LEVEL II SCOUR ANALYSIS FOR BRIDGE 17 (RIPTTH00180017) on TOWN HIGHWAY 18, crossing the SOUTH BRANCH MIDDLEBURY RIVER, RIPTON, VERMONT

Open-File Report 97-658

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

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

USGS
science for a changing world
LEVEL II SCOUR ANALYSIS FOR BRIDGE 17 (RIPTTH00180017) on TOWN HIGHWAY 18, crossing the SOUTH BRANCH MIDDLEBURY RIVER, RIPTON, VERMONT

By RONDA L. BURNS AND LAURA MEDALIE

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Pembroke, New Hampshire
1997
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

<table>
<thead>
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<th>By</th>
<th>To obtain</th>
</tr>
</thead>
<tbody>
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</tr>
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<td>millimeter (mm)</td>
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<td>mile (mi)</td>
<td>1.609</td>
<td>kilometer (km)</td>
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<tr>
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<td>square kilometer (km²)</td>
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<td><strong>Velocity and Flow</strong></td>
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<td>foot per second (ft/s)</td>
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<td>cubic meter per second (m³/s)</td>
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<td>cubic foot per second per square mile [(ft³/s)/mi²]</td>
<td>0.01093</td>
<td>second per square kilometer [(m³/s)/km²]</td>
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**OTHER ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>BF</td>
<td>bank full</td>
</tr>
<tr>
<td>cfs</td>
<td>cubic feet per second</td>
</tr>
<tr>
<td>D₅₀</td>
<td>median diameter of bed material</td>
</tr>
<tr>
<td>DS</td>
<td>downstream</td>
</tr>
<tr>
<td>elev.</td>
<td>elevation</td>
</tr>
<tr>
<td>f/p</td>
<td>flood plain</td>
</tr>
<tr>
<td>ft²</td>
<td>square feet</td>
</tr>
<tr>
<td>ft/ft</td>
<td>feet per foot</td>
</tr>
<tr>
<td>JCT</td>
<td>junction</td>
</tr>
<tr>
<td>LAB</td>
<td>left abutment</td>
</tr>
<tr>
<td>LABUT</td>
<td>face of left abutment</td>
</tr>
<tr>
<td>LB</td>
<td>left bank</td>
</tr>
<tr>
<td>LOB</td>
<td>left overbank</td>
</tr>
<tr>
<td>LWW</td>
<td>left wingwall</td>
</tr>
<tr>
<td>MC</td>
<td>main channel</td>
</tr>
<tr>
<td>RAB</td>
<td>right abutment</td>
</tr>
<tr>
<td>RABUT</td>
<td>face of right abutment</td>
</tr>
<tr>
<td>RB</td>
<td>right bank</td>
</tr>
<tr>
<td>ROB</td>
<td>right overbank</td>
</tr>
<tr>
<td>RWW</td>
<td>right wingwall</td>
</tr>
<tr>
<td>TH</td>
<td>town highway</td>
</tr>
<tr>
<td>UB</td>
<td>under bridge</td>
</tr>
<tr>
<td>US</td>
<td>upstream</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>VTAOT</td>
<td>Vermont Agency of Transportation</td>
</tr>
<tr>
<td>WSPRO</td>
<td>water-surface profile model</td>
</tr>
</tbody>
</table>

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.
INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure RIPTTH00180017 on Town Highway 18 crossing the South Branch Middlebury River, Ripton, 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 west-central Vermont. The 15.5-mi² drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest except on the upstream left bank where it is shrubs and brush.

In the study area, the South Branch Middlebury River has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 86 ft and an average bank height of 10 ft. The channel bed material ranges from gravel to boulders with a median grain size (D₅₀) of 111 mm (0.364 ft). In addition, there is a bedrock outcrop across the channel downstream of the bridge. The geomorphic assessment at the time of the Level I and Level II site visit on June 10, 1996, indicated that the reach was stable.

The Town Highway 18 crossing of the South Branch Middlebury River is a 61-ft-long, one-lane bridge consisting of one 58-foot steel-beam span (Vermont Agency of Transportation, written communication, November 30, 1995). The opening length of the structure parallel to the bridge face is 56.8 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening while the computed opening-skew-to-roadway is 30.
A scour hole 1.25 ft deeper than the mean thalweg depth was observed along the right abutment and the downstream right wingwall during the Level I assessment. The scour protection measures at the site include type-2 stone fill (less than 36 inches diameter) along the left abutment and its wingwalls and at the upstream end of the right abutment. Also, type-3 stone fill (less than 48 inches diameter) is along the upstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and 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 0.1 to 1.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 5.6 to 9.0 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.
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**  RIPTTH00180017  **Stream**  South Branch Middlebury River

**County**  Addison  **Road**  TH 18  **District**  5

---

### Description of Bridge

- **Bridge length**: 61 ft  
- **Bridge width**: 15 ft  
- **Max span length**: 58 ft

- **Alignment of bridge to road (on curve or straight)**: Curve
- **Abutment type**: Vertical, concrete
- **Embankment type**: Sloping
- **Stone fill on abutment?**: Yes
- **Date of inspection**: 06/10/96

**Description of stone fill**:
Type-2, along the upstream end of the right abutment, along the left abutment and its wingwalls, and type-3 along the upstream right wingwall.

- Abutments and wingwalls are concrete. There is a one and one quarter foot deep scour hole in front of the right abutment and the downstream right wingwall.
- Yes  40

- **Is bridge skewed to flood flow according to Level I survey?**: Yes

The channel makes a moderate bend through the bridge. The scour hole has developed in the location where the flow impacts the right abutment.

---

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

<table>
<thead>
<tr>
<th>Date of inspection</th>
<th>Percent of channel blocked horizontally</th>
<th>Percent of channel blocked vertically</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I</td>
<td>06/10/96</td>
<td>0</td>
</tr>
<tr>
<td>Level II</td>
<td>06/10/96</td>
<td>0</td>
</tr>
</tbody>
</table>

**Moderate. There is a fallen tree in the upstream reach.**

---

### Potential for debris

None.  06/10/96

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

---

7
Description of the Geomorphic Setting

General topography  The channel is located within a moderate relief valley setting with steep valley walls on both sides.

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

Date of inspection  06/10/96

DS left:  Steep channel bank to a moderately sloped overbank

DS right:  Steep channel bank to a narrow terrace and a steep valley wall

US left:  Steep channel bank to a moderately sloped overbank

US right:  Steep valley wall

Description of the Channel

Average top width  86  Predominant bed material  Cobble/Boulder

Average depth  10  Bank material  Sinuous but stable

with non-alluvial channel boundaries.

Vegetative cover on channel banks near bridge:  Date of inspection

DS left:  Trees

DS right:  Trees

US left:  Shrubs and brush

US right:  Trees

Do banks appear stable?  Date of observation.

