LEVEL II SCOUR ANALYSIS FOR BRIDGE 45B (BRIDTH0004045B) on TOWN HIGHWAY 4, crossing an unnamed DAILEY HOLLOW BRANCH TRIBUTARY, BRIDGEWATER, VERMONT

U.S. Geological Survey
Open-File Report 96-568

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

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By ERICK M. BOEHMLER

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Pembroke, New Hampshire

1996

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 45B (BRIDTH0004045B) ON TOWN HIGHWAY 4, CROSSING AN UNNAMED DAILEY HOLLOW BRANCH TRIBUTARY, BRIDGEWATER, VERMONT

By **Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BRIDTH0004045B on town highway 4 crossing an unnamed Dailey Hollow Branch Tributary, Bridgewater, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in central Vermont. The 2.47-mi^2 drainage area is in a predominantly rural and forested basin. Surface cover in the vicinity of the study site is variable. A gravel road is adjacent to the left bank with the immediate upstream left bank covered by grass and the immediate downstream left bank covered by shrubs and brush. The upstream right bank is densely forested; the downstream right overbank is covered by grass with trees and brush on the immediate channel bank.

In the study area, this unnamed Dailey Hollow Branch Tributary has an incised channel with a slope of approximately 0.04 ft/ft, an average channel top width of 29 ft and an average channel depth of 4 ft. The predominant channel bed material is gravel with a median grain size (D_{50}) of 47.0 mm (0.154 ft). The geomorphic assessment at the time of the Level I and Level II site visit on November 15, 1994, indicated that the reach was stable.

The town highway 4 crossing of the unnamed Dailey Hollow Branch Tributary is a 62-ft-long, corrugated steel multi-plate arch structure. It is supported by concrete footings leaving natural stream bed exposed (Vermont Agency of Transportation, written communication, January, 1996). The road embankments are protected by stone fill, however, the size is unknown due to sand and grass covering the fill except for the upstream left embankment which has type-2 stone fill (less than 36 inches diameter). The downstream left bank is protected by type-3 stone fill (less than 48 inches diameter) extending 25 feet downstream of the culvert. The channel approach to the culvert has a mild s-curve bend with the opening skewed ten degrees to flow. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). 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 1.1 to 1.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 7.7 to 11.7 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, 1993, p. 48). 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.

Delectable Mountain, 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 BRIDTH0004045B ***Stream*** Dailey Hollow Branch Tributary

County Windsor ***Road*** TH 4 ***District*** 04

Description of Bridge

Bridge length 62 ***ft*** ***Bridge width*** 19 ***ft*** ***Max span length*** -- ***ft***

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

Abutment type None ***Embankment type*** sloping

Stone fill on abutment? no ***Date of inspection*** 11/15/94

Description of stone fill Upstream left road approach has type-2 stone fill. The upstream right and both downstream road embankments are protected with stone fill covered by sand and gravel and grass. Type-3 stone fill protects the downstream left bank for 25 feet.

Brief description of piers/abutments There are no abutments. This is a corrugated steel multi-plate arch supported on concrete footers. About 0.5 feet of the footers are exposed on each side of the culvert.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 10

Culvert is located on a mild s-curve type bend in the channel. The upstream right bank at the culvert entrance is impacted by flood flows.

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	11/15/94	0	0
Level II	11/15/94	-	-

Potential for debris Moderate

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

Description of the Geomorphic Setting

General topography The culvert is at the headwaters of Dailey Hollow Branch in a steep, upland, incised channel.

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

Date of inspection 11/15/94

DS left: Steep bank to gravel roadway to steep valley wall

DS right: Steep bank to gently rolling over-bank to valley wall

US left: Steep bank to gravel roadway to steep valley wall

US right: Steep bank to moderately sloped over-bank to steep valley wall

Description of the Channel

Average top width 29 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material Gravel ***Bank material*** Gravel

The stream is perennial and flashy, in a narrow, incised, sinuous channel with non-alluvial boundaries.

11/15/94

Vegetative co

DS left: Shrubs and brush with gravel road adjacent to channel.

DS right: Young trees, shrubs and brush on immediate bank; grass on overbank.

US left: Grass and brush with gravel road adjacent to channel.

US right: Grass and dense forest

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

11/15/95--Some moderate but very localized bank erosion is indicated on the upstream right bank. While this erosion appears active, its localized nature does not indicate overall channel instability.

Describe any obstructions in channel and date of observation. 11/15/94--None.

Hydrology

Drainage area 2.47 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None. Area is mostly forested, high-elevation, headwater drainage.

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

USGS gage description

USGS gage number

Gage drainage area ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 975 ***ft³/s*** ***Q500*** 1200 ***ft³/s***

Q100 was obtained from VTAOT files (written communication, 5/4/95). Q500 was based on an area relationship with Bridgewater bridge 30. Bridge 30 is on Dailey Hollow Branch with drainage area of 7.5 square miles. The Q500 at bridge 30 was estimated from empirical methods (Talbot, 1887; Potter, 1957a; Potter, 1957b; written communication, 1971, written communication, 5/4/95; Johnson and Tasker, 1974; Federal Highway Administration, 1983).

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 Add 1261.85 to USGS survey to obtain VTAOT plans' datum at structure BRIDTH000400**42**.

Description of reference marks used to determine USGS datum. RM1 is a chiseled 'X' on the top, bankward edge of a 2 meter size boulder near the roadway elevation on the US right bank road approach side of structure (elev. 201.05 feet, arbitrary datum). RM2 is the center of engraved triangle in VTAOT brass survey mark on top, downstream end of right abutment on structure BRIDTH000400**42** (elev. 192.49 feet, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-25	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Culvert section
APPRO	80	2	Modelled Approach section (Templated from APTEM)
APTEM	97	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.065 and overbank "n" values ranged from 0.032 to 0.090.

