Culvert Design for Fish Passage

Gian Dodici & Carl Schwartz
USFWS

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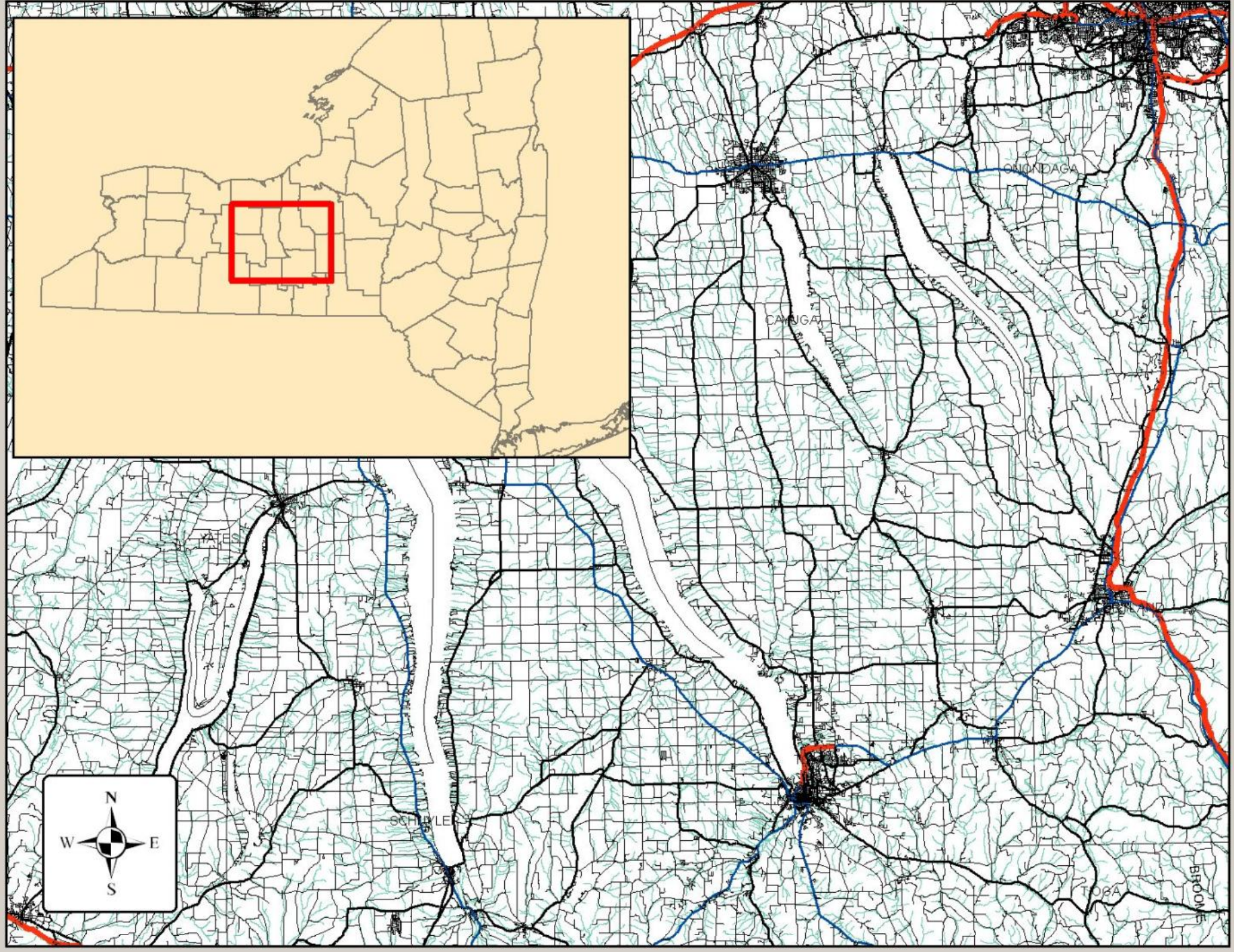
ONONDAGA
CAYUGA
YATES
SCHUYLER
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How do crossings affect a watershed?

- Alter drainage patterns and stream flows
- Affect temperatures
- Alter sedimentation, organic matter
- Introduce contaminants

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Effects of crossing on aquatic organisms..

- Passage barriers
- Increased erosion and sedimentation
- Source for pollution

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Why is fish passage important?

- Migration for spawning
- Movement for survival temperatures, flows, available food and cover
- Prevent population fragmentation
- After a catastrophic event, recolonization

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Fish Passage Criteria

- Culvert Diameter
- Culvert Slope
- Roughness
- Velocity
- Fish species/size

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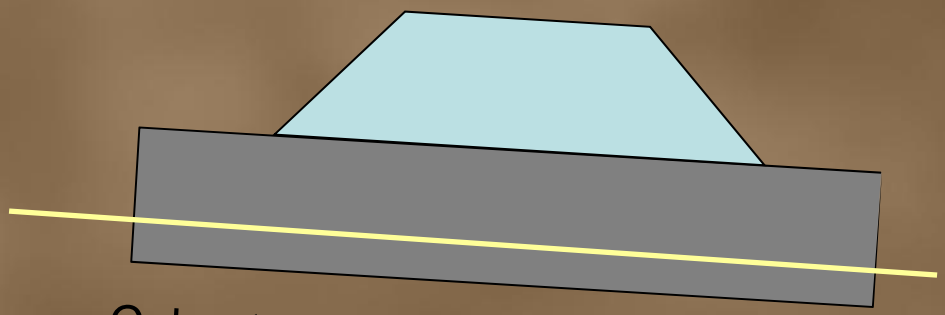
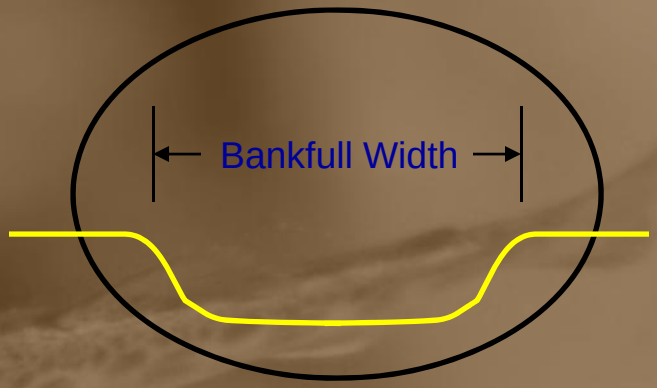
Active Channel vs. Hydraulic Culvert Design

- **Active Channel** – Sized to allow natural movement of bedload and formation of a stable streambed inside the culvert



Culvert slope matches channel slope



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Active Channel vs. Hydraulic Culvert Design

- **Hydraulic** – Matches hydraulics of culvert with swimming abilities of target species. Some problems include:
  - Super critical flow
  - Hydraulic jumps
  - Highly turbulent conditions
  - Abrupt changes in water surface elevation at inlet and outlet

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Culvert conditions that create barriers to fish

- Excess drop at culvert outlet
- High velocity within culvert
- Inadequate depth in culvert
- Turbulence in culvert
- Debris at culvert inlet

