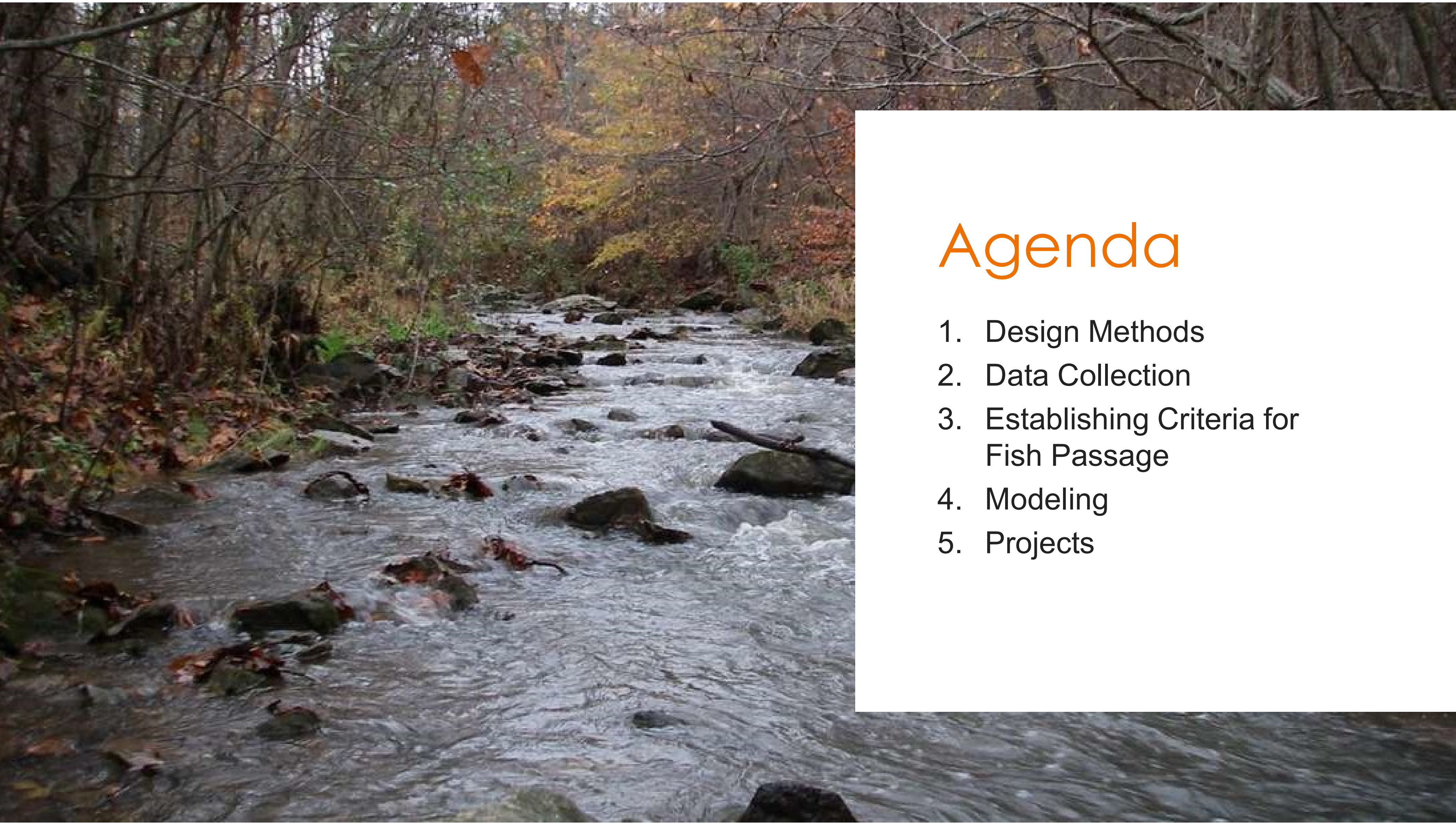
EcoStream 2018: Stream Ecology and Restoration Conference

Fish Passage Analysis at Highway Culverts



Agenda

1. Design Methods
2. Data Collection
3. Establishing Criteria for Fish Passage
4. Modeling
5. Projects

Design Methods

Design Methods

Stream Simulation

- Stream simulation is an approach to designing crossing structures (usually culverts), that creates a structure that is as similar as possible to the natural channel. When channel dimensions, slope, and streambed structure are similar, water velocities and depths also will be similar. Thus, the simulated channel should present no more of an obstacle to aquatic animals than the natural channel.

Hydraulic Design

- The goal of hydraulic design is creating water depths and velocities suited to the swimming ability of a target fish at the range of flows when the fish moves in the natural channel. To accomplish this, the design process simultaneously considers the hydraulic effects of culvert size, slope, material, and length.

Hybrid Design

- Hybrid design and roughened-channel design are styles of hydraulic design that create a nonadjustable streambed inside of a culvert to pass at least some aquatic species. The channel usually resembles the general shape of a natural channel although it may be quite different from the channel in which it is constructed.

Data Collection

Data Collection

Watershed Assessment

- Hydrology/Baseflow
- Fish population
- Upstream Habitat
- Culvert Characteristics
- Geomorphology