Critical depth at the exit section (EXITX) was assumed as the starting water surface. The slope of the channel, determined from surveyed thalweg points downstream of the exit, was 0.055 ft/ft. For each of the modelled discharges, assuming a energy-grade-line slope of 0.055 ft/ft resulted in a supercritical solution at the exit. However, between the exit section and the culvert the channel slope decreased to 0.021 ft/ft, allowing a subcritical solution at the full valley section if the exit section was at critical depth. This demonstrated that the exit section was located at a transition in channel slope--upstream of the exit section being a subcritical slope and downstream of the exit being a supercritical slope. Thus, critical depth was allowed in the exit section and the subcritical results at the full valley section were used as the tailwater elevations for the culvert analysis.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.055 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 200.4 *ft*
Average low steel elevation 196.3 *ft*

100-year discharge 975 *ft³/s*
Water-surface elevation in bridge opening 190.8 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 93.0 *ft²*
Average velocity in bridge opening 10.5 *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge 195.0 *ft*
Water-surface elevation at Approach section without bridge -- *ft*
Amount of backwater caused by bridge -- *ft*

500-year discharge 1200 *ft³/s*
Water-surface elevation in bridge opening 191.3 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 102.4 *ft²*
Average velocity in bridge opening 11.7 *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge 196.4 *ft*
Water-surface elevation at Approach section without bridge -- *ft*
Amount of backwater caused by bridge -- *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, 1993). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1993, p. 35, equation 18). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The large computed depths to armoring suggest that streambed armoring will not limit the amount of contraction scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.1	1.8	--
Depth to armoring	19.9	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour	10.3	11.7	--
Left abutment	7.7–	9.7-	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:	1.9	2.2	--
Left abutment	1.9	2.2	--
Right abutment			
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

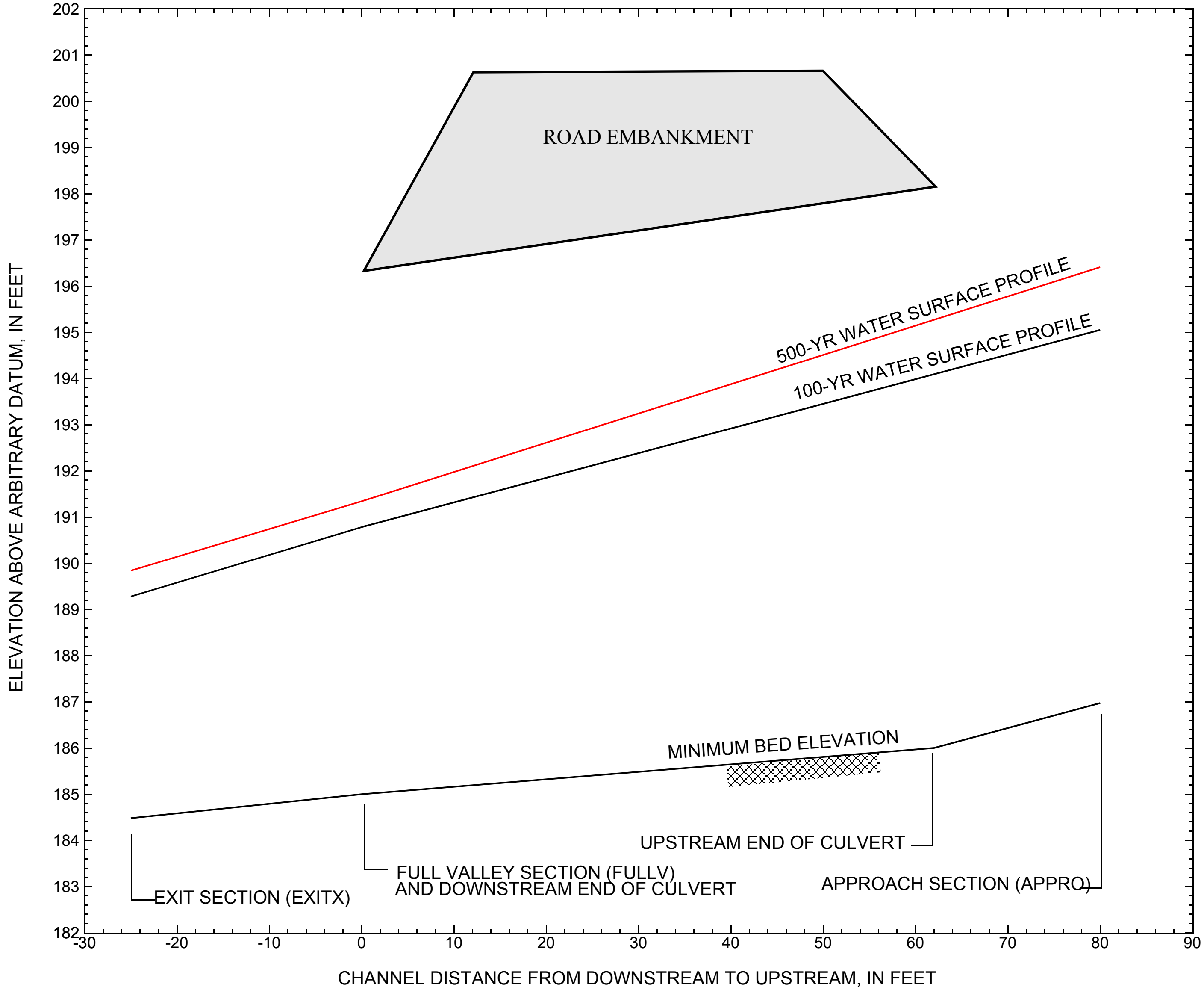


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BRIDTH0004045B on town highway 4, crossing an unnamed Dailey Hollow Branch Tributary, Bridgewater, Vermont.

