# LEVEL II SCOUR ANALYSIS FOR BRIDGE 21 (MONKTH00340021) on TOWN HIGHWAY 34, crossing LITTLE OTTER CREEK, MONKTON, VERMONT

Open-File Report 97-672

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

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

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# LEVEL II SCOUR ANALYSIS FOR BRIDGE 21 (MONKTH00340021) on TOWN HIGHWAY 34, crossing LITTLE OTTER CREEK, MONKTON, VERMONT

By ERICK M. BOEHMLER AND LAURA MEDALIE

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**Pembroke, New Hampshire**

**1997**

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

U.S. GEOLOGICAL SURVEY
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## CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

## OTHER ABBREVIATIONS

| | | | |
|---|---|---|---|
| BF | bank full | LWW | left wingwall |
| cfs | cubic feet per second | 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 21 (MONKTH00340021) ON TOWN HIGHWAY 34, CROSSING LITTLE OTTER CREEK, MONKTON, VERMONT

*By* **Erick M. Boehmler and Laura Medalie**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MONKTH00340021 on Town Highway 34 crossing Little Otter Creek, Monkton, 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 D 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 C.

The site is in the Champlain section of the Saint Lawrence Valley physiographic province in northwestern Vermont. The 34.1-$mi^2$ drainage area is in a predominantly rural and forested basin with pasture in the valleys. In the vicinity of the study site, the surface cover consists of pasture. The most significant tree cover is immediately adjacent to the channel on the right bank downstream.

In the study area, Little Otter Creek has a sinuous channel with a slope of approximately 0.008 ft/ft, an average channel top width of 92 feet and an average bank height of 6 feet. The predominant channel bed materials are silt and clay. Sieve analysis indicates that greater than 50% of the sample is silt and clay and thus a median grain size by use of sieve analysis was indeterminate. Therefore, the median grain size was assumed to be medium silt with a size ($D_{50}$) of 0.0310 mm (0.000102 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 19 and June 20, 1996, indicated that the reach was stable.

The Town Highway 34 crossing of Little Otter Creek is a 50-ft-long, one-lane bridge consisting of one 26-foot concrete span and three “boiler tube” smooth metal pipe culverts through the left road approach (Vermont Agency of Transportation, written communication, December 15, 1995). The opening length of the bridge parallel to the bridge face is 25.1 feet. The bridge is supported by vertical, concrete abutments with wingwalls on the right abutment only. The channel is skewed approximately 25 degrees to the opening. The VTAOT records indicate the opening-skew-to-roadway is 20 degrees but measurement from surveyed data suggests the skew is five degrees.

The scour protection measures at the site were type-1 stone fill (less than 12 inches diameter) on the upstream and downstream embankments of the left road approach and type-2 stone fill (less than 36 inches diameter) surrounding the entrance of each culvert. Additional details describing conditions at the site are included in the Level II Summary and Appendices C and D.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 10.3 to 12.3 feet. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.6 to 22.5 feet. The worst-case abutment scour occurred at the 500-year discharge for the left abutment and at the incipient overtopping discharge for the right abutment. 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.

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*** MONKTH00340021 ***Stream*** Little Otter Creek

***County*** Addison ***Road*** TH 34 ***District*** 5

## Description of Bridge

***Bridge length*** 50 ***ft*** ***Bridge width*** 18.2 ***ft*** ***Max span length*** 26 ***ft***

***Alignment of bridge to road (on curve or straight)*** Curved, left and straight, right

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

***Stone fill on abutment?*** No ***Date of inspection*** 6/19/96

***Description of stone fill*** Type-1 stone fill on the upstream and downstream embankments of the left road approach and type-2 surrounding each culvert entrance.

***Brief description of piers/abutments*** Abutments and wingwalls are concrete. Only the right abutment has wingwalls.

***Is bridge skewed to flood flow according to*** Yes ***survey?*** Yes ***Angle*** 25

There is a mild channel bend in the upstream reach.

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

| | *Date of inspection* | *Percent of channel blocked horizontally* | *Percent of channel blocked vertically* |
|---|---|---|---|
| ***Level I*** | 6/19/96 | 0 | 0 |
| ***Level II*** | 6/19/96 | 0 | 0 |

***Potential for debris*** Moderate. There are few trees along the banks but there is a large debris pile across the channel about 400 feet downstream.

***Describe any features near or at the bridge that may affect flow (include observation date)*** On 6/19/96 there were three smooth metal culverts through the left road approach, which will divert some channel flow away from the bridge at flood stage.

## Description of the Geomorphic Setting

***General topography*** The channel is located in a moderate relief valley setting with narrow flood plains upstream and moderately sloping valley walls on both sides.

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

***Date of inspection*** 6/19/96

***DS left:*** Moderately sloping channel bank to a narrow over-bank.

***DS right:*** Moderately sloping channel bank.

***US left:*** Moderately sloping channel bank and an irregular flood plain.

***US right:*** Moderately sloping channel bank and an irregular flood plain.

## Description of the Channel

***Average top width*** 92 ***ft*** ***Average depth*** 6 ***ft***

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

Perennial and sinuous with semi-alluvial channel boundaries and a constant width.

6/19/96

***Vegetative co*** Tall grass and a few trees.

***DS left:*** Trees and brush.

***DS right:*** Tall grass and a few shrubs and trees.

***US left:*** Tall grass.

***US right:***

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

Although banks appear stable in the vicinity of this site, there were debris accumulations, leaning trees, cut-banks, and a more sinuous channel particularly upstream but generally more than 100 feet away from the site noted on 6/19/96.

***Describe any obstructions in channel and date of observation.*** The assessment of 6/19/96 noted a large accumulation of debris (e.g. whole trees, stumps, branches) across the channel about 400 feet downstream.

## Hydrology

***Drainage area*** 34.1 ***mi²***

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

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

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

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

***USGS gage description*** Little Otter Creek at Ferrisburg, VT

***USGS gage number*** 04282650

***Gage drainage area*** 57.1 ***mi²***

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

### Calculated Discharges

***Q100*** 3,350 ***ft³/s*** ***Q500*** 4,800 ***ft³/s***

The gage has less than 7 years of record. Hence, the record was not considered in the selection of the 100- and 500-year discharges for this analysis. The 100- and 500-year discharges selected were the median discharges from a range of flood frequency curves defined by use of several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957; Talbot, 1887) and extrapolated 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 the center point of a chiseled X on top of the downstream end of the downstream right wingwall (elev. 498.86 feet, arbitrary survey datum). RM2 is the center point of a chiseled X on top of the upstream left corner of the bridge deck (elev. 500.18 feet, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

| [1]*Cross-section* | *Section Reference Distance (SRD) in feet* | [2]*Cross-section development* | *Comments* |
|---|---|---|---|
| EXITX | -54 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 10 | 1 | Road Grade section |
| APPRO | 45 | 2 | Approach section |

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

### Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.050, and overbank "n" values ranged from 0.045 to 0.060.

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 0.008 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1963).

The surveyed approach section (APTEM) was moved with no bed slope correction 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.

Culvert routines provided with WSPRO are not fully integrated. Therefore, it was necessary to develop individual ratings for the culvert and bridge / weir flow to model this bridge and culvert multiple-opening situation. The ratings were combined to determine the quantity of the total discharge diverted from the bridge through the culverts. The combined ratings indicate the culverts divert 20% of the total discharge on average for the discharges modeled.

