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =  496.36       0.00     493.44     494.64
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    1000.     492.82

            <<<<<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       25      0       90  1.91 *****  494.73  492.82    1000  492.82
         0     25     24     6850  1.00 ***** *******    1.00   11.08

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  495.85 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    30.  0.03  0.04  495.49    0.00    250.  495.34

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    250.   163.  -223.   -61.   0.7   0.5   3.6   3.1   0.6   3.1
   RT:      0.     6.    12.    18.   0.3   0.1   4.5  22.4   1.0   3.0

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

APPRO:AS       20   -198      783  0.04  0.11  495.51  492.75    1250  495.47
        51     25     37    42154  1.12  0.67    0.01    0.16    1.60

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.843  0.702   12502.   -10.    14. ********

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -25.   -53.   223.   1250.    9315.     330.    3.79  491.48
   FULLV:FV       0.   -93.   228.   1250.   13242.     436.    2.87  492.01
   BRIDG:BR       0.     0.    24.   1000.    6850.      90.   11.08  492.82
   RDWAY:RG      13.*******   250.    250.*********       0.    1.00  495.34
   APPRO:AS      51.  -199.    37.   1250.   42154.     783.    1.60  495.47

    XSID:CODE    XLKQ   XRKQ       KQ
   APPRO:AS     -10.    14.   12502.