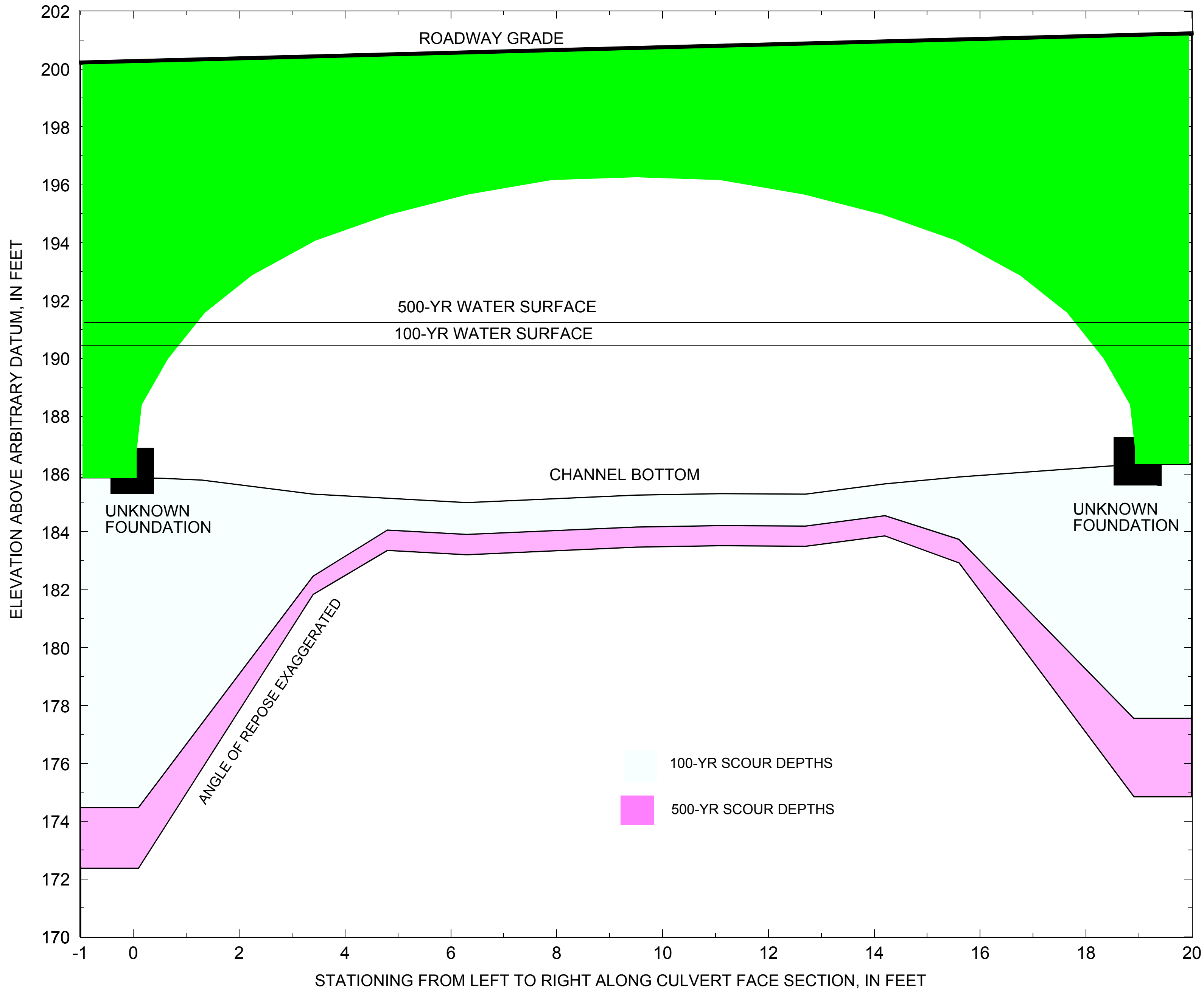


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BRIDTH0004045B on town highway 4, crossing an unnamed Dailey Hollow Branch Tributary, Bridgewater, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRIDTH0004045B on Town Highway 4, crossing an unnamed Dailey Hollow Branch Tributary, Bridgewater, 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 975 cubic-feet per second											
Left abutment	0.0	--	--	--	185.9	1.1	10.3	--	11.4	174.5	--
Right abutment	19.0	--	--	--	186.4	1.1	7.7	--	8.8	177.6	--

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 BRIDTH0004045B on Town Highway 4, crossing an unnamed Dailey Hollow Branch Tributary, Bridgewater, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 1,200 cubic-feet per second											
Left abutment	0.0	--	--	--	185.9	1.8	11.7	--	13.5	172.4	--
Right abutment	19.0	--	--	--	186.4	1.8	9.7	--	11.5	174.9	--

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

SELECTED REFERENCES

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

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

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

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

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

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

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

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

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

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Richardson, J.R.,Chang, F., 1991, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 195 p.

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

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

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

Richardson, E.V. and Davis, S.R., 1993, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 131 p.

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

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

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

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

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

U.S. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1966, Delectable, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid45b.wsp
T2        CREATED ON 07-DEC-95 FOR BRIDGE BRIDTH00040045 USING FILE brid45b.dca
T3        HYDRAULIC ANALYSIS OF EXIT of BRID45B      SAO
*
Q           975 975 1200 1200
SK         0.055 0.021 0.055 0.021
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS   EXITX    -25
GR          -26.6, 195.43     -8.1, 196.01      0.0, 189.12      6.0, 185.09
GR            7.9, 184.62     10.8, 184.71     14.2, 184.48     15.9, 185.04
GR           20.3, 185.16     26.1, 188.08     31.2, 194.19     53.9, 196.30
GR           73.6, 198.92
N           0.035        0.065        0.035
SA                  -8.1         31.2
*
XS   FULLV      0  * * *   0.021
*
EX           0 1 0 1
ER


T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid45b.wsp
T2        CREATED ON 07-DEC-95 FOR BRIDGE BRIDTH00040045 USING FILE brid45b.dca
T3        HYDRAULIC ANALYSIS OF BRID45B CULVERT     SAO
*
Q           975   1200
WS          190.78 191.34
*
CV   BRIDG   0 9.5 62 185.2 186.0 1
CG           321 131 228
CC           * * * 0.040
*
EX
ER