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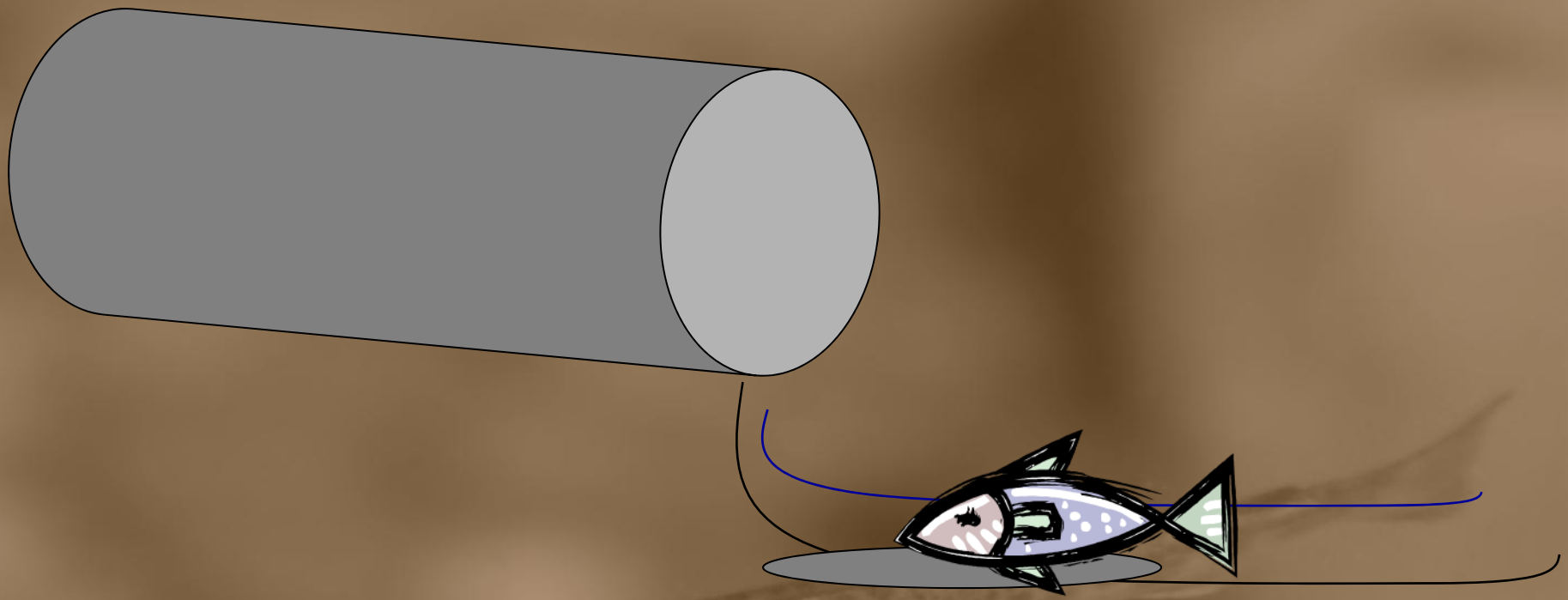
What's the problem?

- Pool Depth



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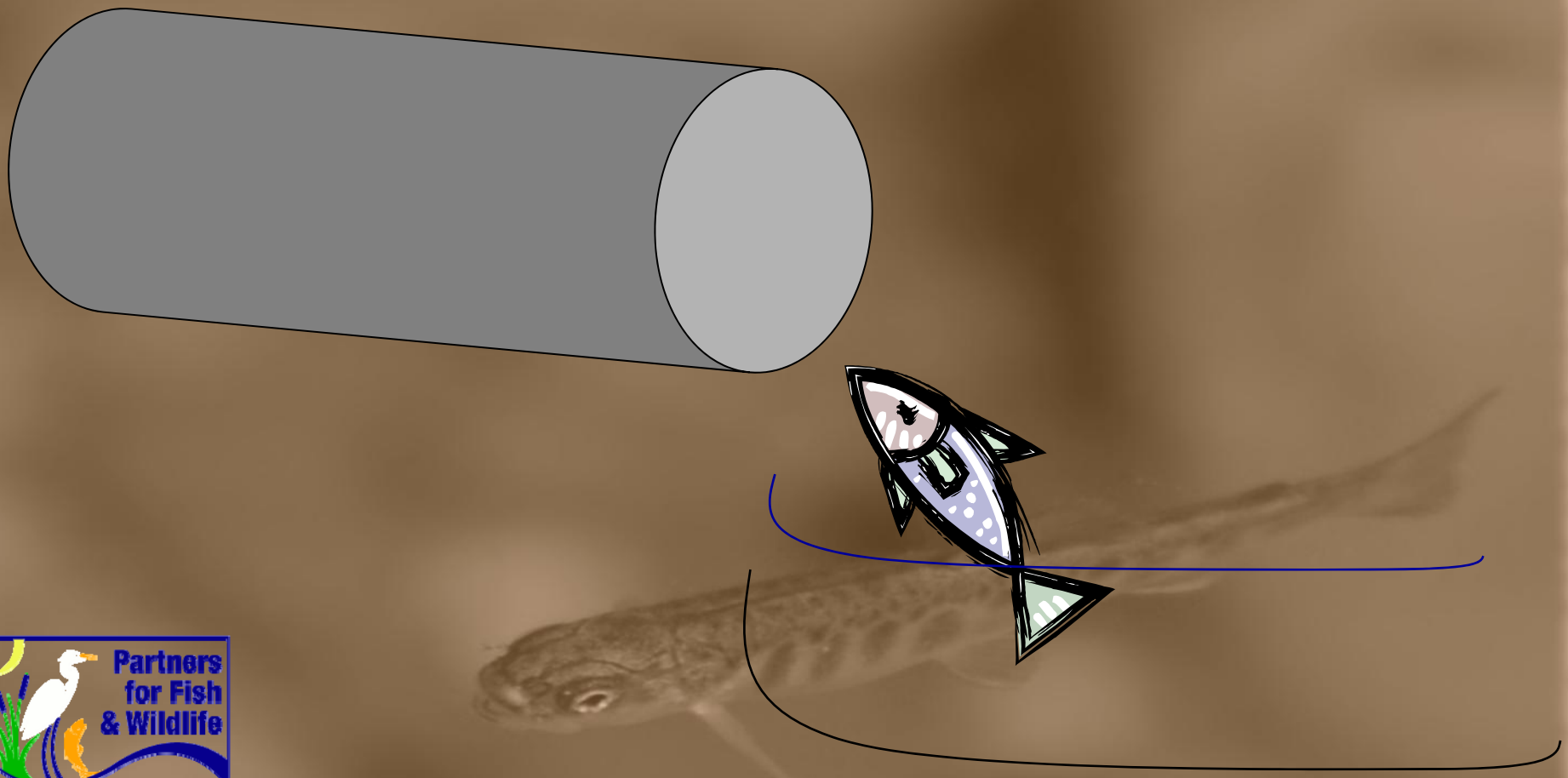
What's the problem?