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS     491.43    0.89  487.64  508.83************  0.47  491.96  491.48
   FULLV:FV   ********    0.61  487.82  509.01  0.32  0.00  0.26  492.27  492.01
   BRIDG:BR     492.82    1.00  488.68  495.90************  1.91  494.73  492.82
   RDWAY:RG   ****************  494.64  514.87  0.03******  0.04  495.49  495.34
   APPRO:AS     492.75    0.16  487.91  514.79  0.11  0.67  0.04  495.51  495.47
```

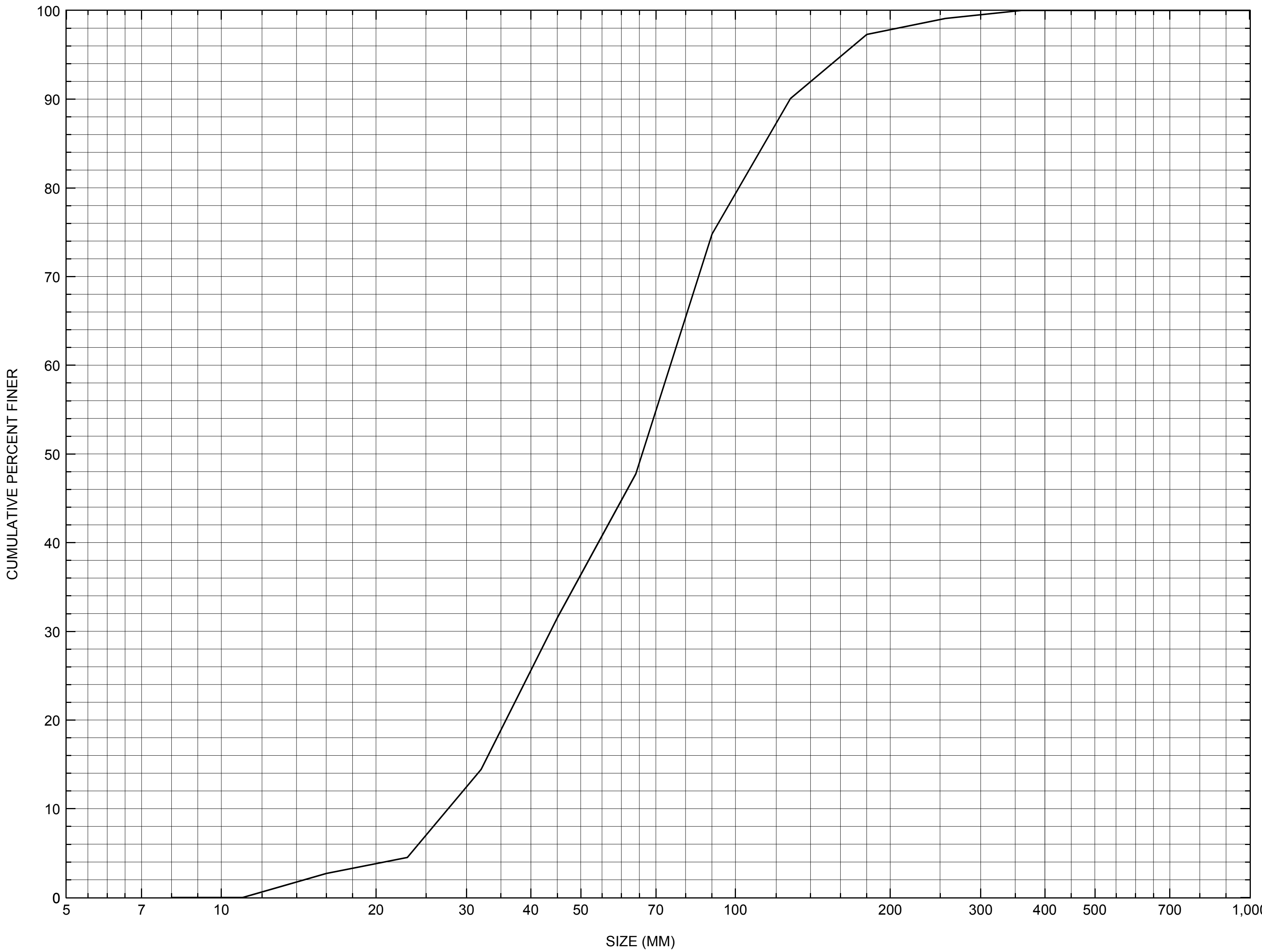
# WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File nfie045.wsp
       Hydraulic analysis for structure NFIETH00250045   Date: 18-APR-97
       TH 25 CROSSING UNION BROOK IN NORTHFIELD, VT                       RLB
          *** RUN DATE & TIME: 05-23-97  13:40

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

EXIT1:XS   ******    -95      464  0.53 *****  492.45  491.85    1930  491.92
       -24 ******    229    14380  1.96 ***** *******    0.86    4.16

FULLV:FV       25   -108      587  0.30  0.33  492.77 *******    1930  492.47
         0     25    234    19754  1.81  0.00   -0.01    0.60    3.29
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     2.96     492.09     493.25
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.97     514.79    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.97     514.79     493.25
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   493.25     514.79     493.25

APPRO:AS       51   -141      314  0.80 *****  494.05  493.25    1930  493.25
        51     51     30    12263  1.36 ***** *******    0.94    6.14
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   498.58       0.00     494.93     494.64
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   493.26     495.97     496.12     495.85
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                       YU/Z,WSIU,WS = 1.08     496.37     496.44
 ===270 REJECTED FLOW CLASS 2 (5) SOLUTION.
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    1176.     493.26

             <<<<<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       25      0      101  2.11 *****  495.38  493.26    1176  493.26
         0     25     24     8076  1.00 ***** *******    1.00   11.66

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  495.85 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    30.  0.04  0.07  496.15    0.00    754.  495.90

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   754.   182.  -231.   -48.   1.3   1.0   5.1   4.3   1.2   3.1
   RT:     0.    19.    12.    31.   1.0   0.6   5.7  10.6   1.6   3.1

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

APPRO:AS       20   -206      939  0.07  0.14  496.19  493.25    1930  496.12
        51     27     38    55288  1.10  0.67    0.00    0.19    2.05

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.862  0.769   12774.   -14.    10. ********

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -25.   -96.   229.   1930.   14380.     464.    4.16  491.92
   FULLV:FV       0.  -109.   234.   1930.   19754.     587.    3.29  492.47
   BRIDG:BR       0.     0.    24.   1176.    8076.     101.   11.66  493.26
   RDWAY:RG      13.*******   754.    754.*********       0.    1.00  495.90
   APPRO:AS      51.  -207.    38.   1930.   55288.     939.    2.05  496.12

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    491.85    0.86  487.64  508.83************  0.53  492.45  491.92
   FULLV:FV  ********    0.60  487.82  509.01  0.33  0.00  0.30  492.77  492.47
   BRIDG:BR    493.26    1.00  488.68  495.90************  2.11  495.38  493.26
   RDWAY:RG  ****************  494.64  514.87  0.04******  0.07  496.15  495.90
   APPRO:AS    493.25    0.19  487.91  514.79  0.14  0.67  0.07  496.19  496.12
```

```
        U.S. Geological Survey WSPRO Input File nfie045.wsp
        Hydraulic analysis for structure NFIETH00250045   Date: 18-APR-97
        TH 25 CROSSING UNION BROOK IN NORTHFIELD, VT                       RLB
           *** RUN DATE & TIME: 05-23-97  13:40

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

EXIT1:XS   ******    -13      229  0.43 *****  491.51  491.07     790  491.08
       -24 ******    217     5885  2.33 ***** *******    0.93    3.44

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

FULLV:FV       25    -43      309  0.22  0.31  491.80 *******     790  491.58
         0     25    222     8573  2.15  0.00   -0.02    0.61    2.56
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.32     492.02     492.29
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   491.08     514.79    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   491.08     514.79     492.29
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   492.29     514.79     492.29

APPRO:AS       51   -107      168  0.57 *****  492.86  492.29     790  492.29
        51     51     25     5888  1.65 ***** *******    0.95    4.71
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =      790.     492.28

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

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

BRIDG:BR       25      0       77  1.62 *****  493.90  492.28     790  492.28
         0     25     24     5426  1.00 ***** *******    1.00   10.20

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  495.85 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<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       20   -188      591  0.03  0.10  494.66  492.29     790  494.63
        51     24     36    27679  1.18  0.67    0.01    0.16    1.34

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.821  0.600   11023.    -6.    17.   494.61

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

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD     LEW     REW       Q        K      AREA     VEL    WSEL
   EXIT1:XS      -25.    -14.    217.    790.    5885.     229.     3.44  491.08
   FULLV:FV        0.    -44.    222.    790.    8573.     309.     2.56  491.58
   BRIDG:BR        0.      0.     24.    790.    5426.      77.    10.20  492.28
   RDWAY:RG       13.**************       0.******************     1.00********
   APPRO:AS       51.   -189.     36.    790.   27679.     591.     1.34  494.63

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -6.    17.   11023.

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF     HO   VHD      EGL    WSEL
   EXIT1:XS    491.07    0.93  487.64  508.83************  0.43  491.51  491.08
   FULLV:FV  ********    0.61  487.82  509.01  0.31  0.00  0.22  491.80  491.58
   BRIDG:BR    492.28    1.00  488.68  495.90************  1.62  493.90  492.28
   RDWAY:RG ****************  494.64  514.87**********************************
   APPRO:AS    492.29    0.16  487.91  514.79  0.10  0.67  0.03  494.66  494.63
```

APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure NFIETH00250045, in Northfield, Vermont.

APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

## Structure Number NFIETH00250045

## 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)* 50275

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

Waterway *(I - 6)* UNION BROOK

Road Name *(I - 7)*: -

Route Number C3025

Vicinity *(I - 9)* 0.15 MI TO JCT W CL3 TH8

Topographic Map Northfield

Hydrologic Unit Code: -

Latitude *(I - 16; nnnn.n)* 44098

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

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10121300451213

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

Maximum span length *(I - 48; nnnn)* 0026

Year built *(I - 27; YYYY)* 1949

Structure length *(I - 49; nnnnnn)* 000028

Average daily traffic, ADT *(I - 29; nnnnnn)* 000200

Deck Width *(I - 52; nn.n)* 214

Year of ADT *(I - 30; YY)* 92

Channel & Protection *(I - 61; n)* 4

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)* N

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 17.9

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

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

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

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

Comments:

**According to the structural inspection report dated 9/19/94, the deck is a concrete slab with asphalt overlay. Abutments and wings are concrete. A section of concrete footing is showing on the right abutment and the upstream right wingwall. A gravel bar in front of the right abutment blocks a third of channel flow. A couple of small manmade stone dams extend across the channel under this structure. The channel has poor US alignment; it flows in at nearly a 90 degree angle. The right abutment and the upstream right wingwall were undermined in the past. The deck and abutments were recently widened.**

## Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

Downstream distance (*miles*): -  Town: -  Year Built: -
Highway No. : -  Structure No. : -  Structure Type: -
Clear span (*ft*): -  Clear Height (*ft*): -  Full Waterway ($ft^2$): -

Comments:
-

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **4.04** $mi^2$  Lake/pond/swamp area **0.005** $mi^2$
Watershed storage *(ST)* **0.12** %
Bridge site elevation **900** ft  Headwater elevation **2386** ft
Main channel length **4.04** mi
10% channel length elevation **960** ft  85% channel length elevation **1880** ft
Main channel slope *(S)* **303.63** 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: U (*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 cord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low cord to bed length | - | - | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low cord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low cord to bed length | - | - | - | - | - | - | - | - | - | - | - |

