ANR’s Work to Improve Aquatic Organism Passage at Stream Crossing Structures Throughout Vermont

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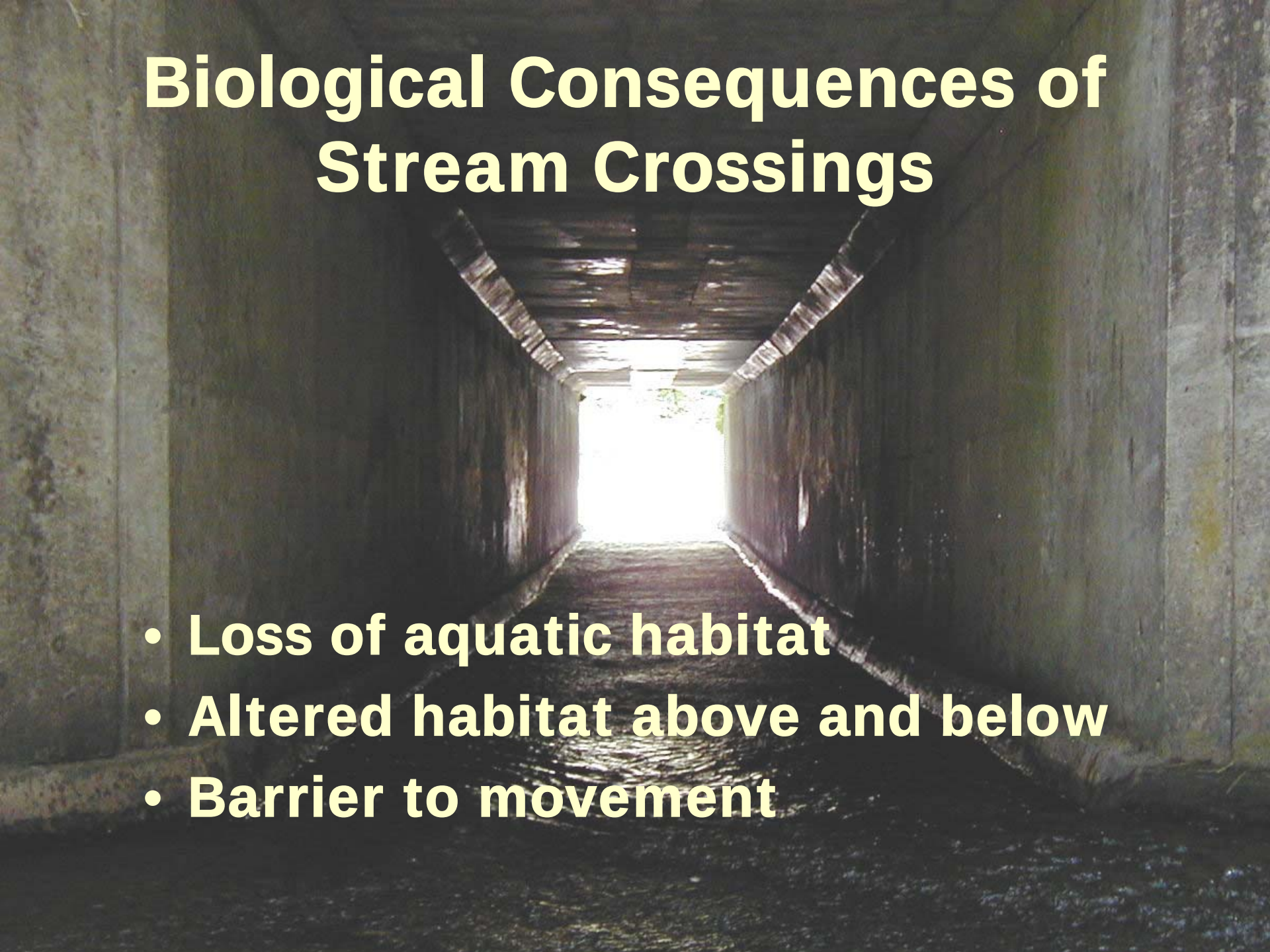
Vermont DEC, River Management Program

Presentation Outline

- The Problem
- Regulatory Obligations
- ANR Work to Improve AOP: A recent History
- Bridge and Culvert Assessment
- AOP and Geomorphic Compatibility Analyses
- AOP Guidelines
- Passable structures, a few examples

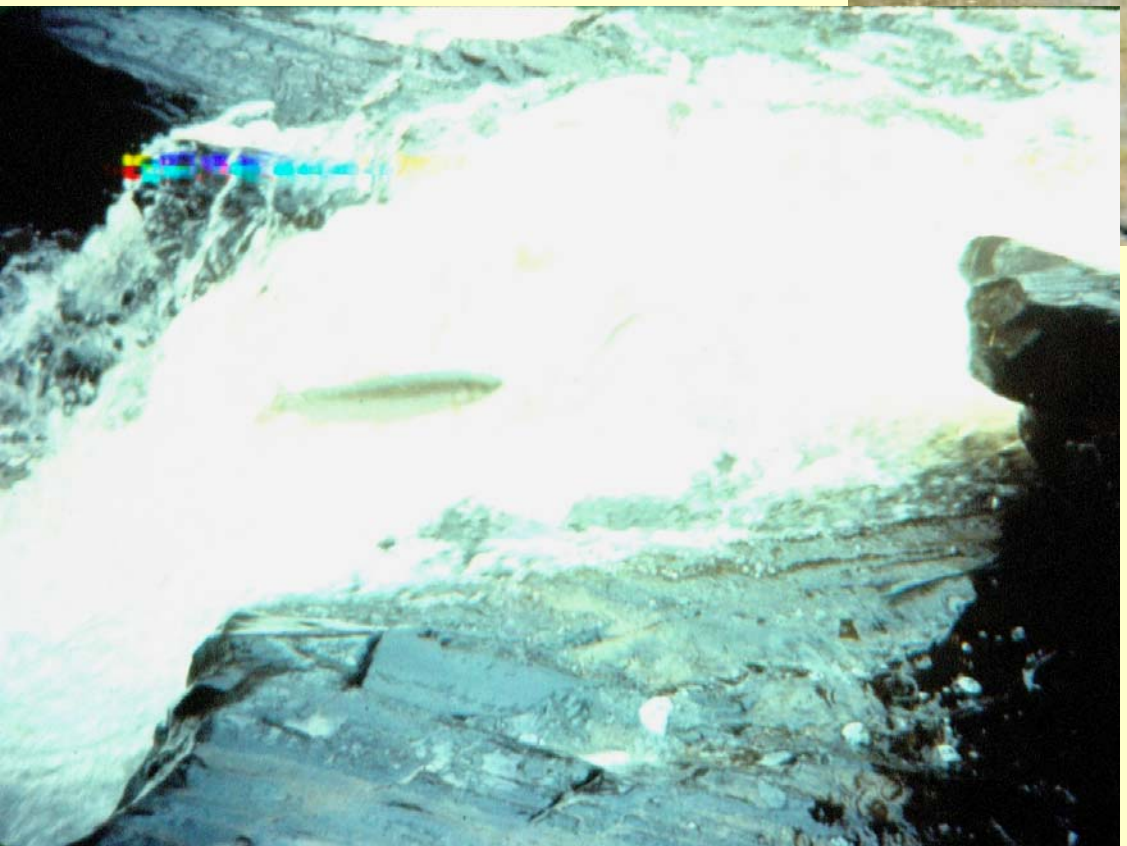
Biological Consequences of Stream Crossings



