GROVER
ENGINEERING PC

Water and Wastewater – Site Design
Stormwater Management – Environmental Consulting

2044 Main Road Huntington, Vermont 05462
phone: 802-434-2989 dean@groverengineeringpc.com

July 22, 2009; **Revised August 20, 2009**

Ann Smith
Program Director
Friends of the Winooski River
PO Box 777
Montpelier, Vermont 05601

Re: Existing Conditions Analysis and Hydraulics Alternatives Analysis
Holt Road Bridge at Naismith Brook
Marshfield, VT

Dear Ann,

On behalf of your organization, the Friends of the Winooski River, Grover Engineering PC has investigated the existing conditions of the concrete bridge beneath Holt Road on the Naismith Brook in Marshfield to determine existing hydraulic conditions and to explore design alternatives that may permit passage by juvenile and adult brook trout, and other aquatic organisms. A site survey coupled with modeling software and additional calculations were used in this assessment. This letter report summarizes our analytical methodologies, findings, and conclusions & recommendations to date. We consider these results to be a tool for discussions with you, and with local, state and federal representatives toward a final plan of action that will improve aquatic organism passage.

Existing Conditions Survey

A State of Vermont survey crew led by Shayne Jaquith of the Water Quality Division provided us with a total station survey of the site, including the locations and elevations of the bridge geometry, of the brook thalweg, and of existing water depths & edges of water observed during the surveys. The Town of Marshfield's dry hydrant was also surveyed. Initial surveying was performed on June 10, 2009, then following a meeting at the site between Dean Grover, Dori Barton and Shayne Jaquith and his crew member on June 22, 2009, additional details of the bridge and stream below the bridge were collected to complete the existing data set. Grover Engineering then created an AutoCAD drawing from these data to better understand the site, and to simplify and compliment data entry for the FishXing model used to simulate stream conditions and to analyze retrofit alternatives. An assumed datum of 1000.00-feet at the Station 1 hub was used in the survey. A scaled site plan of the Holt Road bridge environs is provided (Appendix 1, page 1), and the stream profile and five channel cross-sections (A-A' through E-E') have been drafted from the survey data (Appendix 1, pages 2 to 3). Annotated photographs collected by the Water Quality Division survey crew are also provided (Appendix 3).

The photos, along with four pebble counts help characterize the Naismith Brook. We consider this to be a stable channel with coarse sediment not likely to aggrade or incise in the anticipated life of this bridge (estimated at roughly 50-years). The pebble count results (summary table, Appendix 1, page 4) indicate that less than 5% of the channel sediment is finer than gravel, 80% is gravel, pebble or cobble, and 15% consists of boulders up to 4-feet in diameter. Some woody debris is present that has a potential to migrate to the bridge and cause blockage, but the relatively high bridge ceiling (about 10-feet) makes complete blockage unlikely in all but the most extreme floods. Floodplains are generally not well expressed beside the Naismith Brook channel near this bridge – lower ground beside the right bank below the bridge and dry hydrant likely floods during exceptionally high flows.

The lowest point of the concrete floor of the bridge at its outlet is at 997.20-feet, while the water surface elevation at this point was 997.45 feet during the survey. The water surface elevation in the plunge pool directly below the bridge outlet was at elevation 995.4-feet, representing an outlet drop of nearly 2-feet. The bridge constriction and outlet drop have created a sizeable plunge pool downstream, with a maximum depth (during the survey) of about six feet. The lowest point at the bridge inlet is 997.95-feet with a water surface elevation of 998.4-feet at the time of the survey. The length of the bridge floor is 24.5 feet and the slope of the smooth, concrete bottom is 3.1%, and is chamfered where the floor meets the vertical walls. The concrete ceiling is the bottom of prestressed concrete slabs that form the bridge deck, and these slabs appear to be a newer addition to the bridge floor and abutments. Concrete wingwalls are provided on the bridge inlet and outlet. A typical cross-section geometry of the bridge is provided (Appendix 1, page 5). As the site plan indicates, the bridge is well-aligned with the stream channel. However, the bankfull channel width varies from about 20 to 25 feet (locally widening to about 40 feet below the plunge pool), and the total width of the bridge is 17.7 feet from abutment wall to abutment wall, and only 11.2 feet from toe to toe of the concrete chamfers. Clearly, the bridge width is undersized relative to the channel width.

Existing Conditions Modeling

High and low fish passage design flows of the brook were calculated from the applicable equations provided in the "Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont" (Final Draft-Feb. 2008) (the "Guidelines"), section 7.3.4. The brook's watershed area of 7.36 square miles, 1.47% of watershed covered by lakes, and mean annual precipitation of 42.5 inches, were found with the USGS web-based "Vermont Streamstats" tool at
http://water.usgs.gov/osw/streamstats/Vermont.html (results, Appendix 1, pages 6 to 7). Minimum and maximum flows were calculated as follows:

Low Fish Passage Design Flow:

7Q2 = 0.139 cfs/ sq. mi.
= 0.139 x 7.36
= **1.02 cfs**

High Fish Passage Design Flow – Fall Spawning:

Nov Q(2-20) = A(Basin) x (-13.709 + 0.4555 x P + 3.0855 x ln (1+A(lakes))
= 7.36 sq. mi. x (-13.709 + 0.4555 x 42.5 in.+ 3.0855 x ln(1+0.0147))
= 7.36 x 5.467
= **41.9 cfs**

Brook trout were originally selected by the Department of Fish and Wildlife as the target species of concern for this retrofit analysis, which was confirmed by a survey completed by Rich Kirn from F&W in July 2009, finding over 150 brook trout, and few additional species in the reach below the bridge. The biological design constraints suggested in the Guidelines for brook trout passage are provided in Tables 7-2, 7-3, and 7-4, and are summarized below:

Brook Trout Biological Design Constraints

	Max. Velocity (feet/second)	Max. Outlet Drop (feet)	Min. Flow Depth (feet)
Juvenile	1.0	0.33	0.18
Adult	2.6	0.67	0.35

These data are entered into all runs of the FishXing model (Version 3.0.14). Bridge geometry measurements are input, and the channel cross-section just below the plunge pool, collected during the total station survey, are input to enable the model to develop a rating curve for calculation of the tailwater into the bridge. Summary results of FishXing existing conditions and of alternatives analyses models are provided for juvenile and adult fish in the Appendix 2. Predicted water depths generated by this existing-conditions model appear to be within a few tenths of a foot of actual measured depths during the survey, when we visually estimate that brook flows were approximately 15 or 20 cfs during the survey. It appears that the model is reasonably well calibrated to existing conditions. If anything, the depths predicted by the model are lower than actual depths by a few tenths of a foot.

As expected, under existing conditions, adult and juvenile brook trout cannot pass up through the culvert. The first obstacle is the large vertical drop (about 2-feet) of the water surface from the bridge outlet to the plunge pool just below the outlet. The second obstacle, if the drop could somehow be remedied, is the 24.5-foot smooth concrete floor of the bridge with a slope of 3.1%. Velocities along this reach, combined with its length affect passage. Shallow depths above the floor during low flows are also a deterrent to passage.

Hydraulics Alternatives Analyses

Following our generation of the existing conditions model, we simulated three alternative conditions of increasing heights of boulder check dams installed just downstream of the plunge pool. In these model runs, the tailwater cross section (ie the geometry of the bottom of the channel that controls the water level just below the plunge pool) was set at 997-feet, 998-feet, and 999-feet. The existing, surveyed cross-section at this location has a channel bottom elevation varying between 994.6 and 995.0, so these increases are substantial.

The model was run under a variety of flow conditions between the low and high design flows of 1.02 cfs and 41.9 cfs. The inlet and outlet elevations of the bridge remained constant for all model runs, since we assume it is not feasible to alter the floor of the bridge. The brook trout biological design constraints were also fixed for all model runs. A summary table of some hydraulics alternatives analysis model runs, and input parameters, generated by Fish Xing, is provided are provided (Appendix 2). A spreadsheet summary table (Appendix 1, page 8) lists the barriers to fish passage predicted by FishXing for all model runs, both for adult and juvenile fish.

At a tailwater bottom elevation of 997-feet the fish could jump the drop, but velocities were too high for the fish to swim up the bridge floor. At 998-feet velocities were still too strong for the juveniles. Adults had the strength to swim against the velocities at lower flows, but depth was limiting for the adults. At 999-feet, nearly complete passage was provided, with the exception that velocity was too high for juveniles at high brook flows. We conclude that the stream bottom needs to be raised about 4 to 4.5 feet to permit passage of adults and juveniles over the range of flows between high and low fish passage discharges.

After finding a tailwater cross-section that makes the culvert crossable to fish, our next design objective is to insure that the new high tailwater cross section is passable. It would be possible to create a second high tailwater, downstream from the first, which would raise the water level to a sufficient height where trout can jump over the first tailwater. This approach would create a series of approximately half-foot high waterfalls down the stream so that a third tailwater barrier would be needed to raise the water in front of the second and so on. We did not evaluate this approach to see how far down stream these barriers would need to be carried, on the conjecture that this stepped approach would require stream alterations that would extend into the existing reach of river with slope instabilities along the left bank. We are concerned that stream alterations here could cause long-term bank erosion problems by undermining the toe of slope.

Rather, it made more intuitive sense to create a chute (Guidelines, Section 9.4) in the brook with cobbles and boulders, mimicking the existing distribution of grain sizes to develop the higher stream channel bottom required for the tailwater effect. In this manner we introduced a simulated chute extending from just below cross-section B-B' to a point about 70-feet downstream, where the chute tapers into the existing streambed (see stream profile, Appendix 1, page 2). The slope of the introduced chute is about 8%.
To estimate depths of flow and mean stream velocities in this chute, we applied the geometry at Section C-C' and used the Manning's equation for open channel flow to iteratively calculate the depth and velocity under flows varying from 1.02 cfs to 41.9 cfs. A flat channel bottom, and planar side slopes matching the existing surveyed channel slopes were used. In one scenario, the width of the stream was kept at the approximate bank full width of 40 feet and in a second scenario the width was reduced to 10 feet to increase channel depth.

Our calculations (summary table, Appendix 1, page 9) indicate that the chute will not in theory be passable by either juvenile or adult brook trout under any flow conditions, but the results were not far in excess of the biological design constraints for depth and velocity. In reality, the simplified Manning's equation does not account for the complicated geometry and flow paths of a boulder-strewn chute. Since the numbers we calculated are close to passable, we predict that a raised streambed of this sort would be passable. It will be important to mimic the surrounding stream's environment by strategically placing boulders throughout the new chute and lining it with similar rocks and pebbles on the bottom. Reducing the width of the streambed appears to increase depth of flows that prove to be a benefit for low flow conditions without too much of a penalty in increased velocities. Although we modeled a new channel width at only 10 feet, we consider this reduction to be excessive, and the likely optimal chute width will be about 25-feet – the bankfull width of most reaches of the brook.

We are concerned that a chute length of 70-feet will be a fish barrier, and consequently recommend installation of a small "resting pool" halfway up this chute to increase the likelihood of successful passage.

Conclusions and Recommendations

Our stream models of existing conditions at the Holt Road bridge on the Naismith River indicate that FishXing provides predicted water elevations that fairly well match observed elevations. Predicted elevations may be somewhat lower than actual elevations, so are likely conservative for the depth-dependant fish passage criteria.

Our hydraulics alternatives analyses focused on installation of a boulder weir of progressively increased height until tailwater effects allowed passage of juveniles and adults up the outlet drop and up the inclined concrete floor of the bridge. We calculated that construction of a boulder weir to an elevation of 999-feet followed by a chute tapering from the high weir to the downstream bed is required for passage of fish at the low and high design flows as well as intervening flows. This represents a build-up of about 4 to 4.5 feet above the existing streambed elevation, so many large boulders will be required to construct this weir and chute, especially in the upper half of the structure. Based on the simple wedge geometry of this structure, a total volume of about 250 cubic yards of materials (about eighteen – 14-yard truckloads) will be required.

To satisfy our concern that the proposed boulder weir would not also be a barrier to aquatic organism passage we have proposed a chute with a total length of about 70-feet and a longitudinal bottom slope of about 8%. It will be important to create significant channel roughness in this chute with boulders and cobbles varying widely in sizes (mimicking existing channel roughness) to provide low-velocity zones and micro-pools.