- Jump Height



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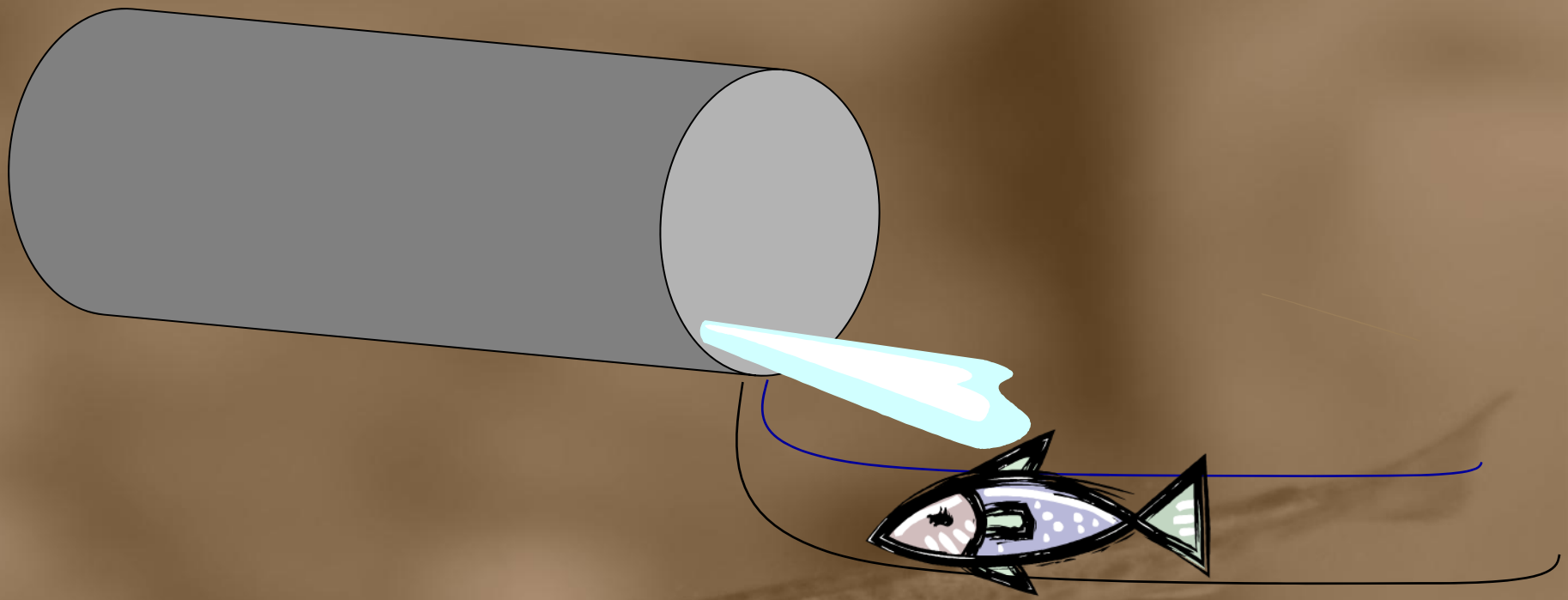
High
Weed
And
Lots

What's the problem?

- Flow velocity



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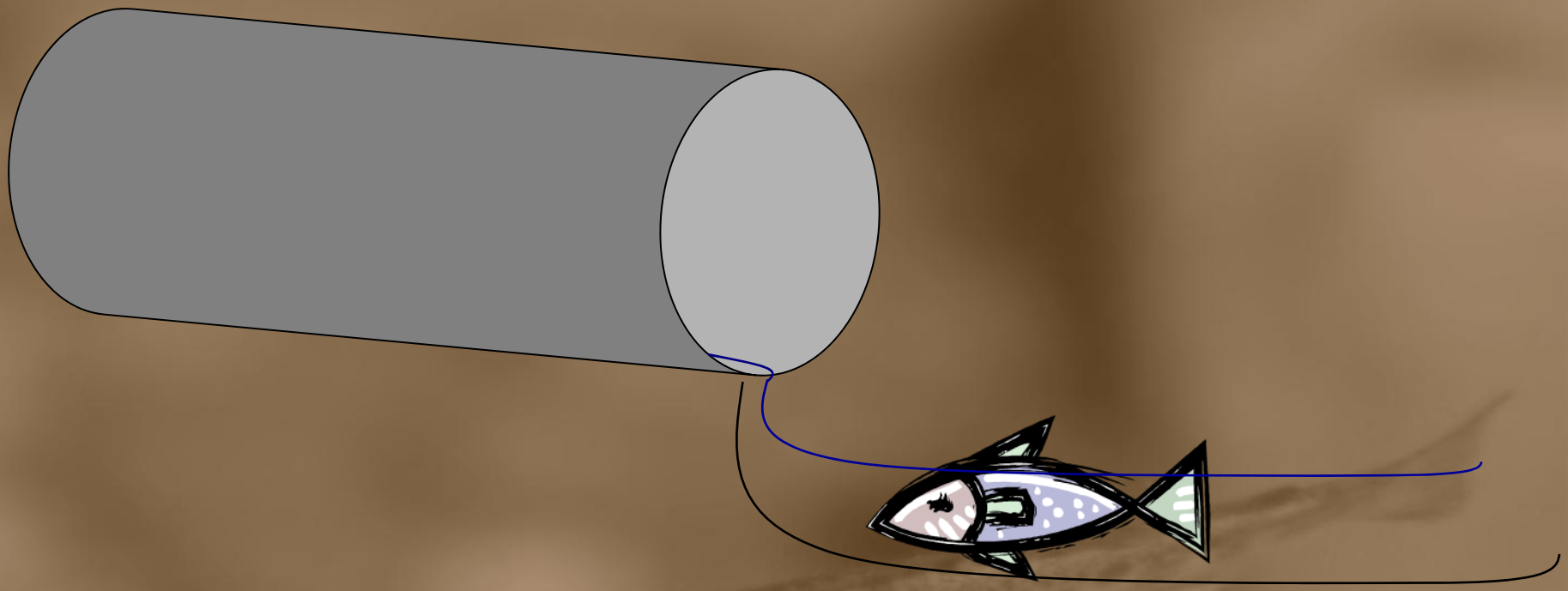
What's the problem?

- Flow depth



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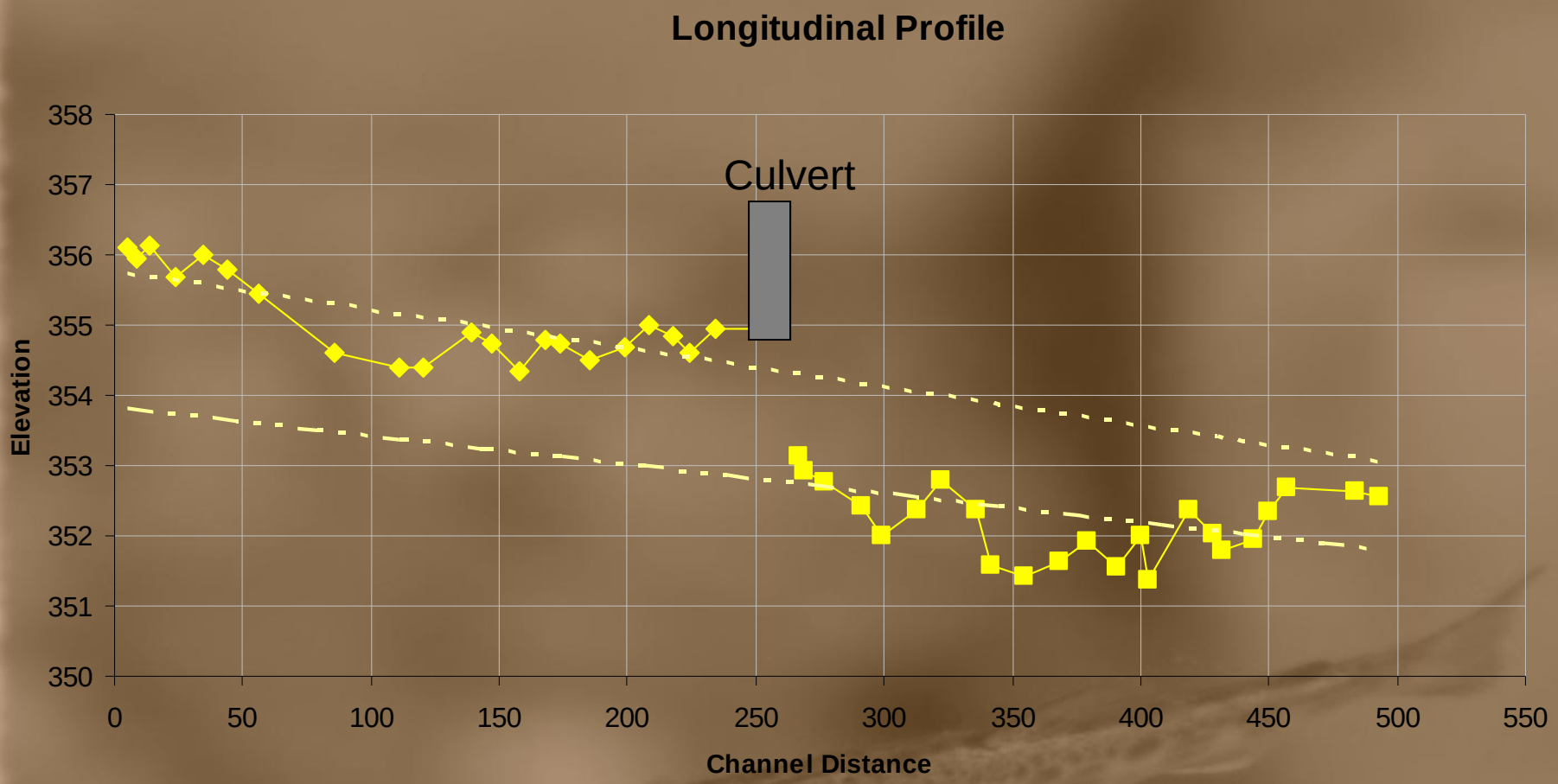
35