- Loss of aquatic habitat
- Altered habitat above and below
- Barrier to movement

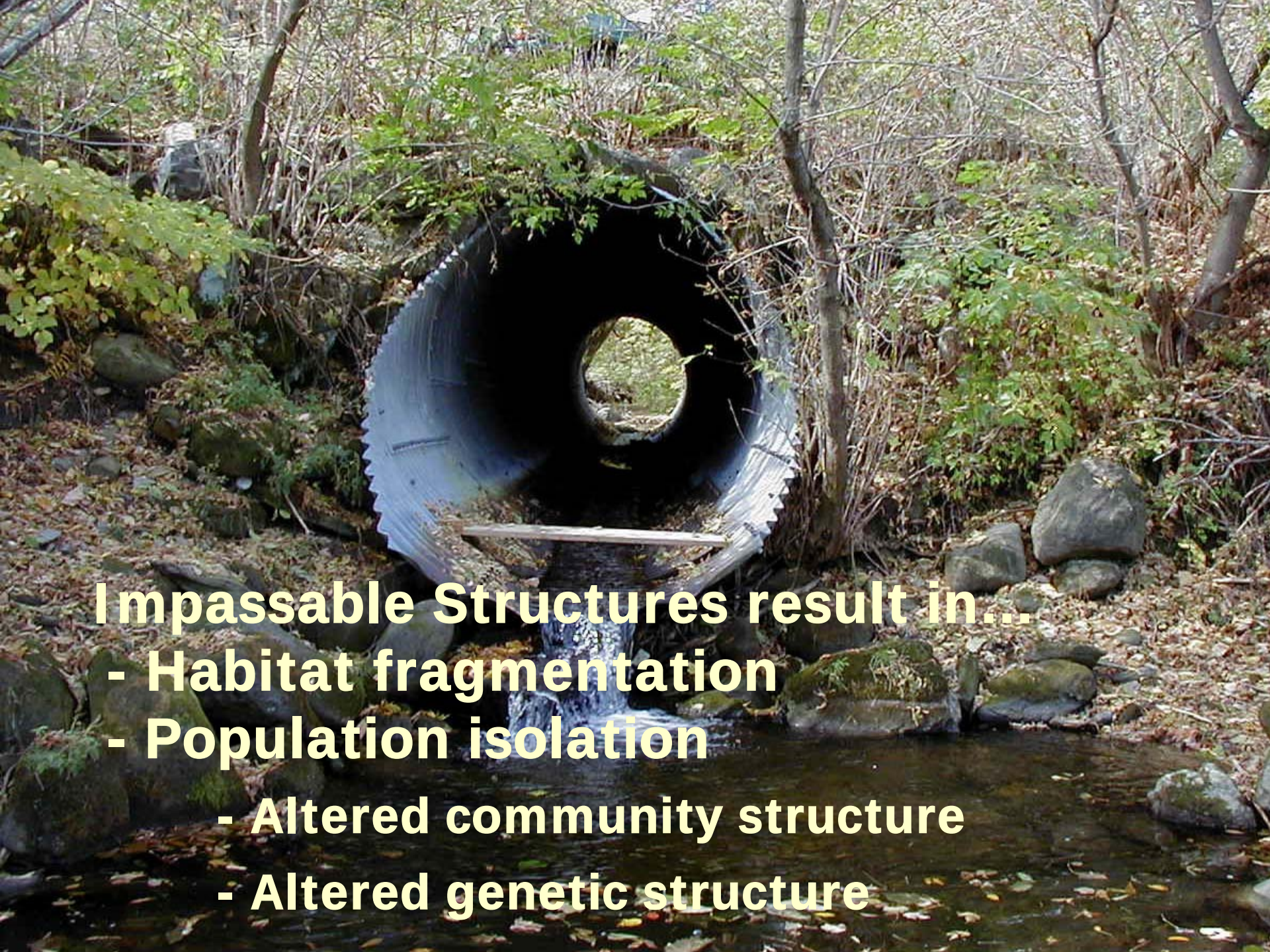
Aquatic Organism Movement

- Daily
  - feeding
  - resting



- Seasonal
  - reproduction
  - thermal refuge

(summer / winter)



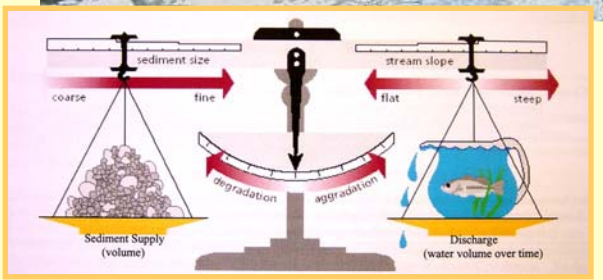
Impassable Structures result in…

- **Habitat fragmentation**
- **Population isolation**
  - **Altered community structure**
  - **Altered genetic structure**