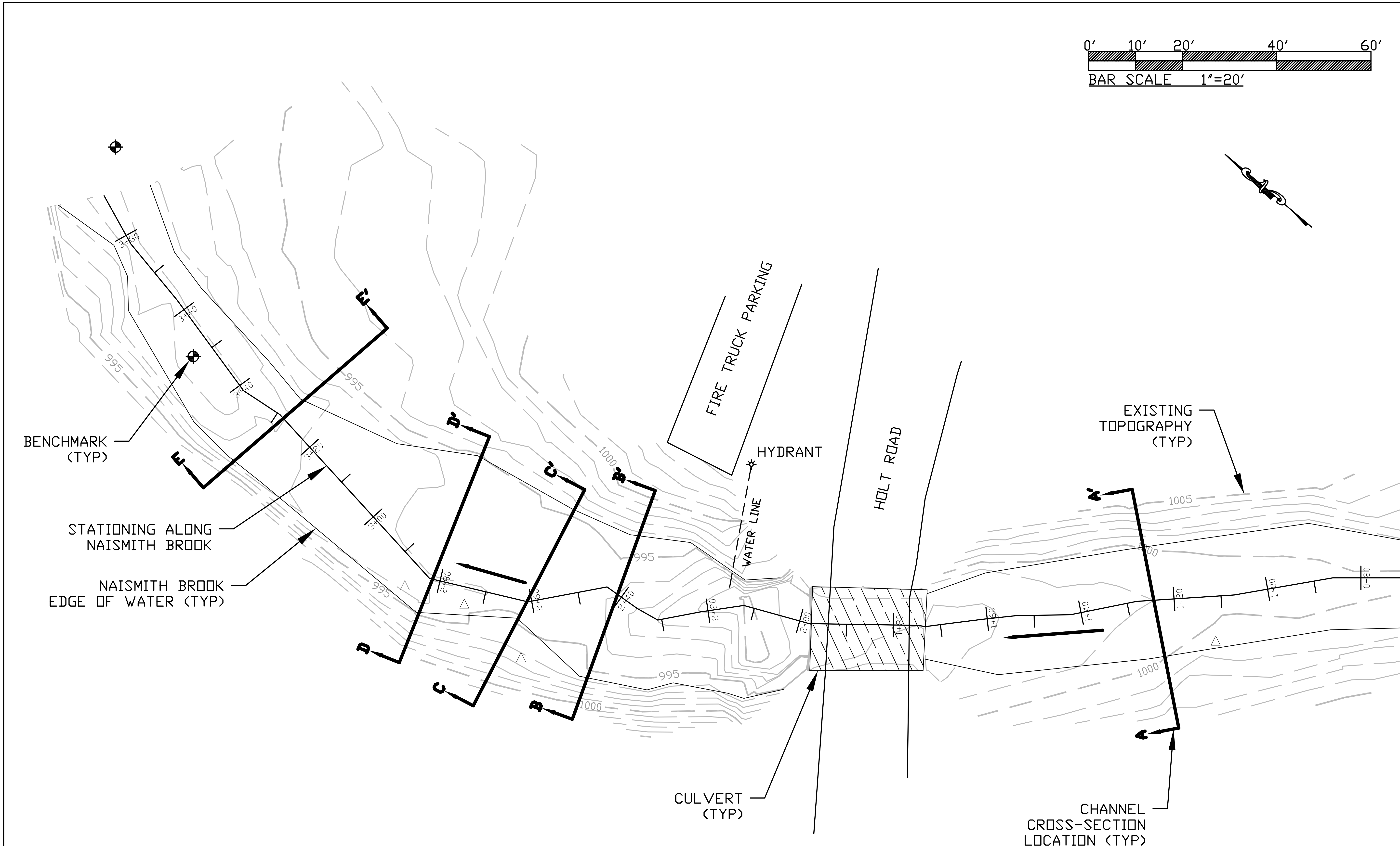
We have not modeled installation of baffling in the floor of the bridge, as we are very concerned that thick ice build-up noted in the bridge floor in January 2009 would likely take out any baffles that are introduced. We did try changing the bridge material in the model from smooth concrete to corrugations 15-inches long and 5.5 inches high. This sensitivity analysis demonstrated that little improvement to juvenile and adult fish passage was achieved – raising the tailwater as described above was still required to eliminate the drop, velocity and depth barriers.

We look forward to discussing these results and conclusions with you, with the other fish passage design members of the team, and with the Town of Marshfield representatives, to advance this project to the construction stage.

Sincerely

Dean A. Grover

Dean A. Grover, P.E.
Grover Engineering PC



FWR: NAISMITH BROOK

MARSHFIELD VERMONT

SITE MAP

GROVER ENGINEERING PC
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DATE JULY 21, 2009

DWG NO * of *

PROJ 07015

SCALE 1"=20'

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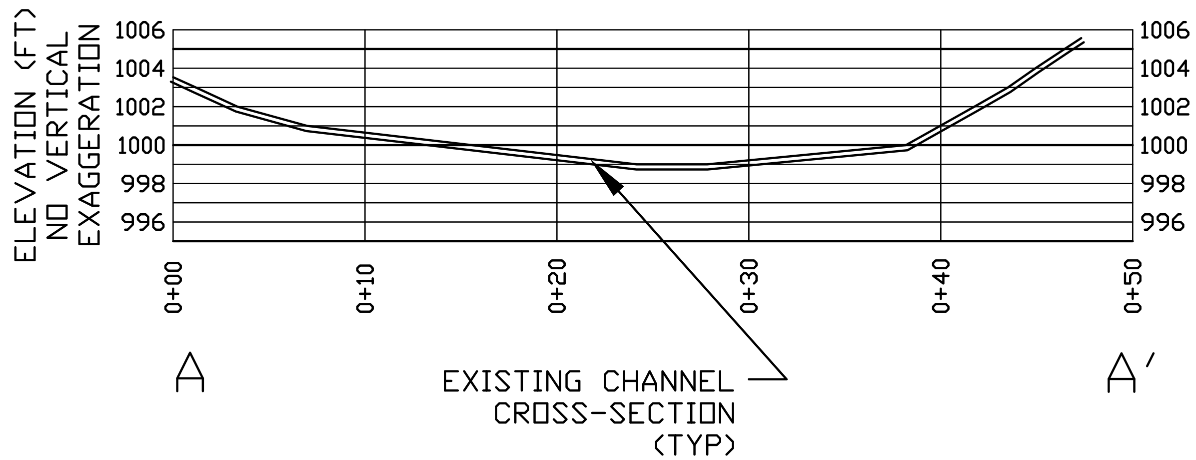
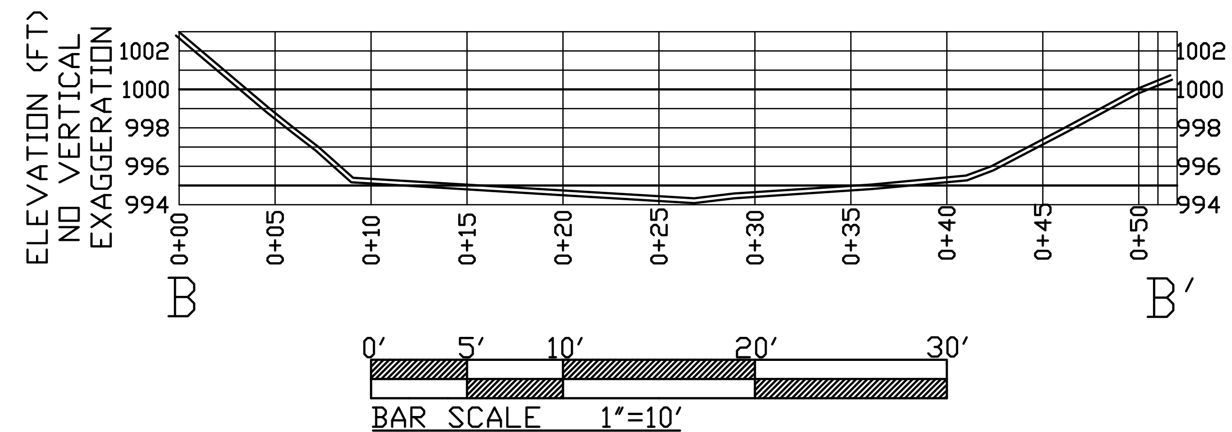
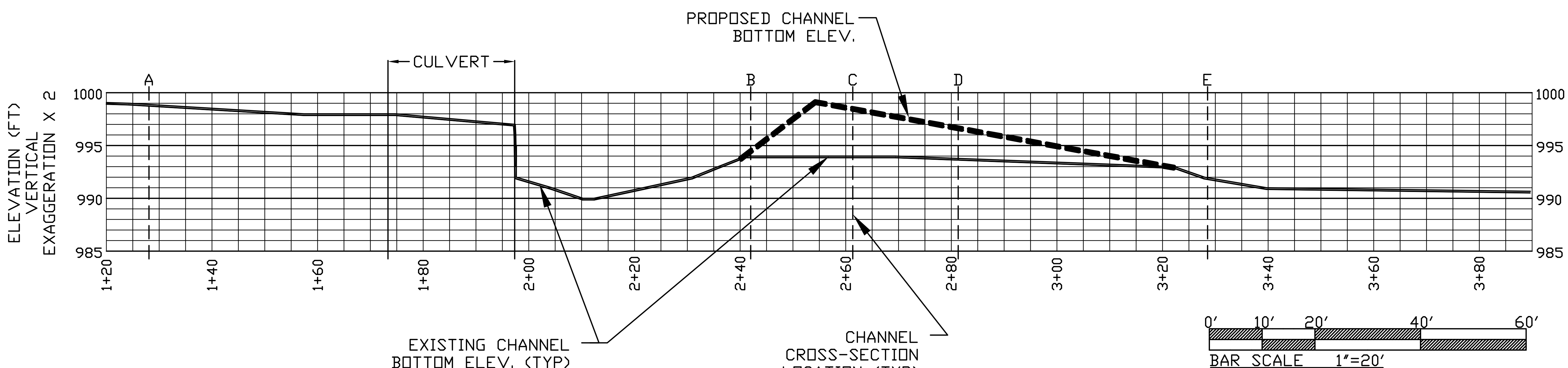
CHANNEL CROSS-SECTIONS







PROFILE OF STREAM CHANNEL BOTTOM

FWR: NAISMITH BROOK

MARSHFIELD VERMONT

PROFILES

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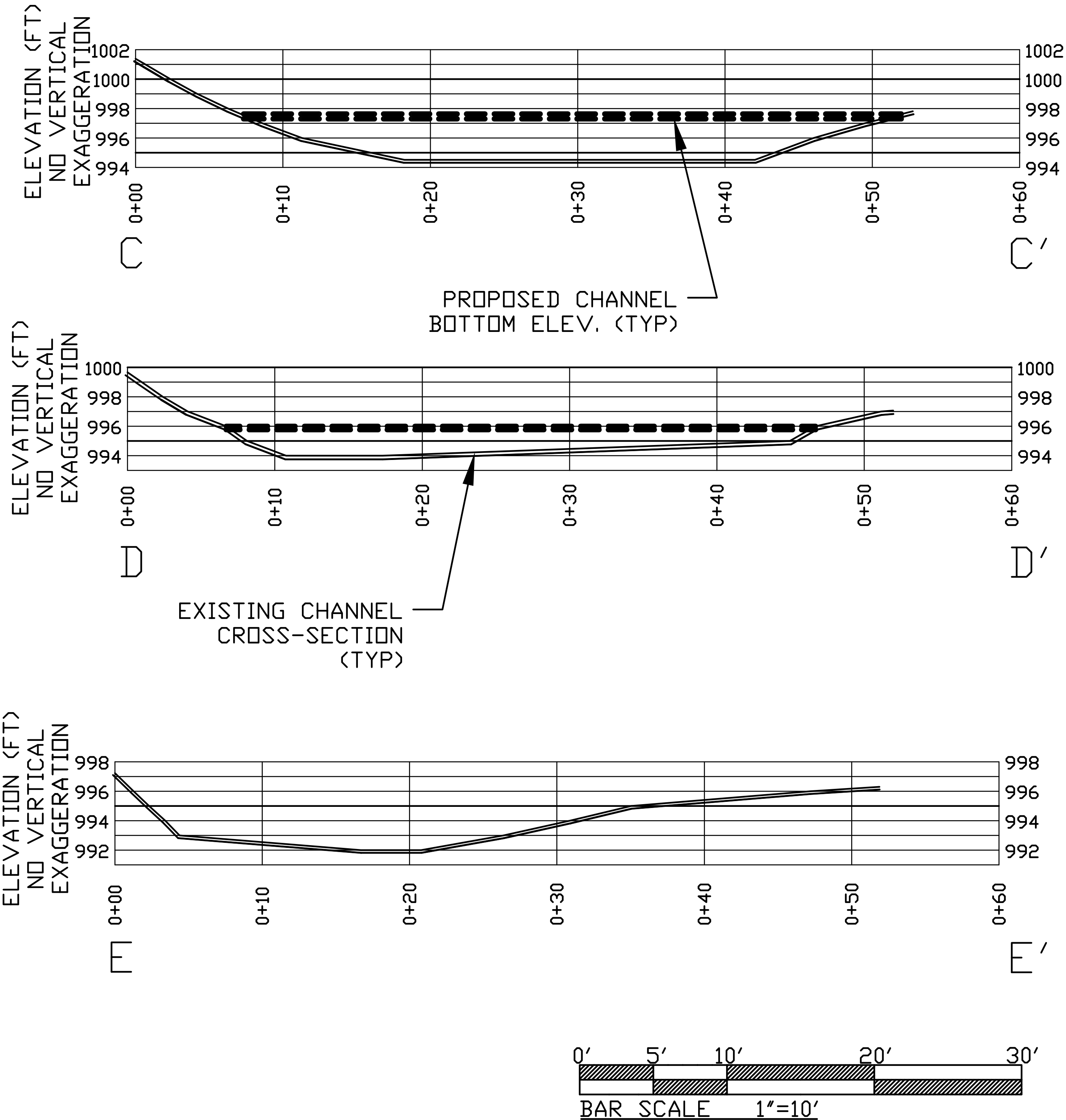
DWG NO 2 of 4