For the incipient over-topping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profile, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

**Bridge Hydraulics Summary**

***Average bridge embankment elevation*** 500.3 ***ft***
***Average low steel elevation*** 498.9 ***ft***

***100-year discharge*** 3,350 ***ft³/s***
***Water-surface elevation in bridge opening*** 498.9 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 86 ***ft³/s***
***Discharge through culverts*** 760 ***ft³/s***
***Area of flow in bridge opening*** 262 ***ft²***
***Average velocity in bridge opening*** 9.6 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 11.8 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 500.9 ***ft***
***Water-surface elevation at Approach section without bridge*** 496.1 ***ft***
***Amount of backwater caused by bridge*** 4.8 ***ft***

***500-year discharge*** 4,800 ***ft³/s***
***Water-surface elevation in bridge opening*** 498.9 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 1,080 ***ft³/s***
***Discharge through culverts*** 820 ***ft³/s***
***Area of flow in bridge opening*** 262 ***ft²***
***Average velocity in bridge opening*** 11.0 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 13.5 ***ft/s***
***Water-surface elevation at Approach section with bridge*** 502.0
***Water-surface elevation at Approach section without bridge*** 497.8 ***ft***
***Amount of backwater caused by bridge*** 4.2 ***ft***

***Incipient overtopping discharge*** 3,070 ***ft³/s***
***Water-surface elevation in bridge opening*** 495.0 ***ft***
***Discharge through culverts*** 640 ***ft³/s***
***Area of flow in bridge opening*** 166 ***ft²***
***Average velocity in bridge opening*** 14.6 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 18.4 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 498.9
***Water-surface elevation at Approach section without bridge*** 495.8
***Amount of backwater caused by bridge*** 3.1 ***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. Scour results are shown in figure 8, and tables 1 and 2.

Contraction scour for each modeled discharge was computed by use of the Laursen live-bed contraction scour equation (Richardson and others, 1995, p. 30, equation 17). The 100- and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow usually is estimated best by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Because the Chang equation is based on clear-water scour data exclusively (Richardson and others, 1995, p. 145-146), it is not understood at the present time how well the Chang equation performs for scour prediction under live-bed conditions. Therefore, the reported contraction scour results were computed by use of Laursen's live-bed contraction scour equation and presented in figure 8, and tables 1 and 2. Results from the Chang equation are presented only in Appendix E.

Abutment scour for the left abutment was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Froehlich's equation also was used for scour at the right abutment for the incipient roadway over-topping 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.

For the 100- and 500-year events, scour at the right abutment 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* | 12.1 | 12.3 | 10.3 |
| *Depth to armoring* | N/A | N/A | N/A |
| ***Left overbank*** | -- | -- | -- |
| ***Right overbank*** | -- | -- | -- |

| Local scour: | 100-yr discharge | 500-yr discharge | Incipient overtopping discharge |
|---|---|---|---|
| ***Abutment scour*** | | | |
| *Left abutment* | 21.5 | 22.5 | 19.8 |
| *Right abutment* | 8.6 | 10.0 | 15.0 |
| ***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* | 2.9 | 2.6 | 2.8 |
| *Right abutment* | 2.9 | 2.6 | 2.8 |
| ***Piers:*** | -- | -- | -- |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

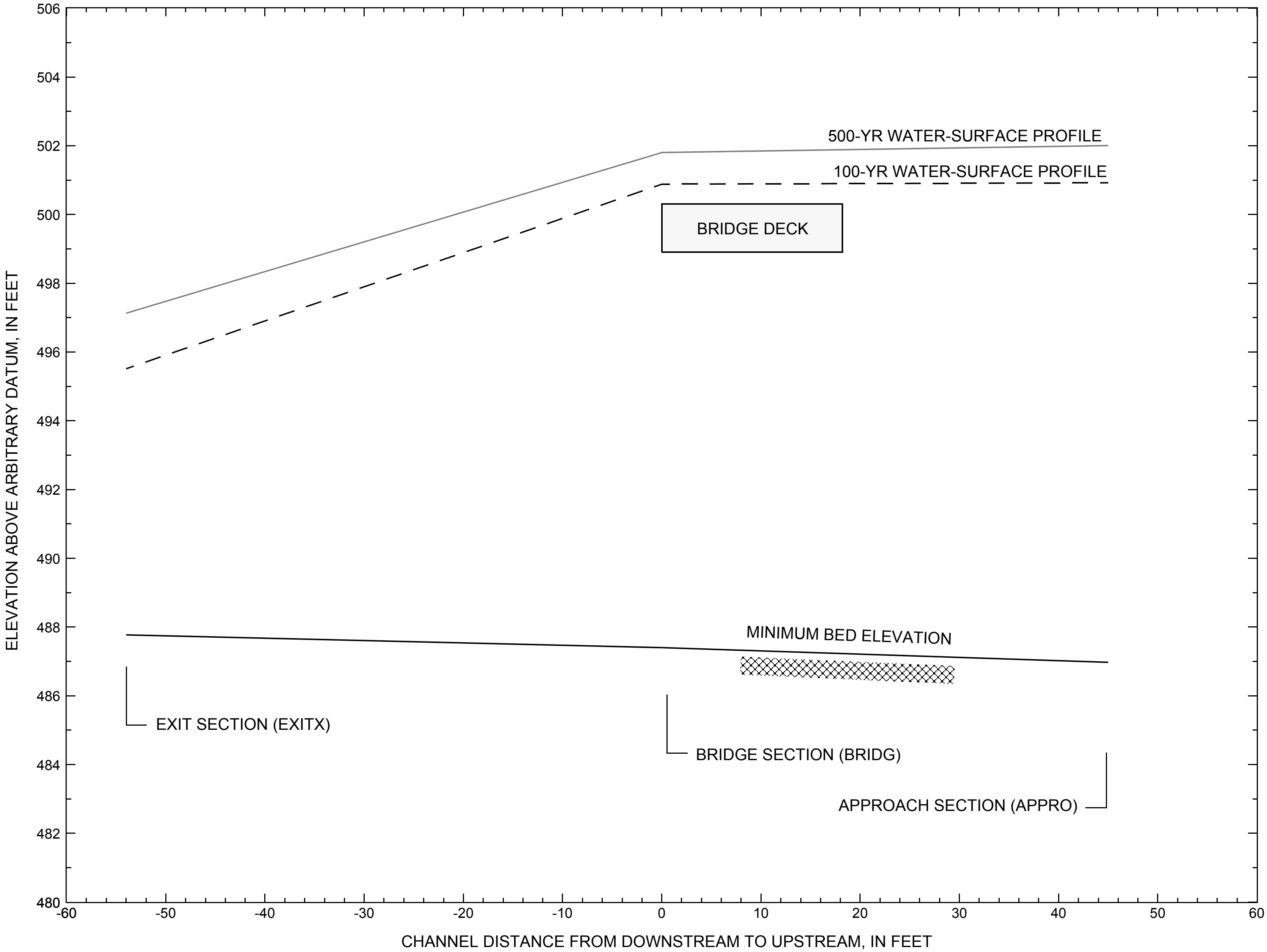


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure MONKTH00340021 on Town Highway 34, crossing Little Otter Creek, Monkton, Vermont.