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

Comments: **NO CROSS SECTION INFORMATION**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low cord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low cord to bed length | - | - | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low cord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low cord to bed length | - | - | - | - | - | - | - | - | - | - | - |

# APPENDIX E:

# LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **09/23/96**
Computerized by: **RB** Date: **09/24/96**
Reviewd by: **RB** Date: **05/20/97**

Structure Number **NFIETH00250045**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **07** / **24** / 19**96**

2. Highway District Number **06** Mile marker **0000**

County **WASHINGTON (023)** Town **NORTHFIELD (50275)**

Waterway *(I - 6)* **UNION BROOK** Road Name **WESTWALL ROAD**

Route Number **TH25** Hydrologic Unit Code: **02010003**

3. Descriptive comments:

**Located 0.15 miles from the junction with TH 8, Union St.**

## B. Bridge Deck Observations

4. Surface cover... LBUS **5** RBUS **6** 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 **2** UB **1** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **28** *(feet)* Span length **26** *(feet)* Bridge width **21.4** *(feet)*

### Road approach to bridge:

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

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

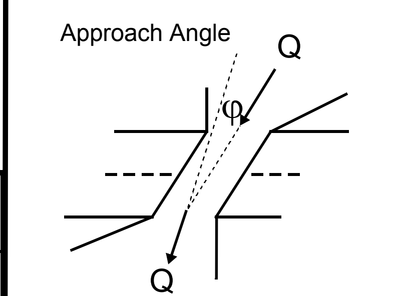
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

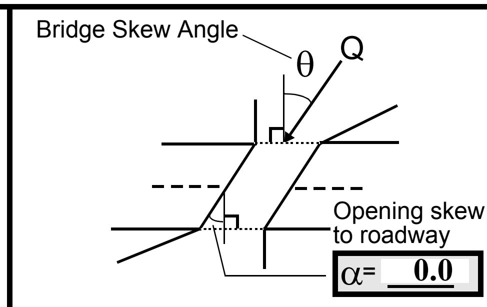
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 0 | - | 0 | - |
| RBUS | 5 | 1 | 0 | - |
| RBDS | 0 | - | 2 | 2 |
| LBDS | 0 | - | 0 | - |

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

### Channel approach to bridge (BF):

15. Angle of approach: **15** 16. Bridge skew: **50**



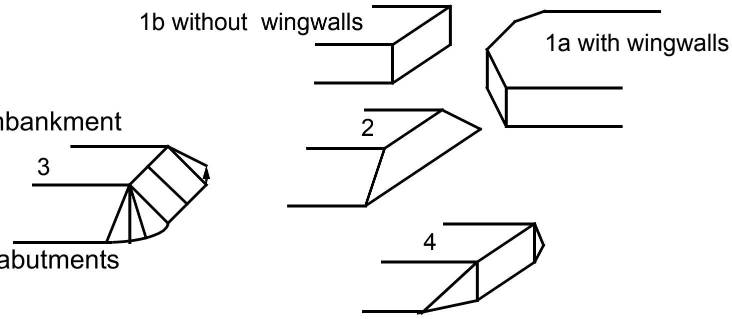

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **45** feet **US** *(US, UB, DS)* to **90** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **20** feet **US** *(US, UB, DS)* to **0** feet **US**

*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 perpendicular 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 VT AOT files. The structural inspection of 1994 stated the deck and abutments were widened. Measured bridge length is 25.2 ft., bridge span is 23.9 ft., and bridge width is 26.2 ft.**

## C. Upstream Channel Assessment

| 20. SRD | 21. Bank height (BF) LB | 21. Bank height (BF) RB | 22. Bank angle (BF) LB | 22. Bank angle (BF) RB | 26. % Veg. cover (BF) LB | 26. % Veg. cover (BF) RB | 27. Bank material (BF) LB | 27. Bank material (BF) RB | 28. Bank erosion (BF) LB | 28. Bank erosion (BF) RB |
|---|---|---|---|---|---|---|---|---|---|---|
| **26.0** | **1.5** | | | **3.0** | **2** | **4** | **31** | **34** | **0** | **1** |

23. Bank width **5.0** 24. Channel width **60.0** 25. Thalweg depth **50.0** 29. Bed Material **34**

30 .Bank protection type: LB **0** RB **5** 31. Bank protection condition: LB **-** 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.):

**The right bank protection consists of a laid up wall of concrete slabs extending from the end of the US right wingwall at 20 ft. US to 40 ft. US.**