PROJ 07015

DATE AUGUST 18, 2009

SCALE VARIES

FILE 09003\design\sitePlan_2009-07-21



CHANNEL CROSS-SECTIONS

GROVER ENGINEERING PC

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FWR: NAISMITH BROOK

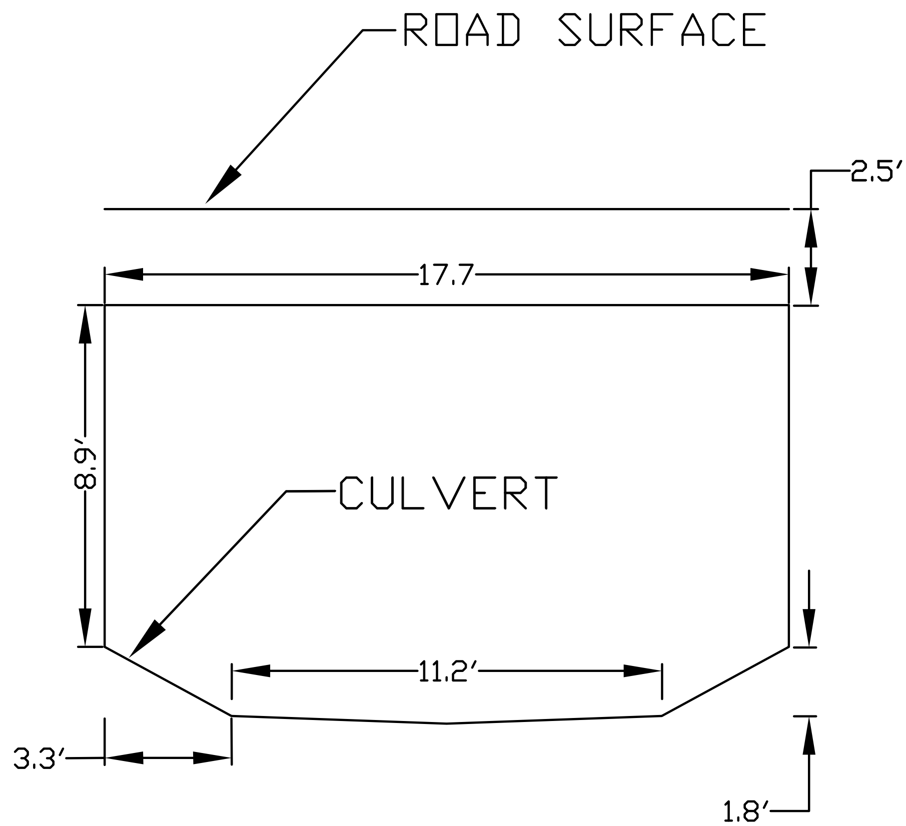
MARSHFIELD VERMONT

PROFILES 2

DATE: 07/21/09	DWG.#: 3	SCALE: 1"=10'	DRN.:DKG

Inches	Particle		Upstream Of culvert	Upstream x sec on right bank	Upstream x sec left bank	Below culvert	Tot#	Item %	%Cum
	Silt/clay								
	Very fine		1				1	.005	0.005
	Fine								
	Medium								
	Coarse		3				3	.015	0.02
.04-.08	Very Course					2	2	.01	0.03
.08-.16	Very Fine								
.16-.22	Fine		3				3	.015	0.045
.22-.31	Fine		1			5	6	.03	0.075
.31-.44	Medium		3				3	.015	0.09
.44-.63	Medium		2			5	7	.03	0.12
.63-.89	Coarse		2			1	3	.015	0.135
.89-1.26	Coarse		4	1		7	12	.06	0.195
1.26-1.77	Very Coarse		2	4		13	19	.09	0.285
1.77-2.5	Very Coarse		7		1	11	19	.09	0.375
2.5-3.4	Small		4	2		4	10	.05	0.425
3.5-5.0	Small		7	1	6	14	28	.14	0.565
5.0-7.1	Large		7		1	8	16	.08	0.645
7.1-10.1	Large		6	1	3	12	22	.11	0.755
10.1-14.3	Small		6	3		11	20	.09	0.845
14.3-20	Small		8		1	5	14	.07	0.915
20-40	Meduim		7			2	9	.04	0.955
40-80	Lg-Very Lg		6		2		8	.04	0.995
	Bedrock								
Totals			79	12	14	100	205		

Nasmith Brook Pebble Count June 10, 2009 data taken Above and Below Holt Rd Culvert



TYPICAL BRIDGE CROSS-SECTION

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FWR: NAISMITH BROOK

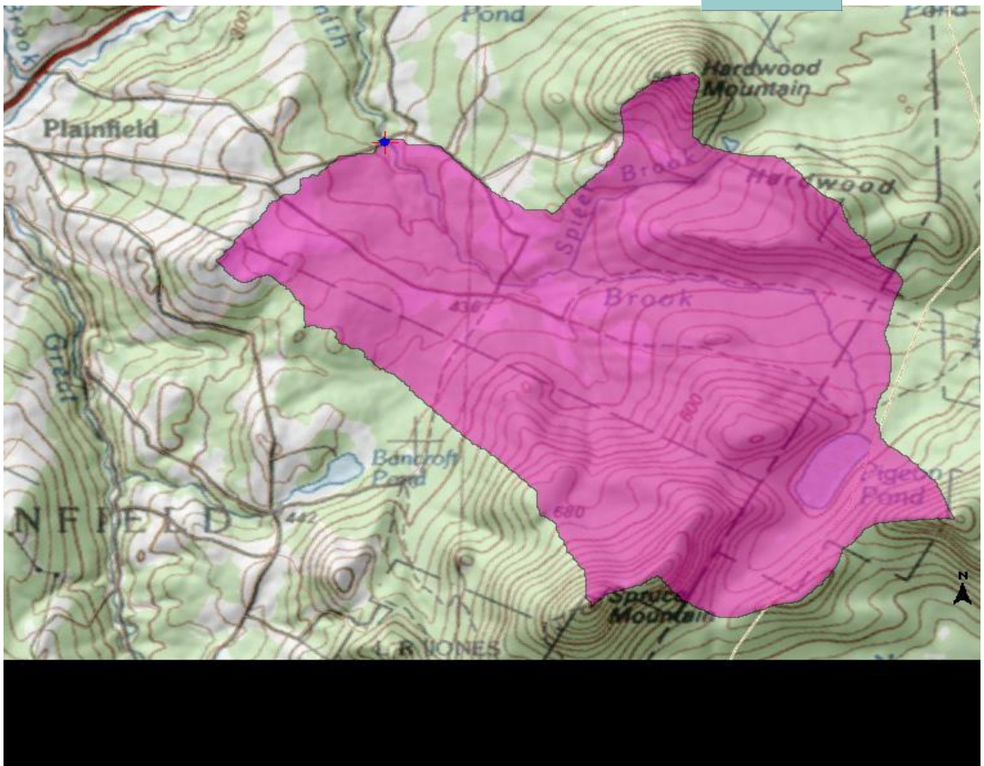
MARSHFIELD VERMONT

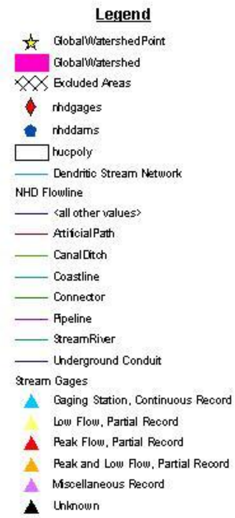
BRIDGE CROSS-SECTION

DATE: 07/21/09	DWG.#: 4	SCALE: 1"=5'	DRN.:RMC

Naismith Brook Watershed

Print





6/12/2009 2:01:28 PM

USGS Vermont Streamstats

Basin Characteristics Report

Date: Tue Jul 21 2009 09:05:56
NAD83 Latitude: 44.2777 (44 16 39)
NAD83 Longitude: -72.3775 (-72 22 39)
NAD27 Latitude: 44.2777 (44 16 39)
NAD27 Longitude: -72.3780 (-72 22 40)

Parameter	Value
Area in square miles	7.36
Percent of area covered by lakes and ponds	1.47
Y coordinate of the centroid in map coordinates	195389.8
Mean annual precipitation, in inches	42.5
High Elevation Index - Percent of area with elevation > 1200 ft	100

Naismith Brook Bridge at Holt Road, Marshfield Vermont
Barriers to Brook Trout Passage vs. Elevation of Channel Bottom at Tailwater Control Cross-Section
July 22, 2009

FishXing Hydraulics Alternatives Analysis - Raising the channel bottom elevation below the plunge pool

	Age of Fish	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult
	Bot. Elev. - feet	Ex. 994	Ex. 994	997	997	998	998	998.2	998.2	998.4	998.4	999	999
Flow - cfs	1.02	drop	drop	dep/vel	depth	depth @ 3	Depth @ 8	None	Depth @ 3	None	None	None	None
	2.00	drop	drop	dep/vel	depth	vel @ 3	Depth @ 7	None	Depth @ 3	None	None	None	None
	5.00	drop	drop	dep/vel	dep/vel	vel @ 3	Depth @ 5	None	None	None	None	None	None
	10.00	drop	drop	dep/vel	dep/vel	vel @ 10	Depth @ 4	vel @ 4	None	vel @ 4	None	None	None
	15.00	drop	drop	dep/vel	dep/vel	vel @ 17	Depth @ 5	vel @ 11	None	vel @ 12	None	None	None
	20.00	drop	drop	Vel @ 24	dep/vel	vel@ 24	vel @ 7	vel @ 18	vel @ 3	vel @ 19	None	None	None
	30.00	drop	drop	Vel @ 24	dep/vel	vel@ 24	vel @ 10	vel @ 24	d/v @ 3	vel @ 24	None	vel @ 7	None
	41.90	drop	drop	Vel @ 24	dep/vel	vel@ 24	vel @ 14	vel @ 24	vel @ 8	vel @ 24	vel @ 3	vel @ 24	None

Key to Fish B=Passage Barriers:

drop = The drop, or distnce from the outlet of the culvert to the water surface, is to too large for the fish to jump.
depth @ 3 = The depth of the water at 3 feet from the inlet is too shallow for fish to swim in.
vel @ 10 = The velocity at 10 feet from the inlet is too strong for the fish to swim against.
dep/vel = Both the depth and the velocity are barriers.
None = No barriers exist in this secnario, and fish are able to cross the culvert.