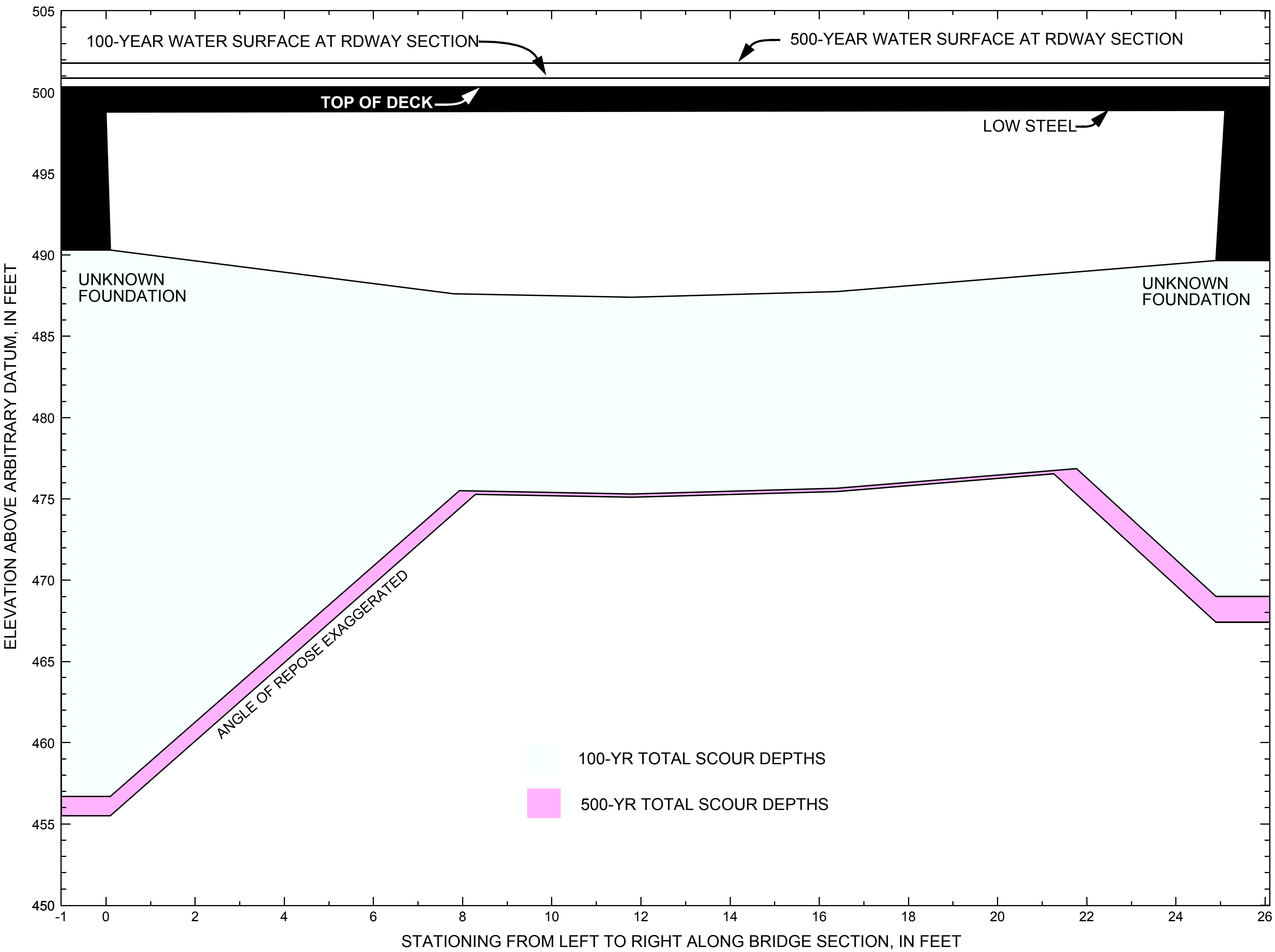


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure MONKTH00340021 on Town Highway 34, crossing Little Otter Creek, Monkton, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure MONKTH00340021 on Town Highway 34, crossing Little Otter Creek, Monkton, 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 3,350 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 498.8 | -- | 490.3 | 12.1 | 21.5 | -- | 33.6 | 456.7 | -- |
| Right abutment | 25.1 | -- | 498.9 | -- | 489.7 | 12.1 | 8.6 | -- | 20.7 | 469.0 | -- |

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 MONKTH00340021 on Town Highway 34, crossing Little Otter Creek, Monkton, 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 4,800 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 498.8 | -- | 490.3 | 12.3 | 22.5 | -- | 34.8 | 455.5 | -- |
| Right abutment | 25.1 | -- | 498.9 | -- | 489.7 | 12.3 | 10.0 | -- | 22.3 | 467.4 | -- |

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, 1963, Monkton, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Photorevised 1972; Contour interval, 10 feet; Scale 1:24,000.

# APPENDIX A:

# **WSPRO INPUT FILE**

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File monk021.wsp
T2        Hydraulic analysis for structure MONKTH00340021   Date: 30-MAY-97
T3        Town Highway 34 crossing Little Otter Creek, Monkton, VT          EMB
*
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
*           The Q100 of 3350 cfs and the Q500 of 4800 cfs have been reduced
*           by the flow expected through the culverts to the left of this
*           bridge site. Ratings were developed for the culvert and bridge
*           flow to determine the approach water surface and discharges
*           through the bridge, over the roadway, and through the culverts.
Q           2590.0   3980.0   2430.0
WS          495.51   497.13   495.16
*
XS   EXITX    -54
GR         -417.6, 508.83   -238.3, 500.13    -34.1, 497.98    -17.5, 491.82
GR          -12.9, 489.74     -8.3, 489.62      0.0, 488.03     11.9, 487.77
GR           22.1, 488.01     30.8, 489.57     42.5, 491.84     45.2, 495.29
GR           60.7, 499.04     82.6, 500.95    148.0, 505.61    207.1, 512.42
*
N           0.045        0.050        0.060
SA                 -34.1         60.7
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL
BR   BRIDG     0    498.85
GR            0.0, 498.79      0.0, 491.93      0.1, 490.30      7.8, 487.61
GR           11.8, 487.40     16.4, 487.75     24.9, 489.65     25.0, 491.93
GR           25.1, 498.90      0.0, 498.79
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      22.7
*           * *     36.9      7.8
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      18.2     2
GR         -278.4, 505.76   -191.8, 500.83    -92.4, 501.18    -32.0, 500.68
GR            0.0, 500.34     27.9, 500.34    175.0, 505.11    463.2, 512.53
*
*           The approach section below was surveyed at srd = 85. Since there
*           is no significant bed slope between the bridge and this section,
*           the section was placed at srd = 45 where it is expected applying
*           the one bridge length rule...
*
AS   APPRO     45
GR         -278.4, 505.76   -147.2, 498.29    -34.8, 498.29
GR          -20.7, 491.92    -15.6, 489.87      0.0, 486.97     12.3, 487.40
GR           23.4, 489.17     28.5, 489.80     34.1, 490.17     40.2, 490.90
GR           43.6, 491.95     53.4, 496.30    125.5, 500.68    209.7, 500.74
GR          395.6, 506.11
*           -87.5, 501.15    -70.4, 500.23    -60.4, 499.71
*
N           0.045        0.045        0.045
SA                 -34.8         53.4
```

```
*
HP 1 BRIDG 498.90 1 498.90
HP 2 BRIDG 498.90 * * 2510
HP 2 BRIDG 495.82 * * 2510
HP 2 RDWAY 500.88 * * 86
HP 1 APPRO 500.92 1 500.92
HP 2 APPRO 500.92 * * 3350
*