T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid45b.wsp
T2        CREATED ON 07-DEC-95 FOR BRIDGE BRIDTH00040045 USING FILE brid45b.dca
T3        HYDRAULIC ANALYSIS OF BRID45B      SAO
*
Q           975   1200
WS         195.05 196.41
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XT   APTEM     97
GR          -55.7, 201.06    -20.7, 199.38     -9.1, 193.64      0.0, 188.62
GR            6.0, 188.37     10.6, 187.91     14.9, 188.39     17.9, 188.39
GR           22.8, 193.41     35.4, 194.67     51.0, 203.94
*
XS   APPRO    80
GT           -0.94
N           0.032        0.055        0.090
SA                 -20.7         22.8
*
```

APPENDIX B:

WSPRO OUTPUT FILE

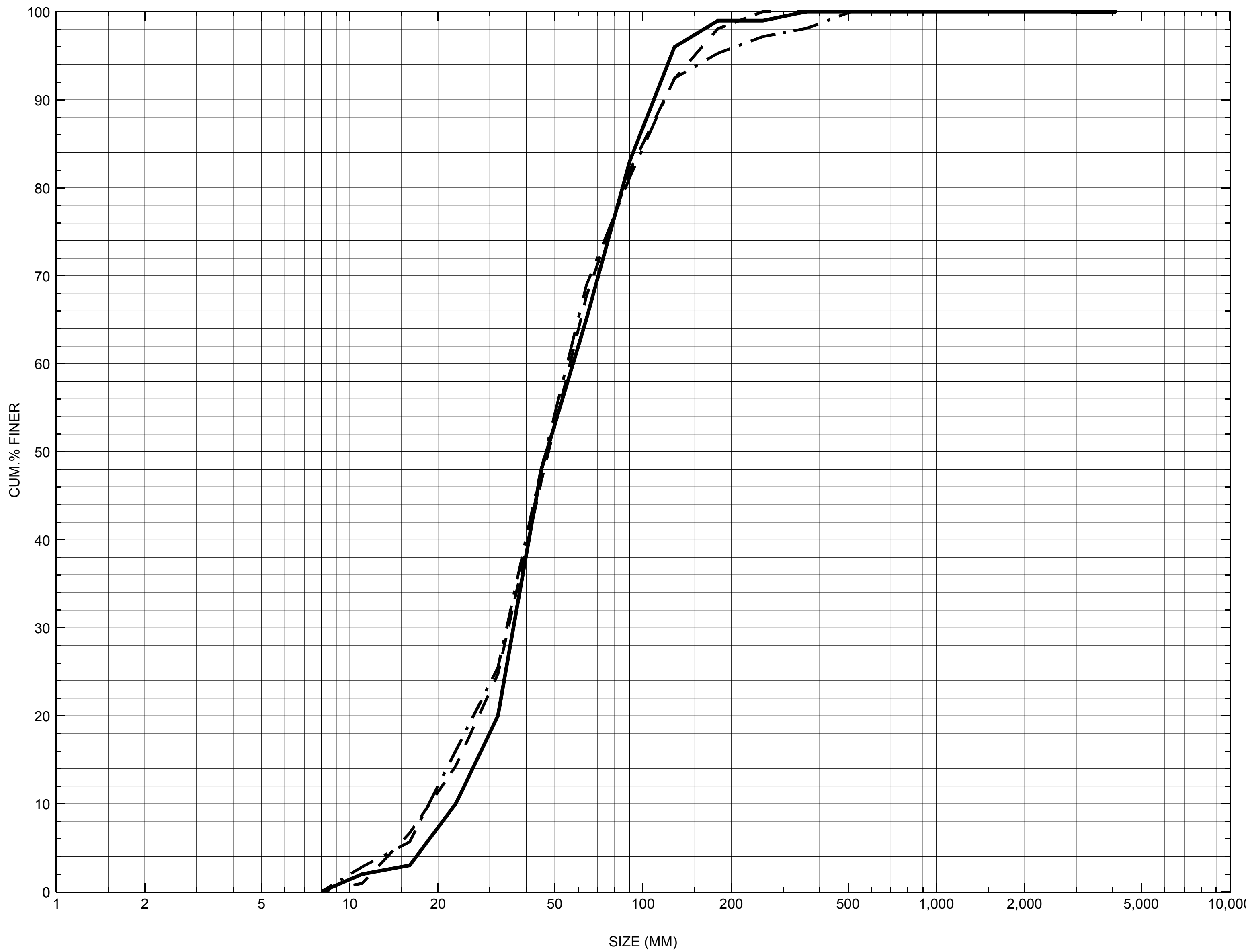
```
       U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid45b.wsp
       CREATED ON 07-DEC-95 FOR BRIDGE BRIDTH00040045 USING FILE brid45b.dca
       HYDRAULIC ANALYSIS OF EXIT of BRID45B      SAO

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                             WSI,CRWS =   189.08     189.28

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

EXITX:XS   ******     0.      93.  1.71 *****  190.99  189.28    975.  189.28
      -25. ******    27.    4529.  1.00 ***** *******    1.00   10.49

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.45

FULLV:XS      25.    -1.     121.  1.02  0.80  191.80 *******    975.  190.78
        0.    25.    28.    6582.  1.00  0.00    0.01    0.70    8.09

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -25.     0.    27.    975.    4529.      93.   10.49  189.28
   FULLV:XS       0.    -1.    28.    975.    6582.     121.    8.09  190.78

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    189.28    1.00  184.48  198.92************  1.71  190.99  189.28
   FULLV:XS  ********    0.70  185.00  199.44  0.80  0.00  1.02  191.80  190.78

       U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid45b.wsp
       CREATED ON 07-DEC-95 FOR BRIDGE BRIDTH00040045 USING FILE brid45b.dca
       HYDRAULIC ANALYSIS OF EXIT of BRID45B      SAO

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                             WSI,CRWS =   189.58     189.84

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

EXITX:XS   ******    -1.     109.  1.90 *****  191.74  189.84   1200.  189.84
      -25. ******    28.    5668.  1.00 ***** *******    1.00   11.05