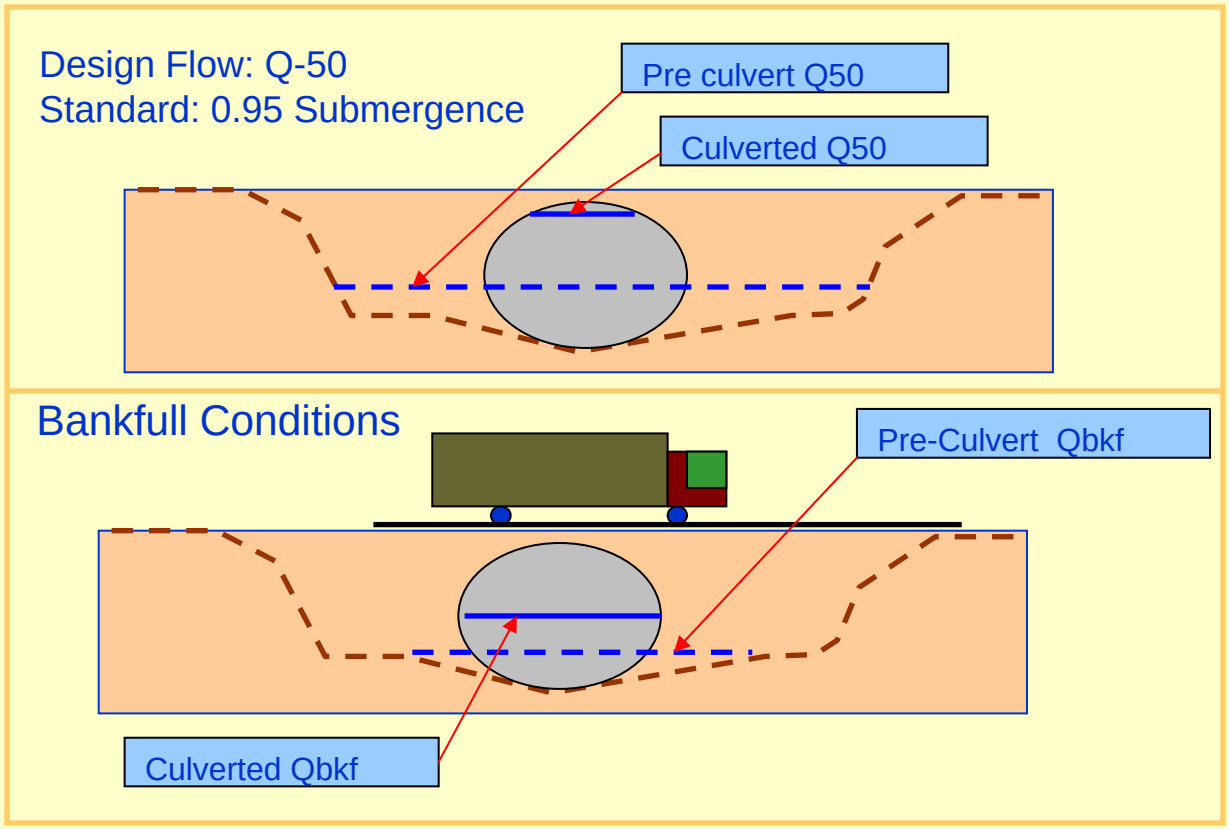
Barriers impact more than just trout:

Past structure design considered hydraulic capacity but did not always consider other stream functions – most importantly the transport of *sediment* and *debris!*

The most common problem created by crossing structures is a localized decrease in sediment transport capacity.

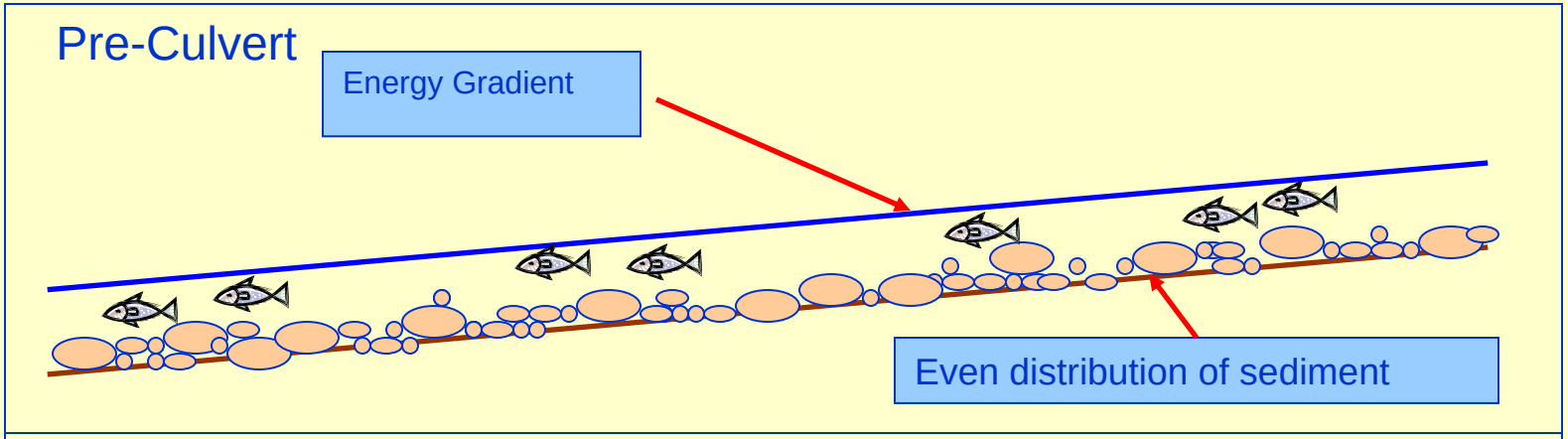


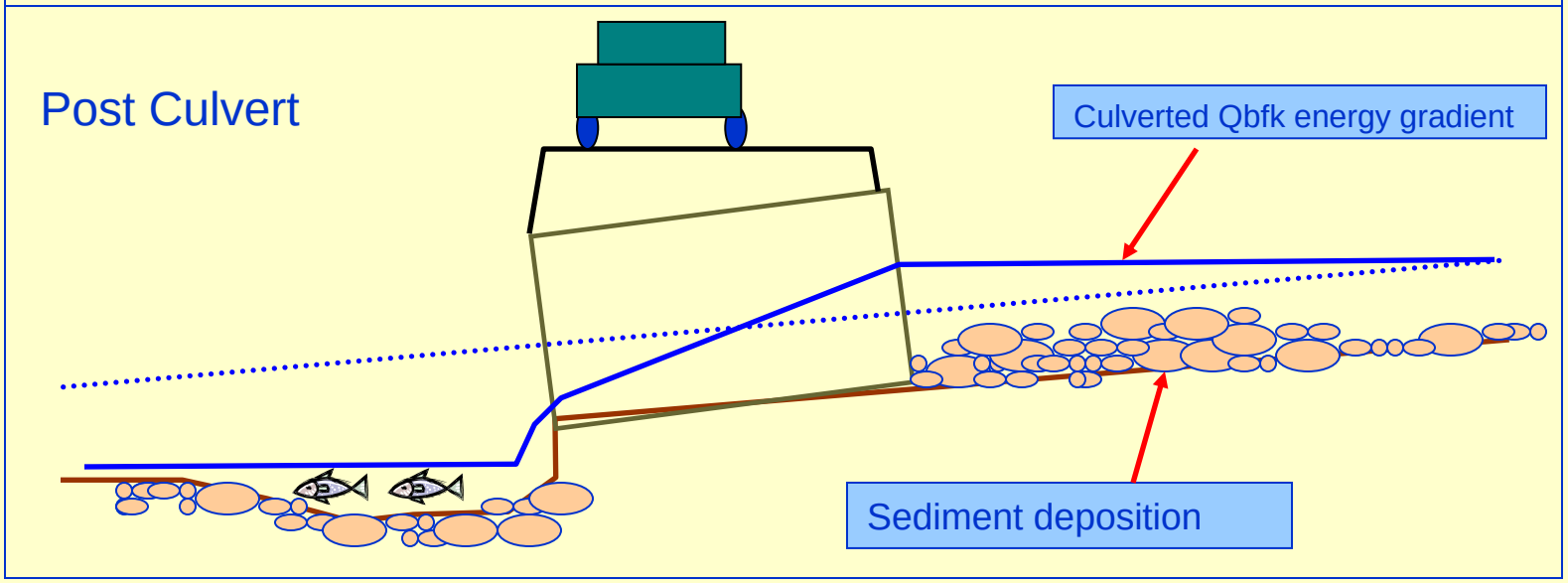
Hydraulic or flow criterion based design (i.e., pass design flow with max. specified submergence) results in decreased flow width and increased flow depth. Even at flows as low as Q2



The flattened water surface upstream of the culvert results in sediment deposition.