HP 1 BRIDG 498.90 1 498.90
HP 2 BRIDG 498.90 * * 2881
HP 2 BRIDG 497.50 * * 2881
HP 2 RDWAY 501.80 * * 1080
HP 1 APPRO 502.00 1 502.00
HP 2 APPRO 502.00 * * 4800
*
HP 1 BRIDG 495.04 1 495.04
HP 2 BRIDG 495.04 * * 2430
HP 1 APPRO 498.88 1 498.88
HP 2 APPRO 498.88 * * 3070
*
EX
ER
```

APPENDIX B:

# WSPRO OUTPUT FILE

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      262     21186      0     68                            0
    498.90           262     21186      0     68  1.00      0     25        0

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        498.90     0.0    25.1   261.5   21186.    2510.   9.60

 X STA.         0.0        2.6        4.2        5.5        6.7        7.7
   A(I)             23.5       15.0       13.3       12.3       11.6
   V(I)             5.33       8.39       9.45      10.23      10.78

 X STA.         7.7        8.7        9.7       10.7       11.6       12.6
   A(I)             11.5       10.8       10.9       10.8       10.8
   V(I)            10.95      11.65      11.51      11.59      11.57

 X STA.        12.6       13.5       14.5       15.4       16.4       17.5
   A(I)             10.7       10.9       10.8       11.1       11.4
   V(I)            11.78      11.49      11.60      11.29      11.04

 X STA.        17.5       18.6       19.7       21.0       22.5       25.1
   A(I)             11.9       12.4       13.2       14.7       24.0
   V(I)            10.58      10.13       9.49       8.55       5.24

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        495.82     0.0    25.1   185.6   17958.    2510.  13.52

 X STA.         0.0        3.0        4.5        5.8        7.0        8.0
   A(I)             17.8       10.6        9.5        8.8        8.2
   V(I)             7.05      11.83      13.18      14.21      15.33

 X STA.         8.0        8.9        9.9       10.7       11.6       12.5
   A(I)              7.8        7.6        7.4        7.3        7.3
   V(I)            16.05      16.55      17.01      17.12      17.10

 X STA.        12.5       13.4       14.3       15.2       16.1       17.1
   A(I)              7.4        7.3        7.6        7.6        7.8
   V(I)            16.99      17.13      16.49      16.46      16.09

 X STA.        17.1       18.2       19.3       20.6       22.2       25.1
   A(I)              8.3        8.9        9.2       11.1       18.0
   V(I)            15.13      14.12      13.60      11.33       6.96

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        500.88  -192.7    44.6    34.2     531.      86.   2.51

 X STA.      -192.7      -27.9      -20.3      -15.0      -10.7       -7.0
   A(I)              3.7        2.2        1.9        1.7        1.6
   V(I)             1.16       1.99       2.30       2.50       2.61

 X STA.        -7.0       -3.9       -1.0        1.6        4.2        6.8
   A(I)              1.5        1.5        1.4        1.4        1.4
   V(I)             2.84       2.94       3.03       3.05       3.05

 X STA.         6.8        9.4       12.0       14.6       17.2       19.8
   A(I)              1.4        1.4        1.4        1.4        1.4
   V(I)             3.09       3.09       3.05       3.08       3.02

 X STA.        19.8       22.5       25.2       28.2       31.9       44.6
   A(I)              1.5        1.5        1.6        1.8        2.6
   V(I)             2.95       2.91       2.73       2.45       1.65

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      356     20236    159    159                         3031
              2      919    141612     88     92                        16836
              3      193      7190    163    163                         1198
    500.92          1469    169038    409    413  1.54   -192    216    12743

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

          WSEL     LEW     REW    AREA        K        Q    VEL
        500.92  -193.4   215.9  1468.9  169038.    3350.   2.28

 X STA.      -193.4     -107.2      -55.4      -23.1      -16.1      -11.2
   A(I)            165.9      136.3      115.6       65.7       56.1
   V(I)             1.01       1.23       1.45       2.55       2.99

 X STA.       -11.2       -6.9       -3.1        0.4        3.7        7.2
   A(I)             52.9       49.4       48.4       46.1       47.2
   V(I)             3.17       3.39       3.46       3.63       3.55

 X STA.         7.2       10.6       14.1       17.8       21.9       26.2
   A(I)             46.2       47.1       48.3       50.2       50.3
   V(I)             3.62       3.56       3.47       3.34       3.33

 X STA.        26.2       30.9       35.9       41.6       50.8      215.9
   A(I)             52.7       54.5       57.4       71.7      207.0
   V(I)             3.18       3.07       2.92       2.34       0.81
```

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

       WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
               1      262     21186      0     68                            0
     498.90           262     21186      0     68  1.00      0     25        0

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

           WSEL     LEW     REW    AREA         K        Q    VEL
         498.90     0.0    25.1   261.5    21186.    2881.  11.02

 X STA.         0.0         2.6         4.2         5.5         6.7         7.7
   A(I)             23.5        15.0        13.3        12.3        11.6
   V(I)             6.12        9.63       10.85       11.74       12.37

 X STA.         7.7         8.7         9.7        10.7        11.6        12.6
   A(I)             11.5        10.8        10.9        10.8        10.8
   V(I)            12.57       13.37       13.21       13.30       13.28

 X STA.        12.6        13.5        14.5        15.4        16.4        17.5
   A(I)             10.7        10.9        10.8        11.1        11.4
   V(I)            13.52       13.18       13.32       12.96       12.67

 X STA.        17.5        18.6        19.7        21.0        22.5        25.1
   A(I)             11.9        12.4        13.2        14.7        24.0
   V(I)            12.14       11.63       10.90        9.81        6.01

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

           WSEL     LEW     REW    AREA         K        Q    VEL
         497.50     0.0    25.1   227.8    23833.    2881.  12.65

 X STA.         0.0         3.0         4.5         5.8         7.0         8.0
   A(I)             22.8        13.2        11.7        10.5         9.9
   V(I)             6.32       10.89       12.30       13.72       14.52

 X STA.         8.0         8.9         9.8        10.7        11.6        12.5
   A(I)              9.5         9.2         8.9         8.8         8.9
   V(I)            15.24       15.72       16.18       16.29       16.28

 X STA.        12.5        13.4        14.3        15.2        16.1        17.1
   A(I)              8.9         8.8         9.2         9.2         9.4
   V(I)            16.21       16.32       15.68       15.63       15.25

 X STA.        17.1        18.1        19.3        20.6        22.2        25.1
   A(I)              9.8        10.8        11.3        13.7        23.1
   V(I)            14.63       13.29       12.71       10.49        6.24

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

           WSEL     LEW     REW    AREA         K        Q    VEL
         501.80  -208.8    72.9   254.7     7786.    1080.   4.24

 X STA.      -208.8      -183.5      -169.5      -154.7      -137.7      -118.6
   A(I)             16.2        12.9        12.8        13.8        14.2
   V(I)             3.34        4.20        4.21        3.93        3.80

 X STA.      -118.6       -95.4       -73.3       -57.6       -44.6       -33.8
   A(I)             15.6        15.3        13.3        12.5        11.4
   V(I)             3.47        3.54        4.07        4.32        4.74

 X STA.       -33.8       -23.6       -14.5        -6.6         0.7         7.8
   A(I)             11.9        11.4        10.6        10.4        10.5
   V(I)             4.54        4.73        5.09        5.19        5.16

 X STA.         7.8        15.1        22.4        29.8        39.6        72.9
   A(I)             10.6        10.6        10.8        12.1        18.0
   V(I)             5.09        5.11        4.99        4.47        2.99

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

       WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
               1      538     37271    178    178                         5312
               2     1014    166909     88     92                        19520
               3      389     20079    200    200                         3081
     502.00          1941    224260    466    469  1.59   -211    253    17850

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

           WSEL     LEW     REW    AREA         K        Q    VEL
         502.00  -212.4   253.3  1941.4  224260.    4800.   2.47

 X STA.      -212.4      -126.8       -87.1       -47.5       -22.7       -15.4
   A(I)            196.6       147.0       146.9       124.9        79.0
   V(I)             1.22        1.63        1.63        1.92        3.04

 X STA.       -15.4       -10.0        -5.3        -1.2         2.8         6.7
   A(I)             67.8        64.1        59.7        59.1        58.7
   V(I)             3.54        3.75        4.02        4.06        4.09

 X STA.         6.7        10.7        14.8        19.2        23.9        29.2
   A(I)             58.5        59.4        60.6        62.7        65.6
   V(I)             4.10        4.04        3.96        3.83        3.66

 X STA.        29.2        34.7        40.8        49.9        79.9       253.3
   A(I)             65.3        69.7        83.9       152.5       259.3
   V(I)             3.67        3.44        2.86        1.57        0.93
```

```
       U.S. Geological Survey WSPRO Input File monk021.wsp
       Hydraulic analysis for structure MONKTH00340021   Date: 30-MAY-97
       Town Highway 34 crossing Little Otter Creek, Monkton, VT          EMB
          *** RUN DATE & TIME: 06-27-97  08:06