Hydrology

Baseflow Hydrology Estimation

- Gaged stream
- Ungaged stream

Direct measurement

- Flow meter
- Cross sections

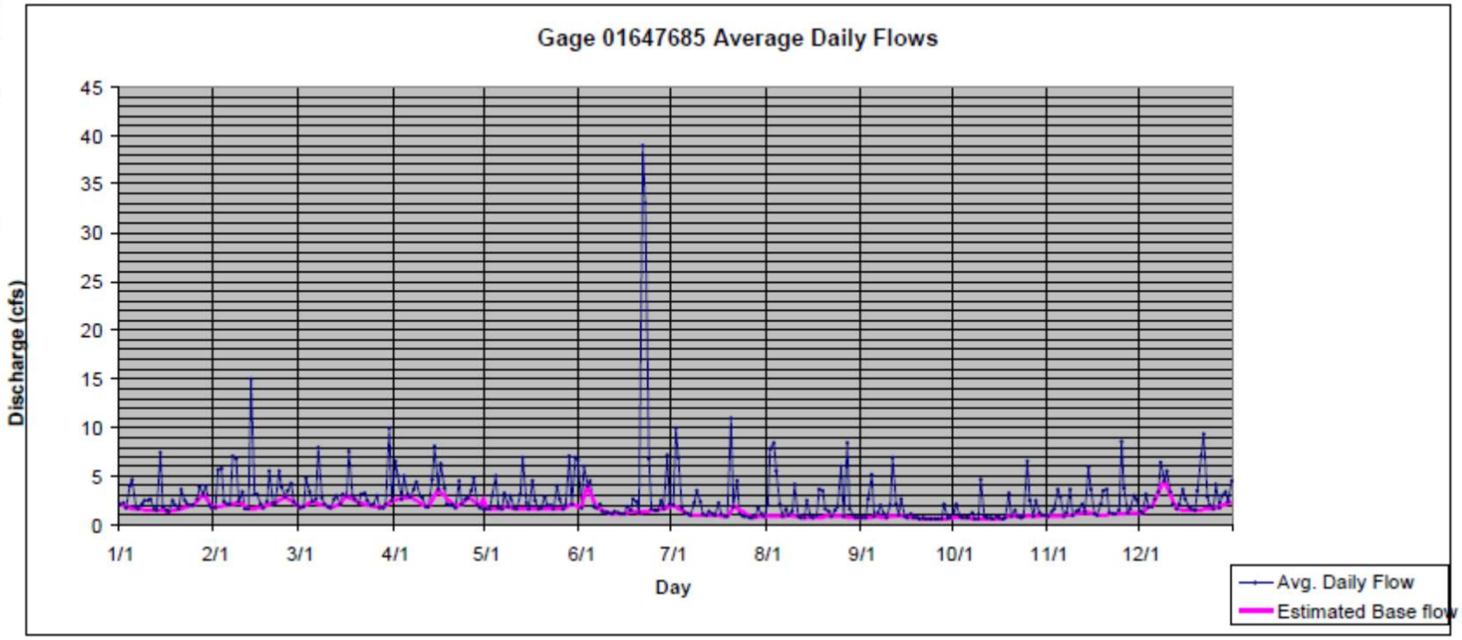
Alternate Minimum Flow

- 1 cfs (MDOT SHA, CA Dept or Fish & Game)

Baseflow Hydrology Estimation

Methods of hydrograph analysis:

- Local Minimum (HYSEP)
- Fixed Interval (HYSEP)
- Sliding Interval (H
- Base-Flow Index (
- PART
- Recession-curve (



Baseflow Separation in Gaged Streams

Frequency analysis for yearly or seasonal discharge

$$P(\%) = \frac{m - 0.375}{N + 0.25} \times 100$$

where:

P = probability in % of the observation of the rank m
m = the rank of the observation
N = total number of observations used

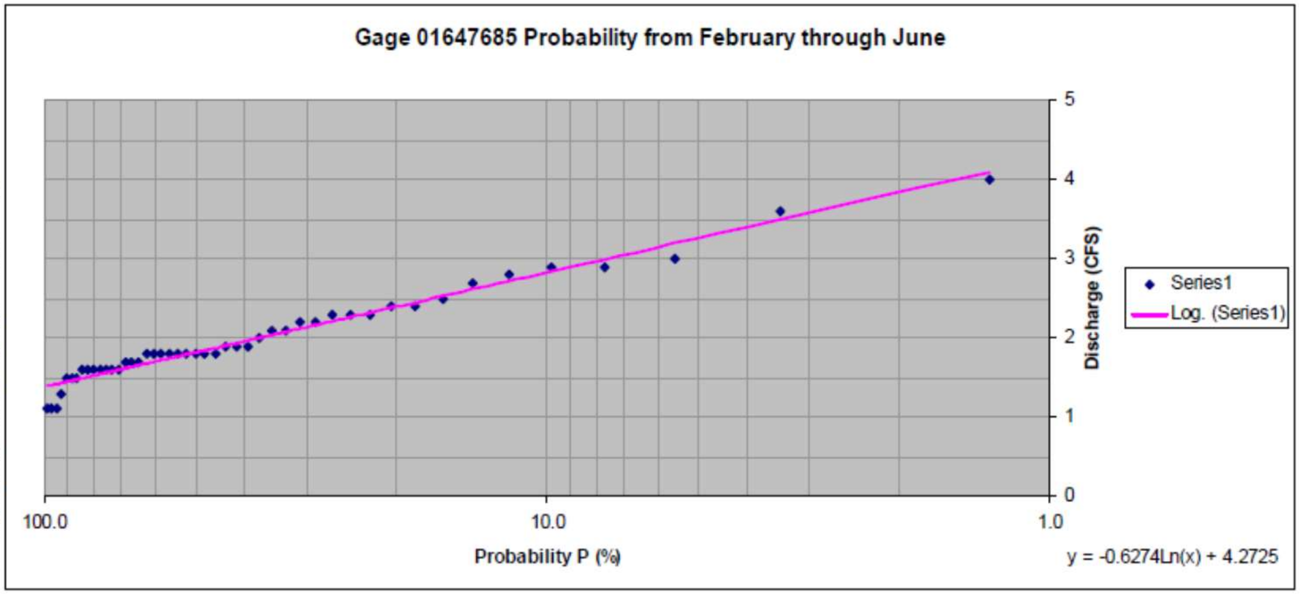
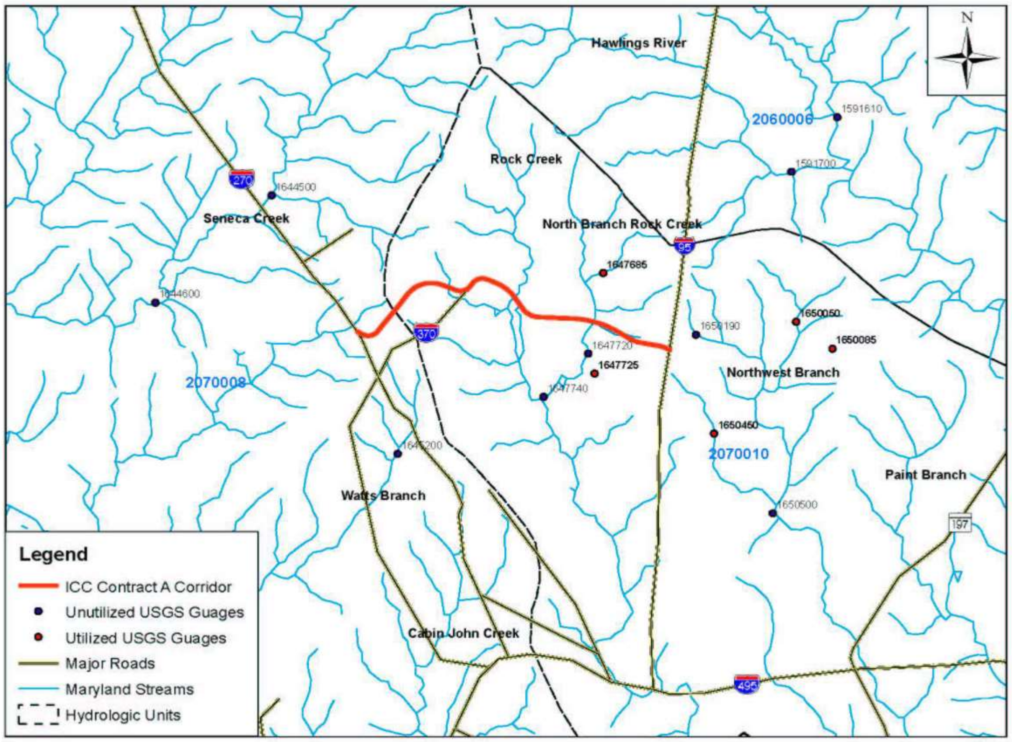