The elevated water surface in the structure results in increased velocities and scour at the culvert outlet which can create a barrier to fish movement.





Undersized Structures

Loss of stream sediment / debris transport – *aggradation above*

Undersized Structures

increased slope through the structure leads to incision

Undersized Structures

Loss of stream sediment / debris transport – *degradation below*

Undersized Structures

Habitat degradation above and below structure

Federal Regulatory Obligations

US Army Corps of Engineers Vermont General Permit:

"Waterway Crossings.

(a) All temporary and permanent crossings of waterbodies shall be suitably culverted, bridged, or otherwise designed to withstand and to prevent the restriction of high flows, to maintain existing low flows, and ***so as not to obstruct the movement of aquatic life indigenous to the waterbody beyond the actual duration of construction."***

Federal Regulatory Obligations

Clean Water Act: Nationwide Roads Exemption BMP 40CFR 232.3 c(6)

"The design, construction and maintenance of the road crossing shall not disrupt the migration or other movement of those species of aquatic life inhabiting the waterbody."

State Regulatory Obligations

VSA Title 10, Chapter 041

§1023. Regulation of Streamflow

"The permit shall be granted, subject to such conditions determined to be warranted, if it appears that the change:

2) ***will not significantly damage fish life or wildlife,"***

State Regulatory Obligations

VSA Title 10, Chapter 111

§ 4607. Obstructing streams

"(a) A person shall not, unless authorized by the commissioner, ***prevent the passing of fish*** in a stream or the outlet or inlet of a natural or artificial pond on a public stream, by means of a rack, screen, weir or other obstruction, and shall comply with the terms of the notice provided in subsection (b) of this section."

ANR Work to Improve AOP Throughout Vermont, A Recent History

- 2003, DEC & VT F&W Develop Bridge and Culvert Assessment Protocol to identify both AOP and Geomorphic Process issues.
- 2004-2007, VT F&W B&C Inventory for Vtrans
- ????, Development of critical culvert list review process (Vtrans and VT F&W)
- Increased pressure on Vtrans to comply with Federal and State Regulations
- Increased efforts by Vtrans to design passable structures
- 2004-2007, Cooperative Effort between Vtrans and ANR to develop Guidelines for Design of AOP in Stream Crossing Structures

ANR Work to Improve AOP Throughout Vermont, A Recent History

- 2007, VT AOP Guidelines referenced in ACOE General Permit
- 2007 and 2008, Workshops on use of the AOP design guidelines
- 2008, Improved AOP and Geomorphic Compatibility screening tools
- 2008, Continued work with Vtrans to make coarse screen data readily available
- 2008 and beyond, Use of ANR B&C screening tools by other agencies/orgs to help focus expenditure of AOP dollars (WHIP, USFWS, TNC)

Bridge and Culvert Assessment

Vermont Stream Geomorphic Assessment

Appendix G

Bridge and Culvert Assessment

Vermont Agency of Natural Resources
April, 2008

Aquatic Organism Passage (AOP) Assessment

- **Coarse screen** – watershed level assessment based upon of physical criteria. (ANR Geomorphic Assessment, Appendix G)

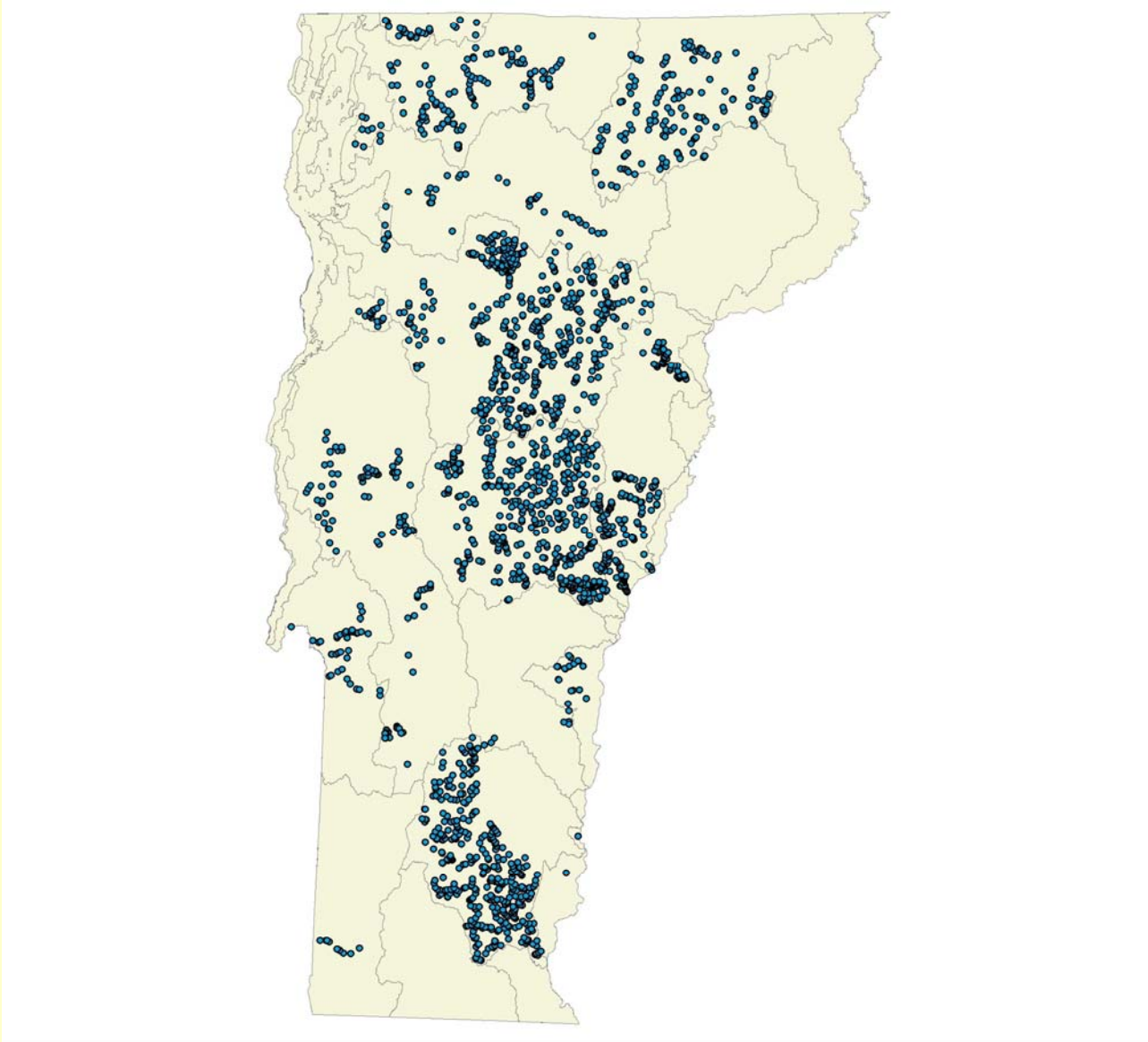
- **Hydraulic model (FishXing)** – uses site specific stream and structure measures; species specific biological criteria.