FULLV:XS      25.    -2.     137.  1.19  0.80  192.53 *******   1200.  191.34
        0.    25.    28.    7919.  1.00  0.00   -0.01    0.73    8.74

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -25.    -1.    28.   1200.    5668.     109.   11.05  189.84
   FULLV:XS       0.    -2.    28.   1200.    7919.     137.    8.74  191.34

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    189.84    1.00  184.48  198.92************  1.90  191.74  189.84
   FULLV:XS  ********    0.73  185.00  199.44  0.80  0.00  1.19  192.53  191.34

 NORMAL  END  OF  WSPRO  EXECUTION.
```

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid45b.wsp
        CREATED ON 07-DEC-95 FOR BRIDGE BRIDTH00040045 USING FILE brid45b.dca
        HYDRAULIC ANALYSIS OF EXIT of BRID45B      SAO

--- DATA SUMMARY FOR SECID “BRIDG” AT SRD =      0.  ERR-CODE =      0

CULVERT PARAMETERS:  ISHAPE   IEQNO     CKE  CVALPH      CN
                         3.      4.    0.90    1.16   0.040

                       NBBL  CVLENG   USINV   DSINV    XCTR
                         1.    62.0  186.00  185.20     9.5

                       RISE    SPAN  BOTRAD  TOPRAD  CORRAD
                     131.00  228.00  365.23  114.14   18.00

+++ BEGINNING PROFILE CALCULATIONS --   2

    CULVERT SUMMARY:

        ISHAPE      RISE      SPAN    BOTRAD    TOPRAD    CORNER
             3    131.00    228.00    365.23    114.14     18.00

         IEQNO       CKE        CN    CVALPH    CVLENG    CVSLPE
             4      0.90     0.040      1.16     62.00    0.0129

         TWDEP      QBBL      HWIC      HWOC    OTFULL
          5.58    975.00      8.94      9.85     -3.37

         DSUBC     ASUBC     DSUBN     ASUBN
          5.08     84.37      5.95     99.18

         VELOT      AOUT     VELIN       AIN       HWE
         10.48     93.00     10.07     96.84    195.05

    CULVERT SUMMARY:

        ISHAPE      RISE      SPAN    BOTRAD    TOPRAD    CORNER
             3    131.00    228.00    365.23    114.14     18.00

         IEQNO       CKE        CN    CVALPH    CVLENG    CVSLPE
             4      0.90     0.040      1.16     62.00    0.0129

         TWDEP      QBBL      HWIC      HWOC    OTFULL
          6.14   1200.00     10.13     11.21     -2.86

         DSUBC     ASUBC     DSUBN     ASUBN
          5.74     95.76      7.01    116.30

         VELOT      AOUT     VELIN       AIN       HWE
         11.72    102.41     10.81    111.03    196.41

 NORMAL  END  OF  WSPRO  EXECUTION.

        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid45b.wsp
        CREATED ON 07-DEC-95 FOR BRIDGE BRIDTH00040045 USING FILE brid45b.dca
        HYDRAULIC ANALYSIS OF EXIT of BRID45B      SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  2;  SECID = APPRO;  SRD =      80.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     212.  17315.    37.    41.                         2900.
             3      26.    616.    15.    15.                          196.
   195.05          238.  17931.    51.    56.  1.14   -14.    38.   2729.

    VELOCITY DISTRIBUTION:  ISEQ =  2;  SECID = APPRO;  SRD =      80.
         WSEL     LEW     REW    AREA        K        Q    VEL
       195.05   -13.8    37.6   238.4   17931.     975.   4.09

X STA.       -13.8       -4.6       -2.0       -0.1        1.4        2.7
  A(I)            21.7       14.7       12.4       11.0       10.4
  V(I)            2.24       3.32       3.93       4.44       4.71

X STA.         2.7        4.0        5.3        6.6        7.8        8.9
  A(I)             9.8        9.8        9.4        9.4        8.9
  V(I)            4.98       4.98       5.20       5.20       5.45

X STA.         8.9       10.0       11.1       12.3       13.4       14.6
  A(I)             9.0        8.8        8.9        9.1        9.1
  V(I)            5.42       5.54       5.45       5.36       5.38

X STA.        14.6       15.9       17.1       18.6       21.0       37.6
  A(I)             9.5        9.8       10.7       13.9       32.2
  V(I)            5.15       5.00       4.58       3.51       1.51
```

```
    CROSS-SECTION PROPERTIES:  ISEQ =  2;  SECID = APPRO;  SRD =      80.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2      264.   23721.    39.    44.                      3879.
             3       48.    1520.    17.    18.                       453.
   196.41           312.   25241.    57.    62.  1.17   -17.    40.   3848.

    VELOCITY DISTRIBUTION:  ISEQ =  2;  SECID = APPRO;  SRD =      80.
         WSEL     LEW     REW    AREA         K        Q    VEL
       196.41   -16.6    39.9   311.8   25241.    1200.   3.85

X STA.       -16.6        -6.0        -2.9        -0.8         0.9         2.4
  A(I)             28.3        19.2        15.9        14.7        13.3
  V(I)             2.12        3.12        3.78        4.08        4.52

X STA.         2.4         3.8         5.2         6.5         7.8         9.1
  A(I)             12.5        12.6        12.0        11.8        11.6
  V(I)             4.78        4.78        4.99        5.09        5.17

X STA.         9.1        10.3        11.5        12.7        14.0        15.2
  A(I)             11.2        11.3        11.3        11.5        11.5
  V(I)             5.34        5.31        5.32        5.22        5.24

X STA.        15.2        16.6        18.0        19.9        24.5        39.9
  A(I)             12.1        12.4        15.3        22.1        41.2
  V(I)             4.97        4.82        3.91        2.71        1.46

        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid45b.wsp
        CREATED ON 07-DEC-95 FOR BRIDGE BRIDTH00040045 USING FILE brid45b.dca
        HYDRAULIC ANALYSIS OF BRID45B      SAO
           *** RUN DATE & TIME: 01-18-96  08:01

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

APPRO:XS   ******   -14.     238.  0.30 *****  195.35  191.49    975.  195.05
       80. ******    38.   17931.  1.14 ***** *******    0.36    4.09

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   APPRO:XS      80.   -14.    38.    975.   17931.     238.    4.09  195.05

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   APPRO:XS    191.49    0.36  186.97  203.00************  0.30  195.35  195.05

        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid45b.wsp
        CREATED ON 07-DEC-95 FOR BRIDGE BRIDTH00040045 USING FILE brid45b.dca
        HYDRAULIC ANALYSIS OF BRID45B      SAO
           *** RUN DATE & TIME: 01-18-96  08:01

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

APPRO:XS   ******   -17.     312.  0.27 *****  196.68  192.03   1200.  196.41
       80. ******    40.   25241.  1.17 ***** *******    0.31    3.85

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   APPRO:XS      80.   -17.    40.   1200.   25241.     312.    3.85  196.41

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   APPRO:XS    192.03    0.31  186.97  203.00************  0.27  196.68  196.41
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure BRIDTH0004045B, in Bridgewater, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BRIDTH0004045B

General Location Descriptive

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

Date *(MM/DD/YY)* 08 / 25 / 94