Yes

A bedrock outcrop downstream of the bridge crosses the channel with one foot of channel scour downstream of the outcrop as of 06/10/96.
**Hydrology**

*Drainage area* 15.5 mi²

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

<table>
<thead>
<tr>
<th>Physiographic province/section</th>
<th>Percent of drainage area</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England/Green Mountain</td>
<td>100</td>
</tr>
</tbody>
</table>

*Is drainage area considered rural or urban?* Rural

*Describe any significant urbanization:* None

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

<table>
<thead>
<tr>
<th>USGS gage description</th>
<th>USGS gage number</th>
<th>Gage drainage area</th>
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</thead>
<tbody>
<tr>
<td>--</td>
<td>--</td>
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</table>

*Is there a lake/pond that will significantly affect hydrology/hydraulics?* No

<table>
<thead>
<tr>
<th>Calculated Discharges</th>
<th>Q100 (ft³/s)</th>
<th>Q500 (ft³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,100</td>
<td>4,450</td>
<td></td>
</tr>
</tbody>
</table>

The 100-year discharge is from flood frequency estimates available from the VTAOT database which were extended graphically to the 500-year discharge. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).
Description of the Water-Surface Profile Model (WSPRO) Analysis

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

Datum tie between USGS survey and VTAOT plans  
None

Description of reference marks used to determine USGS datum.  
RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 500.10 ft, arbitrary survey datum). RM2 is a metal U.S. Department of Agriculture benchmark on top of the upstream end of the left abutment (elev. 500.02 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

<table>
<thead>
<tr>
<th>Cross-section</th>
<th>Section Reference Distance (SRD) in feet</th>
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<th>Comments</th>
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<td>EXIT1</td>
<td>-52</td>
<td>1</td>
<td>Exit section</td>
</tr>
<tr>
<td>FULLV</td>
<td>0</td>
<td>2</td>
<td>Downstream Full-valley section (Templated from EXIT1)</td>
</tr>
<tr>
<td>BRIDG</td>
<td>0</td>
<td>1</td>
<td>Bridge section</td>
</tr>
<tr>
<td>RDWAY</td>
<td>11</td>
<td>1</td>
<td>Road Grade section</td>
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<td>APTEM</td>
<td>64</td>
<td>1</td>
<td>Approach section as surveyed (Used as a template)</td>
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<tr>
<td>APPRI1</td>
<td>71</td>
<td>2</td>
<td>Modelled Approach section (Templated from APTEM)</td>
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</table>

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 0.060 to 0.075, and overbank “n” values ranged from 0.065 to 0.085.

Normal depth at the exit section (EXIT1) 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 0.0258 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1944).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0119 ft/ft) to establish the modelled approach section (APPR1), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

For the 500-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles for this discharge, it can be 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 499.4 ft
Average low steel elevation 495.5 ft

100-year discharge 3,100 ft³/s
Water-surface elevation in bridge opening 490.9 ft
Road overtopping? No Discharge over road - ft³/s
Area of flow in bridge opening 263 ft²
Average velocity in bridge opening 11.8 ft/s
Maximum WSPRO tube velocity at bridge 14.4 ft/s

Water-surface elevation at Approach section with bridge 493.6 ft
Water-surface elevation at Approach section without bridge 492.7 ft
Amount of backwater caused by bridge 0.9 ft

500-year discharge 4,450 ft³/s
Water-surface elevation in bridge opening 491.9 ft
Road overtopping? No Discharge over road - ft³/s
Area of flow in bridge opening 311 ft²
Average velocity in bridge opening 14.3 ft/s
Maximum WSPRO tube velocity at bridge 17.6 ft/s

Water-surface elevation at Approach section with bridge 495.8 ft
Water-surface elevation at Approach section without bridge 494.1 ft
Amount of backwater caused by bridge 1.7 ft

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

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

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. However, bedrock is exposed across the channel immediately downstream of the bridge. 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 and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

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 Results

<table>
<thead>
<tr>
<th>Contraction scour:</th>
<th>100-yr discharge</th>
<th>500-yr discharge</th>
<th>Incipient overtopping discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Scour depths in feet)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Main channel</strong></td>
<td></td>
<td></td>
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<tr>
<td>Live-bed scour</td>
<td>0.1</td>
<td>1.1</td>
<td>--</td>
</tr>
<tr>
<td>Clear-water scour</td>
<td>12.9</td>
<td>26.5</td>
<td>--</td>
</tr>
<tr>
<td>Depth to armoring</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Left overbank</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Right overbank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Local scour:</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Abutment scour</td>
<td>5.6</td>
<td>8.4</td>
<td>--</td>
</tr>
<tr>
<td>Left abutment</td>
<td>6.1</td>
<td>9.0</td>
<td>--</td>
</tr>
<tr>
<td>Right abutment</td>
<td>--</td>
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<td>--</td>
</tr>
<tr>
<td><strong>Pier scour</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pier 1</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Pier 2</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Pier 3</td>
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<td>--</td>
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### Riprap Sizing

<table>
<thead>
<tr>
<th>Riprap Sizing</th>
<th>Incipient overtopping discharge</th>
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</thead>
<tbody>
<tr>
<td>(D&lt;sub&gt;50&lt;/sub&gt; in feet)</td>
<td>100-yr discharge</td>
</tr>
<tr>
<td><strong>Abutments:</strong></td>
<td></td>
</tr>
<tr>
<td>Left abutment</td>
<td>2.2</td>
</tr>
<tr>
<td>Right abutment</td>
<td>--</td>
</tr>
<tr>
<td><strong>Piers:</strong></td>
<td></td>
</tr>
<tr>
<td>Pier 1</td>
<td>--</td>
</tr>
<tr>
<td>Pier 2</td>
<td>--</td>
</tr>
</tbody>
</table>
Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RIPTTH00180017 on Town Highway 18, crossing the South Branch Middlebury River, Ripton, Vermont.
Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RIPTTH00180017 on Town Highway 18, crossing the South Branch Middlebury River, Ripton, Vermont.
Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RIPTTH00180017 on Town Highway 18, crossing the South Branch Middlebury River, Ripton, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

<table>
<thead>
<tr>
<th>Description</th>
<th>Station</th>
<th>VTAOT minimum low-chord elevation (feet)</th>
<th>Surveyed minimum low-chord elevation (feet)</th>
<th>Bottom of footing/pile elevation (feet)</th>
<th>Channel elevation at abutment (feet)</th>
<th>Contraction scour depth (feet)</th>
<th>Abutment scour depth (feet)</th>
<th>Pier scour depth (feet)</th>
<th>Depth of total scour (feet)</th>
<th>Elevation of scour (feet)</th>
<th>Remaining footing/pile depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Left abutment</td>
<td>0.0</td>
<td>--</td>
<td>495.5</td>
<td>--</td>
<td>489.3</td>
<td>0.1</td>
<td>5.6</td>
<td>--</td>
<td>5.7</td>
<td>483.6</td>
<td>--</td>
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<tr>
<td>Right abutment</td>
<td>56.8</td>
<td>--</td>
<td>495.6</td>
<td>--</td>
<td>483.9</td>
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<td>6.1</td>
<td>--</td>
<td>6.2</td>
<td>477.7</td>
<td>--</td>
</tr>
</tbody>
</table>