- **Biological assessment** – site specific sampling above and below structure.

VTrans/VDFW Culvert Inventory Project 2004-2007

Year	Streams	Coarse Screen	FishXing Surveys
2004	White River direct tributaries	243	40
2005	1st, 2nd & 3rd Branches of White; Lower Winooski, Lulls Brook, Black River..	334	36
2006	Upper Winooski, Neshobe, Clyde, Black, Barton, Baker	575	0
2007	Lower Winooski, Waits, Ompompanoosuc, Ottauquechee	700+	0
Total		***1852***	***76***

ANR Coarse Screen
Culvert Inventory Database
(2006)



AOP SWG – Culvert Screening Tool

- Contracted with Milone & McBroom
  - Evaluate and refine coarse screen criteria
  - Create screening tool which would further refine selection of potential AOP enhancement projects
  - Obtain or create and test a GIS tool to measure potential habitat gains for individual structures

VT Aquatic Organism Passage Coarse Screen	Full AOP	Reduced AOP	No AOP	
Updated 2/25/2008	for all aquatic organisms	for all aquatic organisms	for all aquatic organisms except adult salmonids	for all aquatic organisms including adult salmonids
AOP Function Variables / Values	Green (if all are true)	Gray (if any are true)	Orange	Red
Culvert outlet invert type	at grade OR backwatered	cascade	free fall AND	free fall AND
Outlet drop (ft)	= 0		> 0 , < 1 ft OR	≥ 1 ft OR
Downstream pool present			= yes (= yes AND	= no OR (= yes AND
Downstream pool entrance depth / outlet drop			n/m ≥ 1)	n/a < 1) OR
Water depth in culvert at outlet (ft)				< 0.3 ft
Number of culverts at crossing	1	> 1		
Structure opening partially obstructed	= none	≠ none		
Sediment throughout structure	yes	no		

Aquatic Organism Passage Criteria

- Outlet configuration (free-fall vs. cascade)
- Height of outlet drop
- Stream substrate within structure
- Inlet obstruction

Full Passage (Green)

- Outlet at grade
- Stream substrate throughout structure
- No inlet obstruction

Indeterminate (Grey)

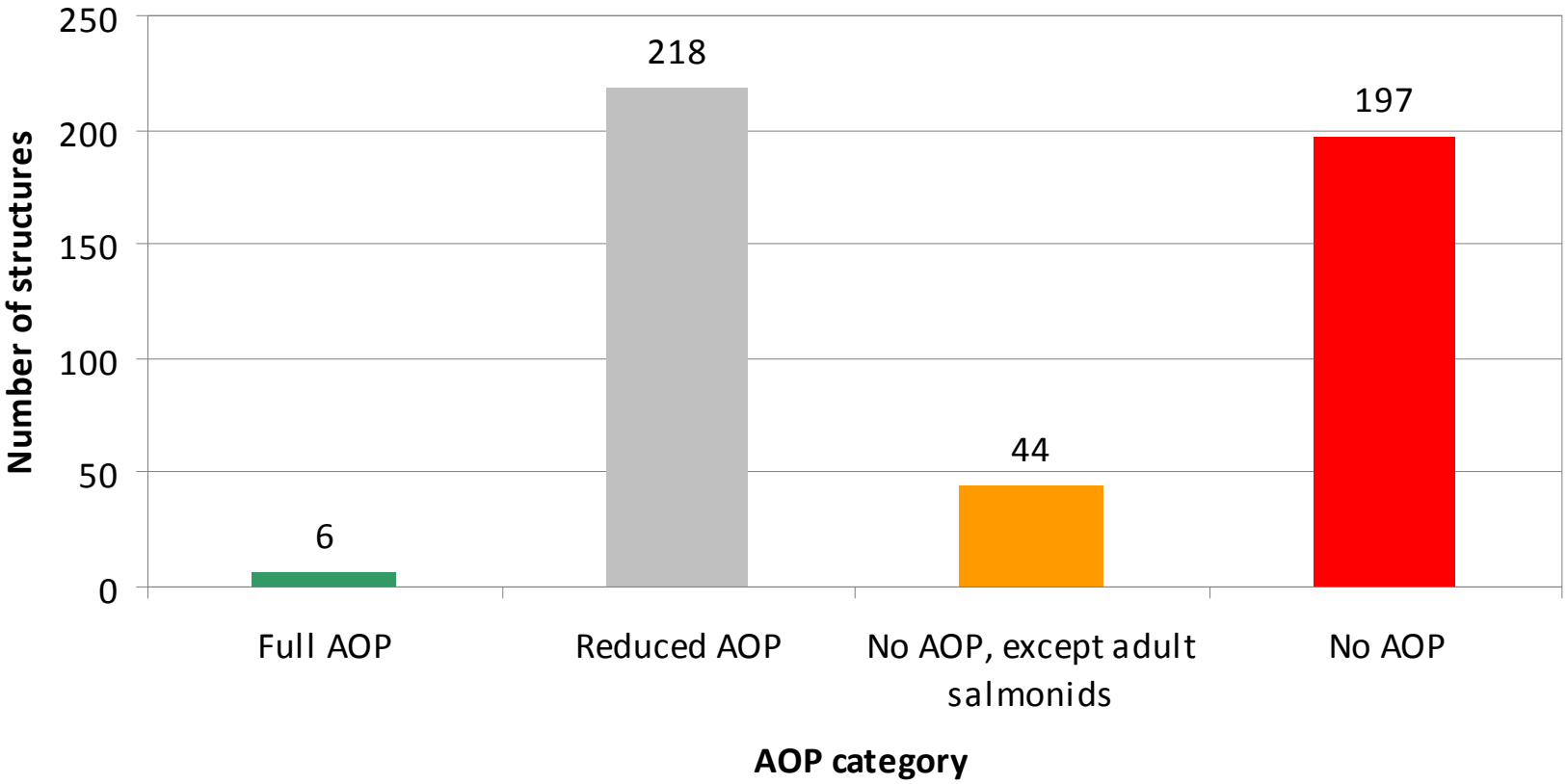
- Stream substrate <u>not</u> throughout structure
- Inlet obstruction
- Cascade at outlet