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

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 08275

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

Waterway *(I - 6)* Dailey Hollow Branch Tributary

Road Name *(I - 7)*: -

Route Number TH004

Vicinity *(I - 9)* 0.1 MI JCT TH 4 + TH 30

Topographic Map Delectable.Mtn

Hydrologic Unit Code: 01080106

Latitude *(I - 16; nnnn.n)* 43378

Longitude *(i - 17; nnnnn.n)* 72431

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10140500451405

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

Maximum span length *(I - 48; nnnn)* 0024

Year built *(I - 27; YYYY)* 1939

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

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

Deck Width *(I - 52; nn.n)* 14.6

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

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

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

Waterway adequacy *(I - 71; n)* 7

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

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

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

Year Reconstructed *(I - 106)* 1969

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

Clear span (*nnn.n ft*) 024.0

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

Vertical clearance from streambed (*nnn.n ft*) 009.0

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

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

Comments:

Structural inspection report of 10/18/93 indicates a steel beam and timberdeck type bridge with a very narrow gravel roadway surface on approach. Channel scour is noted heaviest near the bottom of the downstream end of the right abutment. *Since the inspection of 10/18/93 the bridge was replaced with a culvert. Information on this culvert is not available. The information on this form pertains to the structure that was removed.*

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: 2.5

Terrain character: **Rural, forested, mountainous**

Stream character & type: -

Streambed material: **Stone and boulder with some gravel**

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} **475** Q_{25} **675**

Q_{50} **825** Q_{100} **975** 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*)	-	**4.0**	**5.0**	**5.7**	**6.3**
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

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

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

Highway No. : **TH26** Structure No. : **11** Structure Type: **LOG STRINGER**

Clear span (*ft*): **7.0** Clear Height (*ft*): **3.5** Full Waterway (*ft²*): -

Downstream distance (*miles*): - Town: BRIDGEWATER Year Built: 1980

Highway No. : TH33 Structure No. : 30 Structure Type: STEEL BEAM

Clear span (*ft*): 25 Clear Height (*ft*): 9.2 Full Waterway (ft^2): -

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 2.47 mi^2 Lake and pond area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 1460 ft Headwater elevation 2787 ft

Main channel length 2.71 mi

10% channel length elevation 1495 ft 85% channel length elevation 2240 ft

Main channel slope *(S)* 396.07 ft / mi

Watershed Precipitation Data

Average site precipitation ___________ in Average headwater precipitation ___________ in

Maximum 2yr-24hr precipitation event *(I24,2)* _________ in

Average seasonal snowfall *(Sn)* __________ ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

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

If 1: Footing Thickness ______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: SAO Date: 1/27/95
Computerized by: EMB Date: 2/3/95
Reviewd by: SAO Date: 1/18/96

Structure Number BRIDTH0004045B

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. BOEHMLER Date *(MM/DD/YY)* 11 / 15 / 1994
2. Highway District Number 04 Mile marker 000000
County Windsor Town Bridgewater
Waterway *(I - 6)* Dailey Hollow Branch Tributary Road Name Bridgewater Hill Road
Route Number TH04 Hydrologic Unit Code: 01080106
3. Descriptive comments:
Bridge is located about 50 feet from the intersection of TH04 with TH30. Structure is a new corrugated metal culvert. Culvert is a rigid arch structure with stream bed still exposed.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 6 LBDS 5 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 2 UB 2 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 5 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length - *(feet)* Span length - *(feet)* Bridge width - *(feet)*

Road approach to bridge:

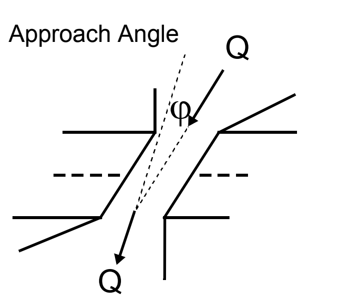
8. LB 0 RB 2 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -:1 US right -:1

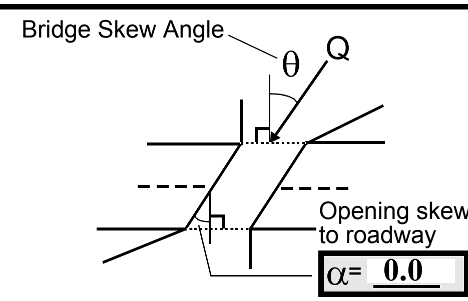
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	0
RBUS	-	1	2	1
RBDS	-	1	2	1
LBDS	-	1	2	1

*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: 10 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 40 feet US *(US, UB, DS)* to 20 feet UB
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 0 feet DS *(US, UB, DS)* to 35 feet DS

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

18. Bridge Type: -

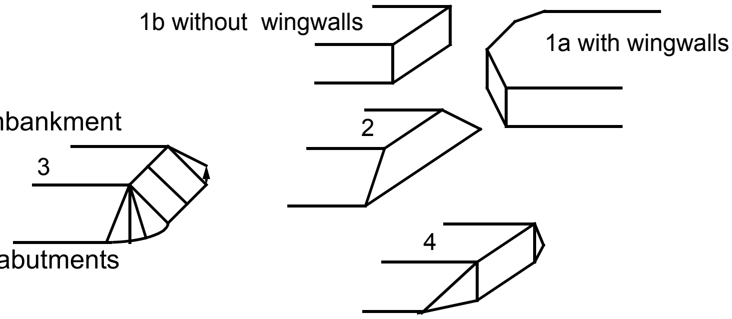
1a- Vertical abutments with wingwalls

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.)

The structure is a pipe arch with footers. Protection is detected under foot at USRB, DSRB and DSLB but is covered with fill and six inch high grass, making it difficult to see and thus class is not given. LBDS coverage is mainly the TH30 roadway with a steep mostly forest hill slope further from channel and a strip of shrub and brush along the bank. The DSRB coverage has a strip of trees along the right bank near the channel before breaking into a grass lawn. The LBUS coverage is mainly fill placed at the time the culvert was built and has grass growing on the slope and a small area of the overbank. TH30 cuts through the left overbank upstream and downstream of the bridge. The current culvert is 19 feet wide at the base, and 62 feet long. The roadway is 38 feet wide.

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
97.1	**5.0**			**5.0**	**1**	**4**	**1**	**1**	**0**	**2**

23. Bank width **30.0**   24. Channel width **45.0**   25. Thalweg depth **32.0**   29. Bed Material **3**

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

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

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

On the right bank, little or no erosion is recognizable until about 35 feet upstream where erosion is moderate in a dense till material. The right bank between the bridge and 35 feet upstream looks recently reconstructed which is likely since bridge is new. The bank material is top soil underlain by a gravel layer underlain by very dense clay till with scattered boulders. Bed material is mostly gravel with boulders and cobbles and some exposures of the dense clay till. The bank protection consists of stone fill which is covered with soil and six inch grass. Class of protection is unknown but it is present under the grass. Bank protection extends about 35 feet upstream on the right bank and 85 feet upstream on the left bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **27** 35. Mid-bar width: **9**