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

100-yr. discharge is 3,100 cubic-feet per second

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure RIPTTH00180017 on Town Highway 18, crossing the South Branch Middlebury River, Ripton, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

<table>
<thead>
<tr>
<th>Description</th>
<th>Station</th>
<th>VTAOT minimum low-chord elevation (feet)</th>
<th>Surveyed minimum low-chord elevation (feet)</th>
<th>Bottom of footing/pile elevation (feet)</th>
<th>Channel elevation at abutment (feet)</th>
<th>Contraction scour depth (feet)</th>
<th>Abutment scour depth (feet)</th>
<th>Pier scour depth (feet)</th>
<th>Depth of total scour (feet)</th>
<th>Elevation of scour (feet)</th>
<th>Remaining footing/pile depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left abutment</td>
<td>0.0</td>
<td>--</td>
<td>495.5</td>
<td>--</td>
<td>489.3</td>
<td>1.1</td>
<td>8.4</td>
<td>--</td>
<td>9.5</td>
<td>479.8</td>
<td>--</td>
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<tr>
<td>Right abutment</td>
<td>56.8</td>
<td>--</td>
<td>495.6</td>
<td>--</td>
<td>483.9</td>
<td>1.1</td>
<td>9.0</td>
<td>--</td>
<td>10.1</td>
<td>473.8</td>
<td>--</td>
</tr>
</tbody>
</table>

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

500-yr. discharge is 4,450 cubic-feet per second
SELECTED REFERENCES


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


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


APPENDIX A:

WSPRO INPUT FILE
## WSPRO INPUT FILE

**T1**
U.S. Geological Survey WSPRO Input File ript017.wsp

**T2**
Hydraulic analysis for structure RIPTTH00180017 Date: 30-JUN-97

**T3**
TH 18 CROSSING THE SOUTH BRANCH MIDDLEBURY RIVER IN RIPTON, VT RLB

**J3**
6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3 *

| Q          | 3100.0 | 4450.0 |
| SK         | 0.0258 | 0.0258 |

| XS | EXIT1 | -52 | 0. |
| GR | -127.1, 508.37 | -118.6, 503.34 | -107.5, 502.43 | -83.1, 494.97 |
| GR | -55.0, 492.94 | -4.6, 491.58 | 0.0, 490.97 | 4.8, 487.38 |
| GR | 15.1, 484.78 | 18.9, 484.46 | 28.9, 484.59 | 36.4, 486.49 |
| GR | 42.0, 486.42 | 49.6, 483.80 | 54.2, 483.15 | 59.0, 483.38 |
| GR | 60.8, 485.09 | 69.5, 485.70 | 77.0, 491.11 | 100.4, 499.80 |
| GR | 135.4, 500.88 | 193.2, 510.43 |

| * GR | -20.0, 491.21 | -18.2, 487.80 | -11.4, 490.85 |

| N | 0.085 | 0.075 | 0.085 |
| SA | -4.6 | 100.4 |

| XS | FULLV | 0 | * * * | 0.0132 |

| * | SRD | LSEL | XSSKEW |
| BR | BRIDG | 0 | 495.54 | 30.0 |
| GR | 0.0, 495.52 | 0.0, 489.29 | 10.0, 487.44 |
| GR | 17.6, 485.60 | 17.8, 485.11 | 25.3, 484.34 | 30.8, 484.51 |
| GR | 34.5, 484.06 | 44.2, 484.44 | 53.3, 483.88 |
| GR | 53.6, 485.34 | 54.0, 485.38 | 54.1, 487.71 | 56.5, 487.69 |
| GR | 56.8, 495.56 | 0.0, 495.52 |
| * GR | 16.7, 488.33 | 49.9, 485.33 |

| * | BRTYPE | BRWDTH | WWANGL | WWWID |
| CD | 1 | 34.0 | * | * | 67.3 | 6.4 |
| N | 0.060 |

| * | SRD | EMBWID | IPAVE |
| XR | RDWAY | 11 | 15.0 | 2 |
| GR | -279.3, 505.91 | -248.2, 504.33 | -155.8, 501.06 | -105.7, 499.17 |
| GR | -44.7, 498.77 | -4.5, 499.24 | -4.3, 500.00 |
| GR | 54.9, 500.07 | 55.4, 499.46 | 60.0, 499.43 | 94.2, 500.19 |
| GR | 118.5, 500.89 | 142.4, 503.76 | 186.7, 512.71 |
| * GR | 0.0, 499.26 |

| * | XT | APTEM | 64 | 0. |
| GR | -38.1, 498.78 | -15.9, 496.88 | -7.8, 494.27 | 0.0, 489.51 |
| GR | 4.4, 486.26 | 7.6, 485.13 | 18.1, 485.03 | 23.8, 484.61 |
| GR | 29.2, 485.77 | 33.2, 486.39 | 37.4, 486.59 | 42.6, 492.41 |
| GR | 52.7, 496.93 | 68.1, 509.85 | 114.7, 515.29 |

| * | AS | APPR1 | 71 | * * | 0.0119 |
| GT | N | 0.065 | 0.070 |

| SA | -15.9 |

| * | HP 1 BRIDG | 490.88 | 1 | 490.88 |
| HP 2 BRIDG | 490.88 | * | * | 3100 |
| HP 1 APPR1 | 493.56 | 1 | 493.56 |
| HP 2 APPR1 | 493.56 | * | * | 3100 |

| * | HP 1 BRIDG | 491.87 | 1 | 491.87 |
| HP 2 BRIDG | 491.87 | * | * | 4450 |
APPENDIX B:

WSPRO OUTPUT FILE
## Cross-Section Properties

### ISEQ = 3; SECID = BRIDG; SRD = 0.

<table>
<thead>
<tr>
<th>WSEL</th>
<th>SA#</th>
<th>AREA</th>
<th>K</th>
<th>TOPW</th>
<th>WETP</th>
<th>ALPH</th>
<th>LEW</th>
<th>REM</th>
<th>QCR</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>263</td>
<td>17834</td>
<td>49</td>
<td>58</td>
<td>58</td>
<td>1.00</td>
<td>0</td>
<td>57</td>
<td>3449</td>
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### Velocity Distribution

<table>
<thead>
<tr>
<th>X STA.</th>
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<tbody>
<tr>
<td>0.0</td>
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<tr>
<td>23.0</td>
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<td>33.1</td>
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### Cross-Section Properties

### ISEQ = 5; SECID = APPR1; SRD = 71.

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<th>ALPH</th>
<th>LEW</th>
<th>REM</th>
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</tr>
</thead>
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<tr>
<td>2</td>
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<td>22169</td>
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<td>57</td>
<td>57</td>
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<td>45</td>
<td>4645</td>
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### Velocity Distribution