Naismith Brook Bridge at Holt Road, Marshfield Vermont
Manning's Open Channel Flow Estimates of Depth and Velocity for a Proposed Chute
July 22, 2009

Base width (ft)	Channel Side Slope 1	Channel Side Slope 2	**Depth (ft)**	X-sect Area	Wet Perim	Manning's n	Hydraulic Radius	Longitudinal Slope(ft/ft)	**Velocity (ft/s)**	Calculated Q (cfs)	Actual Q	**Error***
40	0.465	0.227	**0.032**	1.3	40.22	0.050	0.03	0.073	**0.81**	1.04	1.02	-1.91%
40	0.465	0.227	**0.047**	1.9	40.32	0.050	0.05	0.073	**1.05**	1.97	2	1.33%
40	0.465	0.227	**0.083**	3.3	40.57	0.050	0.08	0.073	**1.52**	5.10	5	-1.91%
40	0.465	0.227	**0.125**	5.1	40.86	0.050	0.12	0.073	**2.00**	10.09	10	-0.92%
40	0.465	0.227	**0.159**	6.4	41.09	0.050	0.16	0.073	**2.34**	15.08	15	-0.55%
40	0.465	0.227	**0.190**	7.7	41.31	0.050	0.19	0.073	**2.63**	20.31	20	-1.55%
40	0.465	0.227	**0.240**	9.8	41.65	0.050	0.24	0.073	**3.07**	30.01	30	-0.05%
40	0.465	0.227	**0.290**	11.9	42.00	0.050	0.28	0.073	**3.47**	41.19	41.9	1.69%

Base width (ft)	Channel Side Slope 1	Channel Side Slope 2	**Depth (ft)**	X-sect Area	Wet Perim	Manning's n	Hydraulic Radius	Longitudinal Slope(ft/ft)	**Velocity (ft/s)**	Calculated Q (cfs)	Actual Q	**Error**
10	0.465	0.227	**0.072**	0.7	10.50	0.050	0.07	0.073	**1.37**	1.01	1.02	0.99%
10	0.465	0.227	**0.108**	1.1	10.74	0.050	0.10	0.073	**1.78**	1.99	2	0.39%
10	0.465	0.227	**0.189**	2.0	11.30	0.050	0.18	0.073	**2.54**	5.11	5	-2.11%
10	0.465	0.227	**0.280**	3.1	11.93	0.050	0.26	0.073	**3.25**	9.93	10	0.70%
10	0.465	0.227	**0.355**	4.0	12.44	0.050	0.32	0.073	**3.75**	14.88	15	0.81%
10	0.465	0.227	**0.420**	4.8	12.89	0.050	0.37	0.073	**4.15**	19.85	20	0.76%
10	0.465	0.227	**0.535**	6.3	13.68	0.050	0.46	0.073	**4.79**	30.15	30	-0.48%
10	0.465	0.227	**0.645**	7.8	14.44	0.050	0.54	0.073	**5.35**	41.77	41.9	0.32%

* Final error following trial of a channel depth to derive a calculated flow, then revise the depth for the next trial, repeated until the error was less than 2%

Crossing Report for Ex Cond - Adult

Project: fishXing

Hydraulic Evaluation Criteria

Maximum Allowed Water Velocity = 2.6 ft/s
Minimum Required Depth = 0.35 ft
Maximum Allowed Outlet Drop = 0.67 ft
Notes: data from VT Guidelines
Tables 7-2, 7-3, 7-4

Crossing Installation Data

Culvert Type: 17.7 X 10 ft Box
Material: Concrete
Installation: Not Embedded
Culvert Length: 24.5 ft
Culvert Slope: 3.06%
Culvert Roughness Coefficient: 0.013
Inlet Invert Elevation: 997.95 ft
Outlet Invert Elevation: 997.2 ft
Inlet Headloss Coefficient (Ke): 0.5

Design Flows

Low Passage Flow: 1.02 cfs
High Passage Flow: 41.9 cfs

Tailwater Information
Tailwater Option: Tailwater Channel Cross-Section
Channel Bottom Slope: 2%
Outlet-Pool Bottom Elevation: 991.97 ft

Crossing Report for Ex Cond - Adult

Table 1. Tailwater Cross Section Data.

Station (ft)	Elevation (ft)	Roughness Coefficient
0.00	1002.98	0.045
3.53	1000.00	
4.72	999.00	
5.97	998.00	
7.28	997.00	
9.08	995.40	
21.54	994.65	
26.83	994.33	
28.90	994.57	
36.09	995.05	
41.00	995.51	
42.31	996.00	
44.23	997.00	
46.13	998.00	
48.01	999.00	
49.86	1000.00	
51.65	1000.72	

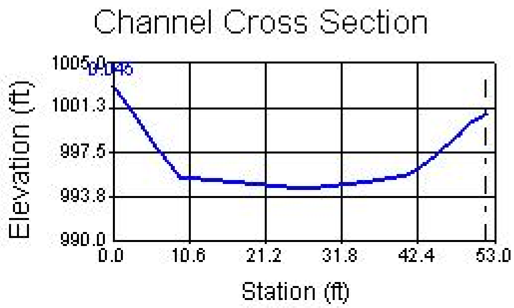


Figure 1. Channel Cross Section at Tailwater Crest.

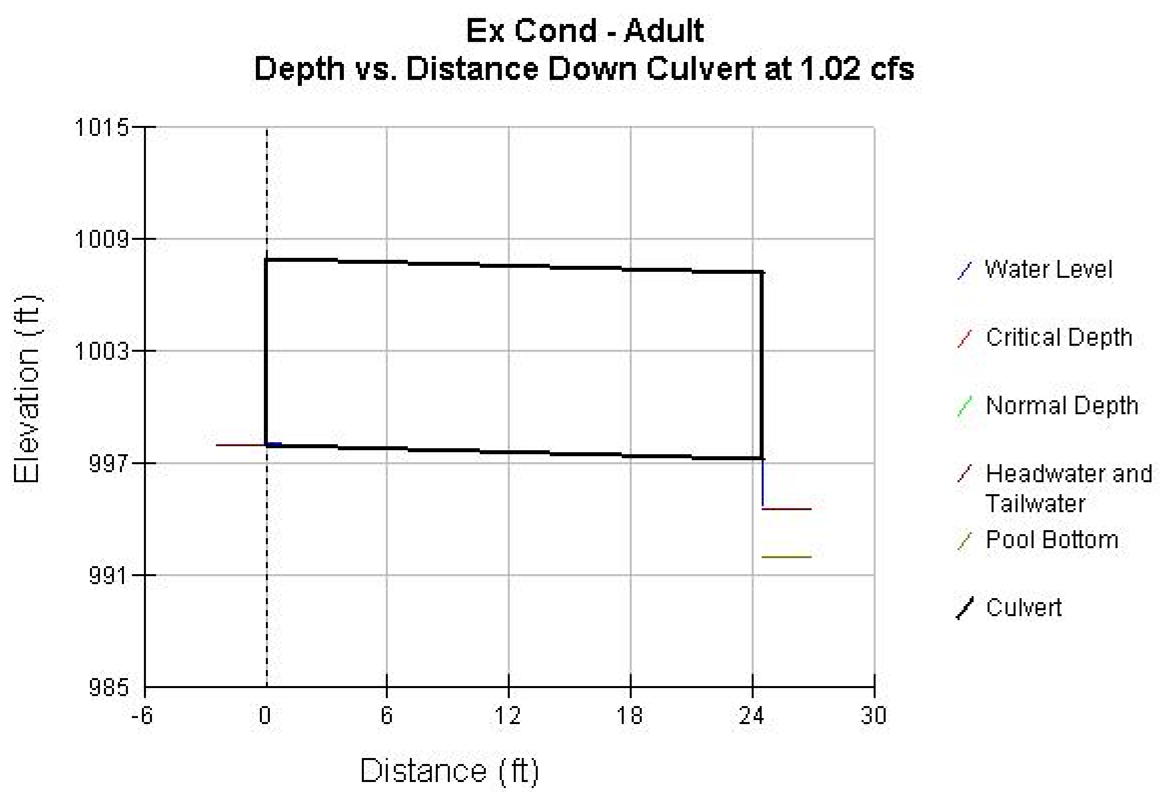


Figure 1. Water Surface Profile at 1.02 cfs

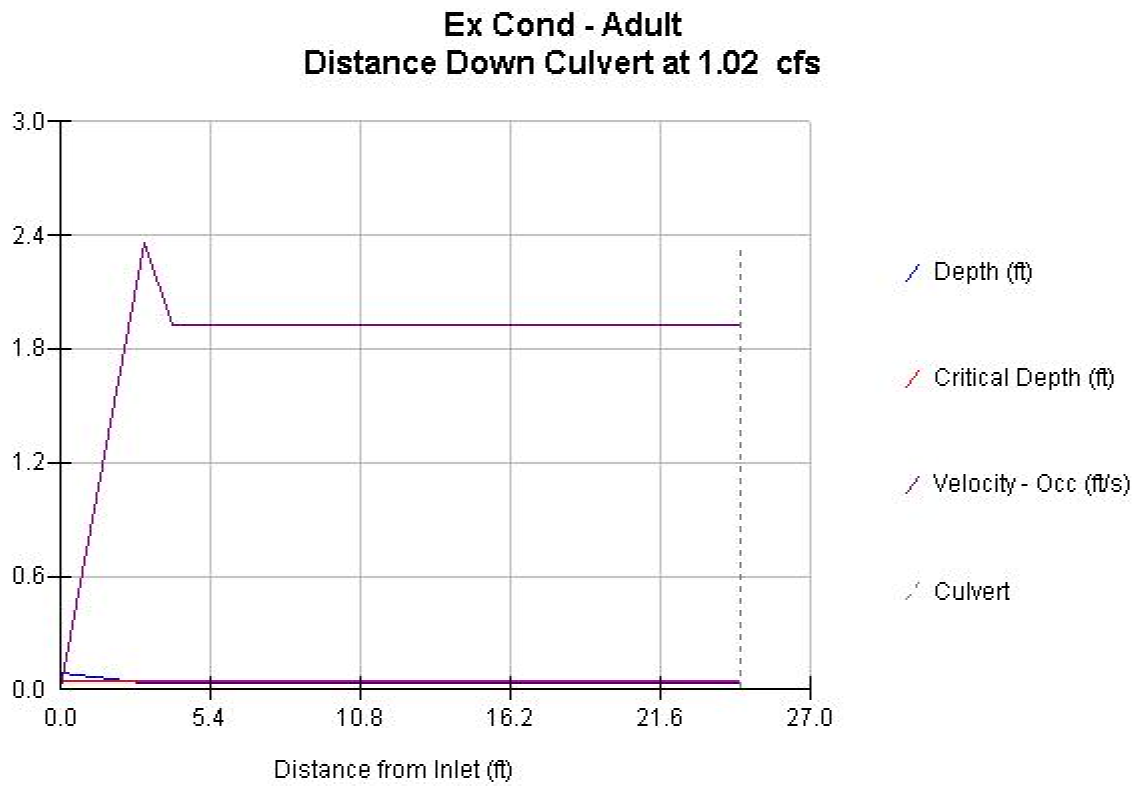


Figure 2. Culvert Profiles at 1.02 cfs

Table 4. Culvert Profiles for 41.9 cfs.