Table 1 - RANKED BASEFLOW DATA FOR FEB THROUGH J 01647685)

Day	Q	m	P	Day	Q	m	P	Day	Q	m	P	Day	Q	m	P	D
	cfs		%		cfs		%		cfs		%		cfs		%	
6/3	4	1	1.3	2/20	2.3	11	22.5	5/8	1.9	21	43.7	5/15	1.7	31	64.8	6
4/15	3.6	2	3.4	2/21	2.3	12	24.6	2/1	1.8	22	45.8	5/23	1.7	32	66.9	6
3/16	3	3	5.6	3/20	2.3	13	26.7	2/17	1.8	23	47.9	6/28	1.7	33	69.0	6
2/24	2.9	4	7.7	4/23	2.2	14	28.8	3/1	1.8	24	50.0	2/12	1.6	34	71.2	6
4/6	2.9	5	9.8	5/29	2.2	15	31.0	3/11	1.8	25	52.1	5/1	1.6	35	73.3	6
4/25	2.8	6	11.9	2/6	2.1	16	33.1	3/27	1.8	26	54.2	5/2	1.6	36	75.4	6
4/3	2.7	7	14.0	3/14	2.1	17	35.2	3/28	1.8	27	56.3	5/6	1.6	37	77.5	6
3/31	2.5	8	16.1	3/24	2	18	37.3	4/21	1.8	28	58.5	5/11	1.6	38	79.6	
2/9	2.4	9	18.3	4/11	1.9	19	39.4	6/1	1.8	29	60.6	5/18	1.6	39	81.7	
3/5	2.4	10	20.4	4/12	1.9	20	41.5	6/6	1.8	30	62.7	5/26	1.6	40	83.9	

The above equation is recommended for N = 10 to 100 (Critchley and Siegert, 1991). There are other, similar equations that are appropriate for larger data sets.

Baseflow Separation in Ungaged Stream

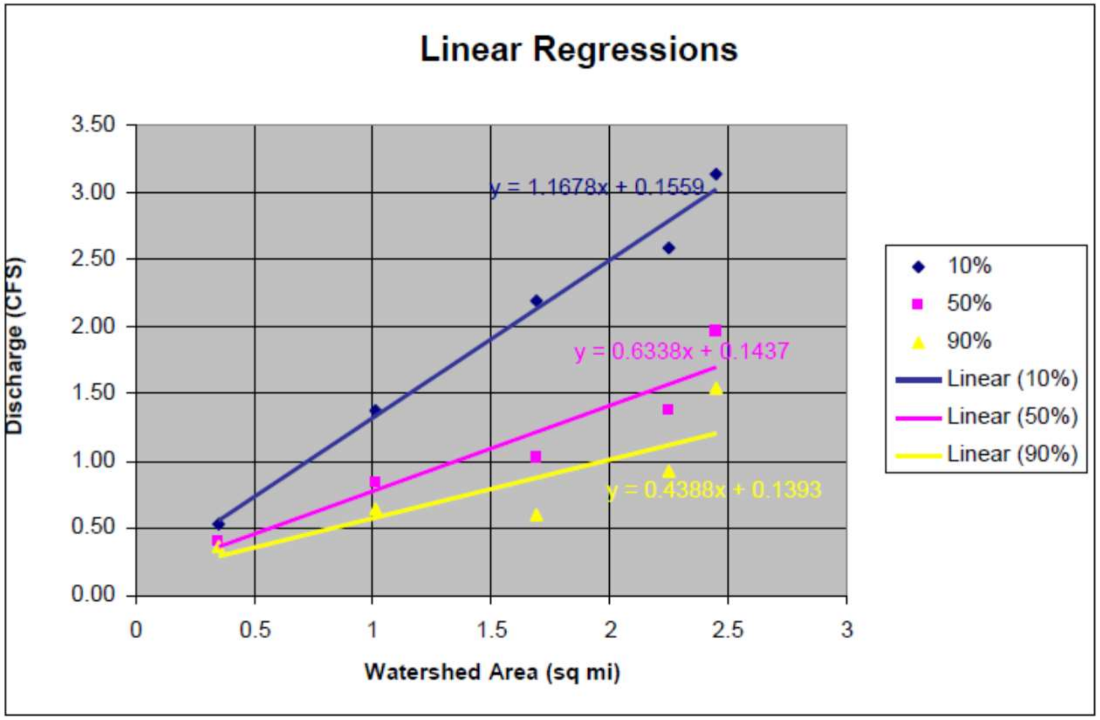


Choose similar gages:

- Proximity to the area of interest
- The same hydrologic unit
- Similar watershed areas
- Sufficiently large gage records
- Availability of daily data (vs. peak flow only)

Baseflow Separation in Ungaged Streams

Gage ID	Gage Description	Watershed Area (mi^2)	10% probability of exceedance discharge (cfs)	50% probability of ex[illegible] di[illegible]	90% probability of
USGS 01647685	WILLIAMSBURG RUN NEAR OLNEY, MD	2.25	2.59		
USGS 01650085	NURSERY RUN AT CLOVERLY, MD	0.35	0.53		
USGS 01647725	MANOR RUN NEAR NORBECK, MD	1.01	1.38		
USGS 01650450	BEL PRE CREEK AT LAYHILL, MD	1.69	2.20		
USGS 01650050	NW BRANCH ANACOSTIA RIVER AT NORWOOD, MD	2.45	3.13		