<table>
<thead>
<tr>
<th>X STA.</th>
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<tbody>
<tr>
<td>493.56</td>
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<td>-6.5</td>
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<tr>
<td>11.4</td>
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<td>19.5</td>
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</tbody>
</table>

### Cross-Section Properties

### ISEQ = 5; SECID = APPR1; SRD = 71.

<table>
<thead>
<tr>
<th>WSEL</th>
<th>SA#</th>
<th>AREA</th>
<th>K</th>
<th>TOPW</th>
<th>WETP</th>
<th>ALPH</th>
<th>LEW</th>
<th>REM</th>
<th>QCR</th>
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</thead>
<tbody>
<tr>
<td>2</td>
<td>326</td>
<td>22169</td>
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<td>57</td>
<td>1.00</td>
<td>0</td>
<td>45</td>
<td>4645</td>
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### Velocity Distribution

<table>
<thead>
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<td>493.56</td>
</tr>
<tr>
<td>-6.5</td>
</tr>
<tr>
<td>11.4</td>
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<tr>
<td>19.5</td>
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U.S. Geological Survey WSPRO Input File ript017.wsp
Hydraulic analysis for structure RIPTTH00180017 Date: 30-JUN-97
TH 18 CROSSING THE SOUTH BRANCH MIDDLEBURY RIVER IN RIPTON, VT RLB
*** RUN DATE & TIME: 07-11-97 13:45

CROSS-SECTION PROPERTIES: ISEQ = 3; SECID = BRIDG; SRD = 0.
WSEL SA# AREA K TOPW WETP ALPH LEMREW QCR
 1 311 23139 49 60 1.00 0 57 4447

VELOCITY DISTRIBUTION: ISEQ = 3; SECID = BRIDG; SRD = 0.
WSEL LEMREW AREA K Q VEL
491.87 0.0 56.7 311.2 23139. 4450. 14.30

WSPRO OUTPUT FILE (continued)

X STA.  A(I)  V(I)
0.0    26.0  8.55
8.8    19.2 11.62
13.5   16.7 13.35
16.9   16.0 13.90
19.7   14.5 15.30

X STA.  A(I)  V(I)
22.1   13.7 16.20
24.2   13.2 16.89
26.3   13.2 17.16
28.3   16.3 17.10
30.3   13.0
32.3   13.0

X STA.  A(I)  V(I)
32.3   12.8 17.33
34.3   12.6 17.62
36.2   12.9 17.30
38.1   16.9 16.90
40.1   16.8 16.86

X STA.  A(I)  V(I)
42.1   13.8 16.11
44.2   14.3 11.91
46.4   14.7 11.91
48.7   16.8 12.80
51.1   28.3
56.7

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPR1; SRD = 71.
WSEL SA# AREA K TOPW WETP ALPH LEMREW QCR
 2 454 34001 62 69 1.00 -11 50 6946
495.83 454 34001 62 69 1.00 -11 50 6946

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPR1; SRD = 71.
WSEL LEMREW AREA K Q VEL
495.83 -12.4 50.1 454.0 34001. 4450. 9.80

X STA.  A(I)  V(I)
-12.4  43.4  5.12
 1.5  27.7  8.03
 4.7  23.2  9.58
 7.0  21.3 10.47
 9.0  20.1 11.06

X STA.  A(I)  V(I)
10.9  18.7 11.91
12.7  18.9 11.76
14.5  18.3 12.14
16.2  18.1 12.26
17.9  18.2
19.6

X STA.  A(I)  V(I)
19.6  17.9 12.44
21.2  18.1 12.31
22.9  18.4 12.08
24.5  18.6 11.99
26.2  19.4
28.1

X STA.  A(I)  V(I)
28.1  17.9 11.01
30.1  20.2 10.51
32.3  21.2  9.78
34.7  22.7  8.60
37.6  25.9  5.11

23
U.S. Geological Survey WSPRO Input File ript017.wsp
Hydraulic analysis for structure RIPTTH00180017   Date: 30-JUN-97
TH 18 CROSSING THE SOUTH BRANCH MIDDLEBURY RIVER IN RIPTON, VT   RLB

*** RUN DATE & TIME: 07-11-97  13:45

XSID:CODE  SRDL  LEW  AREA  VHD  HF  EGL  CRWS  Q  WSEL
SRD  FLEN  REW  K  ALPH  HO  ERR  FR#  VEL
EXIT1:XS  1      356  1.18 *****  491.45  489.20  3100  490.27
         -51 *****  76  19286  1.00 ***** 0.70  8.71
FULLV:FV  52     409  0.89  1.09  492.54 ******* 3100  491.65
0  52  77  23803  1.00  0.01  5.8  7.58

<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

APPR1:AS  71     284  1.86  1.56  494.58 ******* 3100  492.72
71  43  18434  1.00  0.00  7.9  10.92

<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

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

XSID:CODE  SRDL  LEW  AREA  VHD  HF  EGL  CRWS  Q  WSEL
SRD  FLEN  REW  K  ALPH  HO  ERR  FR#  VEL
BRIDG:BR  52     263  1.17  1.45  493.05  490.51  3100  490.88
0  52  57  17837  1.00  0.15  0.9  11.80

TYPE PPCD FLOW  C  P/A  LSEL  BLEN  XLAB  XRAB
1. ****   1.  1.000 ******* 495.54 ******* ******* *******

XSID:CODE  CRWS  FR#  YMIN  YMAX  HF  HO  VHD  EGL  WSEL
EXIT1:XS  489.20  0.70  483.35  510.43********  1.18  491.45  490.27
FULLV:FV  0.58  483.84  511.12  1.09  0.00  0.89  492.54  491.65
BRIDG:BR  490.51  0.90  483.88  495.56  1.45  0.15  2.17  493.05  490.88
RDWAY:RG  498.77  512.71********** 2.00********
APPR1:AS  491.76  0.67  484.69  515.37  0.90  1.03  1.41  494.97  493.56

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

FIRST USER DEFINED TABLE.

XSID:CODE  SRD  LNW  REM  Q  K  AREA  VEL  WSEL
EXIT1:XS  -52.  1.  76.  3100.  19286.  356.  8.71  490.27
FULLV:FV  0.  0.  77.  3100.  23803.  409.  7.58  491.65
BRIDG:BR  0.  0.  57.  3100.  17837.  263.  11.80  490.88
RDWAY:RG  11.**********  0.**********  2.00********
APPR1:AS  37     -6  326  1.41  0.90  494.97  491.76  3100  493.56
71  45  22171  1.00  1.03  0.01  0.67  9.52

M(G)  M(K)  KQ  XLKQ  XRKQ  OTEL
0.000  0.000  22435.  -13.  44.  492.46

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

SECOND USER DEFINED TABLE.