Channel Incision



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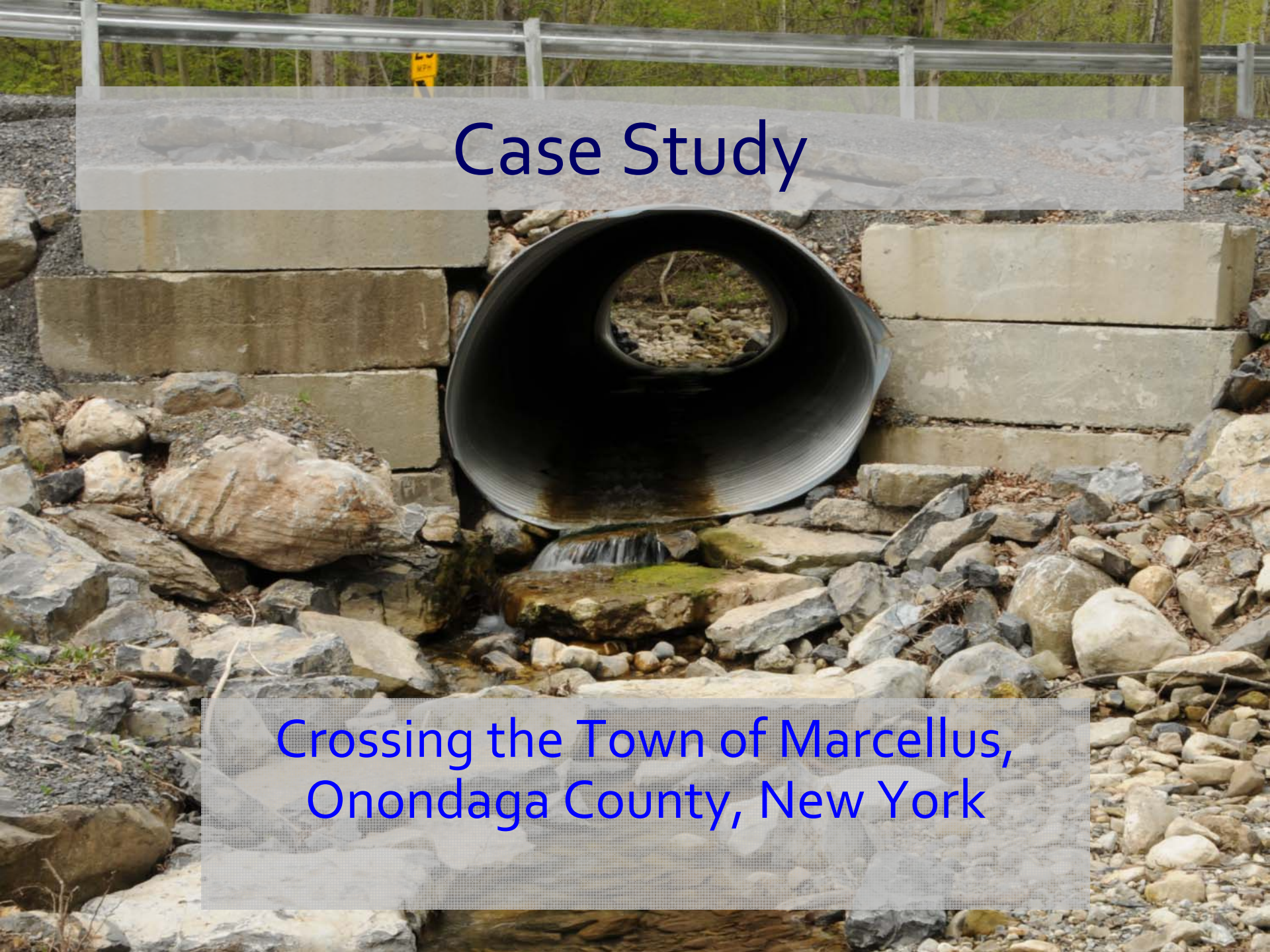

Case Study

Crossing the Town of Marcellus, Onondaga County, New York

Cross vanes installed to back water up into the culvert eliminating the vertical barrier

But was this enough?

How do I know?

FishXing V3 beta

FishXing v3

Created by:

Susan Firor

Michael Love

Michael Furniss

Antonio Llanos

Kathleen Moynan

Jeff Guntle

Bob Gubernick

FishXing 3

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Pacific Northwest Research Station

Forest Service Engineering T&D Program

Federal Highway Administration

Stream Systems Technology Center

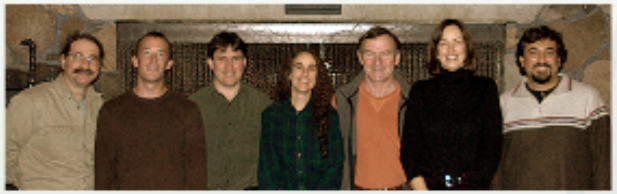
Rocky Mountain Research Station

US Fish & Wildlife Service

Be a Sponsor

Go to the FishXing Website

http://www.stream.fs.fed.us/fishxing/



click to enlarge

Thanks to the following for their guidance:

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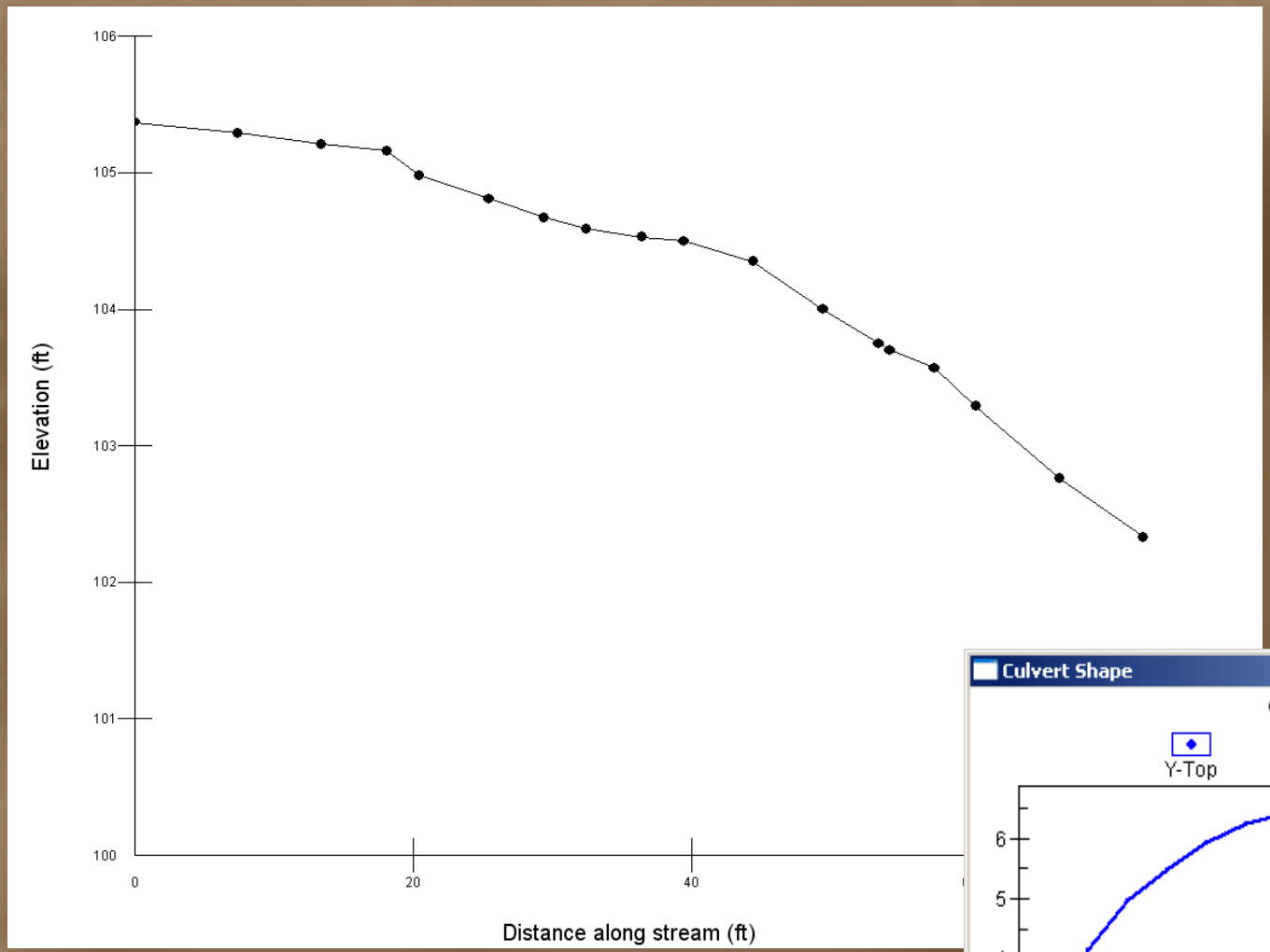
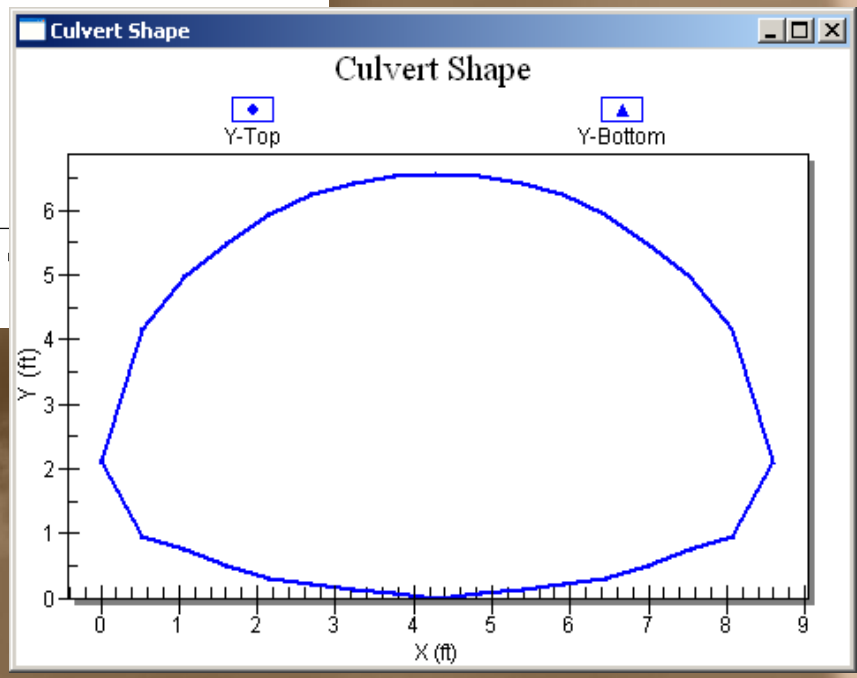
(Make 3.0.15 June 8, 2009)





Need some basic measurements

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Common Name	Swim Category	Min Swim Speed	Max Swim Speed	Swim Speed	Speed Units	Speed Type	Variability	Variab Type	Length Type	Min Length	Max Len
Salmo salar	Burst	NR	NR	Calculated	cm/s	NR	NR	~	TL	35	91.4
Salmo salar	Prolonged	NR	NR	Calculated	cm/s	NR	NR	~	FL	3	5.2
Salmo trutta	Burst	NR	NR	Calculated	cm/s	NR	NR	~	TL	12.8	37.3
Salmo trutta	Prolonged	NR	NR	92	cm/s	R	NR	~	TL	NR	NR
Salmo trutta	Prolonged	NR	NR	Calculated	cm/s	NR	NR	~	FL	5.1	26
Salvelinus alpinus	Burst	NR	NR	133	cm/s	ME	NR	~	TL	NR	NR
Salvelinus alpinus	Burst	NR	NR	109	cm/s	ME	NR	~	TL	NR	NR
Salvelinus alpinus	Prolonged	NR	NR	Calculated	cm/s	NR	NR	~	TL	7	42
Salvelinus alpinus	Prolonged	NR	NR	100.2	cm/s	M	3	SE	FL	NR	NR
Salvelinus alpinus	Prolonged	NR	NR	81	cm/s	R	NR	~	TL	NR	NR
Salvelinus alpinus	Prolonged	NR	NR	67	cm/s	ME	NR	~	TL	NR	NR
Salvelinus alpinus	Prolonged	NR	NR	61	cm/s	R	NR	~	TL	NR	NR
Salvelinus confluentus	Prolonged	27.23	60.07	48.24	cm/s	M	13.65	SD	FL	11	19
Salvelinus confluentus	Prolonged	68.97	79.93	73.99	cm/s	M	4.1	SD	FL	32	42
Salvelinus confluentus	Prolonged	53.4	75.3	54.66	cm/s	M	5.27	SD	FL	14	23
Salvelinus confluentus	Prolonged	NR	NR	Calculated	cm/s	NR	NR	~	FL	11	42
Salvelinus fontinalis	Burst	NR	NR	93	cm/s	R	NR	~	SL	NR	NR
Salvelinus fontinalis	Prolonged	NR	NR	Calculated	cm/s	NR	NR	~	TL	4.2	26
Salvelinus fontinalis	Prolonged	NR	NR	Calculated	cm/s	NR	NR	~	TL	4	27
Salvelinus fontinalis	Prolonged	NR	NR	Calculated	cm/s	NR	NR	~	FL	7.1	40.5
Sander lucioperca	Prolonged	NR	NR	76.1	cm/s	M	5.5	SD	TL	53	73
Sander vitreus	Burst	160	260	Calculated	cm/s	NR	NR	~	FL	16	57
Sander vitreus	Prolonged	NR	NR	Calculated	cm/s	NR	NR	~	FL	8	38