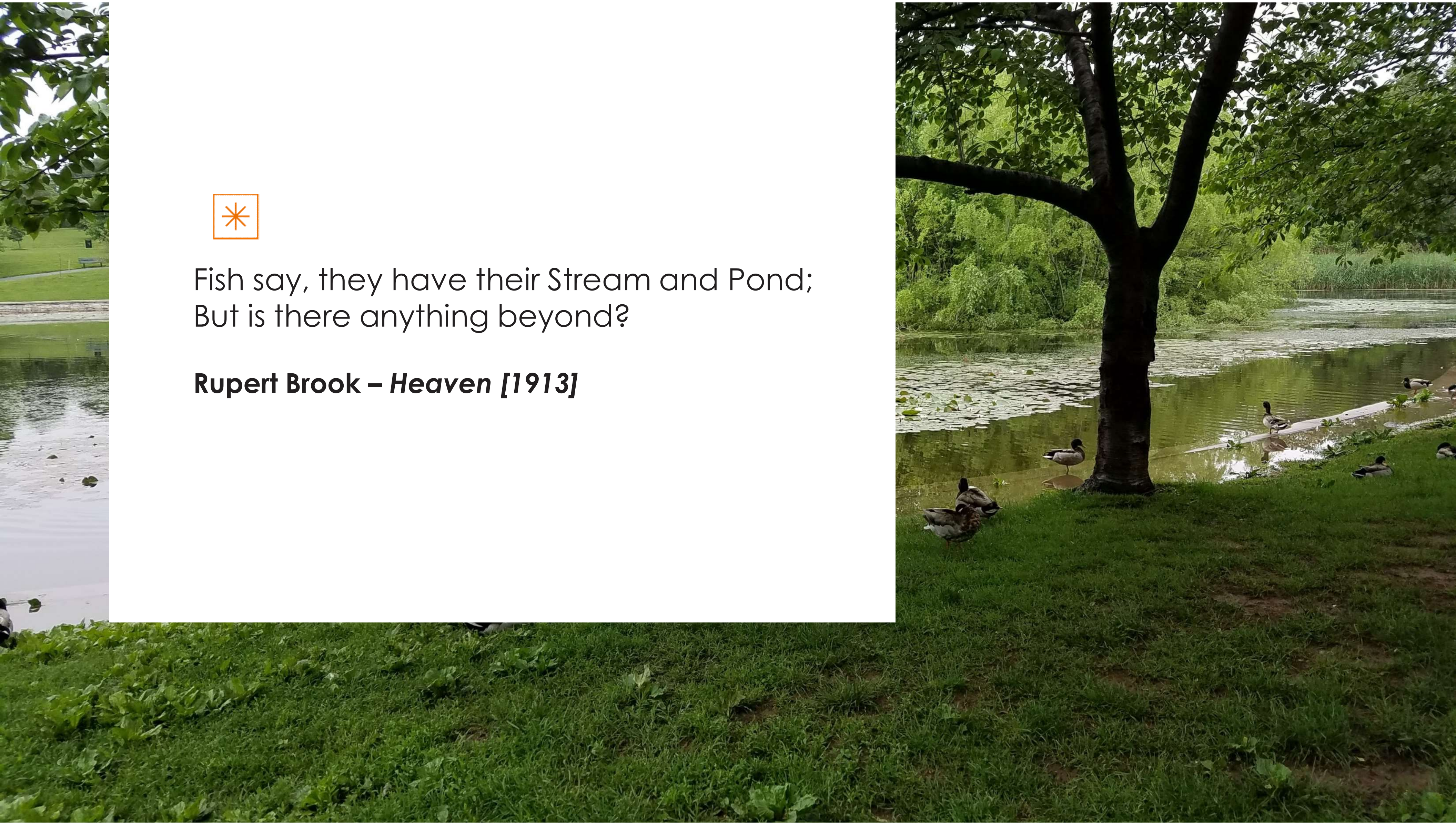
Fish Population

Site specific

- Fish shocking and identification

Department of Natural Resources/Fish and Game

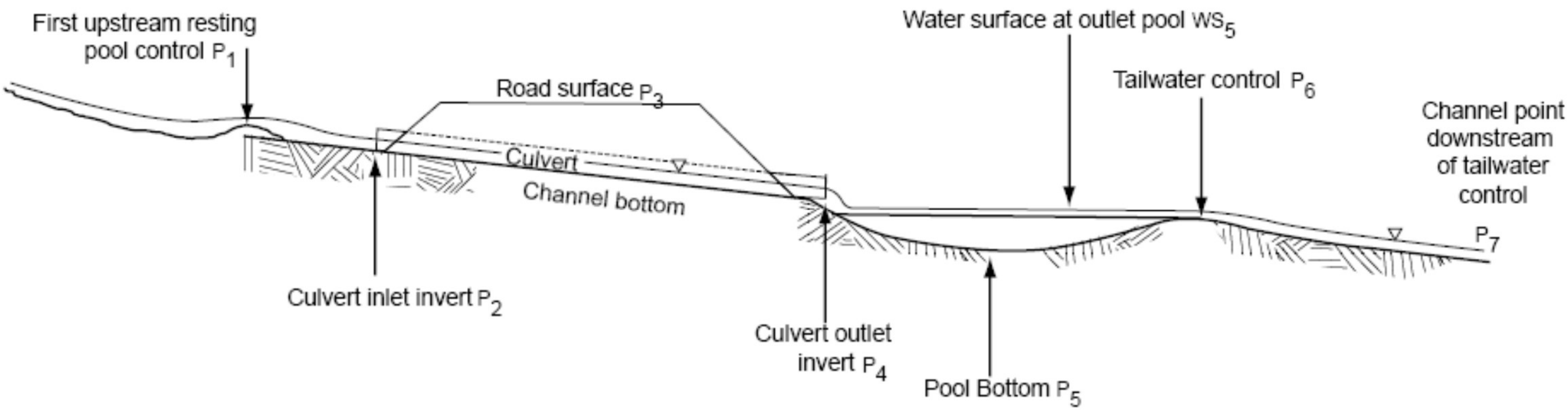
- Regional surveys
    - MBSS (MD DNR)
- Stream classification