36. Point bar extent: **20** feet **UB** (US, UB) to **45** feet **US** (US, UB, DS) positioned **0** %LB to **50** %RB

37. Material: **3**

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

Material is gravel with some boulders and cobbles. Where the bar extends under the bridge the material becomes a medium gravel predominantly.

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

41. Mid-bank distance: **40** 42. Cut bank extent: **77** feet **US** (US, UB) to **28** feet **US** (US, UB, DS)

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

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

The cut bank has developed in the dense clay till due to a mild impact zone at the downstream half of the cut. The upstream half may be due to some anabranching. The cut bank may have extended further downstream through the entire impact. But between the culvert and the cut the channel bank has been reconstructed, rip-rapped, and seeded.

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) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
9.0		0.5		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.):

3

Bed material is gravel primarily with some boulders and the underlying clay. Along the channel's right side a side bar has developed about five feet wide. It is not clear why the side bar has developed in the channel but it appears too "neatly formed" to be fluvially deposited. The side bar is being impacted and its upstream end is opposite a point bar.

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? **1**___ *(Y or N)* Ice Blockage Potential **N**____ *(**1**- Low; **2**- Moderate; **3**- High)*

70. Debris and Ice Comments:

1

Capture efficiency may be more moderate because the culvert projects upstream from the road embankment under a flow depth of about two feet or more.

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		**-**	**-**	**2**	**2**	**0**	**0.5**	**90.0**
RABUT	**3**	**10**	**-**			**2**	**2**	**-**

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

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

0

0.5

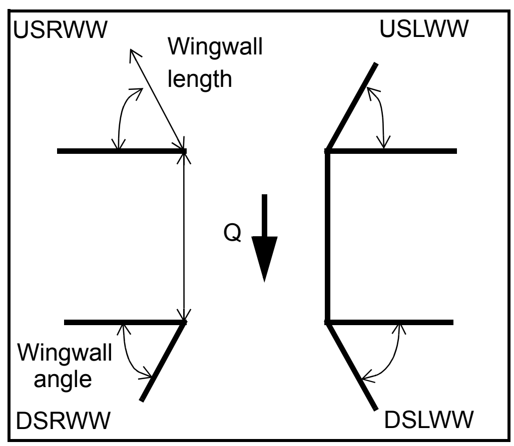
3

The abutment slope angle is not measured here because the structure is a pipe arch. The half pipe arch rests on concrete footings which are exposed. While the scour condition noted indicates the footings are exposed, the exposure seems more likely by design.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**11.0**	
USRWW:	**N**		**-**		**-**	**0.5**	
DSLWW:	**-**				**N**	**62.0**	
DSRWW:	**-**		**-**		**-**	**62.5**	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type		**-**	**N**	**-**	**-**	**-**	**1**	**1**
Condition	**N**	**-**	**-**		**-**	**-**	**4**	**4**
Extent	**-**		**-**	**-**	**-**	**2**	**2**	**-**

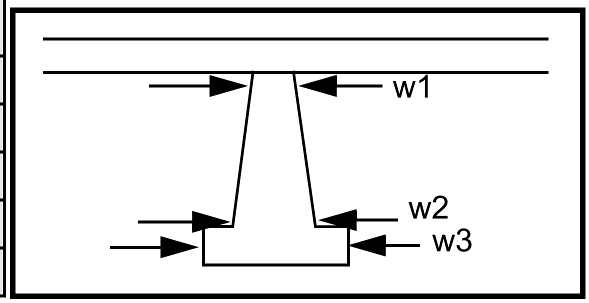
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	0.0	0.0	0.0	0.0	0.0	0.0
Pier 2	0.0	-	-	0.0	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e left	upst	base	this	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	and	ream	with	par-	1- Solid pier, 2- column, 3- bent
88. Material	right	and	no	ticu-	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	abut	dow	pro-	lar	1- Round; 2- Square; 3- Pointed
90. Inclined?	ment	nstre	tec-	case,	Y- yes; N- no
91. Attack ∠ (BF)	pro-	am	tion	the	
92. Pushed	tec-	ends	thro	term	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	tion	of	ugh	abut	
95. Cross-members	exte	the	the	ment	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	nt is	cul-	mid-	refer	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	at	vert	dle.	s to	
98. Exposure depth	the	at its	For	the	

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

left and right sides of the culvert where the culvert steel meet the concrete footing to where the concrete footing intersects the streambed.

N

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

Bank width (BF) - Channel width (Amb) - Thalweg depth (Amb) - Bed Material -

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB -

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

105. Drop structure comments (eg. downstream scour depth):

-
-
-
-
-
-

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

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

Material: -

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

-
-
-
-

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

Cut bank extent: RS feet ____ (US, UB, DS) to _____ feet ____ (US, UB, DS)

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

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

Is channel scour present? _____ (Y or if N type ctrl-n cs) Mid-scour distance: 1

Scour dimensions: Length 1 Width 3 Depth: 3 Positioned 1 %LB to 1 %RB

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

3
3
0
1

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

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

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

Confluence comments (eg. confluence name):

is covered with fill and grass and extends 25 feet downstream from the culvert. Some of the road fill material placed along the left bank from 25 feet to 60 feet downstream appears eroded slightly. The fill appears to have

F. Geomorphic Channel Assessment

107. Stage of reach evolution bee

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 placed recently with no vegetation growth on it and hence some previous erosion may have occurred. The right bank material has the same clay till exposed in some places as found upstream. The downstream channel is incised well and may be constricted by road embankment along the left bank. There is some debris accumulation in the channel downstream. Flow from a storm drainage pipe enters intermittently on the left bank at the downstream end of the culvert.

109. G. Plan View Sketch

N

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR ANALYSIS

Structure Number: BRIDTH00040045b   Town: Bridgewater
Road Number: TH0004   County: Windsor
Stream: Dailey Hollow Branch

Initials SAO   Date: 12/11/95   Checked: EMB

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

Neills Equation
Vc=11.52*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1993, p. 31, eq. 14)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	975	1200	0
Main Channel Area, ft2	212	264	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	26	48	0
Top width main channel, ft	36.6	39.4	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	14.8	17.1	0
D50 of channel, ft	0.154	0.154	0.154
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	5.8	6.7	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	1.8	2.8	ERR
Total conveyance, approach	17931	25241	0
Conveyance, main channel	17315	23721	0
Conveyance, LOB	0	0	0
Conveyance, ROB	616	1520	0
Percent discrepancy, conveyance	0	0	ERR
Qm, discharge, MC, cfs	941.5049	1127.737	ERR
Ql, discharge, LOB, cfs	0	0	ERR
Qr, discharge, ROB, cfs	33.49506	72.26338	ERR
Vm, mean velocity MC, ft/s	4.4	4.3	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	1.3	1.5	ERR
Vc-m, crit. velocity, MC, ft/s	8.3	8.5	N/A
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	N/A

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