Profiles for Q = 41.90 cfs			
Dist Down (ft)	**Depth (ft)**	**Velocity Average (ft/s)**	**Barrier Type**
0	0.98	0.00	
3	0.42	6.92	
4	0.40	5.85	
5	0.39	6.03	
6	0.38	6.19	
7	0.37	6.33	
8	0.37	6.46	
9	0.36	6.58	
10	0.35	6.69	
11	0.35	6.79	Depth
12	0.34	6.88	Depth
13	0.34	6.97	Depth
14	0.34	7.05	Depth
15	0.33	7.13	Depth
16	0.33	7.20	Depth
17	0.33	7.27	Depth
18	0.32	7.33	Depth
19	0.32	7.39	Depth
20	0.32	7.45	Depth
21	0.32	7.50	Depth
22	0.31	7.55	Depth
23	0.31	7.60	Depth
24	0.31	7.64	Depth
25	0.31	7.66	Drop, Depth, Velocity

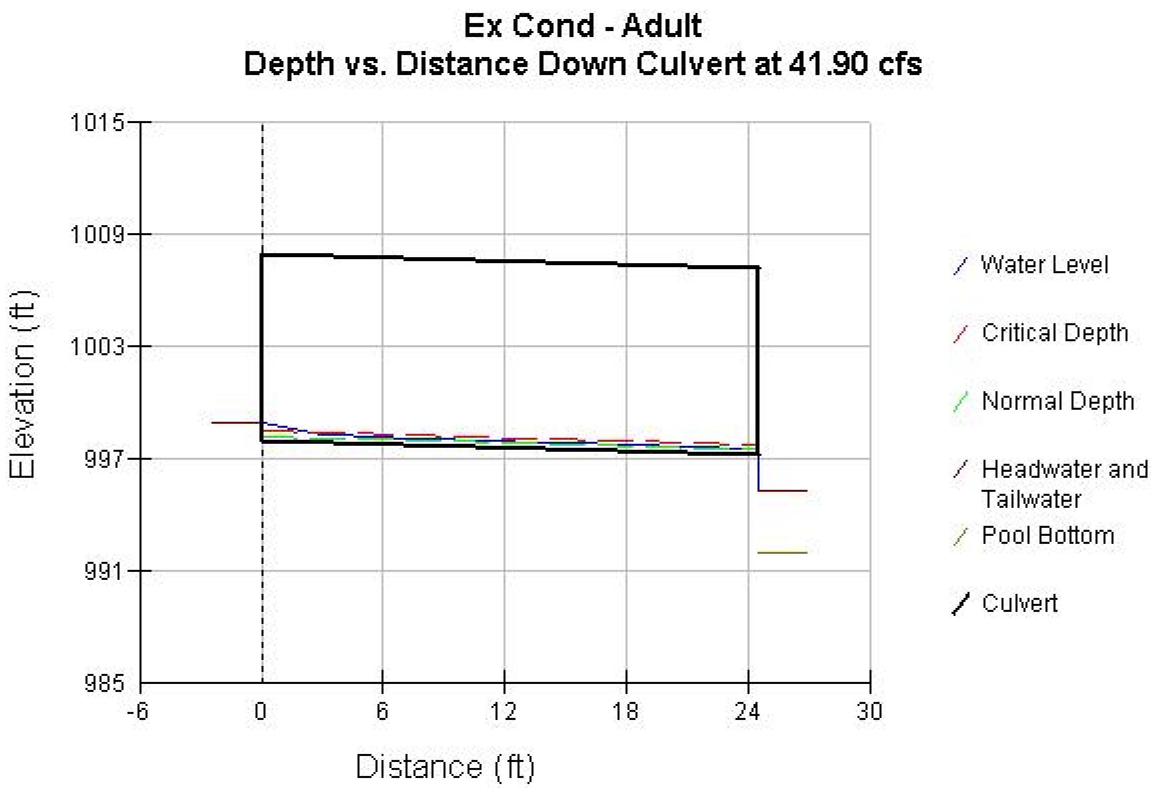


Figure 3. Water Surface Profile at 41.9 cfs

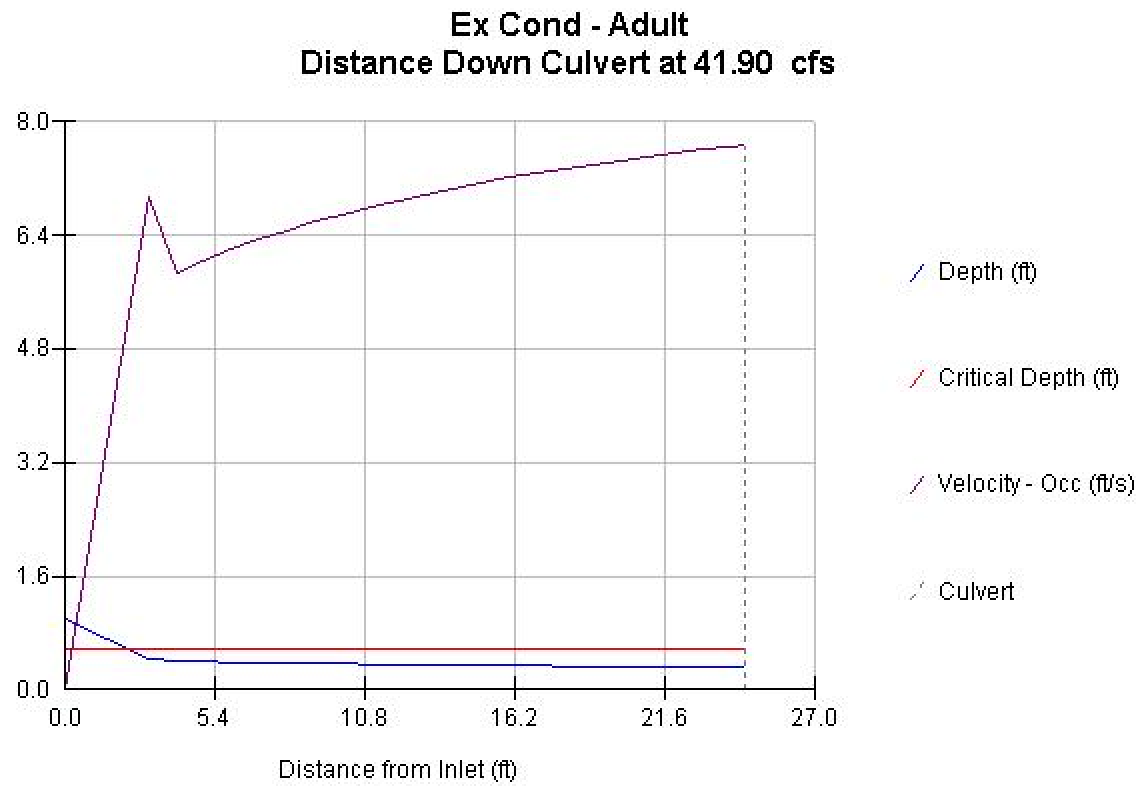


Figure 4. Culvert Profiles at 41.9 cfs

Table 2. Culvert Profiles for 1.02 cfs.

Profiles for Q = 1.02 cfs			
Dist Down (ft)	**Depth (ft)**	**Velocity Average (ft/s)**	**Barrier Type**
0	0.08	0.00	Depth
3	0.03	2.36	Depth
4	0.03	1.93	Depth
5	0.03	1.93	Depth
6	0.03	1.93	Depth
7	0.03	1.93	Depth
8	0.03	1.93	Depth
9	0.03	1.93	Depth
10	0.03	1.93	Depth
11	0.03	1.93	Depth
12	0.03	1.93	Depth
13	0.03	1.93	Depth
14	0.03	1.93	Depth
15	0.03	1.93	Depth
16	0.03	1.93	Depth
17	0.03	1.93	Depth
18	0.03	1.93	Depth
19	0.03	1.93	Depth
20	0.03	1.93	Depth
21	0.03	1.93	Depth
22	0.03	1.93	Depth
23	0.03	1.93	Depth
24	0.03	1.93	Depth
25	0.03	1.93	Drop, Pool, Depth

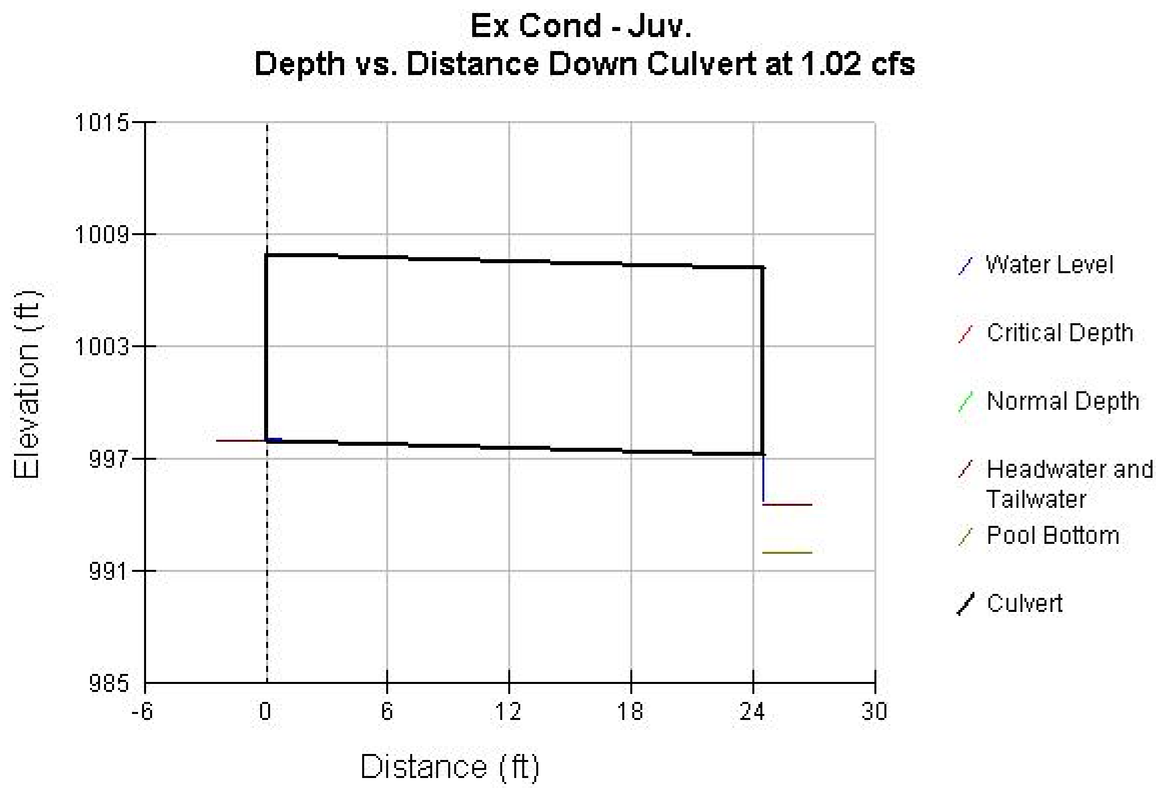


Figure 1. Water Surface Profile at 1.02 cfs

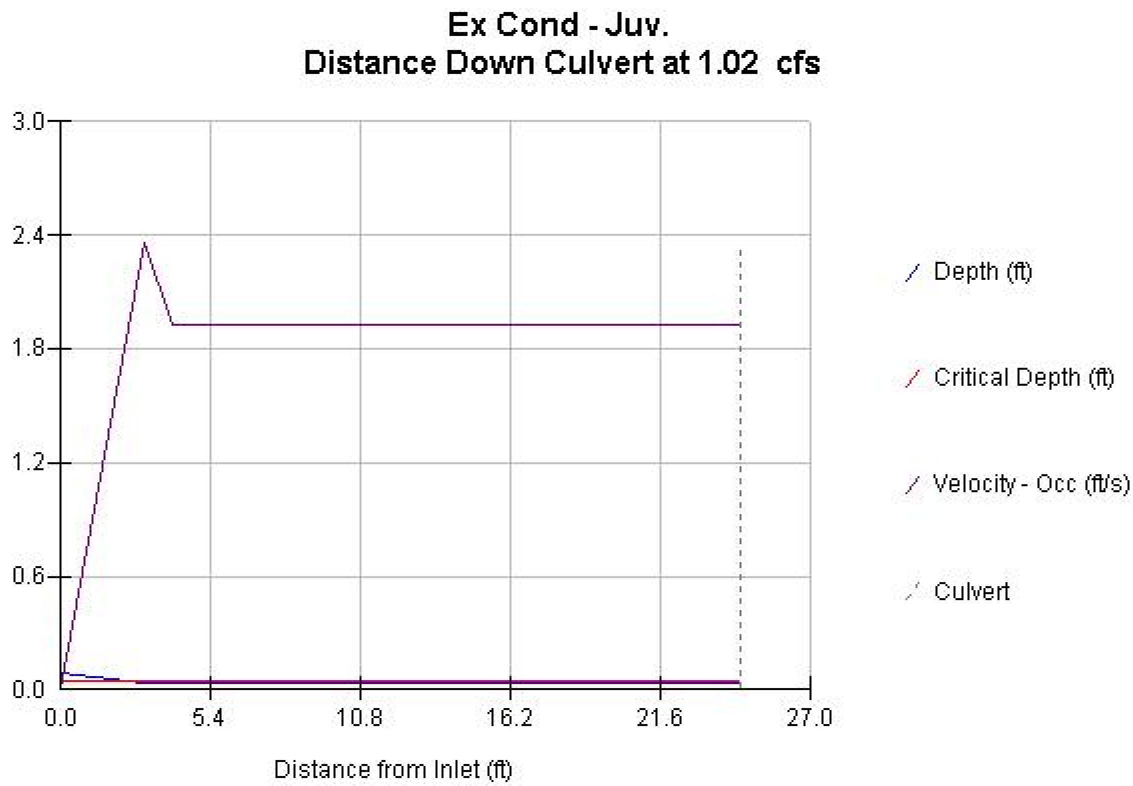


Figure 2. Culvert Profiles at 1.02 cfs

Table 2. Culvert Profiles for 1.02 cfs.