Impassable (Red)

Outlet drop – freefall

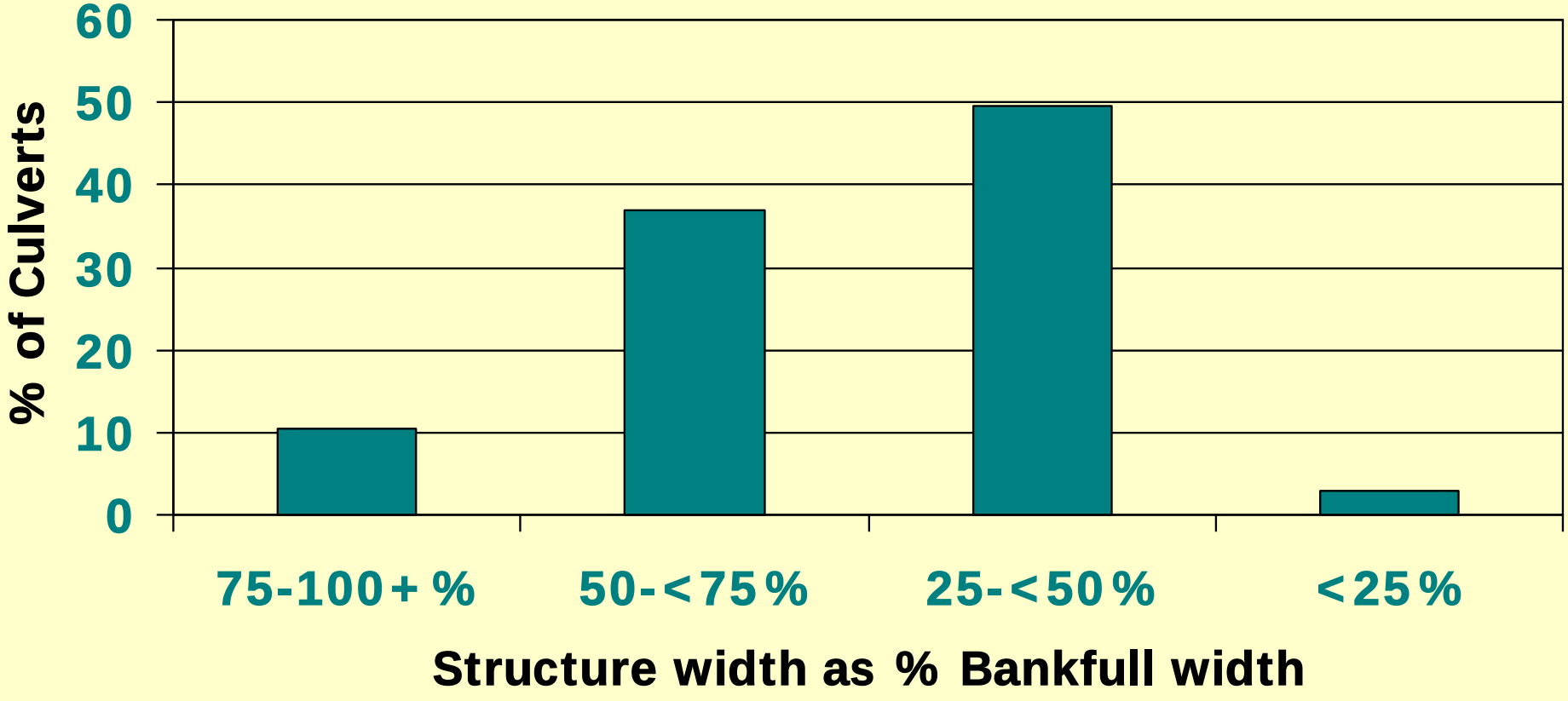
- >0 to <1.0 ft all but adult trout
- >1.0 ft – all including adult trout

AOP Coarse Screen Results (465 structures)



ANR AOP Screening: thru 2005

(464 single culverts, DA>0.25 mi^2)



ANR AOP Screening: thru 2005

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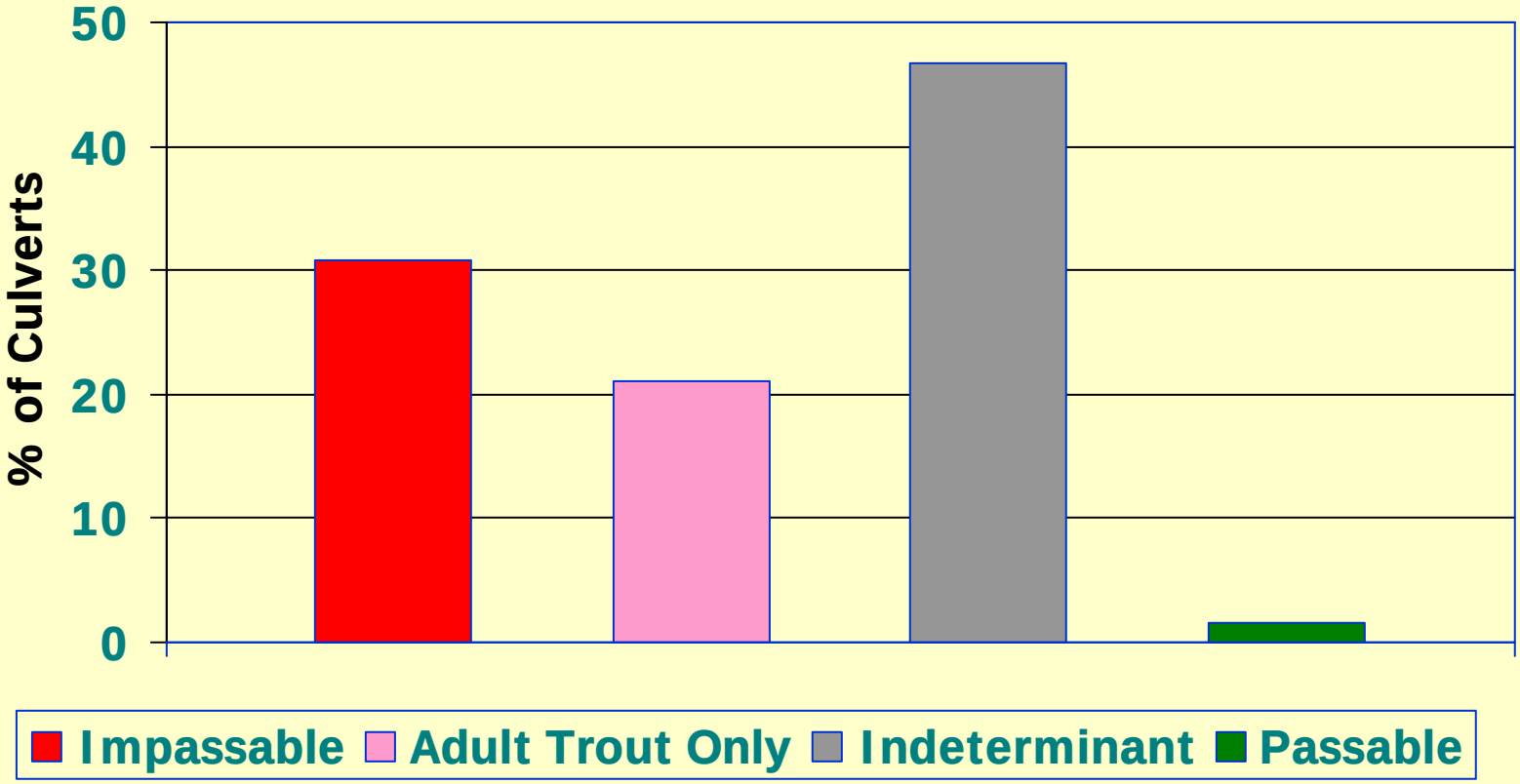