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

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      166     15352    25     36                         2428
  495.04           166     15352    25     36  1.00      0     25     2428

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      495.04     0.0    25.0   166.1   15352.    2430.  14.63

X STA.        0.0        3.0        4.6        5.9        7.0        8.0
  A(I)            15.5        9.6        8.5        7.9        7.4
  V(I)            7.85      12.61      14.32      15.35      16.48

X STA.        8.0        9.0        9.9       10.8       11.6       12.5
  A(I)             7.1        6.8        6.7        6.6        6.6
  V(I)           17.23      17.75      18.24      18.35      18.32

X STA.       12.5       13.4       14.3       15.2       16.1       17.1
  A(I)             6.7        6.6        6.8        6.8        7.2
  V(I)           18.27      18.43      17.75      17.74      16.97

X STA.       17.1       18.2       19.3       20.6       22.2       25.0
  A(I)             7.5        7.7        8.7        9.6       15.9
  V(I)           16.30      15.69      14.00      12.68       7.67

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1       69      1570   123    123                          296
            2      739     98492    88     92                        12142
            3       55      2147    42     43                          353
  498.88           863    102209   253    257  1.22   -157     96     8174

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.88  -157.6    95.9   863.3  102209.    3070.   3.56

X STA.     -157.6      -21.1      -15.1      -10.8       -7.2       -4.0
  A(I)           119.9       47.6       41.0       37.5       35.0
  V(I)            1.28       3.23       3.74       4.10       4.39

X STA.       -4.0       -1.0        1.7        4.5        7.3       10.0
  A(I)            33.7       32.6       32.7       32.1       31.8
  V(I)            4.56       4.71       4.69       4.79       4.83

X STA.       10.0       12.8       15.7       18.8       22.2       25.9
  A(I)            31.9       33.0       33.2       34.4       35.2
  V(I)            4.81       4.66       4.63       4.46       4.36