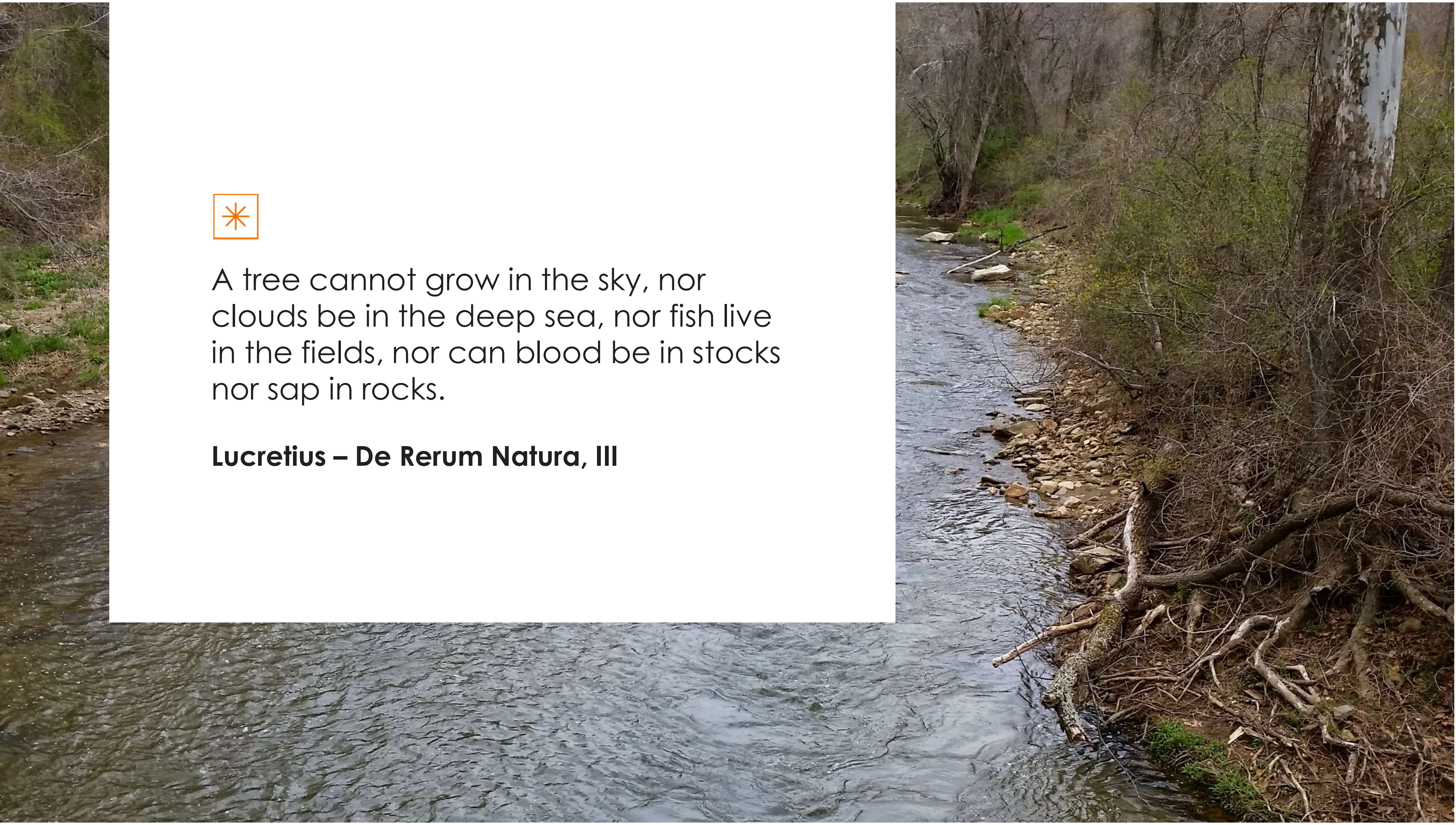
Fish say, they have their Stream and Pond;
But is there anything beyond?

Rupert Brook – *Heaven [1913]*

Culvert Characteristics



Establishing Criteria for Fish Passage



A tree cannot grow in the sky, nor clouds be in the deep sea, nor fish live in the fields, nor can blood be in stocks nor sap in rocks.

Lucretius – De Rerum Natura, III

Fish Passage Criteria

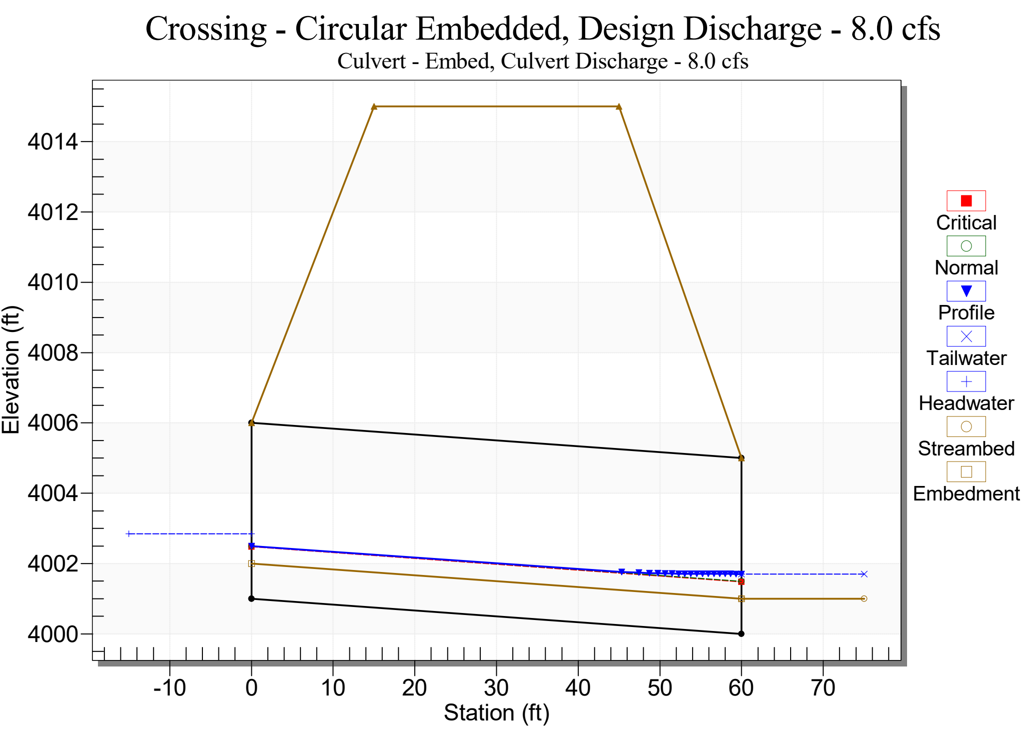
Determine the target species of fish and life stages upon the existing/historic fish population