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **52** 35. Mid-bar width: **12**

36. Point bar extent: **32** feet **US** *(US, UB)* to **93** feet **US** *(US, UB, DS)* positioned **0** %LB to **70** %RB

37. Material: **34**

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

**This is a gravel point bar with some cobbles.**

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: **70** 42. Cut bank extent: **45** feet **US** *(US, UB)* to **93** feet **US** *(US, UB, DS)*

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

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

**-**

45. Is channel scour present? **Y** *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: **16**

47. Scour dimensions: Length **29** Width **15** Depth : **3** Position **10** %LB to **90** %RB

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

**Scour is from 27 ft. US to 2 ft. under the bridge.**

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

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

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

54. Confluence comments (eg. confluence name):

**NO MAJOR CONFLUENCES**

## D. Under Bridge Channel Assessment

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

| 56. Height (BF) | | 57 Angle (BF) | | 61. Material (BF) | | 62. Erosion (BF) | |
|---|---|---|---|---|---|---|---|
| LB | RB | LB | RB | LB | RB | LB | RB |
| **17.0** | | **1.5** | | **2** | **7** | **7** | **0** |

58. Bank width (BF) **-** 59. Channel width (Amb) **-** 60. Thalweg depth (Amb) **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.):

**3**

**-**

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

67. Debris Potential 3____ *( 1- Low; 2- Moderate; 3- High)* 68. Capture Efficiency 3____ *( 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 debris in the channel US and under the bridge and there are downed trees along both banks. There is some beaver activity 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 | | 30 | 90 | 2 | 2 | 0 | 0.1 | 90.0 |
| RABUT | 1 | 0 | 90 | | | 2 | 2 | 24.0 |

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

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

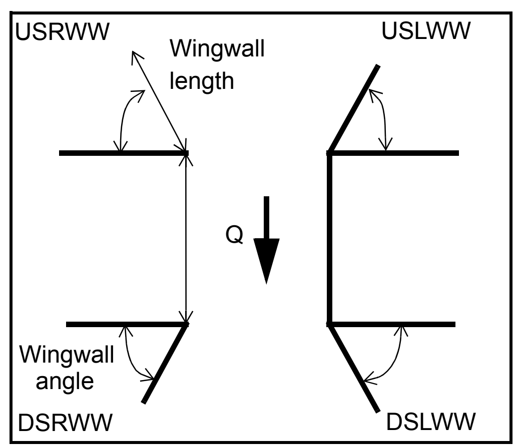
**0**
**0.8**
**1**

**76. The left abutment footing is exposed for 5 ft. at the DS end of the abutment. The right abutment footing is exposed along the entire base length with the most exposure occurring at the DS end.**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 24.0 | |
| USRWW: | Y | | 1 | | 2 | 0.5 | |
| DSLWW: | 0.6 | | 0.8 | | Y | 25.5 | |
| DSRWW: | 1 | | 2 | | 0 | 27.5 | |

*Wingwall materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood*




82. **Bank / Bridge Protection**:

| Location | USLWW | USRWW | LABUT | RABUT | LB | RB | DSLWW | DSRWW |
|---|---|---|---|---|---|---|---|---|
| Type | 1.1 | 0 | Y | - | - | 2 | - | - |
| Condition | Y | - | 1 | - | - | 1 | - | - |
| Extent | 1 | - | 0 | 0 | 5 | 0 | 0 | - |

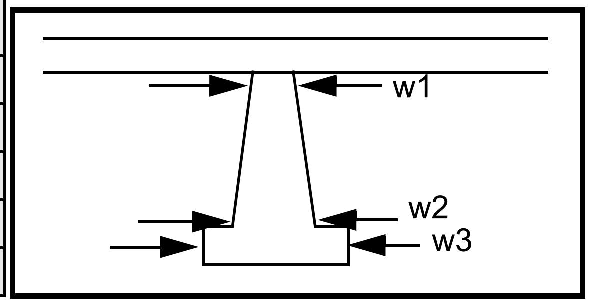
*Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee*
*Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed*
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