Crossing Input

Site Info | Sevier Road | Stream Name: Unnamed Trib

Fish Information

Custom Settings

Literature Swim Speeds | User-defined Swim Speeds | Hydraulic Criteria

Fish Length 20 cm

Select Data

Prolonged | Use Both | Burst

Prolonged Speed 1.4 ft/s

Time to Exhaustion 75.0 min

Burst Speed ft/s

Time to Exhaustion s

Salvelinus fontinalis
Brook trout
Length: 4 to 27 cm
Temp: 15 Deg C
Fish Body Depth: 0.17 ft
Fish Metrics Calculated

Min Depth 0.2 ft

Outlet Criteria

Max Outlet Drop 0 ft

Culvert Information

Culvert 1 of 1

Shape Horizontal Ellipse | Details

Rise 6.6 Span 8.6 ft

Material Annular 5 x 1 inch

Entrance Type Headwall | Details

Installation

Not Embedded

Depth 0 ft

Percent 0 %

Culvert Roughness (n) 0.025 ...

Bottom Roughness (n) ...

Culvert Length 72.4 ft

Inlet Bottom Elevation 105.37 ft

Culvert Slope 4.19 %

Outlet Bottom Elevation 102.34 ft

Velocity Reduction Factors

Inlet 0.8 Barrel 0.8 Outlet 0.8

Fish Passage Flows

Low 1 cfs High 45 cfs

Tailwater **Constant Tailwater**

Save | < Back | Calculate

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Output Summary

Form Edit Info Flows Graphs Tables Customize

Sevier Road

Customize

Fish Passage Summary	
Low Passage Design Flow	1.00 cfs
High Passage Design Flow	5.00 cfs
Percent of Flows Passable	0.0 %
Passable Flow Range	None
Depth Barrier	1.00 to 1.23 cfs
Outlet Drop Barriers	None
Velocity Barrier	1.00 cfs to 5.00 cfs
Pool Depth Barrier	None

Summary for Q = 1.00 cfs	
Normal Depth (ft)	0.20
Critical Depth (ft)	0.23
Headwater Depth (ft)	0.17
HW/D	0.03
Inlet Velocity (ft/s)	3.57
Tailwater Depth (ft)	1.06
Outlet Water Surface Drop (ft)	0.00
Prolonged Swim Time (min)	0.29
Burst Swim Time (s)	0.00
Barrier Code	Depth; V

1.00 cfs 5.00 cfs

Flow Rate Calculator

cfs Calc

Close

Profiles for Q = 1.00 cfs

Dist Down Culvert (ft)	Depth (ft)	Velocity Head (ft)	Velocity Average (ft/s)	Froude Number	Roughness (Manning's n)	Shear Stress (lb/ft2)	Stream Power (lb/ft-s)	EDF ft-lb/ft3/s
0	0.17	0.00	0.00	2.07	0.025	0.00	0.00	9.68
3	0.20	0.20	3.57	1.49	0.025	0.40	0.86	7.61
6	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
10	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
14	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
18	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
22	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
26	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
30	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
34	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
38	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
42	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
46	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
50	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
54	0.20	0.13	2.91	1.49	0.025	0.51	0.89	7.61
58	0.42	0.01	0.86	0.29	0.025	0.00	0.00	2.24
62	0.60	0.00	0.51	0.14	0.025	0.00	0.00	1.33
66	0.77	0.00	0.35	0.09	0.025	0.00	0.00	0.92
70	0.93	0.00	0.26	0.06	0.025	0.00	0.00	0.69