Updated February 25, 2008

Retrofit Potential

A) RPS Ranges and Variable Thresholds for Screen

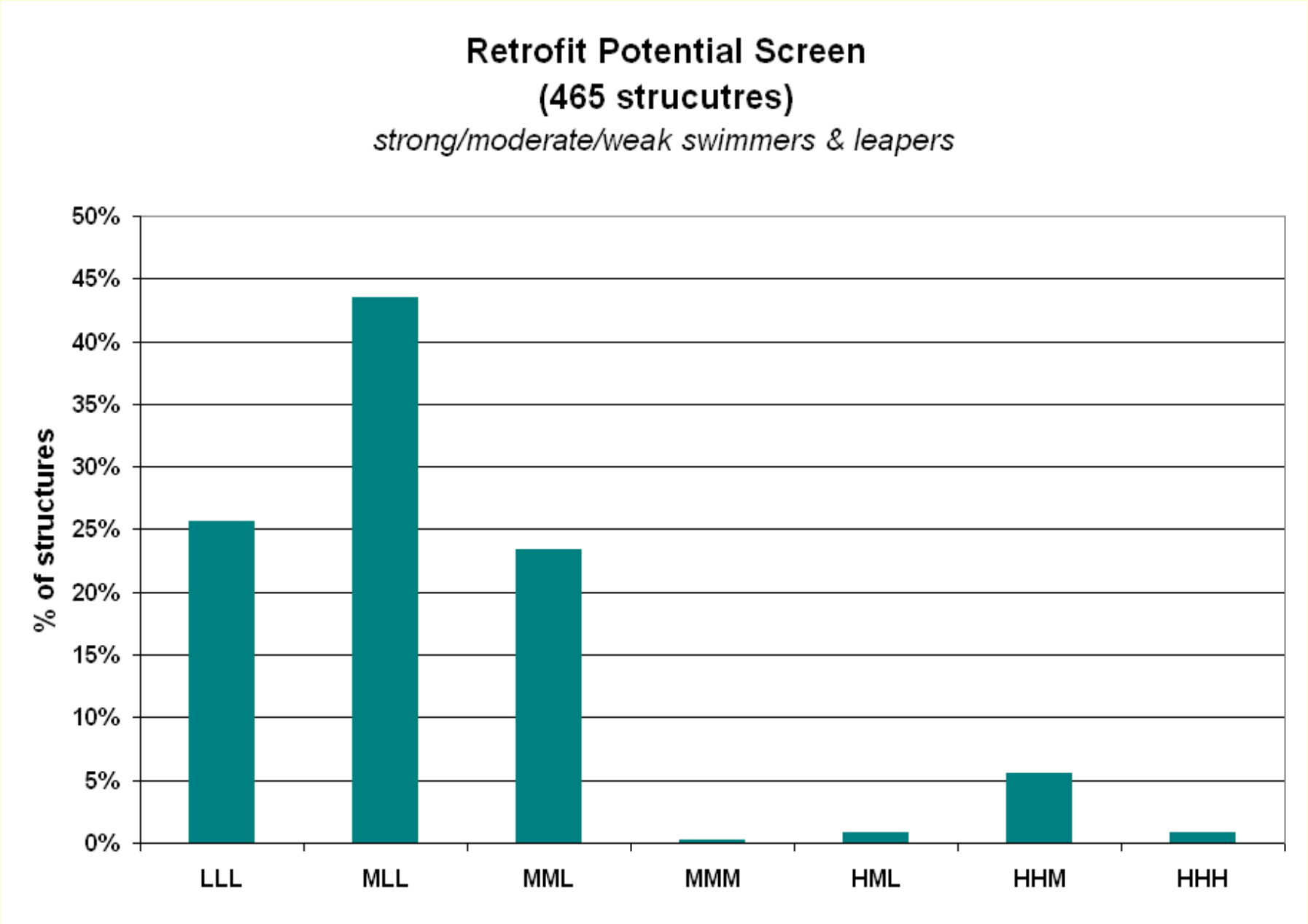
	Strong Swimmers/Leapers	*Moderate Swimmers/Leapers*	*Weak Swimmers/Leapers*
Low	%BFW < 30 **OR**	%BFW < 50 **OR**	%BFW < 75 **OR**
	[(L_{NBW} ≥ 200) **OR** (L ≥ 200 **AND** D < 1)] **OR**	[(L_{NBW} ≥ 100) **OR** (L ≥ 100 **AND** D < 1)] **OR**	[(L_{NBW} ≥ 100) **OR** (L ≥ 100 **AND** D < 1)] **OR**
	Od ≥ 2.5 **OR**	Od ≥ 1.5 **OR**	Od ≥ 1.0 **OR**
	0 ≤ RPS < 5	0 ≤ RPS < 5	0 ≤ RPS < 5
Medium	5 ≤ RPS < 9	5 ≤ RPS < 10	5 ≤ RPS < 12
High	%BFW ≥ 75 **AND**	%BFW ≥ 75 **AND**	%BFW ≥ 100 **AND**
	[(L_{NBW} < 100) OR (L < 100)] **AND**	[(L_{NBW} < 100) OR (L < 100)] **AND**	[(L_{NBW} < 100) OR (L < 100)] **AND**
	Od < 1.5 **AND**	Od < 1.0 **AND**	Od < 0.5 **AND**
	RPS ≥ 9	RPS ≥ 10	RPS ≥ 12