XSID:CODE  CRWS  FR#  YMIN  YMAX  HF  HO  VHD  EGL  WSEL
EXIT1:XS  489.20  0.70  483.35  510.43********  1.18  491.45  490.27
FULLV:FV  0.58  483.84  511.12  1.09  0.00  0.89  492.54  491.65
BRIDG:BR  490.51  0.90  483.88  495.56  1.45  0.15  2.17  493.05  490.88
RDWAY:RG  498.77  512.71********** 2.00********
APPR1:AS  491.76  0.67  484.69  515.37  0.90  1.03  1.41  494.97  493.56

WSPRO OUTPUT FILE (continued)
U.S. Geological Survey WSPRO Input File ript017.wsp  
Hydraulic analysis for structure RIPTTH00180017   Date: 30-JUN-97  
TH 18 CROSSING THE SOUTH BRANCH MIDDLEBURY RIVER IN RIPTON, VT   RLB  
*** RUN DATE & TIME: 07-11-97  13:45  

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

EXIT1:XS  -5  461  491.62  
-51  27686  490.30  
FULLV:FV  52  33845  494.17  
0  80  4450  491.62  

<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

---125 FR# EXCEEDS FNTEST AT SECID "APPR1": TRIALS CONTINUED.  

---110 WSEL NOT FOUND AT SECID "APPR1": REDUCED DELTAY.  

---115 WSEL NOT FOUND AT SECID "APPR1": USED WSMIN = CRWS.  

APPR1:AS  71  46  24564  494.05  
71  46  24564  493.35  
<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

---285 CRITICAL WATER-SURFACE ELEVATION A_S_S_U_M_E_D !!!!!  

<<<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  491.87  
0  57  23136  14.30  

TYPE PPCD FLOW  C  P/A  LSEL  BLEN  XLAB  XRAB  
1.  495.54  

XSID:CODE  SRD  LEW  HF  VHD  EGL  ERR  Q  WSEL  
EXIT1:XS  -52.  78.  4450.  27686.  9.65  
FULLV:FV  0.  536.  33845.  4450.  8.30  
BRIDG:BR  0.  57.  23136.  14.30  
RDWAY:RG  11.  0.  2.00  

APPR1:AS  37  454  1.50  1.02  
71  40  50  33974  1.00  

M(G)  M(K)  KQ  XLKQ  XRKQ  OTEL  
0.000  35239.  -12.  44.  

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

FIRST USER DEFINED TABLE.  

XSID:CODE  SRD  LEW  REM  Q  K  AREA  VEL  WSEL  
EXIT1:XS  -52.  78.  4450.  27686.  461.  9.65  
FULLV:FV  0.  536.  33845.  4450.  8.30  
BRIDG:BR  0.  57.  23136.  14.30  
RDWAY:RG  11.  35239.  -12.  44.  

APPR1:AS  37  454  1.50  1.02  
71  40  50  33974  1.00  

SECOND USER DEFINED TABLE.  

XSID:CODE  CRWS  FR#  YMIN  YMAX  HF  HO  VHD  EGL  WSEL  
EXIT1:XS  490.30  0.73  483.35  510.43  461.  9.65  
FULLV:FV  0.69  493.07  491.62  
BRIDG:BR  3.18  495.05  491.87  
RDWAY:RG  498.77  512.71  

APPR1:AS  493.35  

<<<END OF WSPRO OUTPUT FILE>>>>>
APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION
Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure RIPTTH00180017, in Ripton, Vermont.
APPENDIX D:

HISTORICAL DATA FORM
According to the structural inspection report dated 12/8/94, the abutments, wingwalls, backwalls, and footings are concrete. They have minor fine cracks, small leaks, and small spalls overall. The channel flow is mostly against the RABUT and its DS wingwall, and the channel is scoured down approximately 1.5 ft. Boulders are present in front of the LABUT and its wingwalls, and the US wingwall on the RABUT. Bedrock outcrops appear downstream. Riprap is mostly washed away at the RABUT and it’s DS wingwall. There is 4 ft of exposed footing at the RABUT.
Bridge Hydrologic Data

Is there hydrologic data available? **Y** if No, type ctrl-n h  
VTAOT Drainage area (mi²): 15.6

Terrain character: Hilly and forested

Stream character & type: 

Streambed material: 

Discharge Data (cfs):

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<th>Q10</th>
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<td>800</td>
<td>1600</td>
<td>2100</td>
<td>2600</td>
<td>3100</td>
<td>500</td>
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</tbody>
</table>

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 of the site)

Water Surface Elevation Estimates for Existing Structure:

<table>
<thead>
<tr>
<th>Peak discharge frequency</th>
<th>Q2.33 3.3</th>
<th>Q10 5.1</th>
<th>Q25 6</th>
<th>Q50 6.9</th>
<th>Q100 7.7</th>
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<td>Water surface elevation (ft)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Velocity (ft/sec)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Long term stream bed changes: -

Is the roadway overtopped below the Q100? (Yes, No, Unknown): -  
Frequency: -

Relief Elevation (ft): -  
Discharge over roadway at Q100 (ft³/sec): -

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

Upstream distance (miles): 2.7  
Town: Ripton  
Year Built: 1975

Highway No.: TH21  
Structure No.: 11  
Structure Type: Concrete slab

Clear span (ft): 18  
Clear Height (ft): 10  
Full Waterway (ft²): 180
Downstream distance (miles): ___________ Town: Ripton ________ Year Built: 1978
Highway No.: VT125 _________ Structure No.: 14 _______ Structure Type: Twin call R.C. box
Clear span (ft): 40 _______ Clear Height (ft): 12 _______ Full Waterway (ft²): 480

Comments:
-

**USGS Watershed Data**

**Watershed Hydrographic Data**

- Drainage area (DA) 15.51 mi²
- Watershed storage (ST) 0 %
- Bridge site elevation 1170 ft
- Headwater elevation 3234 ft
- Main channel length 6.73 mi
- 10% channel length elevation 1250 ft
- 85% channel length elevation 1920 ft
- Main channel slope (S) 132.73 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): ___ / ___

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

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: ______

If no, type ctrl-n pl 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 DRILL BORING INFORMATION

Comments:

-
Cross-sectional Data

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

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

Comments: **NO CROSS SECTIONAL INFORMATION**

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<tr>
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<th>Feature</th>
<th>Low cord elevation</th>
<th>Bed elevation</th>
<th>Low cord to bed length</th>
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<th>Bed elevation</th>
<th>Low cord to bed length</th>
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Source *(FEMA, VTAOT, Other)*? -

Comments: -

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<th>Bed elevation</th>
<th>Low cord to bed length</th>
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<th>Feature</th>
<th>Low cord elevation</th>
<th>Bed elevation</th>
<th>Low cord to bed length</th>
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APPENDIX E:

LEVEL I DATA FORM
A. General Location Descriptive

1. Data collected by (First Initial, Full last name) _______ L. MEDALIE _______ Date (MM/DD/YY) __06__ / __10__ / __1996__
2. Highway District Number __05__
   County ADDISON (001) ______________
   Waterway (I - 6) SO. BR. MIDDLEBURY RIVER ______________
   Route Number C3018 ______________

3. Descriptive comments:
   This structure is located 0.1 mile from the intersection of Town Highway 18 with State Route 125.