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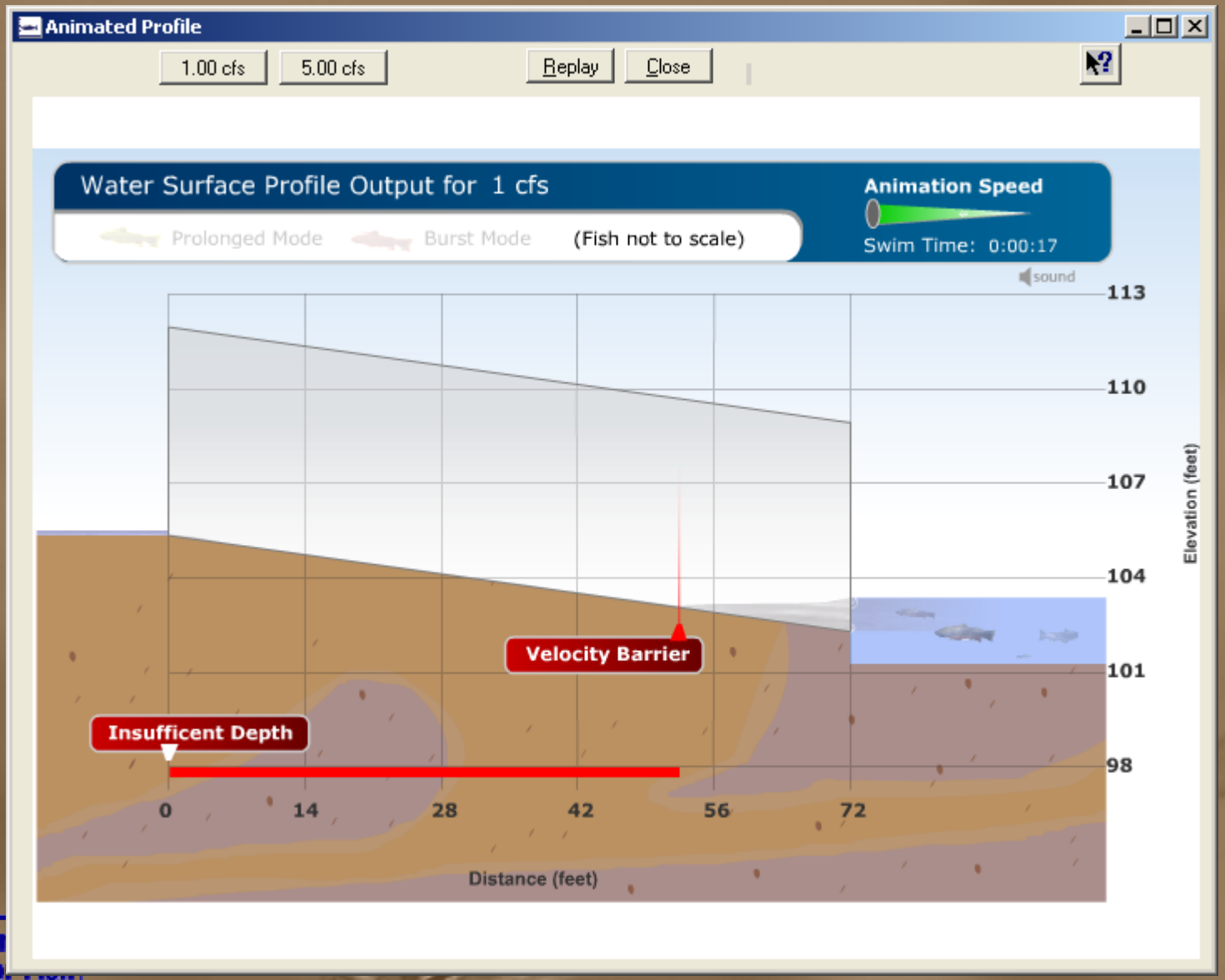
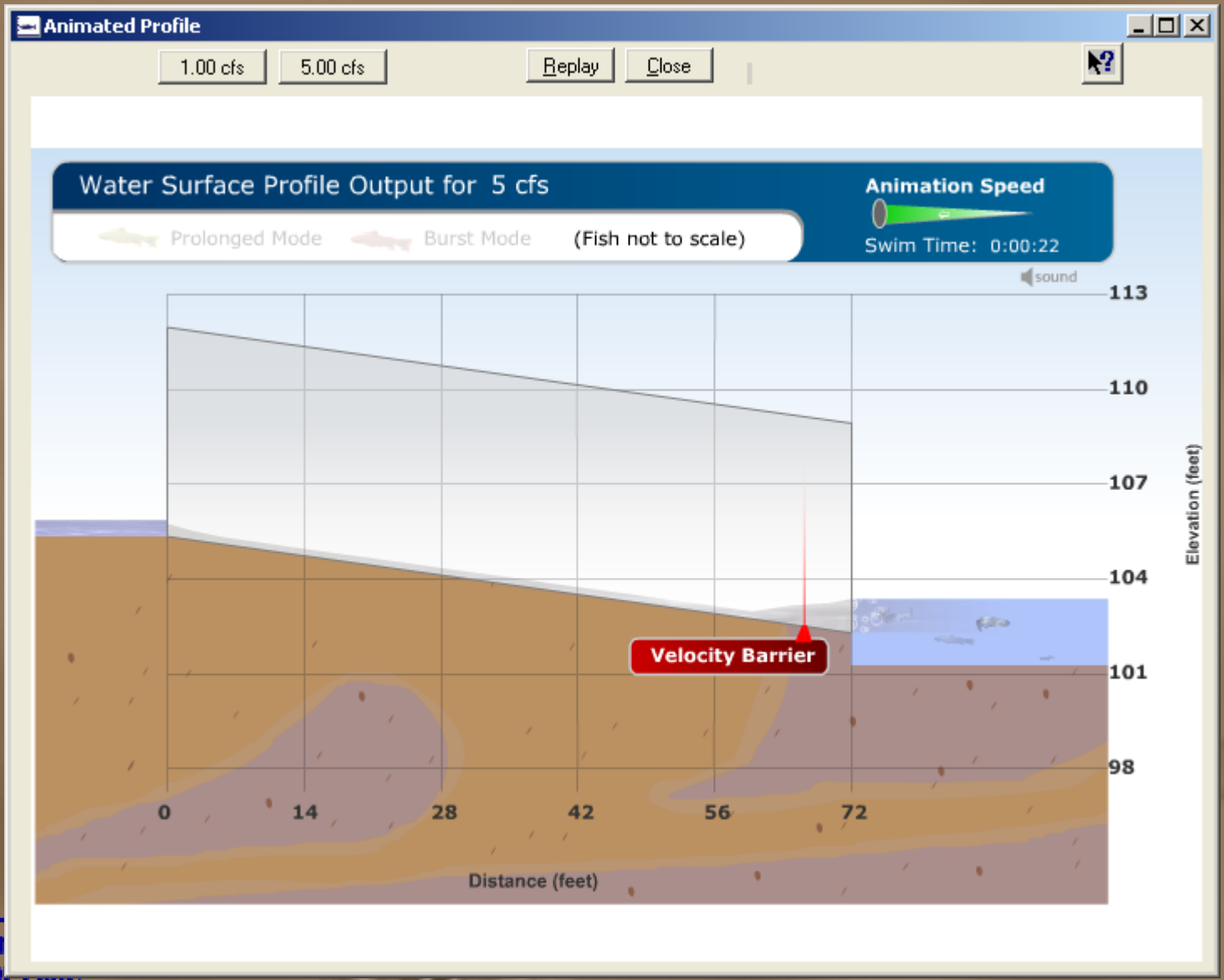
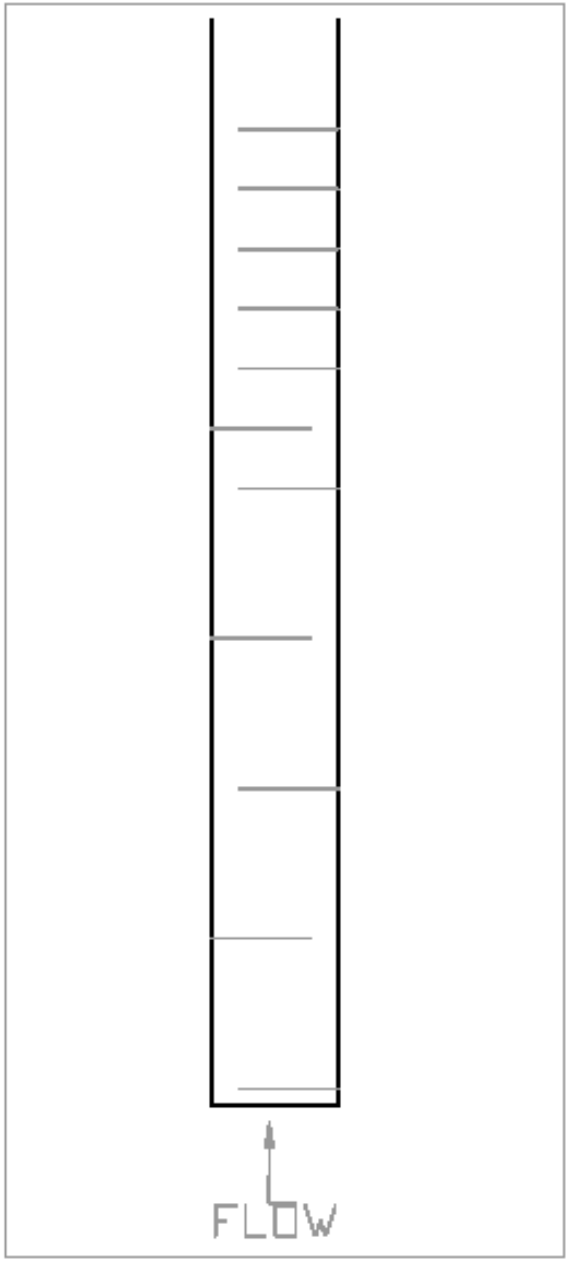
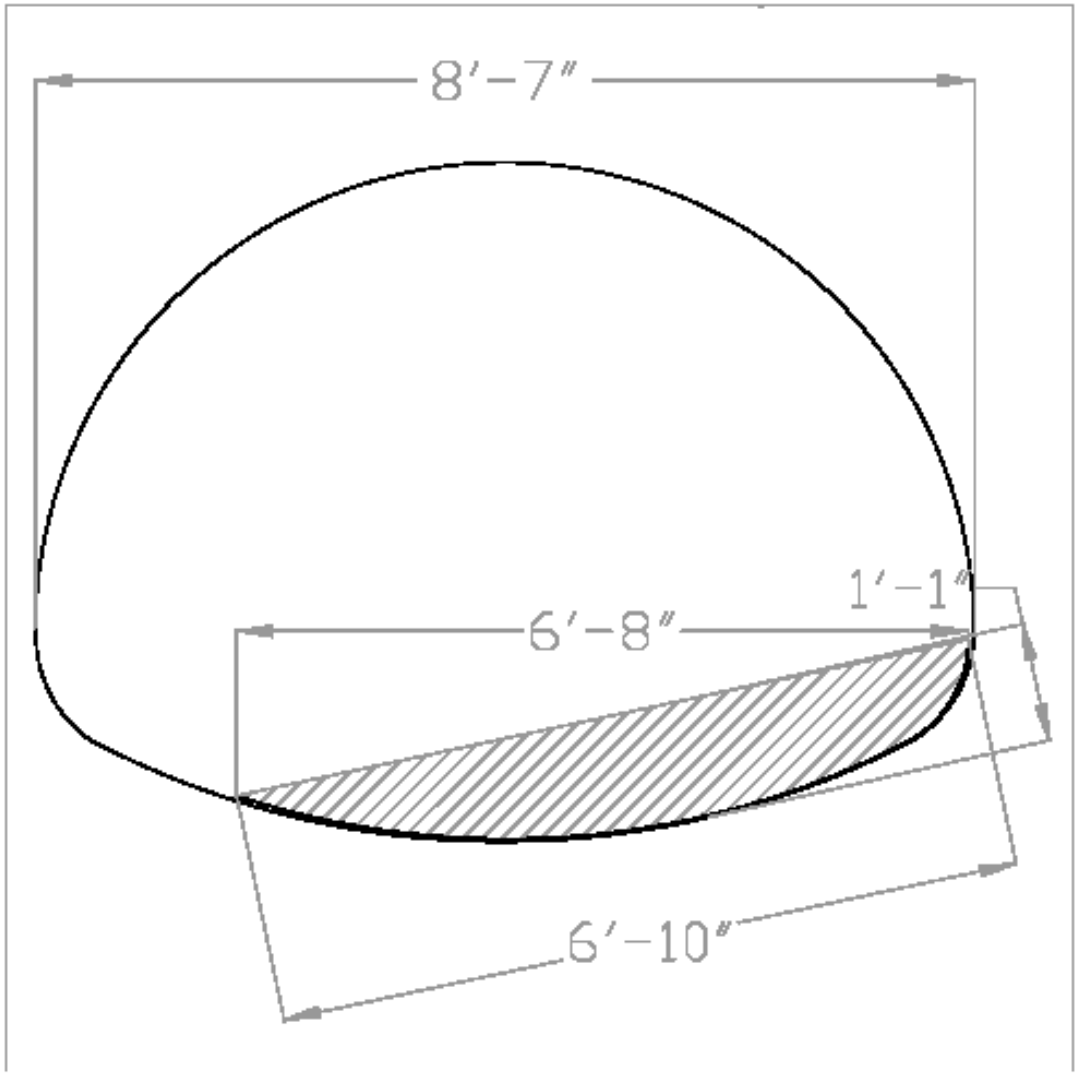
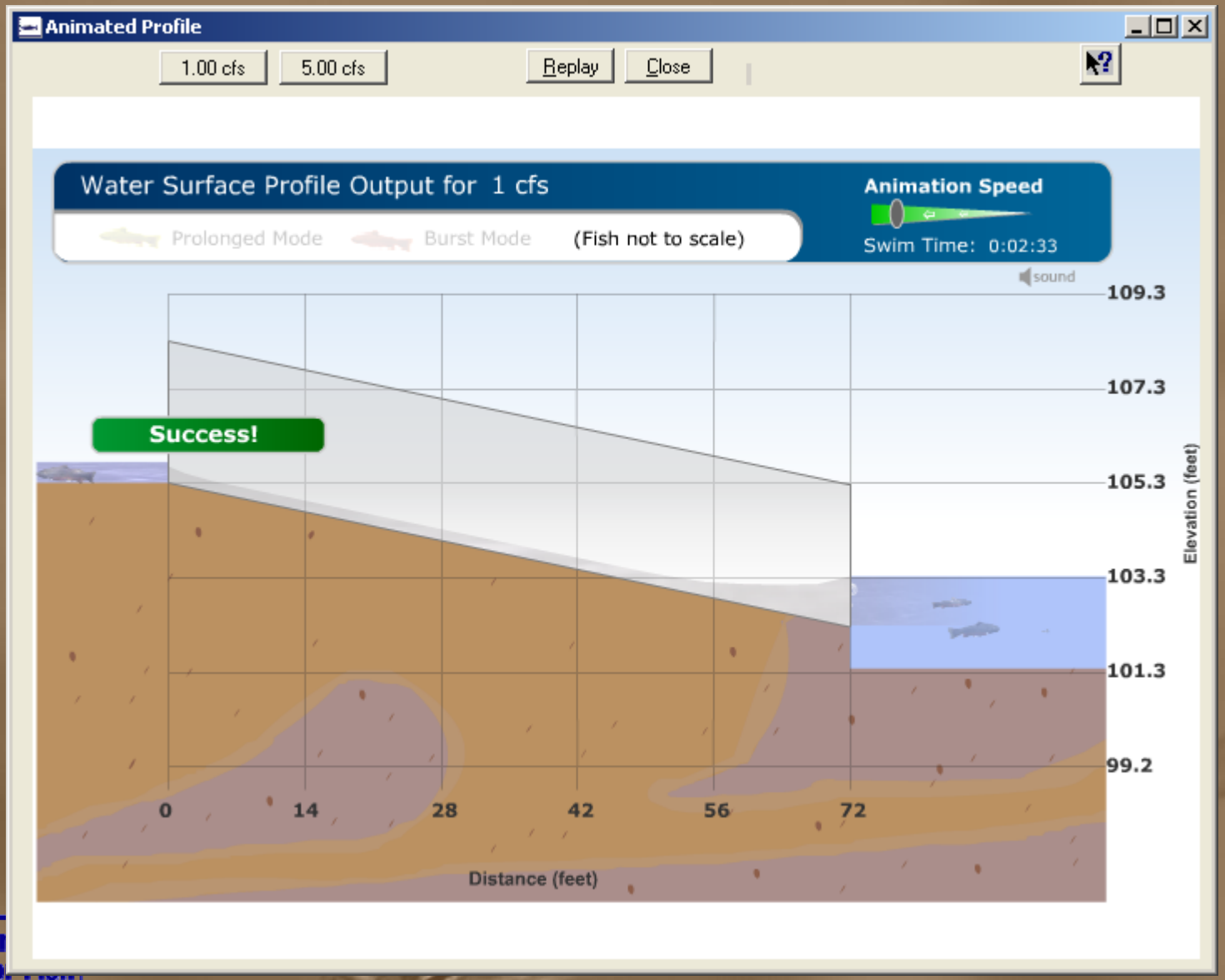

Animated Profile
1.00 cfs
5.00 cfs
Replay
Close
Water Surface Profile Output for 1 cfs
Prolonged Mode
Burst Mode
(Fish not to scale)
Animation Speed
Swim Time: 0:00:17
sound
113
110
107
104
101
98
Elevation (feet)
Velocity Barrier
Insufficent Depth
0
14
28
42
56
72
Distance (feet)


Animated Profile
1.00 cfs
5.00 cfs
Replay
Close
Water Surface Profile Output for 5 cfs
Prolonged Mode
Burst Mode
(Fish not to scale)
Animation Speed
Swim Time: 0:00:22
sound
113
110
107
104
101
98
Elevation (feet)
Velocity Barrier
0
14
28
42
56
72
Distance (feet)

Proposed fish passage baffle design for Sevier Road culvert






Animated Profile
1.00 cfs
5.00 cfs
Replay
Close
Water Surface Profile Output for 1 cfs
Prolonged Mode
Burst Mode
(Fish not to scale)
Animation Speed
Swim Time: 0:02:33
sound
Success!
109.3
107.3
105.3
103.3
101.3
99.2
Elevation (feet)
0
14
28
42
56
72
Distance (feet)

Questions?