X STA.       25.9       29.9       34.1       38.9       45.2       95.9
  A(I)            37.1       37.6       39.9       46.6       90.8
  V(I)            4.14       4.09       3.85       3.30       1.69
```

# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File monk021.wsp
        Hydraulic analysis for structure MONKTH00340021   Date: 30-MAY-97
        Town Highway 34 crossing Little Otter Creek, Monkton, VT          EMB
           *** RUN DATE & TIME: 06-27-97  08:06

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

EXITX:XS   ******    -26      411  0.62 *****  496.13  492.98    2590  495.51
       -53 ******     46    37403  1.00 ***** *******    0.47    6.31

FULLV:FV       54    -27      434  0.55  0.24  496.38 *******    2590  495.82
         0     54     47    40227  1.00  0.00    0.01    0.44    5.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       45    -29      499  0.42  0.14  496.51 *******    2590  496.09
        45     45     53    53403  1.00  0.00    0.00    0.37    5.19
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.34     499.23     499.32     498.85

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR       54      0      262  1.43 *****  500.33  495.20    2510  498.90
         0 ******     25    21186  1.00 ***** *******    0.52    9.60

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.443  0.000  498.85 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      10.    27.  0.01  0.07  500.99    0.00     86.  500.88

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     54.    84.  -193.    12.   0.5   0.3   2.7   2.5   0.4   2.9
   RT:     32.    32.    12.    45.   0.5   0.4   3.0   2.5   0.5   2.8

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

APPRO:AS       22   -192     1469  0.07  0.05  500.99  492.68    2590  500.92
        45     25    216   169046  1.54  0.57    0.00    0.20    1.76

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS      -54.   -27.    46.   2590.   37403.     411.     6.31  495.51
   FULLV:FV        0.   -28.    47.   2590.   40227.     434.     5.97  495.82
   BRIDG:BR        0.     0.    25.   2510.   21186.     262.     9.60  498.90
   RDWAY:RG      10.*******    54.     86.******************     2.00  500.88
   APPRO:AS      45.  -193.   216.   2590.  169046.    1469.     1.76  500.92

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS      FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     492.98     0.47  487.77  512.42************  0.62  496.13  495.51
   FULLV:FV   ********     0.44  487.77  512.42  0.24  0.00  0.55  496.38  495.82
   BRIDG:BR     495.20     0.52  487.40  498.90************  1.43  500.33  498.90
   RDWAY:RG   ***************  500.34  512.53  0.01******  0.07  500.99  500.88
   APPRO:AS     492.68     0.20  486.97  506.11  0.05  0.57  0.07  500.99  500.92
```

```
        U.S. Geological Survey WSPRO Input File monk021.wsp
        Hydraulic analysis for structure MONKTH00340021   Date: 30-MAY-97
        Town Highway 34 crossing Little Otter Creek, Monkton, VT          EMB
           *** RUN DATE & TIME: 06-27-97  08:06

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

EXITX:XS   ******    -31      539  0.85 *****  497.98  494.30    3980  497.13
       -53 ******     53    53569  1.00 ***** *******    0.52    7.39

FULLV:FV       54    -32      571  0.76  0.28  498.26 *******    3980  497.50
         0     54     54    57835  1.00  0.00    0.00    0.48    6.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       45    -33      666  0.58  0.15  498.41 *******    3980  497.83
        45     45     79    80074  1.04  0.00    0.00    0.44    5.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   503.37       0.00     497.64     500.34

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.69     501.52     501.60     498.85

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR       54      0      262  1.89 *****  500.79  495.85    2881  498.90
         0 ******     25    21186  1.00 ***** *******    0.60   11.02

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.474  0.000  498.85 ****** ****** ******

   XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
  RDWAY:RG      10.    27.  0.01  0.10  502.09    0.00   1080.  501.80

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
  LT:    843.   221.  -209.    12.   1.5   0.9   4.8   4.2   1.2   2.9
  RT:    238.    60.    12.    73.   1.5   0.9   4.9   4.3   1.2   3.0

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

APPRO:AS       22   -211     1940  0.10  0.06  502.10  493.95    3980  502.00
        45     25    253   224140  1.59  0.59    0.00    0.22    2.05

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

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

  FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
  EXITX:XS     -54.   -32.    53.   3980.   53569.     539.    7.39  497.13
  FULLV:FV       0.   -33.    54.   3980.   57835.     571.    6.97  497.50
  BRIDG:BR       0.     0.    25.   2881.   21186.     262.   11.02  498.90
  RDWAY:RG      10.*******   843.   1080.*****************    2.00  501.80
  APPRO:AS      45.  -212.   253.   3980.  224140.    1940.    2.05  502.00

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

 SECOND USER DEFINED TABLE.

   XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
  EXITX:XS    494.30    0.52  487.77  512.42************  0.85  497.98  497.13
  FULLV:FV  ********    0.48  487.77  512.42  0.28  0.00  0.76  498.26  497.50
  BRIDG:BR    495.85    0.60  487.40  498.90************  1.89  500.79  498.90
  RDWAY:RG  ****************  500.34  512.53  0.01******  0.10  502.09  501.80
  APPRO:AS    493.95    0.22  486.97  506.11  0.06  0.59  0.10  502.10  502.00
```

```
        U.S. Geological Survey WSPRO Input File monk021.wsp
        Hydraulic analysis for structure MONKTH00340021   Date: 30-MAY-97
        Town Highway 34 crossing Little Otter Creek, Monkton, VT          EMB
           *** RUN DATE & TIME: 06-27-97  08:06

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

 EXITX:XS   ******    -26      385  0.62 *****  495.78  492.83   2430  495.16
        -53 ******     45    34263  1.00 ***** *******    0.48   6.31

 FULLV:FV       54    -26      409  0.55  0.25  496.04 *******   2430  495.49
          0     54     46    37190  1.00  0.00    0.01    0.44   5.94
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS       45    -28      472  0.41  0.14  496.17 *******   2430  495.76
         45     45     52    49279  1.00  0.00   -0.01    0.38   5.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    2430.     495.04

            <<<<<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       54      0      166  3.33 *****  498.37  495.04   2430  495.04
          0     54     25    15355  1.00 ***** *******    1.00  14.63

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  498.85 ****** ****** ******

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

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

 APPRO:AS       22   -157      863  0.15  0.09  499.03  492.51   2430  498.88
         45     25     96   102221  1.22  0.57    0.01    0.30   2.81

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.692  0.537   47254.    -4.    21.   498.87

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

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL   WSEL
   EXITX:XS     -54.   -27.    45.   2430.   34263.     385.    6.31  495.16
   FULLV:FV       0.   -27.    46.   2430.   37190.     409.    5.94  495.49
   BRIDG:BR       0.     0.    25.   2430.   15355.     166.   14.63  495.04
   RDWAY:RG      10.**************      0.*****************    2.00********
   APPRO:AS      45.  -158.    96.   2430.  102221.     863.    2.81  498.88

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -4.    21.   47254.

  SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO   VHD      EGL    WSEL
   EXITX:XS    492.83    0.48  487.77  512.42************  0.62  495.78  495.16
   FULLV:FV  ********    0.44  487.77  512.42  0.25  0.00  0.55  496.04  495.49
   BRIDG:BR    495.04    1.00  487.40  498.90***********  3.33  498.37  495.04
   RDWAY:RG  ****************  500.34  512.53**********************************
   APPRO:AS    492.51    0.30  486.97  506.11  0.09  0.57  0.15  499.03  498.88
  ER

  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

## Structure Number MONKTH00340021

## General Location Descriptive

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

Date *(MM/DD/YY)* 12 / 15 / 95

Highway District Number *(I - 2; nn)* 05

County *(FIPS county code; I - 3; nnn)* 001

Town *(FIPS place code; I - 4; nnnnn)* 45550

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

Waterway *(I - 6)* LITTLE OTTER CREEK

Road Name *(I - 7):* -

Route Number TH 34

Vicinity *(I - 9)* 0.2 MI TO JCT W CL2 TH1

Topographic Map Monkton

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 44111

Longitude *(i - 17; nnnnn.n)* 73106

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011200210112

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

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