B. Bridge Deck Observations

4. Surface cover...
   LBUS 5 RBUS 6 LBDS 6 RBDS 6 Overall 6
   (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 2 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 61 (feet)
   Span length 58 (feet)
   Bridge width 15 (feet)

Road approach to bridge:

8. LB 0 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 2.4:1 US right 2.7:1

Channel approach to bridge (BF):

15. Angle of approach: 30
16. Bridge skew: 40

17. Channel impact zone 1:
    Exist? Y (Y or N)
    Where? RB (LB, RB)
    Severity 1
    Range? 50 feet US (US, UB, DS) to 0 feet UB

Channel impact zone 2:
    Exist? Y (Y or N)
    Where? LB (LB, RB)
    Severity 0
    Range? 75 feet DS (US, UB, DS) to 120 feet DS

Impact Severity: 0 - none to very slight; 1 - Slight; 2 - Moderate; 3 - Severe
The road approach bisects the forest cover on the LBUS and RBDS.

Values are from the VT AOT database. The measured bridge length is 61 ft, span is 55 ft and width is 14.9 ft.

The DS right road embankment has four 36 inch boulders near its top, spaced 6-8 feet apart. There is a 1-1.5 foot wide path 20 feet down the road from the structure that channels road wash. The DS right road approach also has moderate road wash erosion just behind the wingwall. The US right road approach erosion starts 8 feet from the right side of the bridge. Grass at the top of the US right road approach helps slow down erosion in the 2 foot wide channel. The left road approach has road wash erosion behind the upstream and downstream wingwalls.

The channel makes a moderate bend through the bridge, but the banks are naturally protected with boulders and bedrock.

### C. Upstream Channel Assessment

<table>
<thead>
<tr>
<th></th>
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</tr>
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<tbody>
<tr>
<td>20. SRD</td>
<td>LB</td>
<td>RB</td>
<td>LB</td>
<td>RB</td>
</tr>
<tr>
<td>48.5</td>
<td>10.5</td>
<td>10.5</td>
<td>2</td>
<td>3</td>
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<tr>
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<tr>
<td>25.0</td>
<td>35.0</td>
<td>68.5</td>
<td>453</td>
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<table>
<thead>
<tr>
<th>30. Bank protection type:</th>
<th>LB</th>
<th>RB</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>31. Bank protection condition:</th>
<th>LB</th>
<th>RB</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

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 banks are steep and lined with large boulders.
33. Point/Side bar present? Y (Y or N, if N type ctrl-n pb)
34. Mid-bar distance: 35. Mid-bar width: 6
36. Point bar extent: feet US (US, UB) to feet US (US, UB, DS) positioned %LB to %RB
37. Material: 345
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.): The side bar is just DS of a birch tree that has fallen off the left bank.

39. Is a cut-bank present? Y (Y or N type ctrl-n cb)
40. Where? LB (LB or RB)
41. Mid-bank distance: 130
42. Cut bank extent: feet US (US, UB) to feet US (US, UB, DS)
43. Bank damage: 3 (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 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
There is some localized scour around boulders, reaching 0.75 feet in depth.

49. Are there major confluences? Y (Y or N type ctrl-n mc)
50. How many? 1
51. Confluence 1: Distance 65
52. Enters on RB (LB or RB)
53. Type 2 (1- perennial; 2- ephemeral)
Confluence 2: Distance
Enters on (LB or RB)
Type (1- perennial; 2- ephemeral)
54. Confluence comments (eg. confluence name):
There are many large boulders at the mouth of the confluence.

D. Under Bridge Channel Assessment
55. Channel restraint (BF)? LB 2 . - (1- natural bank; 2- abutment; 3- artificial levee)
56. Height (BF) 57 Angle (BF)
61. Material (BF) 62. Erosion (BF)
<table>
<thead>
<tr>
<th>LB</th>
<th>RB</th>
<th>LB</th>
<th>RB</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.0</td>
<td>1.5</td>
<td>2</td>
<td>7</td>
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</tbody>
</table>
58. Bank width (BF) - 59. Channel width - 60. Thalweg depth 90.0
63. Bed Material -

Bed and bank Material: 0- organics; 1- silt / clay, < 1/16mm; 2- sand, 1/16 - 2mm; 3- gravel, 2 - 64mm; 4- cobble, 64 - 256mm; 5- boulder, > 256mm; 6- bedrock; 7- manmade
Bank Erosion: 0- not evident; 1- light fluvial; 2- moderate fluvial; 3- heavy fluvial / mass wasting

64. Comments (bank material variation, minor inflows, protection extent, etc.):
65. Debris and Ice: Is there debris accumulation? ___ (Y or N)  
66. Where? N (1- Upstream; 2- At bridge; 3- Both)  
67. Debris Potential - ___ (1- Low; 2- Moderate; 3- High)  
68. Capture Efficiency 2 (1- Low; 2- Moderate; 3- High)  
69. Is there evidence of ice build-up? 2 (Y or N)  
70. Debris and Ice Comments:  

2 There is a fallen birch tree in the channel 70 feet US of the bridge.

<table>
<thead>
<tr>
<th>Abutments</th>
<th>71. Attack (\angle (BF))</th>
<th>72. Slope (\angle (Q_{max}))</th>
<th>73. Toe loc. (BF)</th>
<th>74. Scour Condition</th>
<th>75. Scour depth</th>
<th>76. Exposure depth</th>
<th>77. Material</th>
<th>78. Length</th>
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</thead>
<tbody>
<tr>
<td>LABUT</td>
<td>0</td>
<td>90</td>
<td>0</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>90.0</td>
<td></td>
</tr>
<tr>
<td>RABUT</td>
<td>1</td>
<td>10</td>
<td>90</td>
<td>2</td>
<td>3</td>
<td></td>
<td>49.0</td>
<td></td>
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</tbody>
</table>

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.):  
1.25  
5  
1

74. The right abutment footing is undermined. A range pole can penetrate 1 ft horizontally under the footing. The undermined section is 1.5 ft long, and 3 in. high. The bed material around the opening is loose gravel that can be easily penetrated with a range pole to 3 in.  
75. Scour depth based on an average thalweg depth of 1.25 ft.  
76. The right abutment has 2.5 feet of exposure on the upper footing and 2.5 feet of exposure on the lower footing. The left abutment is exposed 1 foot above the bed material but is covered by boulders.