Once the target species is selected, set the criteria for each culvert characteristic or barrier:

Culvert Characteristic	Possible Barrier
Outlet drop and outlet perch	Jump barrier
Culvert slope	Velocity barrier
Culvert slope times length	Exhaustion barrier
Presence of natural stream substrate	Depth barrier
Relationship of tailwater control elevation to culvert inlet elevation	Depth and velocity barrier

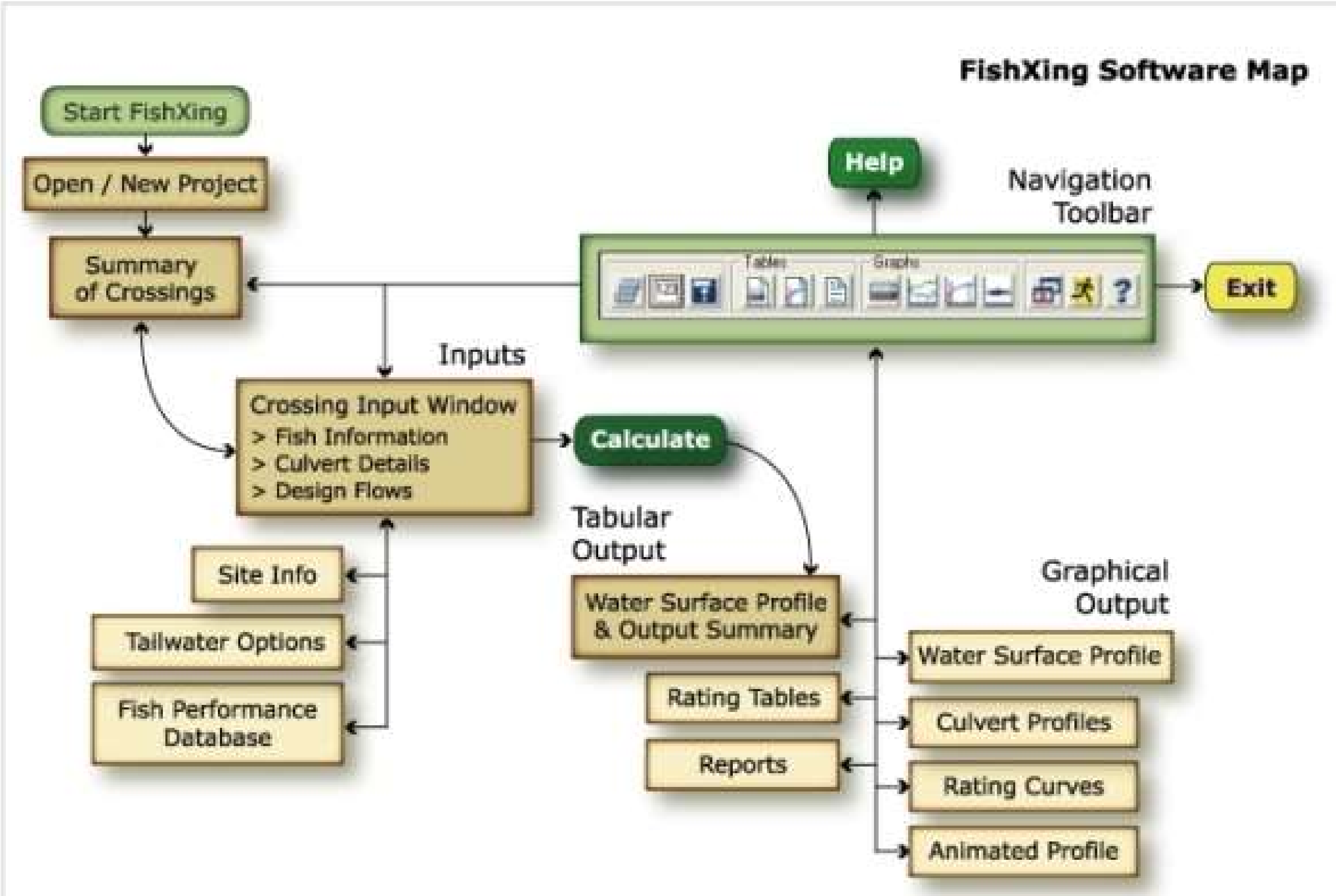
Modelling

Modelling

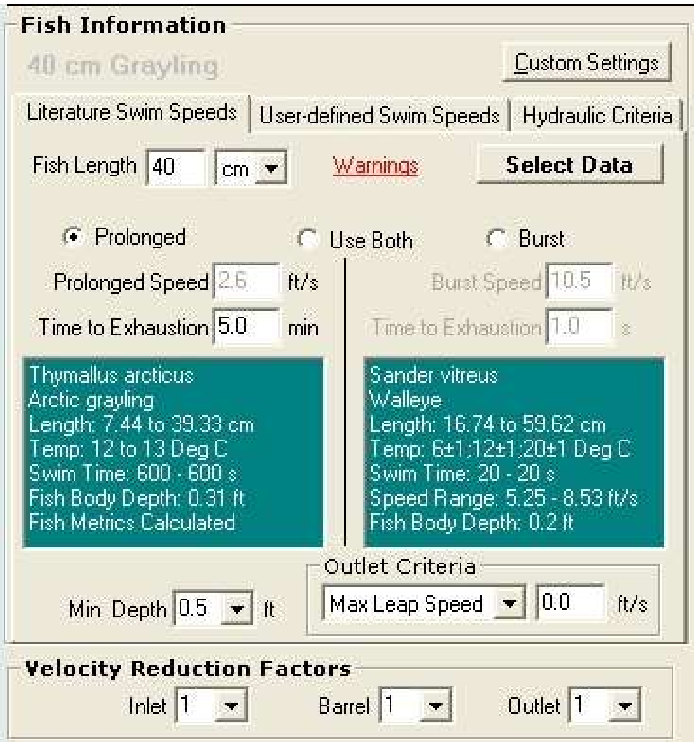


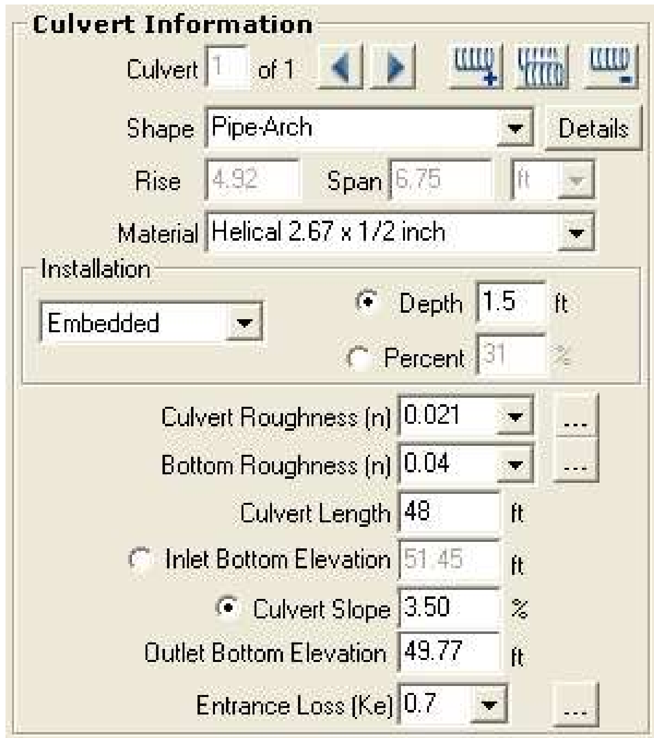
Software

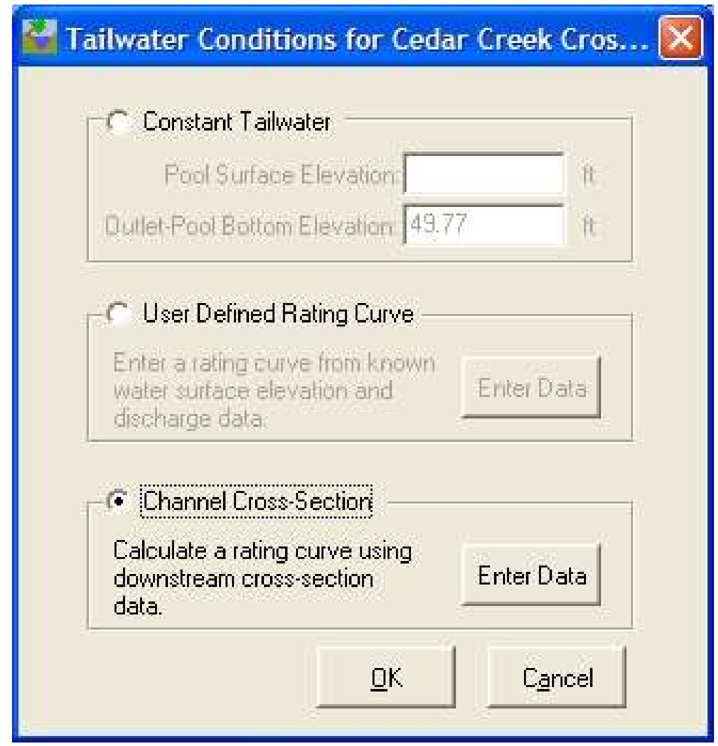
- FishXing - USDA Forest Service
  www.fs.fed.us/biology/nsaec/fishxing
- HEC-RAS - USACE
  www.hec.usace.army.mil/software/hec-ras/
- HY-8 - FHWA
  www.fhwa.dot.gov/engineering/hydraulics/software/hy8/


FishXing Software Map
Start FishXing
Open / New Project
Summary of Crossings
Help
Navigation Toolbar
Tables
Graphs
Exit
Inputs
Crossing Input Window
> Fish Information
> Culvert Details
> Design Flows
Calculate
Site Info
Tailwater Options
Fish Performance Database
Tabular Output
Water Surface Profile & Output Summary
Rating Tables
Reports
Graphical Output
Water Surface Profile
Culvert Profiles
Rating Curves
Animated Profile