```
y2 = (Q2^2/(120*Dm^(2/3)*W2^2))^(3/7)
ys=y2-y_bridge or ys=y2-y1
(Richardson and others, 1993, p. 35, eq. 18, 19)
```

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	212	264	0
Main channel width, ft	36.6	39.4	0
y1, main channel depth, ft	5.79235	6.700508	ERR

Bridge Section	Q100	Q500	Qother
(Q) total discharge, cfs	975	1200	0
(Q) discharge thru bridge, cfs	975	1200	0
Main channel conveyance	--	--	0
Total conveyance	--	--	0
Q2, bridge MC discharge,cfs	975	1200	ERR
Main channel area, ft2	93	102	0
Main channel width (skewed), ft	19.0	19.0	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	19	19	0
y_bridge (avg. depth at br.), ft	4.894737	5.389474	ERR
Dm, median (1.25*D50), ft	0.1925	0.1925	0.1925
y2, depth in contraction,ft	6.015893	7.187773	ERR
ys, scour depth (y2-ybridge), ft	1.12	1.80	N/A
ys, scour depth (y2-y1), ft	0.22	0.49	N/A

ARMORING	Q100	Q500	Qother
D90	0.377	0.377	
D95	0.477	0.477	
Critical grain size,Dc, ft	0.4320	0.5199	ERR
Decimal-percent coarser than Dc	0.061	N/A	
Depth to armoring,ft	19.92	N/A	ERR

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1993, p. 49, eq. 24)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	975	1200	0	975	1200	0
a', abut.length blocking flow, ft	13.8	16.6	0	18.6	20.9	0
Ae, area of blocked flow ft2	49.5	70.3	0	43.8	70.6	0
Qe, discharge blocked abut.,cfs	149.5	208.2	0	89.4	148.4	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	3.020202	2.961593	ERR	2.041096	2.101983	ERR
ya, depth of f/p flow, ft	3.59	4.23	ERR	2.35	3.38	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	0	1	1	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	0	90	90	0
K2	1	1	0	1	1	0
Fr, froude number f/p flow	0.28	0.25	ERR	0.23	0.20	ERR
ys, scour depth, ft	10.29	11.73	N/A	7.72	9.70	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1993, p. 50, eq. 25)

a'(abut length blocked, ft)	13.8	16.6	0	18.6	20.9	0
y1 (depth fp flow, ft)	3.59	4.23	ERR	2.35	3.38	ERR
a'/y1	3.85	3.92	ERR	7.90	6.19	ERR
Froude no. f/p flow	0.28	0.25	N/A	0.23	0.20	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1993, p118-119, eq. 93,94)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.83	0.89		0.83	0.89	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	4.9	5.4		4.9	5.4	
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	0.00	ERR	ERR	0
Fr>0.8 (vertical abut.)	1.94	2.19	ERR	1.94	2.19	ERR