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

## Piers:

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

| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | | 7.0 | 9.5 | 50.0 | 30.0 | 40.0 |
| Pier 2 | | | | 10.5 | 40.0 | 11.0 |
| Pier 3 | - | - | - | - | - | - |
| Pier 4 | - | - | - | - | - | - |




| Level 1 Pier Descr. | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| 86. Location (BF) | e US | the | wall of | | LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP |
| 87. Type | right | road | con- | | 1- Solid pier, 2- column, 3- bent |
| 88. Material | wing | emb | crete | | 1- Wood; 2- concrete; 3- metal; 4- stone |
| 89. Shape | wall | ank- | slabs | | 1- Round; 2- Square; 3- Pointed |
| 90. Inclined? | pro- | ment | at | | Y- yes; N- no |
| 91. Attack ∠ (BF) | tec- | pro- | the | | |
| 92. Pushed | tion | tec- | US | | LB or RB |
| 93. Length (feet) | - | - | - | - | |
| 94. # of piles | is | tion. | end | | |
| 95. Cross-members | also | It is | of | | 0- none; 1- laterals; 2- diagonals; 3- both |
| 96. Scour Condition | men- | a | the | N | 0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed |
| 97. Scour depth | tione | laid | wing | - | |
| 98. Exposure depth | d as | up | wall. | - | |

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 |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | - | - | - | - | - | - |

Bank width (BF) - Channel width (Amb) - Thalweg depth (Amb) - 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: NO

Point bar extent: PIE feet RS (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? 2 (Y or if N type ctrl-n cb) Where? 3 (LB or RB) Mid-bank distance: 31

Cut bank extent: 31 feet 0 (US, UB, DS) to 0 feet 342 (US, UB, DS)

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

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

**1**

**1**

**1**

**The left bank protection extends from 0 ft. DS to 20 ft. DS. On the right bank the protection is from 0 ft. DS to**

Is channel scour present? 8 (Y or if N type ctrl-n cs) Mid-scour distance: ft.

Scour dimensions: Length DS. Width ______ Depth: _____ Positioned ____ %LB to ____ %RB

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

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

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

Confluence 2: Distance N Enters on - (LB or RB) Type NO ( **1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

**DROP STRUCTURE**

## F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

**N**
**-**
**-**
**-**
**-**
**-**
**-**
**-**
**-**
**-**

## 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: NFIETH00250045 Town: NORTHFIELD
Road Number: TH 25 County: WASHINGTON
Stream: UNION BROOK

Initials RLB Date: 05/19/97 Checked: SAO

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

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

Approach Section

| Characteristic | 100 yr | 500 yr | other Q |
|---|---|---|---|
| Total discharge, cfs | 1250 | 1930 | 790 |
| Main Channel Area, ft2 | 176 | 201 | 146 |
| Left overbank area, ft2 | 607 | 739 | 444 |
| Right overbank area, ft2 | 0 | 0 | 0 |
| Top width main channel, ft | 37 | 38 | 36 |
| Top width L overbank, ft | 199 | 207 | 189 |
| Top width R overbank, ft | 0 | 0 | 0 |
| D50 of channel, ft | 0.216 | 0.216 | 0.216 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| | | | |
| y1, average depth, MC, ft | 4.8 | 5.3 | 4.1 |
| y1, average depth, LOB, ft | 3.1 | 3.6 | 2.3 |
| y1, average depth, ROB, ft | ERR | ERR | ERR |
| | | | |
| Total conveyance, approach | 42211 | 55355 | 27648 |
| Conveyance, main channel | 12953 | 15805 | 9625 |
| Conveyance, LOB | 29258 | 39549 | 18023 |
| Conveyance, ROB | 0 | 0 | 0 |
| Percent discrepancy, conveyance | 0.0000 | 0.0018 | 0.0000 |
| Qm, discharge, MC, cfs | 383.6 | 551.1 | 275.0 |
| Ql, discharge, LOB, cfs | 866.4 | 1378.9 | 515.0 |
| Qr, discharge, ROB, cfs | 0.0 | 0.0 | 0.0 |
| | | | |
| Vm, mean velocity MC, ft/s | 2.2 | 2.7 | 1.9 |
| Vl, mean velocity, LOB, ft/s | 1.4 | 1.9 | 1.2 |
| Vr, mean velocity, ROB, ft/s | ERR | ERR | ERR |
| Vc-m, crit. velocity, MC, ft/s | 8.7 | 8.9 | 8.5 |
| Vc-l, crit. velocity, LOB, ft/s | ERR | ERR | ERR |
| Vc-r, crit. velocity, ROB, ft/s | ERR | ERR | ERR |