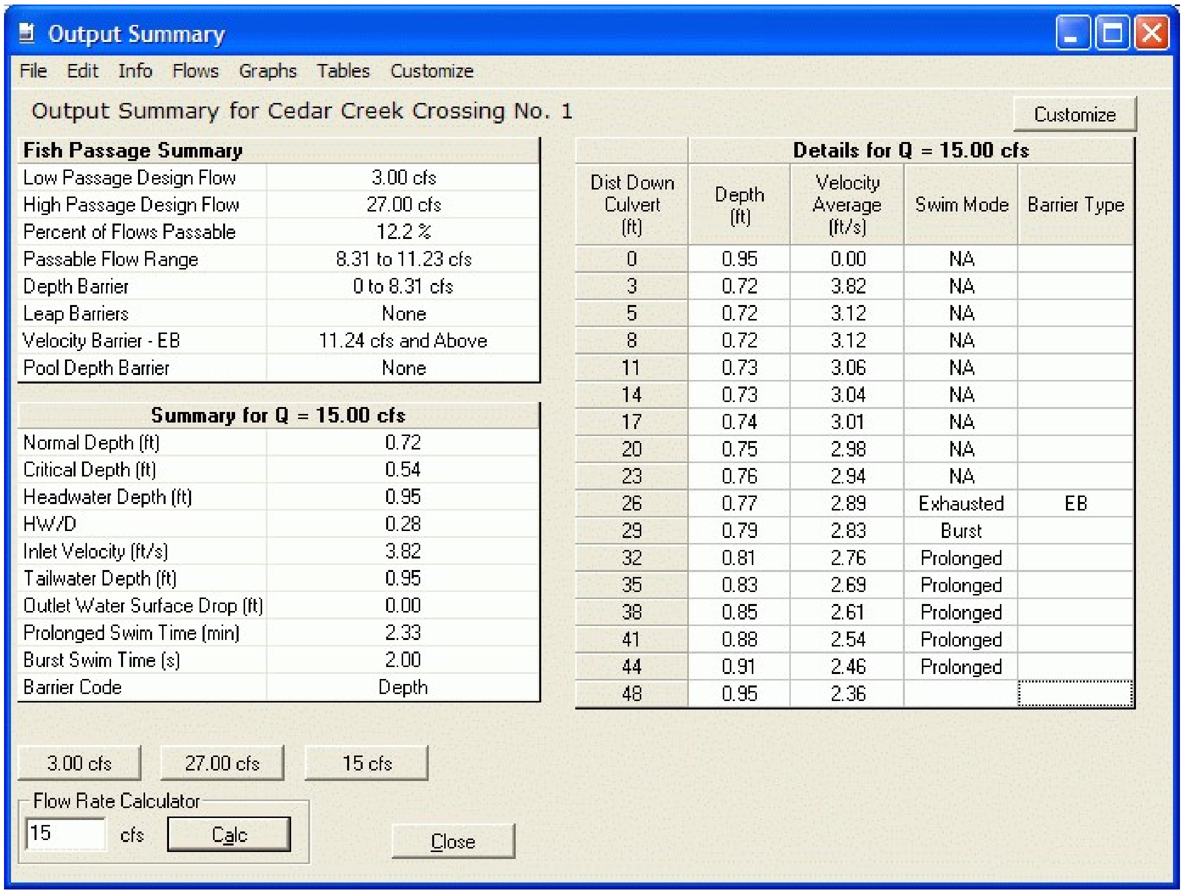
Fish Xing Inputs







Fish Xing Output Summary



Output Summary

File Edit Info Flows Graphs Tables Customize

Output Summary for Cedar Creek Crossing No. 1

Customize

Fish Passage Summary	
Low Passage Design Flow	3.00 cfs
High Passage Design Flow	27.00 cfs
Percent of Flows Passable	12.2 %
Passable Flow Range	8.31 to 11.23 cfs
Depth Barrier	0 to 8.31 cfs
Leap Barriers	None
Velocity Barrier - EB	11.24 cfs and Above
Pool Depth Barrier	None

Summary for Q = 15.00 cfs	
Normal Depth (ft)	0.72
Critical Depth (ft)	0.54
Headwater Depth (ft)	0.95
HW/D	0.28
Inlet Velocity (ft/s)	3.82
Tailwater Depth (ft)	0.95
Outlet Water Surface Drop (ft)	0.00
Prolonged Swim Time (min)	2.33
Burst Swim Time (s)	2.00
Barrier Code	Depth

	Details for Q = 15.00 cfs			
Dist Down Culvert (ft)	Depth (ft)	Velocity Average (ft/s)	Swim Mode	Barrier Type
0	0.95	0.00	NA	
3	0.72	3.82	NA	
5	0.72	3.12	NA	
8	0.72	3.12	NA	
11	0.73	3.06	NA	
14	0.73	3.04	NA	
17	0.74	3.01	NA	
20	0.75	2.98	NA	
23	0.76	2.94	NA	
26	0.77	2.89	Exhausted	EB
29	0.79	2.83	Burst	
32	0.81	2.76	Prolonged	
35	0.83	2.69	Prolonged	
38	0.85	2.61	Prolonged	
41	0.88	2.54	Prolonged	
44	0.91	2.46	Prolonged	
48	0.95	2.36		

3.00 cfs 27.00 cfs 15 cfs

Flow Rate Calculator

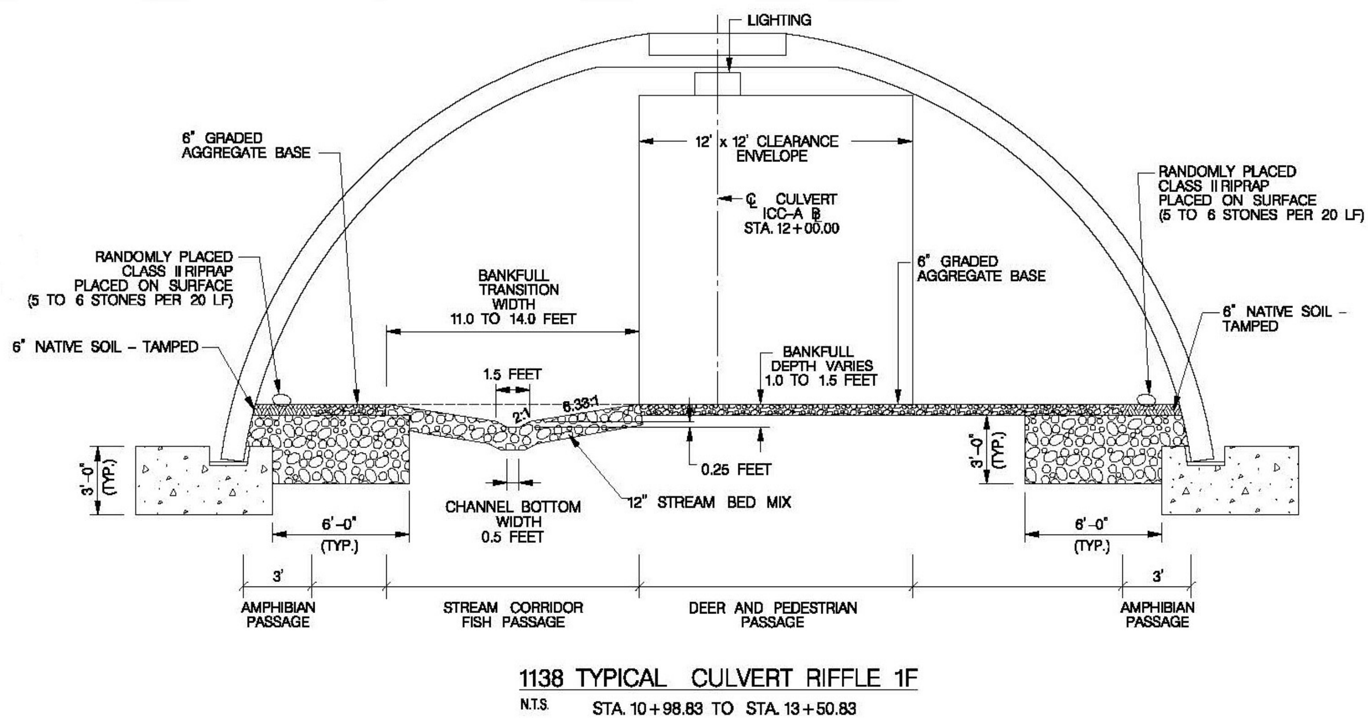
15 cfs Calc

Close

Projects

Hollywood Branch – Hydraulic Design

Unnamed Trib. To Mill Creek – Hybrid Design



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Fish Passage Analysis at Highway Culverts