Year built *(I - 27; YYYY)* 1967

Structure length *(I - 49; nnnnnn)* 000050

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

Deck Width *(I - 52; nn.n)* 182

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

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

Opening skew to Roadway *(I - 34; nn)* 20

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

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

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)* 319

Clear span (*nnn.n ft*) 23.4

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

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

Number of approach spans *(I - 46; nnnn)* 0003

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

Comments:

**According to the structural inspection report dated 12/15/94, the main span is a concrete slab with a gravel build-up. There are three round boiler tube metal pipe culverts included as part of this structure, which pass through the left road approach embankment. Currently, there is no flow through the culverts but there is 6 inches of standing water in each. There are stumps, branches and other vegetation trapped at the outlet end of the pipes by a barbed wire fence. The abutments and wingwalls are concrete. The concrete has a few minor cracks overall. The channel is scoured down approximately 3 feet in front of each abutment but there is no undermining noted.**

## Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): -   Discharge over roadway at $Q_{100}$ (*$ft^3$/ 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)* **34.145** $mi^2$

Lake/pond/swamp area **1.35** $mi^2$

Watershed storage *(ST)* **3.95** %

Bridge site elevation **250** ft

Headwater elevation **900** ft

Main channel length **11.309** mi

10% channel length elevation **253** ft

85% channel length elevation **490** ft

Main channel slope *(S)* **27.94** 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 BENCKMARK 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:

**There were no plans available for this site.**

## Cross-sectional Data

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

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

Comments: **Cross-section data is available but vertical distances are not available.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 D:

# LEVEL I DATA FORM

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

Qa/Qc Check by: **JRD** Date: **6/20/97**

Computerized by: **JRD** Date: **6/20/97**

Reviewd by: **EMB** Date: **7/21/97**

## Structure Number **MONKTH00340021**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. Medalie** Date *(MM/DD/YY)* **06** / **20** / 19**96**

2. Highway District Number **05** Mile marker **0**

County **Addison (001)** Town **Monkton (45550)**

Waterway *(I - 6)* **Little Otter Creek** Road Name **Lime Kiln Road**

Route Number **TH 34** Hydrologic Unit Code: **2010002**

3. Descriptive comments:

**This structure is located two tenths of a mile from the junction with Town Highway One.**

## B. Bridge Deck Observations

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

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

5. Ambient water surface... US **1** UB **1** DS **1** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **50** *(feet)* Span length **26** *(feet)* Bridge width **18.2** *(feet)*

### Road approach to bridge:

8. LB **2** RB **2** *( **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 | 1 | 1 |
| RBUS | 0 | - | 2 | 1 |
| RBDS | 0 | - | 2 | 1 |
| LBDS | 1 | 1 | 1 | 1 |

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

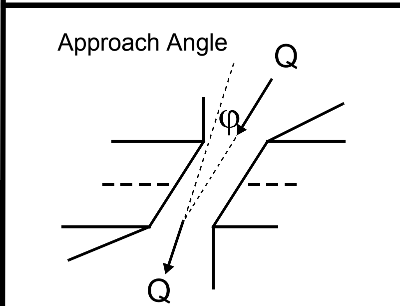
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

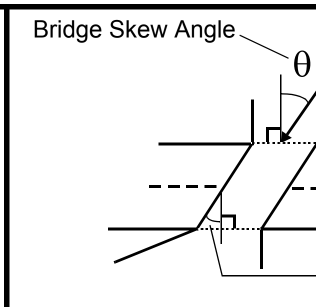
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

### Channel approach to bridge (BF):

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




α= **5.0**

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

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

Range? **60** feet **US** *(US, UB, DS)* to **5** feet **DS**

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

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

Range? **250** feet **US** *(US, UB, DS)* to **180** feet **US**

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

18. Bridge Type: **1a**

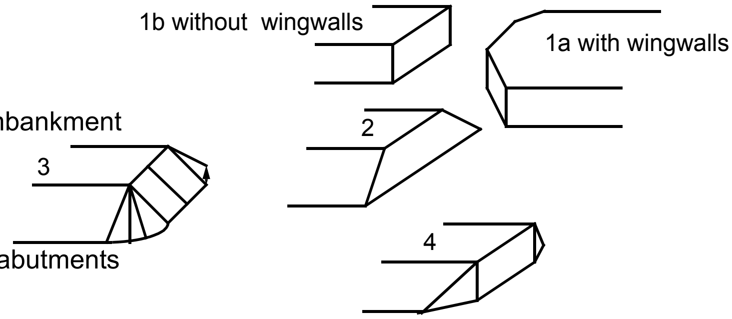
1a- Vertical abutments with wingwalls

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.)

**This structure has a new concrete deck which measures 29.8 feet in length. The additional length of the road measured over three culverts is 38 feet making a total bridge length of 67.5 feet.**
**The protection referred to on the upstream and downstream sides of the left road approach is tightly packed stones around the openings of the culverts.**
**The road wash erosion on the upstream and downstream right road approach consists of one foot wide gullies cutting around the ends of the wingwalls then entering the main channel.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| **67.5** | **6.5** | | | **4.5** | **2** | **1** | **1** | **10** | **1** | **0** |

23. Bank width **25.0** 24. Channel width **25.0** 25. Thalweg depth **88.0** 29. Bed Material **10**

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

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

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

**The thalweg depth upstream is about four and a half feet deep.**
**The protection noted above on the left bank consists of type-2 stone fill held in place around each culvert with concrete reinforcement rods as protection, some of the stones are below the water surface. This is the same stone fill protection mentioned in the road approach section.**

33. Point/Side bar present? **Y** (*Y or N. if N type ctrl-n pb*) 34. Mid-bar distance: **225** 35. Mid-bar width: **10**

36. Point bar extent: **300** feet **US** (*US, UB*) to **190** feet **US** (*US, UB, DS*) positioned **80** %LB to **100** %RB

37. Material: **1**

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

**This point bar is located on the inside of a bend, opposite a cut-bank.**

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

41. Mid-bank distance: **270** 42. Cut bank extent: **300** feet **US** (*US, UB*) to **210** feet **US** (*US, UB, DS*)

43. Bank damage: **2** ( *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? **N** (*Y or if N type ctrl-n cs*) 46. Mid-scour distance: **-**

47. Scour dimensions: Length **-** Width **-** Depth : **-** Position **-** %LB to **-** %RB

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

**NO CHANNEL SCOUR**

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 |
| **64.5** | | **5.0** | | **2** | **7** | **7** | **-** |

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

*Bed and bank Material: 0- organics; 1- silt / clay, < 1/16mm; 2- sand, 1/16 - 2mm; 3- gravel, 2 - 64mm; 4- cobble, 64 - 256mm; 5- boulder, > 256mm; 6- bedrock; 7- manmade*

*Bank Erosion: 0- not evident; 1- light fluvial; 2- moderate fluvial; 3- heavy fluvial / mass wasting*

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

**134**

**-**

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

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

70. Debris and Ice Comments:

**1**

**The debris accumulation consists primarily of grass in the bridge area. There is a large accumulation of logs, however, about four hundred feet downstream where the channel becomes constricted.**

| Abutments | 71. Attack ∠(BF) | 72. Slope ∠ (Qmax) | 73. Toe loc. (BF) | 74. Scour Condition | 75. Scour depth | 76. Exposure depth | 77. Material | 78. Length |
|---|---|---|---|---|---|---|---|---|
| LABUT | | 0 | 90 | 2 | 0 | - | - | 90.0 |
| RABUT | 1 | 30 | 90 | | | 2 | 0 | 25.0 |

*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.):

**-**

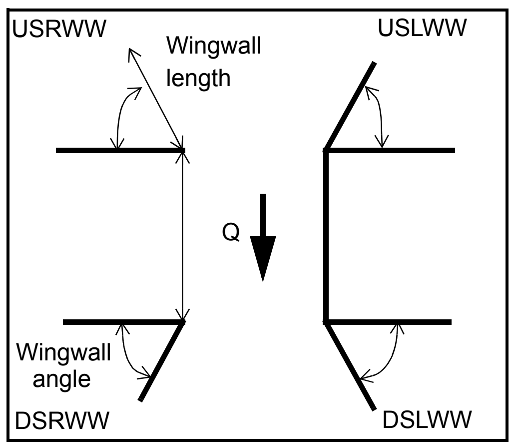
**-**

**1**

**Water depths along the left abutment range from two to four feet. Water depths along the right abutment vary from two to three feet.**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 25.0 | |
| USRWW: | N | | - | | - | 4.5 | |
| DSLWW: | - | | - | | Y | 21.0 | |
| DSRWW: | 1 | | 0 | | - | 18.0 | |




*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 | - | - | Y | - | - | - | - | - |
| Condition | N | - | 1 | - | - | - | - | - |
| Extent | - | - | 0 | - | 0 | 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*

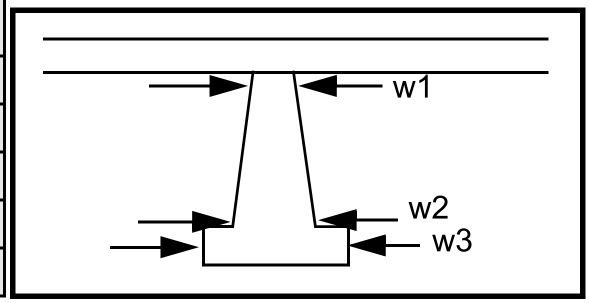
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
-
-
-
0

## Piers:

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

| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | - | | | - | 35.0 | 10.0 |
| Pier 2 | - | | 6.5 | - | 35.0 | - |
| Pier 3 | - | - | - | - | - | - |
| Pier 4 | - | - | - | - | - | - |




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

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

## E. Downstream Channel Assessment

100.

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

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