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

| Bridge Section | Q100 | Q500 | Other Q |
|---|---|---|---|
| (Q) total discharge, cfs | 1250 | 1930 | 790 |
| (Q) discharge thru bridge, cfs | 1000 | 1176 | 790 |
| Main channel conveyance | 6847 | 8070 | 5428 |
| Total conveyance | 6847 | 8070 | 5428 |
| Q2, bridge MC discharge,cfs | 1000 | 1176 | 790 |
| Main channel area, ft2 | 90 | 101 | 77 |
| Main channel width (normal), ft | 23.8 | 23.8 | 23.8 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 23.8 | 23.8 | 23.8 |
| y_bridge (avg. depth at br.), ft | 3.78 | 4.24 | 3.24 |
| Dm, median (1.25*D50), ft | 0.27 | 0.27 | 0.27 |
| y2, depth in contraction,ft | 4.43 | 5.09 | 3.62 |
| ys, scour depth (y2-ybridge), ft | 0.65 | 0.85 | 0.39 |

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 | 1000 | 1176 | 790 |
| Main channel area (DS), ft2 | 90 | 101 | 77 |
| Main channel width (normal), ft | 23.8 | 23.8 | 23.8 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 23.8 | 23.8 | 23.8 |
| D90, ft | 0.4191 | 0.4191 | 0.4191 |
| D95, ft | 0.5297 | 0.5297 | 0.5297 |
| Dc, critical grain size, ft | 0.5632 | 0.5893 | 0.5137 |
| Pc, Decimal percent coarser than Dc | 0.037 | 0.027 | 0.056 |
| Depth to armoring, ft | N/A | N/A | 25.98 |

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1995, p. 48, eq. 28)

| Characteristic | Left Abutment 100 yr Q | Left Abutment 500 yr Q | Left Abutment Other Q | Right Abutment 100 yr Q | Right Abutment 500 yr Q | Right Abutment Other Q |
|---|---|---|---|---|---|---|
| (Qt), total discharge, cfs | 1250 | 1930 | 790 | 1250 | 1930 | 790 |
| a', abut.length blocking flow, ft | 199.2 | 207 | 188.7 | 13.4 | 14.1 | 12.4 |
| Ae, area of blocked flow ft2 | 528.2 | 563.9 | 444.5 | 33.9 | 42 | 25 |
| Qe, discharge blocked abut.,cfs | -- | -- | 515.8 | 46.8 | 76.4 | 27.5 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 1.43 | 1.87 | 1.16 | 1.38 | 1.82 | 1.10 |
| ya, depth of f/p flow, ft | 2.65 | 2.72 | 2.36 | 2.53 | 2.98 | 2.02 |
| --Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru) | | | | | | |
| K1 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 |
| --Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US) | | | | | | |
| theta | 90 | 90 | 90 | 90 | 90 | 90 |
| K2 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Fr, froude number f/p flow | 0.144 | 0.175 | 0.133 | 0.153 | 0.186 | 0.137 |
| ys, scour depth, ft | 12.35 | 14.00 | 10.80 | 5.60 | 6.86 | 4.45 |

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

| | | | | | | |
|---|---|---|---|---|---|---|
| a'(abut length blocked, ft) | 199.2 | 207 | 188.7 | 13.4 | 14.1 | 12.4 |
| y1 (depth f/p flow, ft) | 2.65 | 2.72 | 2.36 | 2.53 | 2.98 | 2.02 |
| a'/y1 | 75.12 | 75.99 | 80.11 | 5.30 | 4.73 | 6.15 |
| Skew correction (p. 49, fig. 16) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Froude no. f/p flow | 0.14 | 0.18 | 0.13 | 0.15 | 0.19 | 0.14 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | 10.17 | 11.15 | 8.81 | ERR | ERR | ERR |
| vertical w/ ww's | 8.34 | 9.14 | 7.22 | ERR | ERR | ERR |
| spill-through | 5.60 | 6.13 | 4.84 | 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 others, 1995, p112, eq. 81,82)

| Downstream bridge face property | Q100 | Q500 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 1 | 1 | 1 | 1 | 1 | 1 |
| y, depth of flow in bridge, ft | 3.78 | 4.24 | 3.24 | 3.78 | 4.24 | 3.24 |
| Median Stone Diameter for riprap at: left abutment | | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | ERR | ERR | ERR | ERR | ERR | ERR |
| Fr>0.8 (vertical abut.) | 1.58 | 1.77 | 1.35 | 1.58 | 1.77 | 1.35 |