80. Wingwalls:  

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<td>USLWW:</td>
<td>____ ____</td>
<td>____ ____ ____</td>
<td>____ ____ ____</td>
<td>____ ____ ____</td>
<td>49.0</td>
<td>____ ____</td>
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<td>USRWW:</td>
<td>Y ____ 1</td>
<td>____ ____ ____</td>
<td>____ ____ Y</td>
<td>____ ____ ____</td>
<td>1.5</td>
<td>____ ____</td>
</tr>
<tr>
<td>DSLWW:</td>
<td>____ ____ -</td>
<td>____ ____ ____</td>
<td>____ ____ Y</td>
<td>____ ____ ____</td>
<td>22.0</td>
<td>____ ____</td>
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<tr>
<td>DSRWW:</td>
<td>1 ____ 2</td>
<td>____ ____ ____</td>
<td>____ ____ ____</td>
<td>____ ____ ____</td>
<td>21.5</td>
<td>____ ____</td>
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Wingwall materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

82. Bank / Bridge Protection:

<table>
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<tr>
<th>Location</th>
<th>USLWW</th>
<th>USRWW</th>
<th>LABUT</th>
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<th>DSRWW</th>
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<td>2</td>
<td>0</td>
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<td>0.75</td>
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<td>1</td>
<td>2</td>
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<td>1</td>
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<tr>
<td>Extent</td>
<td>1</td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
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</table>

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 0 
- 

### Piers:

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

<table>
<thead>
<tr>
<th>Pier no.</th>
<th>width (w) feet</th>
<th>elevation (e) feet</th>
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<tr>
<td></td>
<td>w1  w2  w3</td>
<td>e@w1  e@w2  e@w3</td>
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<tr>
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<td>45.0  17.5  90.0</td>
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<td>Pier 2</td>
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<td>Pier 3</td>
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<td>Pier 4</td>
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### Level 1 Pier Descr.

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<td>e DS and 0.5 wall end.</td>
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</table>

86. Location (BF)

87. Type
- right ft of uppe The
88. Material
- wing expo r lowe
89. Shape
- wall sure foot- r
90. Inclined?
- has 2 on ing is foot-
91. Attack (BF)
- ft of the expo ing is
92. Pushed
- expo DS sed 2 also
93. Length (feet)
- 
94. # of piles
- sure end. ft for expo
95. Cross-members
- on The 5 ft sed 2
96. Scour Condition
- the US from ft at
97. Scour depth
- US right the the
98. Exposure depth
- end wing DS cor-
E. Downstream Channel Assessment

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<tr>
<th>SRD</th>
<th>Bank height (BF)</th>
<th>Bank angle (BF)</th>
<th>% Veg. cover (BF)</th>
<th>Bank material (BF)</th>
<th>Bank erosion (BF)</th>
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<td></td>
<td>LB</td>
<td>RB</td>
<td>LB</td>
<td>RB</td>
<td>LB</td>
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<table>
<thead>
<tr>
<th>Bank width (BF)</th>
<th>Channel width</th>
<th>Thalweg depth</th>
<th>Bed Material</th>
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<table>
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<th>RB</th>
<th>Bank protection condition:</th>
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</table>

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.):

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

There is a 5 ft boulder at the corner of the left abutment and US left wingwall.

101. Is a drop structure present? - (Y or N, if N type ctrl-n ds)

103. Drop: ______ feet

104. Structure material: - (1- steel sheet pile; 2- wood pile; 3- concrete; 4- other)

105. Drop structure comments (eg. downstream scour depth):
106. Point/Side bar present? _____ (Y or N. if N type ctrl-n pb) Mid-bar distance: _____ Mid-bar width: _____
Point bar extent: _____ feet _____ (US, UB, DS) to _____ feet _____ (US, UB, DS) positioned _____ %LB to _____ %RB
Material: _____
Point or side bar comments (Circle Point or Side; note additional bars, material variation, status, etc.):
-
-
-
-

Is a cut-bank present? _____ (Y or if N type ctrl-n cb) Where? _____ (LB or RB) Mid-bank distance: _____
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? _____ (Y or if N type ctrl-n cs) Mid-scour distance: _____
Scour dimensions: Length _____ 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 _____ Enters on _____ (LB or RB) Type _____ (1- perennial; 2- ephemeral)
Confluence comments (eg. confluence name):
-

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____ Be
1- Constructed
2- Stable
3- Aggraded
4- Degraded
5- Laterally unstable
6- Vertically and laterally unstable

There are many boulders along the left bank. A large boulder sits at the DS end of the DS left wingwall, measuring 12 feet long and 2.5 feet high.
108. Evolution comments (Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors):

drock outcrops are across the channel from 53 feet DS to 65 feet DS. The bedrock is on both sides of the channel and flow is over the middle.
APPENDIX F:

SCOUR COMPUTATIONS
SCOUR COMPUTATIONS

Structure Number: RIPTTH00180017  Town: RIPTON
Road Number: TH 18  County: ADDISON
Stream: SOUTH BRANCH MIDDLEBURY RIVER

Initials RLB  Date: 7/11/97  Checked: EB

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

Critical Velocity of Bed Material (converted to English units)

\[ V_c = 11.21 \times y_1^{0.1667} \times D_{50}^{0.33} \text{ with } S_s = 2.65 \]

(Richardson and others, 1995, p. 28, eq. 16)

Approach Section

<table>
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<th>Characteristic</th>
<th>100 yr</th>
<th>500 yr</th>
<th>other Q</th>
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<tr>
<td>Total discharge, cfs</td>
<td>3100</td>
<td>4450</td>
<td>0</td>
</tr>
<tr>
<td>Main Channel Area, ft²</td>
<td>326</td>
<td>454</td>
<td>0</td>
</tr>
<tr>
<td>Left overbank area, ft²</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Right overbank area, ft²</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Top width main channel, ft</td>
<td>51</td>
<td>62</td>
<td>0</td>
</tr>
<tr>
<td>Top width L overbank, ft</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Top width R overbank, ft</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D50 of channel, ft</td>
<td>0.3636</td>
<td>0.3636</td>
<td>0</td>
</tr>
<tr>
<td>D50 left overbank, ft</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>D50 right overbank, ft</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>y₁, average depth, MC, ft</td>
<td>6.4</td>
<td>7.3</td>
<td>ERR</td>
</tr>
<tr>
<td>y₁, average depth, LOB, ft</td>
<td>ERR</td>
<td>ERR</td>
<td>ERR</td>
</tr>
<tr>
<td>y₁, average depth, ROB, ft</td>
<td>ERR</td>
<td>ERR</td>
<td>ERR</td>
</tr>
</tbody>
</table>

Total conveyance, approach  22169  34001  0
Conveyance, main channel  22169  34001  0
Conveyance, LOB  0  0  0
Conveyance, ROB  0  0  0
Percent discrepancy, conveyance  0.0000  0.0000  ERR
Qm, discharge, MC, cfs  3100.0  4450.0  ERR
Ql, discharge, LOB, cfs  0.0  0.0  ERR
Qr, discharge, ROB, cfs  0.0  0.0  ERR

Vm, mean velocity MC, ft/s  9.5  9.8  ERR
Vl, mean velocity, LOB, ft/s ERR ERR ERR
Vr, mean velocity, ROB, ft/s ERR ERR ERR
Vc-m, crit. velocity, MC, ft/s  10.9  11.1  N/A
Vc-l, crit. velocity, LOB, ft/s ERR ERR ERR
Vc-r, crit. velocity, ROB, ft/s ERR ERR ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?