Profiles for Q = 1.02 cfs			
Dist Down Culvert (ft)	**Depth (ft)**	**Velocity Average (ft/s)**	**Barrier Type**
0	0.08	0.00	Depth
3	0.03	2.36	Depth
4	0.03	1.93	Depth
5	0.03	1.93	Depth
6	0.03	1.93	Depth
7	0.03	1.93	Depth
8	0.03	1.93	Depth
9	0.03	1.93	Depth
10	0.03	1.93	Depth
11	0.03	1.93	Depth
12	0.03	1.93	Depth
13	0.03	1.93	Depth
14	0.03	1.93	Depth
15	0.03	1.93	Depth
16	0.03	1.93	Depth
17	0.03	1.93	Depth
18	0.03	1.93	Depth
19	0.03	1.93	Depth
20	0.03	1.93	Depth
21	0.03	1.93	Depth
22	0.03	1.93	Depth
23	0.03	1.93	Depth
24	0.03	1.93	Depth
25	0.03	1.93	Drop, Pool, Depth, Velocity

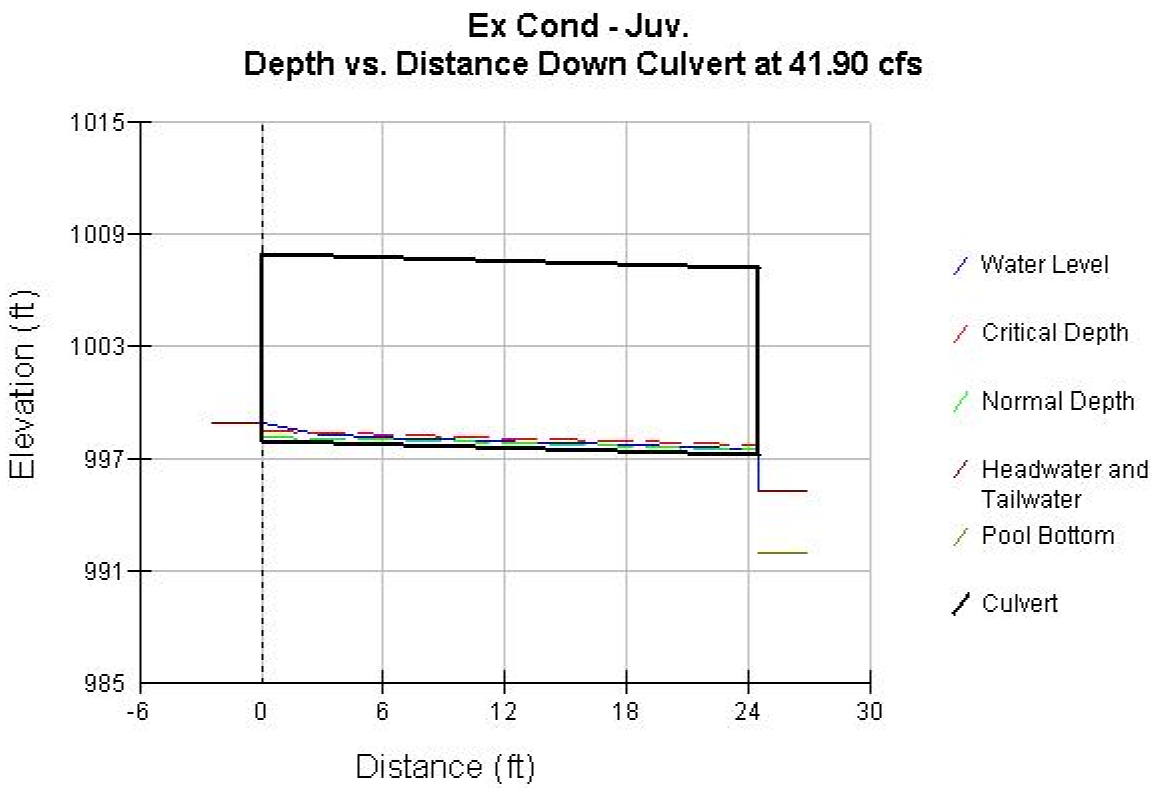


Figure 3. Water Surface Profile at 41.9 cfs

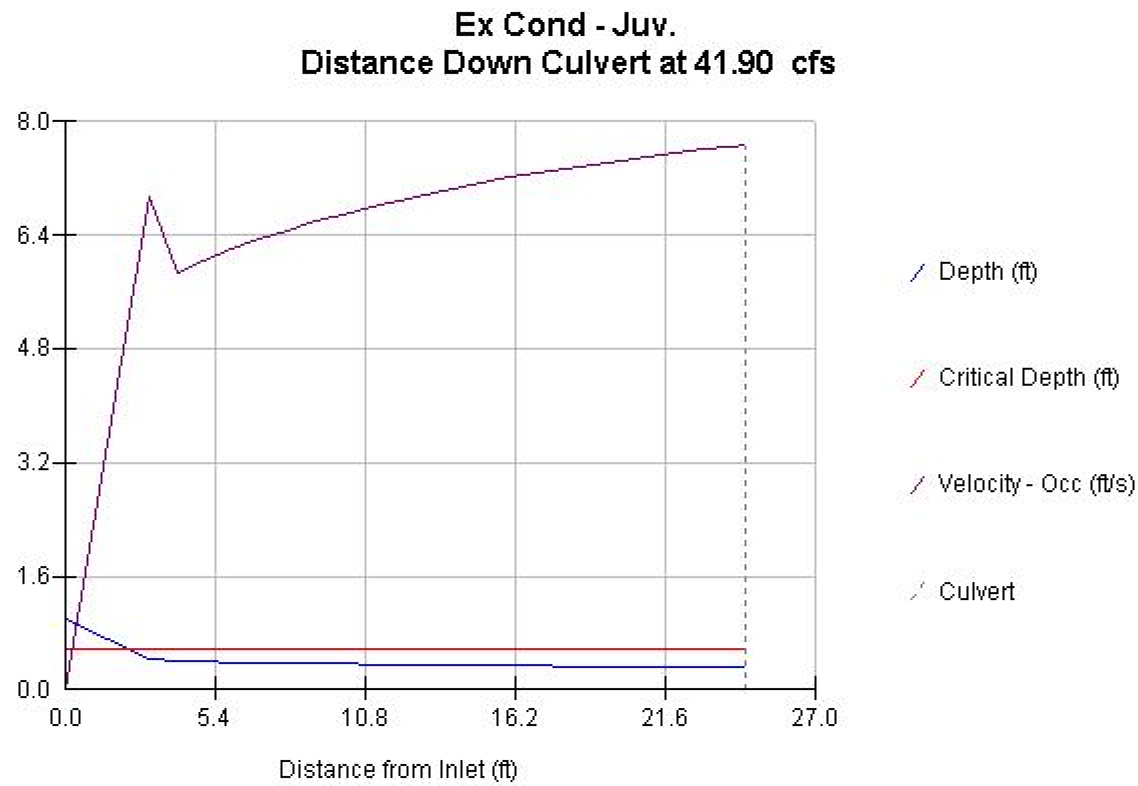


Figure 4. Culvert Profiles at 41.9 cfs

Table 4. Culvert Profiles for 41.9 cfs.

Profiles for Q = 41.90 cfs			
Dist Down Culvert (ft)	**Depth (ft)**	**Velocity Average (ft/s)**	**Barrier Type**
0	0.98	0.00	
3	0.42	6.92	
4	0.40	5.85	
5	0.39	6.03	
6	0.38	6.19	
7	0.37	6.33	
8	0.37	6.46	
9	0.36	6.58	
10	0.35	6.69	
11	0.35	6.79	Depth
12	0.34	6.88	Depth
13	0.34	6.97	Depth
14	0.34	7.05	Depth
15	0.33	7.13	Depth
16	0.33	7.20	Depth
17	0.33	7.27	Depth
18	0.32	7.33	Depth
19	0.32	7.39	Depth
20	0.32	7.45	Depth
21	0.32	7.50	Depth
22	0.31	7.55	Depth
23	0.31	7.60	Depth
24	0.31	7.64	Depth
25	0.31	7.66	Drop, Depth, Velocity

Crossing Report for 999 - Adult

Table 1. Fish Passage Summary.

Fish Passage Summary	
Low Passage Design Flow	1.02 cfs
High Passage Design Flow	41.90 cfs
Percent of Flows Passable	10000.0 %
Passable Flow Range	1.02 to 41.90 cfs
Depth Barrier	None
Outlet Drop Barriers	None
Velocity Barrier	None
Pool Depth Barrier	None

Table 2. Tailwater Cross Section Data.

Station (ft)	Elevation (ft)	Roughness Coefficient
0.00	1002.98	0.045
8.00	999.00	
42.00	999.00	
51.65	1000.72	

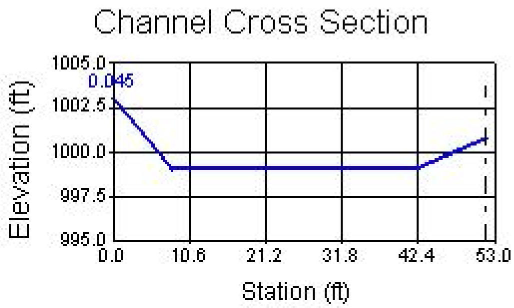


Figure 1. Channel Cross Section at Tailwater Crest.