**1**
**3**
**1**
**1**
**0**
**1**
**1**
**2**
**2**
**2**
**1**
**The left bank vegetation cover consists solely of grass. The thalweg downstream is four feet deep.**
**The left bank protection is under water and extends from zero feet to ten feet downstream. The right bank**

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

103. Drop: - feet 104. Structure material: **ote** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
**ction extends from zero to eighteen feet downstream. There is also some channel bed protection extending across the stream from five feet under the bridge to fifteen feet downstream.**

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 **N** %LB to **-** %RB

Material: **NO**

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

**DROP STRUCTURE**

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

Cut bank extent: **-** 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? **NO** *(Y or if N type ctrl-n cs)* Mid-scour distance: **POIN**

Scour dimensions: Length **T** Width **BAR** Depth: **S** Positioned ____ %LB to ____ %RB

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

**N**
-
-

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 **NO** Enters on **CU** *(LB or RB)* Type **T** *( **1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

**BANKS**

## F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

**N**
**-**
**-**
**-**
**-**
**-**
**-**
**NO CHANNEL SCOUR**

**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 E:

# SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

| | | | |
|---|---|---|---|
| Structure Number: | MONKTH00340021 | Town: | Monkton |
| Road Number: | TH 34 | County: | Addison |
| Stream: | Little Otter Creek | | |

Initials EMB    Date: 6/18/97   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 | 3350 | 4800 | 3070 |
| Main Channel Area, ft2 | 919 | 1014 | 739 |
| Left overbank area, ft2 | 356 | 538 | 69 |
| Right overbank area, ft2 | 193 | 389 | 55 |
| Top width main channel, ft | 88 | 88 | 88 |
| Top width L overbank, ft | 159 | 178 | 123 |
| Top width R overbank, ft | 163 | 200 | 42 |
| D50 of channel, ft | 0.000102 | 0.000102 | 0.000102 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 10.4 | 11.5 | 8.4 |
| y1, average depth, LOB, ft | 2.2 | 3.0 | 0.6 |
| y1, average depth, ROB, ft | 1.2 | 1.9 | 1.3 |
| Total conveyance, approach | 169038 | 224260 | 102209 |
| Conveyance, main channel | 141612 | 166909 | 98492 |
| Conveyance, LOB | 20236 | 37271 | 1570 |
| Conveyance, ROB | 7190 | 20079 | 2147 |
| Percent discrepancy, conveyance | 0.0000 | 0.0004 | 0.0000 |
| Qm, discharge, MC, cfs | 2806.5 | 3572.5 | 2958.4 |
| Ql, discharge, LOB, cfs | 401.0 | 797.7 | 47.2 |
| Qr, discharge, ROB, cfs | 142.5 | 429.8 | 64.5 |
| Vm, mean velocity MC, ft/s | 3.1 | 3.5 | 4.0 |
| Vl, mean velocity, LOB, ft/s | 1.1 | 1.5 | 0.7 |
| Vr, mean velocity, ROB, ft/s | 0.7 | 1.1 | 1.2 |
| Vc-m, crit. velocity, MC, ft/s | 0.8 | 0.8 | 0.7 |
| 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 | 1 | 1 | 1 |

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 | 2510 | 2881 | 2430 |
| Main channel area (DS), ft2 | 186 | 228 | 166 |
| Main channel width (normal), ft | 25.1 | 25.1 | 25.0 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 25.1 | 25.1 | 25.0 |
| D90, ft | 0.0000 | 0.0000 | 0.0000 |
| D95, ft | 0.0000 | 0.0000 | 0.0000 |
| Dc, critical grain size, ft | ERR | ERR | ERR |
| Pc, Decimal percent coarser than Dc | 0.000 | 0.000 | 0.000 |
| Depth to armoring, ft | N/A | N/A | N/A |

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and others, 1995, p. 30, eq. 17 and 18)

| Characteristic | Approach 100 yr | 500 yr | Other Q | Bridge 100 yr | 500 yr | Other Q |
|---|---|---|---|---|---|---|
| Q1, discharge, cfs | 3350 | 4800 | 3070 | 2510 | 2881 | 2430 |
| Total conveyance | 169038 | 224260 | 102209 | 21186 | 21186 | 15352 |
| Main channel conveyance | 141612 | 166909 | 98492 | 21186 | 21186 | 15352 |
| Main channel discharge | 2806 | 3572 | 2958 | 2510 | 2881 | 2430 |
| Area - main channel, ft2 | 919 | 1014 | 739 | 262 | 262 | 166 |
| (W1) channel width, ft | 88 | 88 | 88 | 25.1 | 25.1 | 25 |
| (Wp) cumulative pier width, ft | 0 | 0 | 0 | 0 | 0 | 0 |
| W1, adjusted bottom width(ft) | 88 | 88 | 88 | 25.1 | 25.1 | 25 |
| D50, ft | 0.000102 | 0.000102 | 0.000102 | | | |
| w, fall velocity, ft/s (p. 32) | 0.0033 | 0.0033 | 0.0033 | | | |
| y, ave. depth flow, ft | 10.44 | 11.52 | 8.40 | 10.44 | 10.44 | 6.64 |
| S1, slope EGL | 0.0029 | 0.0033 | 0.0029 | | | |
| P, wetted perimeter, MC, ft | 92 | 92 | 92 | | | |
| R, hydraulic Radius, ft | 9.989 | 11.022 | 8.033 | | | |
| V*, shear velocity, ft/s | 0.966 | 1.082 | 0.866 | | | |
| V*/w | 292.669 | 327.941 | 262.447 | | | |
| Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33) | | | | | | |
| k1 | 0.69 | 0.69 | 0.69 | | | |
| y2,depth in contraction, ft | 22.55 | 22.77 | 16.91 | | | |
| ys, scour depth, ft (y2-y_bridge) | 12.11 | 12.33 | 10.27 | | | |

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation    Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc    Cf=1.5*Fr^0.43 (<=1)    Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

| | Q100 | Q500 | OtherQ |
|---|---|---|---|
| Q, total, cfs | 3350 | 4800 | 3070 |
| Q, thru bridge MC, cfs | 2510 | 2881 | 2430 |
| Vc, critical velocity, ft/s | 0.77 | 0.79 | 0.75 |
| Va, velocity MC approach, ft/s | 3.05 | 3.52 | 4.00 |
| Main channel width (normal), ft | 25.1 | 25.1 | 25.0 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 25.1 | 25.1 | 25.0 |
| qbr, unit discharge, ft2/s | 100.0 | 114.8 | 97.2 |
| Area of full opening, ft2 | 262.0 | 262.0 | 166.0 |
| Hb, depth of full opening, ft | 10.44 | 10.44 | 6.64 |
| Fr, Froude number, bridge MC | 0.52 | 0.6 | 0 |
| Cf, Fr correction factor (<=1.0) | 1.00 | 1.00 | 0.00 |
| **Area at downstream face, ft2 | 186 | 228 | N/A |
| **Hb, depth at downstream face, ft | 7.41 | 9.08 | N/A |
| **Fr, Froude number at DS face | 0.87 | 0.74 | ERR |
| **Cf, for downstream face (<=1.0) | 1.00 | 1.00 | N/A |
| Elevation of Low Steel, ft | 498.85 | 498.85 | 0 |
| Elevation of Bed, ft | 488.41 | 488.41 | -6.64 |
| Elevation of Approach, ft | 500.92 | 502 | 0 |
| Friction loss, approach, ft | 0.05 | 0.06 | 0 |
| Elevation of WS immediately US, ft | 500.87 | 501.94 | 0.00 |
| ya, depth immediately US, ft | 12.46 | 13.53 | 6.64 |
| Mean elevation of deck, ft | 500.34 | 500.34 | 0 |
| w, depth of overflow, ft (>=0) | 0.53 | 1.60 | 0.00 |
| Cc, vert contrac correction (<=1.0) | 0.97 | 0.97 | 1.00 |
| **Cc, for downstream face (<=1.0) | 0.868259 | 0.93196 | ERR |
| Ys, scour w/Chang equation, ft | 123.04 | 140.27 | N/A |
| Ys, scour w/Umbrell equation, ft | 20.16 | 23.68 | N/A |

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

| | | | |
|---|---|---|---|
| **Ys, scour w/Chang equation, ft | 141.32 | 147.38 | N/A |
| **Ys, scour w/Umbrell equation, ft | 23.19 | 25.04 | ERR |

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

| | | | |
|---|---|---|---|
| y2, from Laursen's equation, ft | 22.55 | 22.77 | 16.91 |
| WSEL at downstream face, ft | 495.82 | 497.50 | -- |
| Depth at downstream face, ft | 7.41 | 9.08 | N/A |
| Ys, depth of scour (Laursen), ft | 15.14 | 13.69 | N/A |

Abutment Scour

Froehlich's Abutment Scour

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

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

| Characteristic | Left Abutment 100 yr Q | 500 yr Q | Other Q | Right Abutment 100 yr Q | 500 yr Q | Other Q |
|---|---|---|---|---|---|---|
| (Qt), total discharge, cfs | 3350 | 4800 | 3070 | 3350 | 4800 | 3070 |
| a', abut.length blocking flow, ft | 12.5 | 12.5 | 6.7 | 190.8 | 228.2 | 70.9 |
| Ae, area of blocked flow ft2 | 154.2 | 155.6 | 75.3 | 456.2 | 644.5 | 260.6 |
| Qe, discharge blocked abut.,cfs | -- | -- | -- | -- | -- | 804.8 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 1.85 | 2.16 | 3.35 | 1.93 | 2.03 | 3.09 |
| ya, depth of f/p flow, ft | 12.34 | 12.45 | 11.24 | 2.39 | 2.82 | 3.68 |
| --Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru) | | | | | | |
| K1 | 1 | 1 | 1 | 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 | 0.160 | 0.182 | 0.239 | 0.220 | 0.207 | 0.284 |
| ys, scour depth, ft | 21.54 | 22.46 | 19.77 | 14.01 | 16.12 | 15.01 |

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) | 12.5 | 12.5 | 6.7 | 190.8 | 228.2 | 70.9 |
| y1 (depth f/p flow, ft) | 12.34 | 12.45 | 11.24 | 2.39 | 2.82 | 3.68 |
| a'/y1 | 1.01 | 1.00 | 0.60 | 79.80 | 80.80 | 19.29 |
| Skew correction (p. 49, fig. 16) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Froude no. f/p flow | 0.16 | 0.18 | 0.24 | 0.22 | 0.21 | 0.28 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | ERR | ERR | ERR | 10.55 | 12.21 | ERR |
| vertical w/ ww's | ERR | ERR | ERR | 8.65 | 10.02 | ERR |
| spill-through | ERR | ERR | ERR | 5.80 | 6.72 | 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 | 0.8 | 0.68 | 1 | 0.8 | 0.68 | 1 |
| y, depth of flow in bridge, ft | 7.41 | 9.08 | 6.64 | 7.41 | 9.08 | 6.64 |
| Median Stone Diameter for riprap at: left abutment | | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | 2.93 | 2.60 | ERR | 2.93 | 2.60 | ERR |
| Fr>0.8 (vertical abut.) | ERR | ERR | 2.78 | ERR | ERR | 2.78 |