Main Channel  0  0  N/A
Left Overbank  N/A  N/A  N/A
Right Overbank  N/A  N/A  N/A
Clear Water Contraction Scour in MAIN CHANNEL

\[ y_2 = \left( \frac{Q_2^2}{131 \cdot D_m^{(2/3)} \cdot W_2^2} \right)^{3/7} \]  
Converted to English Units

\[ y_s = y_2 - y_{\text{bridge}} \]

(Richardson and others, 1995, p. 32, eq. 20, 20a)

<table>
<thead>
<tr>
<th>Bridge Section</th>
<th>Q100</th>
<th>Q500</th>
<th>Other Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Q) total discharge, cfs</td>
<td>3100</td>
<td>4450</td>
<td>0</td>
</tr>
<tr>
<td>(Q) discharge thru bridge, cfs</td>
<td>3100</td>
<td>4450</td>
<td>0</td>
</tr>
<tr>
<td>Main channel conveyance</td>
<td>17834</td>
<td>23139</td>
<td>0</td>
</tr>
<tr>
<td>Total conveyance</td>
<td>17834</td>
<td>23139</td>
<td>0</td>
</tr>
<tr>
<td>Q2, bridge MC discharge, cfs</td>
<td>3100</td>
<td>4450</td>
<td>ERR</td>
</tr>
<tr>
<td>Main channel area, ft^2</td>
<td>263</td>
<td>311</td>
<td>0</td>
</tr>
<tr>
<td>Main channel width (normal), ft</td>
<td>49.0</td>
<td>49.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Cum. width of piers in MC, ft</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>W, adjusted width, ft</td>
<td>49.0</td>
<td>49.1</td>
<td>0.0</td>
</tr>
<tr>
<td>y_{\text{bridge}} (avg. depth at br.), ft</td>
<td>5.37</td>
<td>6.33</td>
<td>ERR</td>
</tr>
<tr>
<td>Dm, median (1.25*D50), ft</td>
<td>0.4545</td>
<td>0.4545</td>
<td>0</td>
</tr>
<tr>
<td>y_2, depth in contraction, ft</td>
<td>5.42</td>
<td>7.38</td>
<td>ERR</td>
</tr>
<tr>
<td>y_s, scour depth (y_2 - y_{\text{bridge}}), ft</td>
<td>0.06</td>
<td>1.05</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Armoring**

\[ D_c = \left( \frac{1.94 \cdot V^2}{(5.75 \cdot \log(12.27 \cdot y/D_{90}))^2} \right) / [0.03 \cdot (165-62.4)] \]

Depth to Armoring = \(3 \cdot (1/P_c - 1)\)

(Federal Highway Administration, 1993)

<table>
<thead>
<tr>
<th>Downstream bridge face property</th>
<th>100-yr</th>
<th>500-yr</th>
<th>Other Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q, discharge thru bridge MC, cfs</td>
<td>3100</td>
<td>4450</td>
<td>N/A</td>
</tr>
<tr>
<td>Main channel area (DS), ft^2</td>
<td>263</td>
<td>311</td>
<td>0</td>
</tr>
<tr>
<td>Main channel width (normal), ft</td>
<td>49.0</td>
<td>49.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Cum. width of piers, ft</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Adj. main channel width, ft</td>
<td>49.0</td>
<td>49.1</td>
<td>0.0</td>
</tr>
<tr>
<td>D90, ft</td>
<td>1.7455</td>
<td>1.7455</td>
<td>0.0000</td>
</tr>
<tr>
<td>D95, ft</td>
<td>2.2112</td>
<td>2.2112</td>
<td>0.0000</td>
</tr>
<tr>
<td>D_c, critical grain size, ft</td>
<td>1.0654</td>
<td>1.4360</td>
<td>ERR</td>
</tr>
<tr>
<td>P_c, Decimal percent coarser than D_c</td>
<td>0.199</td>
<td>0.140</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Depth to armoring, ft | 12.87 | 26.46 | ERR
### Abutment Scour

**Froehlich’s Abutment Scour**

\[
Y_s/Y_1 = 2.27 \times K_1 \times K_2 \times (a'/Y_1)^{0.43} \times Fr_1^{0.61} + 1
\]

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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Left Abutment</th>
<th>Right Abutment</th>
</tr>
</thead>
<tbody>
<tr>
<td>((Q_t)), total discharge, cfs</td>
<td>3100</td>
<td>3100</td>
</tr>
<tr>
<td>(a'), abut. length blocking flow, ft</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>(A_e), area of blocked flow ft²</td>
<td>3.94</td>
<td>4.06</td>
</tr>
<tr>
<td>(Q_e), discharge blocked abut., cfs</td>
<td>20.56</td>
<td>21.38</td>
</tr>
</tbody>
</table>

(If using \(Q_{total \ overbank}\) to obtain \(V_e\), leave \(Q_e\) blank and enter \(V_e\) and \(Fr\) manually)

\(V_e\), \((Q_e/A_e)\), ft/s            | 5.22          | 5.27           |
\(y_a\), depth of f/p flow, ft          | 3.03          | 3.06           |

\(--\) Coeff., \(K_1\), for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)

\(K_1\) | 0.82          | 0.82           | 0.82           |

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

\(\theta\) | 60            | 120            |
\(K_2\) | 0.95          | 1.04           |

\(Fr\), froude number f/p flow          | 0.528         | 0.505          |
\(y_s\), scour depth, ft                | 5.55          | 6.14           |

**HIRE equation** (\(a'/(a' + y_a) > 25\))

\(y_s = 4 \times Fr^{0.33} \times y_1 \times K/0.55\)

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

\(a'\), (abut length blocked, ft)       | 1.3           |
\(y_1\), (depth f/p flow, ft)           | 3.03          |
\(a'/y_1\)                              | 0.43          |

Skew correction (p. 49, fig. 16)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Left Abutment</th>
<th>Right Abutment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skew correction (p. 49, fig. 16)</td>
<td>0.90</td>
<td>0.90</td>
</tr>
<tr>
<td>Froude no. f/p flow</td>
<td>0.53</td>
<td>0.50</td>
</tr>
</tbody>
</table>

\(Y_s\) w/ corr. factor \(K_1/0.55\):

- **vertical**
  - ERR
- **vertical w/ ww’s**
  - ERR
- **spill-through**
  - ERR
Abutment riprap Sizing

Ishbash 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)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Q100</th>
<th>Q500</th>
<th>Other Q</th>
<th>Q100</th>
<th>Q500</th>
<th>Other Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fr, Froude Number</td>
<td>0.9</td>
<td>1</td>
<td>0</td>
<td>0.9</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>y, depth of flow in bridge, ft</td>
<td>5.37</td>
<td>6.33</td>
<td>0.00</td>
<td>5.37</td>
<td>6.33</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Median Stone Diameter for riprap at: left abutment | right abutment, ft
Fr<=0.8 (vertical abut.) | ERR | ERR | 0.00 | ERR | ERR | 0.00 |
Fr>0.8 (vertical abut.) | 2.18 | 2.65 | ERR | 2.18 | 2.65 | ERR |