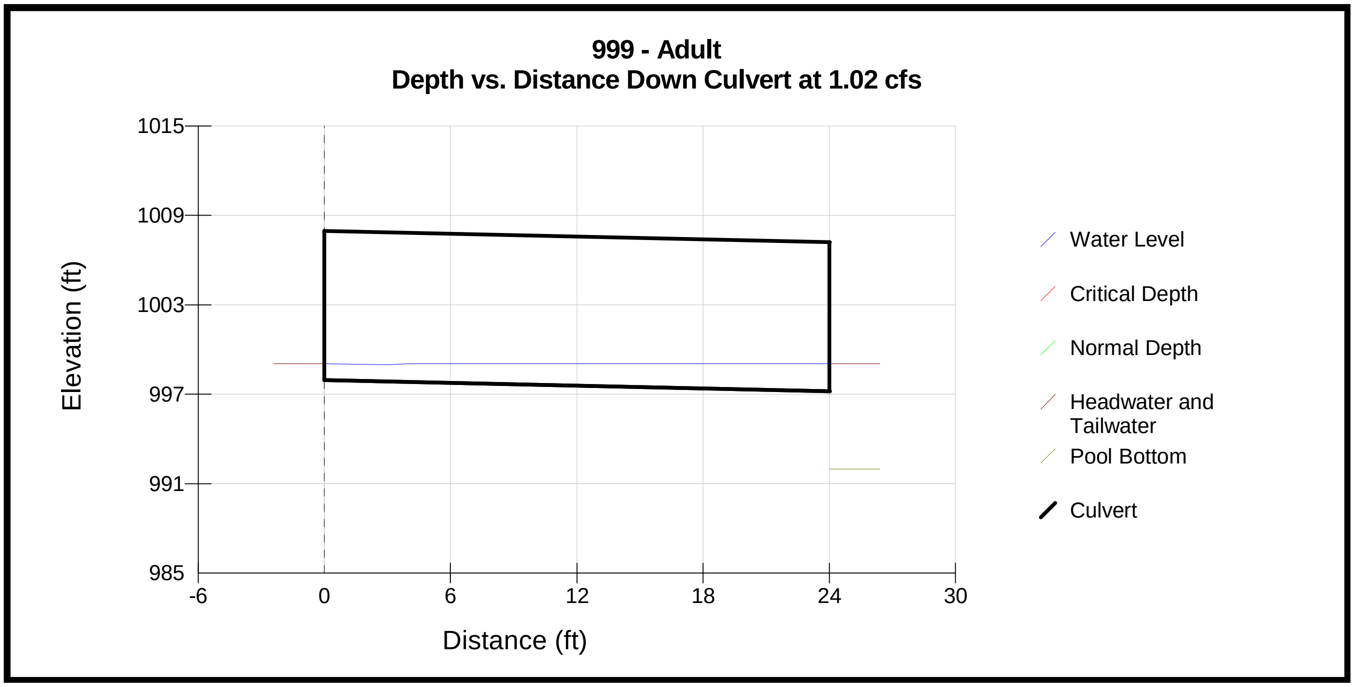


Figure 1. Water Surface Profile at 1.02 cfs

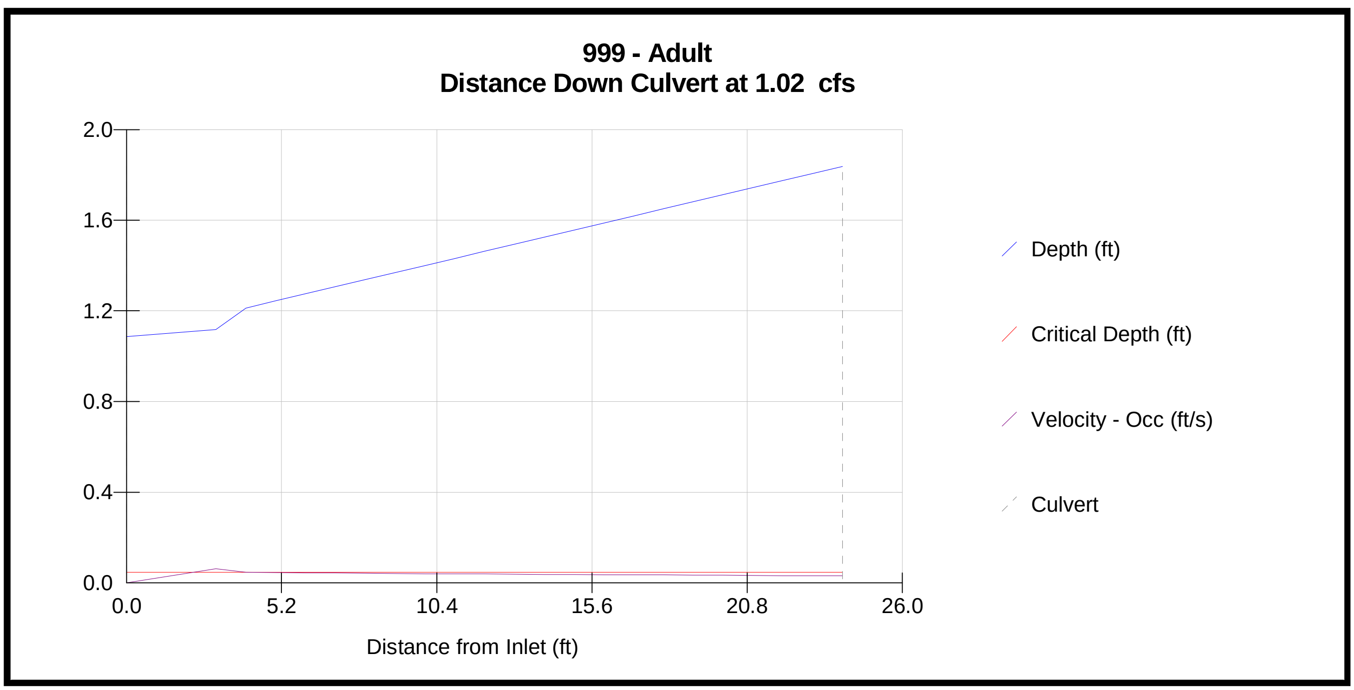


Figure 2. Culvert Profiles at 1.02 cfs

Table 1. Culvert Profiles for 1.02 cfs.

	Profiles for Q = 1.02 cfs		
Dist Down Culvert (ft)	Depth (ft)	Velocity Average (ft/s)	Barrier Type
0	1.09	0.00	NONE
3	1.12	0.06	
4	1.21	0.05	
5	1.24	0.05	
6	1.27	0.04	
7	1.31	0.04	
8	1.34	0.04	
9	1.37	0.04	
10	1.40	0.04	
11	1.43	0.04	
12	1.46	0.04	
13	1.49	0.04	
14	1.53	0.04	
15	1.56	0.04	
16	1.59	0.04	
17	1.62	0.04	
18	1.65	0.03	
19	1.68	0.03	
20	1.71	0.03	
21	1.74	0.03	
22	1.78	0.03	
23	1.81	0.03	
24	1.84	0.03	

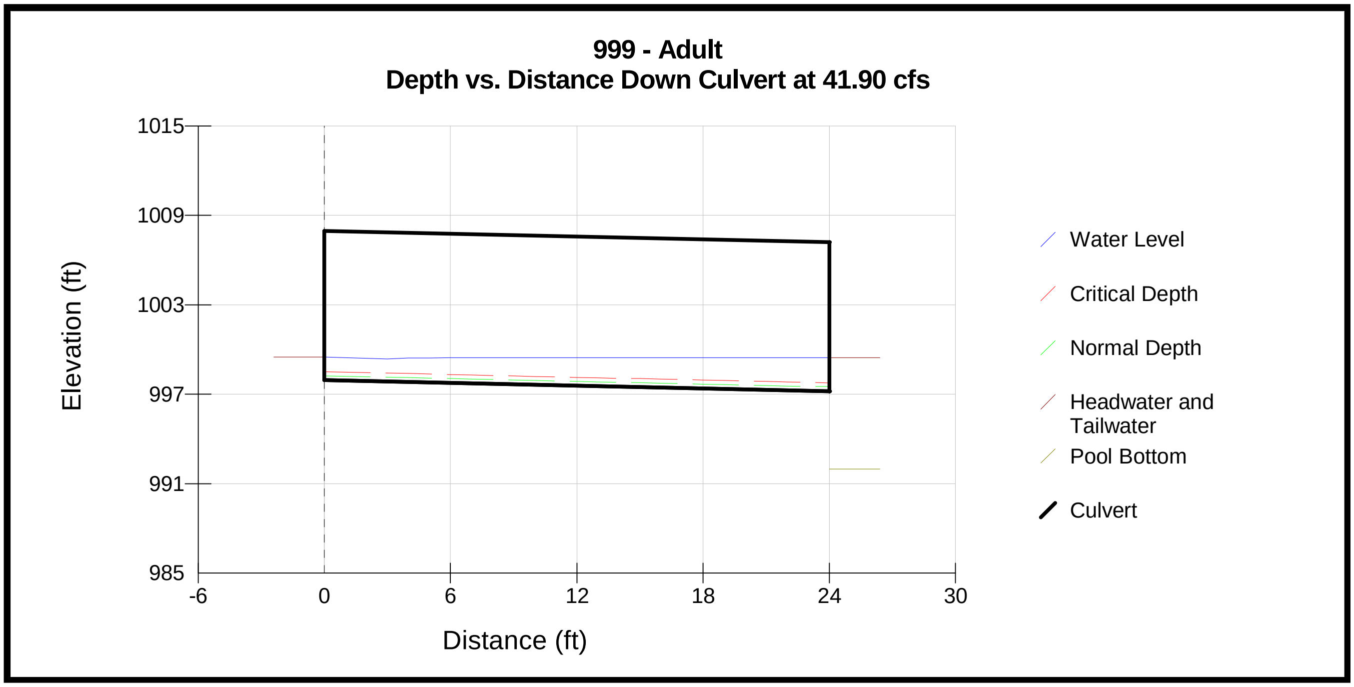


Figure 3. Water Surface Profile at 41.9 cfs

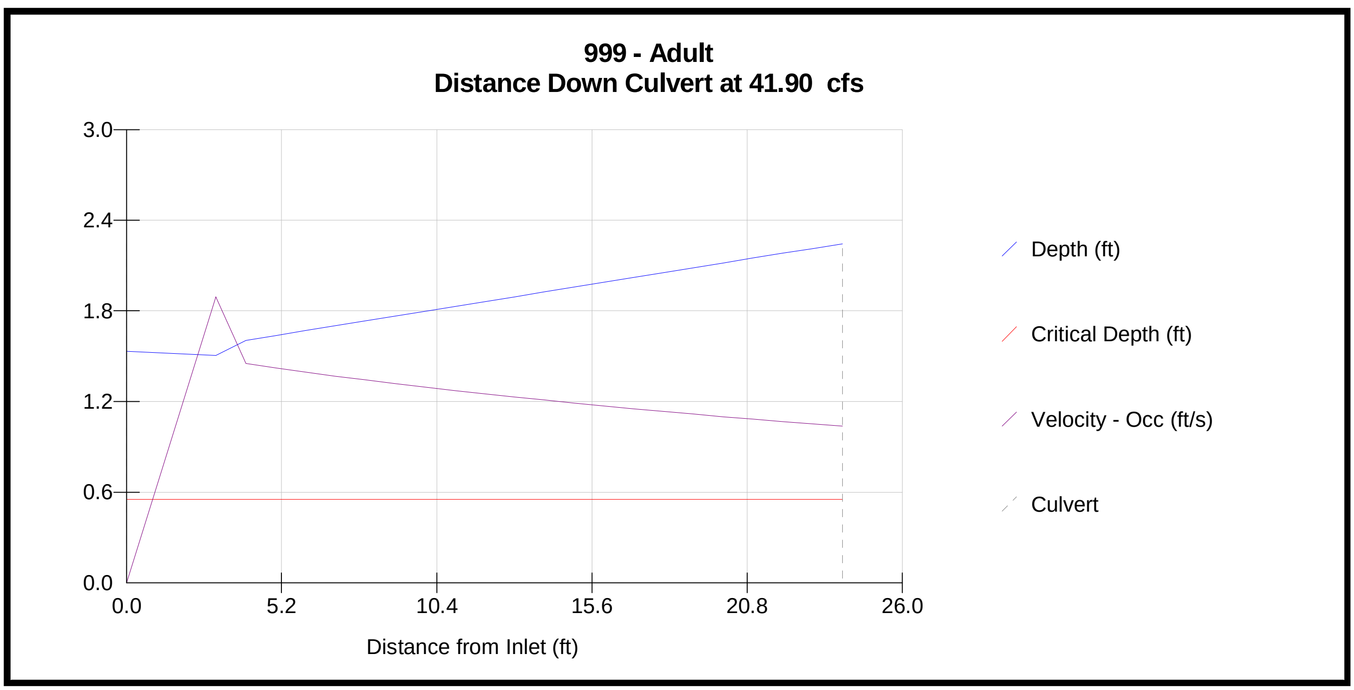


Figure 4. Culvert Profiles at 41.9 cfs

Table 2. Culvert Profiles for 41.9 cfs.

	Profiles for Q = 41.90 cfs		
Dist Down Culvert (ft)	Depth (ft)	Velocity Average (ft/s)	Barrier Type
0	1.53	0.00	NONE
3	1.51	1.89	
4	1.60	1.45	
5	1.64	1.42	
6	1.67	1.40	
7	1.70	1.37	
8	1.73	1.34	
9	1.77	1.32	
10	1.80	1.30	
11	1.83	1.27	
12	1.86	1.25	
13	1.89	1.23	
14	1.93	1.21	
15	1.96	1.19	
16	1.99	1.17	
17	2.02	1.15	
18	2.05	1.13	
19	2.09	1.12	
20	2.12	1.10	
21	2.15	1.08	
22	2.18	1.07	
23	2.21	1.05	
24	2.24	1.04	

Crossing Report for 999 - Juv

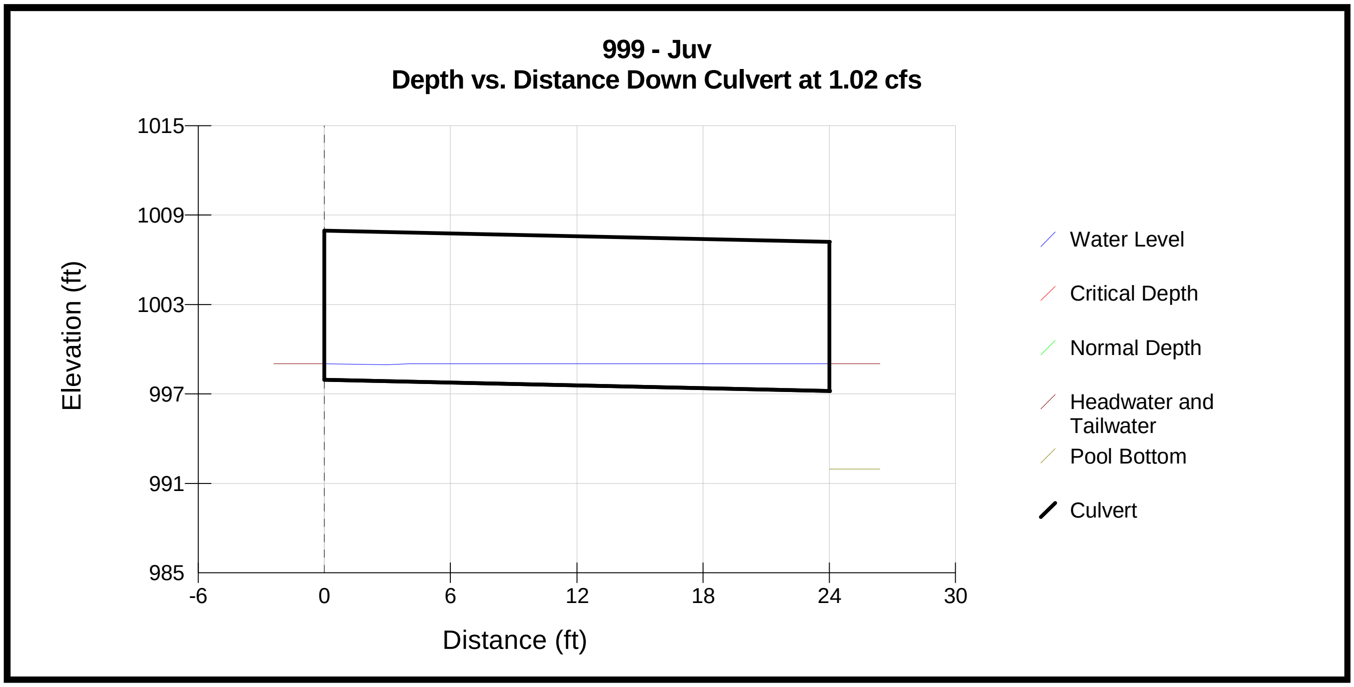


Figure 1. Water Surface Profile at 1.02 cfs

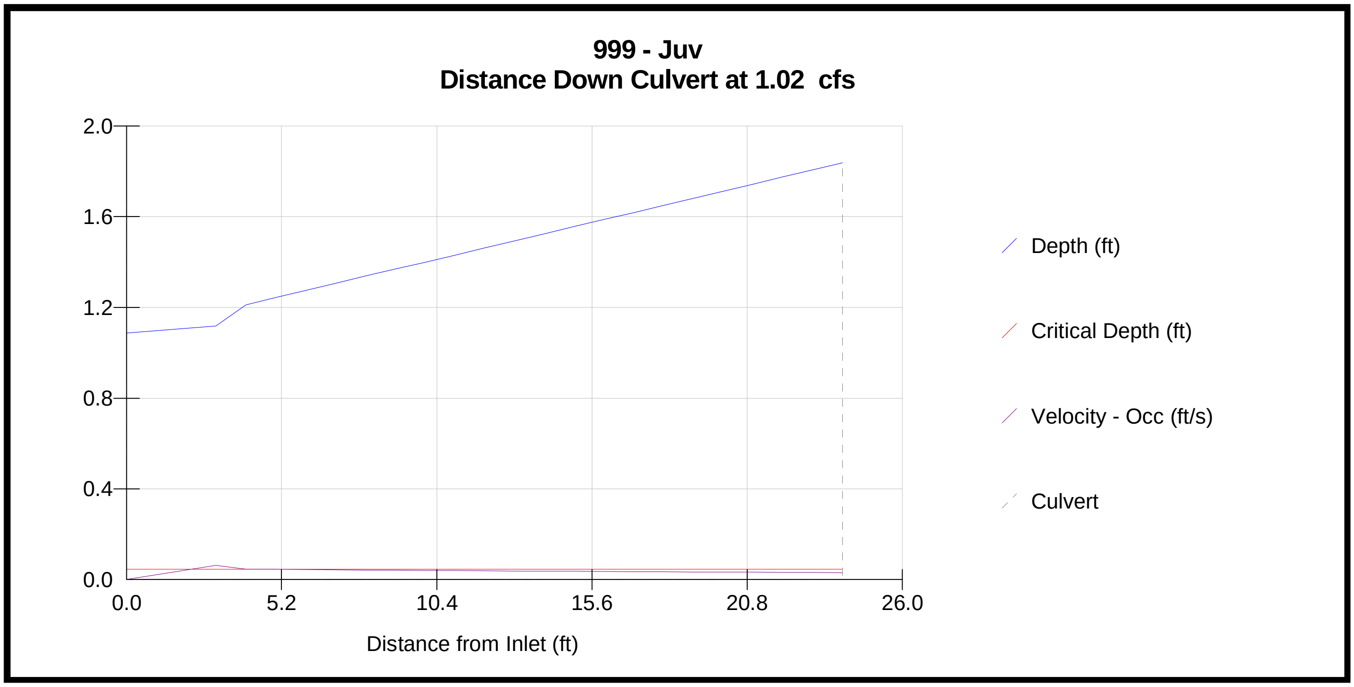


Figure 2. Culvert Profiles at 1.02 cfs

Table 1. Culvert Profiles for 1.02 cfs.

	Profiles for Q = 1.02 cfs		
Dist Down Culvert (ft)	Depth (ft)	Velocity Average (ft/s)	Barrier Type
0	1.09	0.00	NONE
3	1.12	0.06	
4	1.21	0.05	
5	1.24	0.05	
6	1.27	0.04	
7	1.31	0.04	
8	1.34	0.04	
9	1.37	0.04	
10	1.40	0.04	
11	1.43	0.04	
12	1.46	0.04	
13	1.49	0.04	
14	1.53	0.04	
15	1.56	0.04	
16	1.59	0.04	
17	1.62	0.04	
18	1.65	0.03	
19	1.68	0.03	
20	1.71	0.03	
21	1.74	0.03	
22	1.78	0.03	
23	1.81	0.03	
24	1.84	0.03	

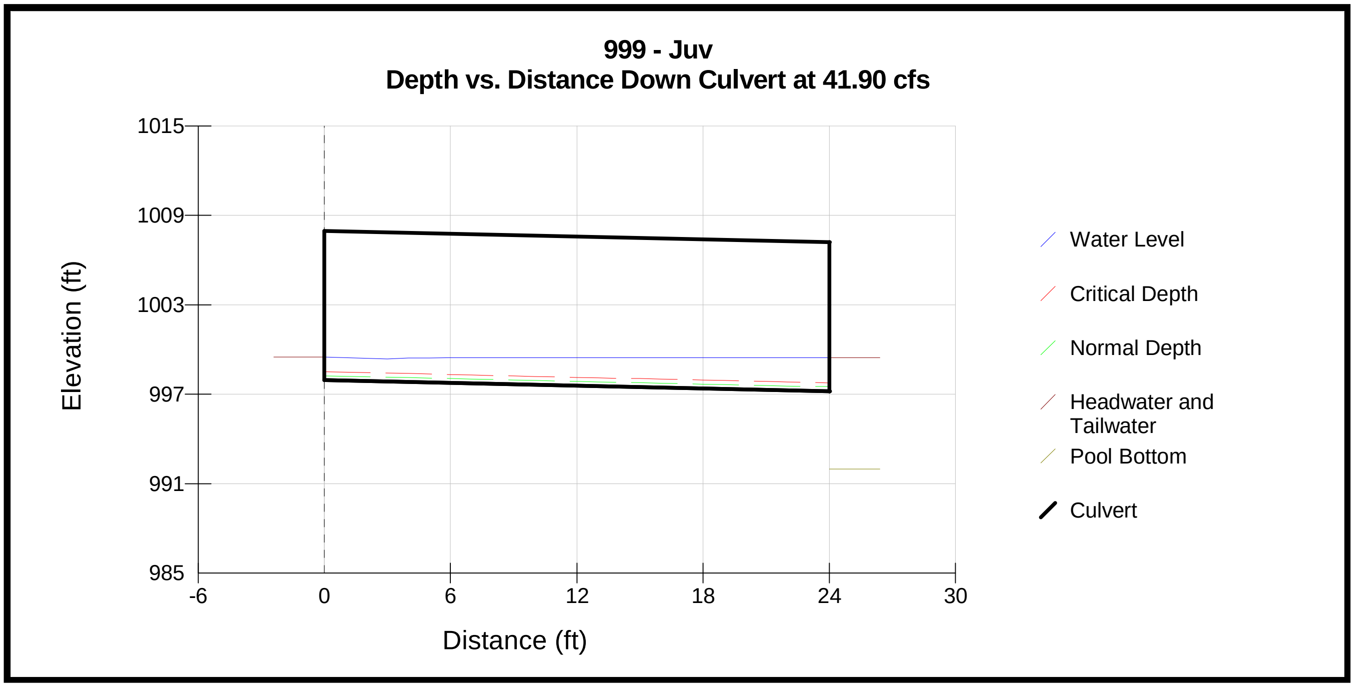


Figure 3. Water Surface Profile at 41.9 cfs

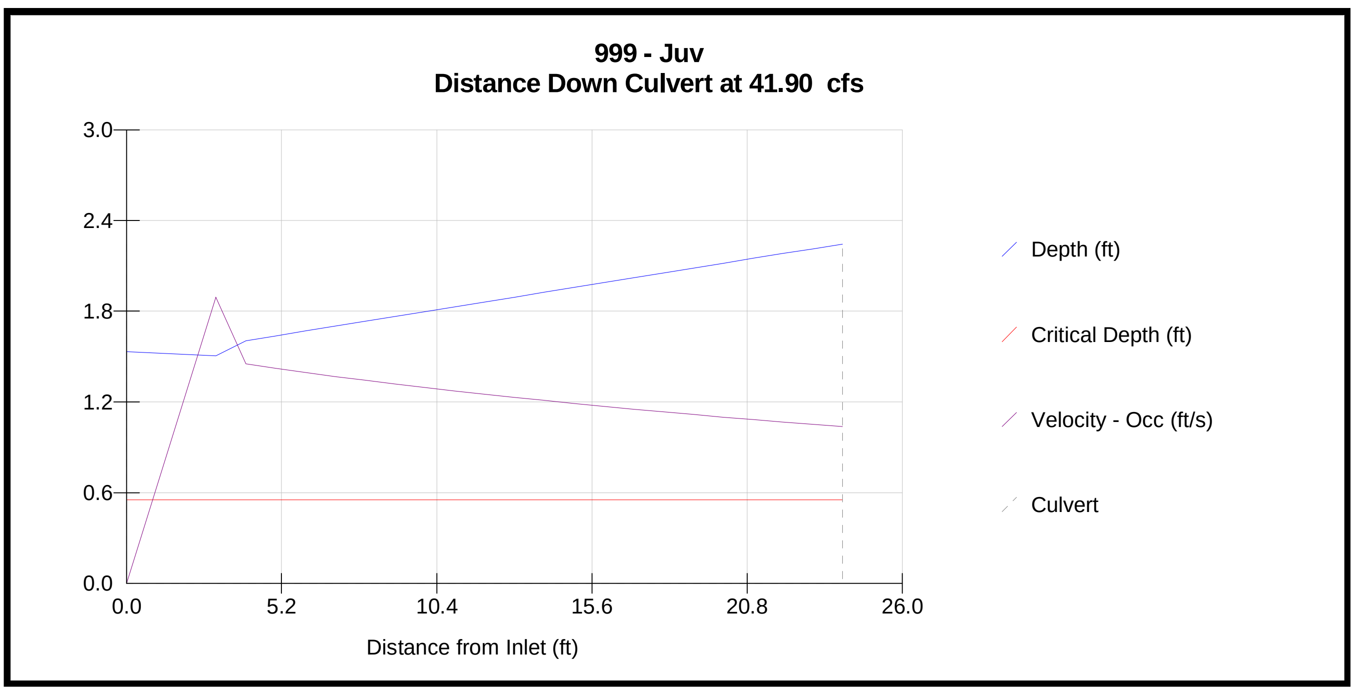


Figure 4. Culvert Profiles at 41.9 cfs

Table 2. Culvert Profiles for 41.9 cfs.

	Profiles for Q = 41.90 cfs		
Dist Down Culvert (ft)	Depth (ft)	Velocity Average (ft/s)	Barrier Type
0	1.53	0.00	
3	1.51	1.89	
4	1.60	1.45	
5	1.64	1.42	
6	1.67	1.40	
7	1.70	1.37	
8	1.73	1.34	
9	1.77	1.32	
10	1.80	1.30	
11	1.83	1.27	
12	1.86	1.25	
13	1.89	1.23	
14	1.93	1.21	
15	1.96	1.19	
16	1.99	1.17	
17	2.02	1.15	
18	2.05	1.13	
19	2.09	1.12	
20	2.12	1.10	
21	2.15	1.08	
22	2.18	1.07	
23	2.21	1.05	
24	2.24	1.04	Velocity