B) Aquatic Organism Groups Based on Swimming/Leaping Ability

Strong Swimmers/Leapers	*Moderate Swimmers/Leapers*	*Weak Swimmers/Leapers*
adult trout	juvenile trout	rainbow smelt
adult salmon	suckers	sculpin
American eel	shad	minnows
	lamprey	bass and sunfish
		pike, pickerel
		darters, perch, walleye
		stickleback
		aquatic salamanders

C) RPS Variable Scoring

Percent structure width of channel width		*Non-backwatered structure length (ft)*†		*Outlet drop height (ft)*	
Score	*Values*	*Score*	*Values*	*Score*	*Values*
0	%BFW < 30	0	L_{NBW} ≥ 300	0	Od ≥ 2.5
1	30 ≤ %BFW < 50	1	200 ≤ L_{NBW} < 300	1	2.0 ≤ Od < 2.5
2	50 ≤ %BFW < 75	2	100 ≤ L_{NBW} < 200	2	1.5 ≤ Od < 2.0
3	75 ≤ %BFW < 100	3	40 ≤ L_{NBW} < 100	3	1.0 ≤ Od < 1.5
4	100 ≤ %BFW < 120	4	25 ≤ L_{NBW} < 40	4	0.5 ≤ Od < 1.0
5	%BFW ≥ 120	5	L_{NBW} < 25	5	Od < 0.5


Retrofit Potential Screen
(465 strucutres)
strong/moderate/weak swimmers & leapers
% of structures
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
LLL
MLL
MML
MMM
HML
HHM
HHH

Geomorphic Compatibility Screen

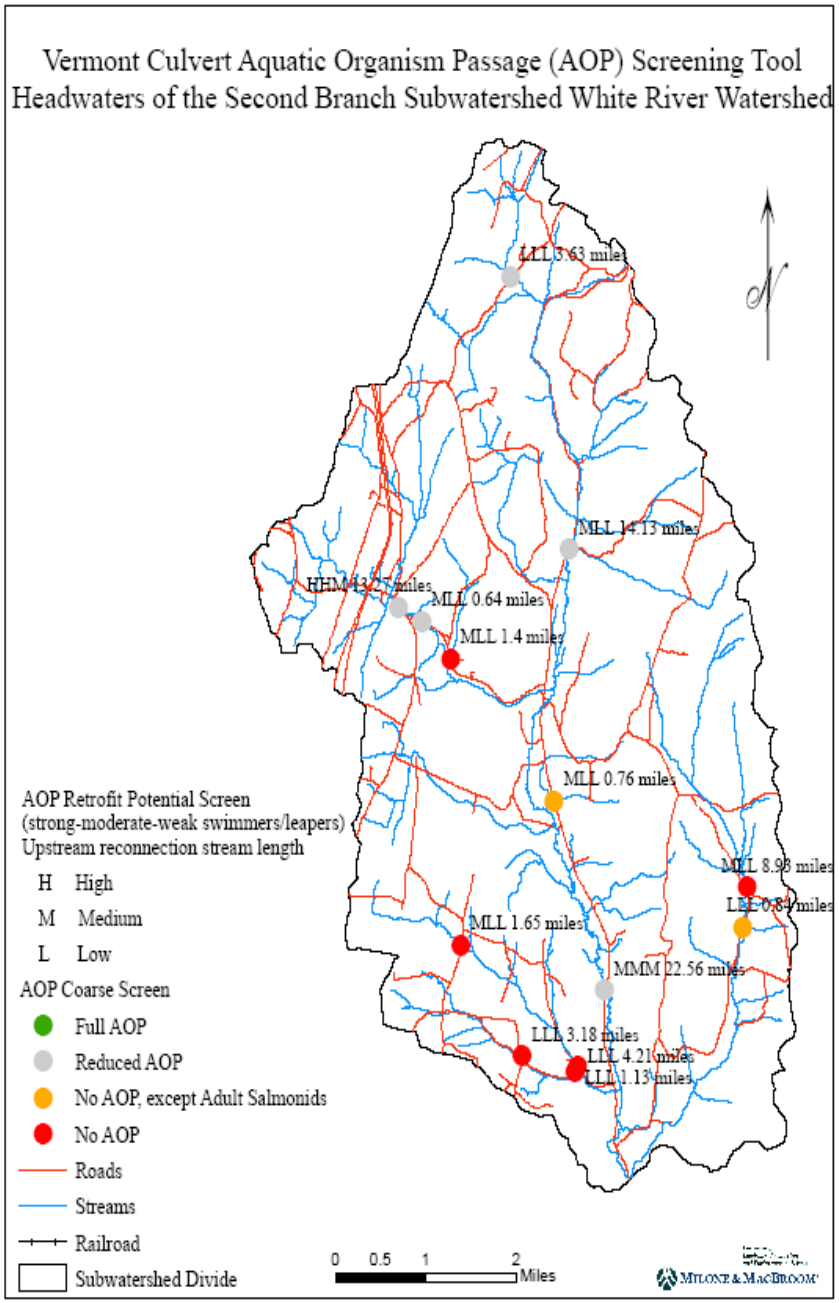
Score	% Bankfull Width	Sediment Continuity	Slope	Approach Angle	Erosion and Armoring
5	$W_{st/bkf} \geq 120$	No upstream deposition or downstream bed scour	Structure slope equal to channel slope, and no break in valley slope	Naturally straight	No erosion **or** armoring
4	$100 \leq W_{st/bkf} < 120$	**Either** upstream deposition **or** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	n/a	No erosion **and** intact armoring, **or** low upstream **or** downstream erosion **without** armoring
3	$75 \leq W_{st/bkf} < 100$	**Either** upstream deposition **or** downstream bed scour, **with** either upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Structure slope equal channel slope, with local break in valley slope	Mild bend	Low upstream **or** downstream erosion **with** armoring
2	$50 \leq W_{st/bkf} < 75$	**Both** upstream deposition **and** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Structure slope higher or lower than channel slope, and no break in valley slope	Channelized straight	Low upstream **and** downstream erosion
1	$30 \leq W_{st/bkf} < 50$	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	n/a	Severe upstream **or** downstream erosion
0	$W_{st/bkf} < 30$	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **and** high downstream banks	Structure slope higher or lower than channel slope, with local break in valley slope	Sharp bend	Severe upstream **and** downstream erosion, **or** failing armoring upstream **or** downstream

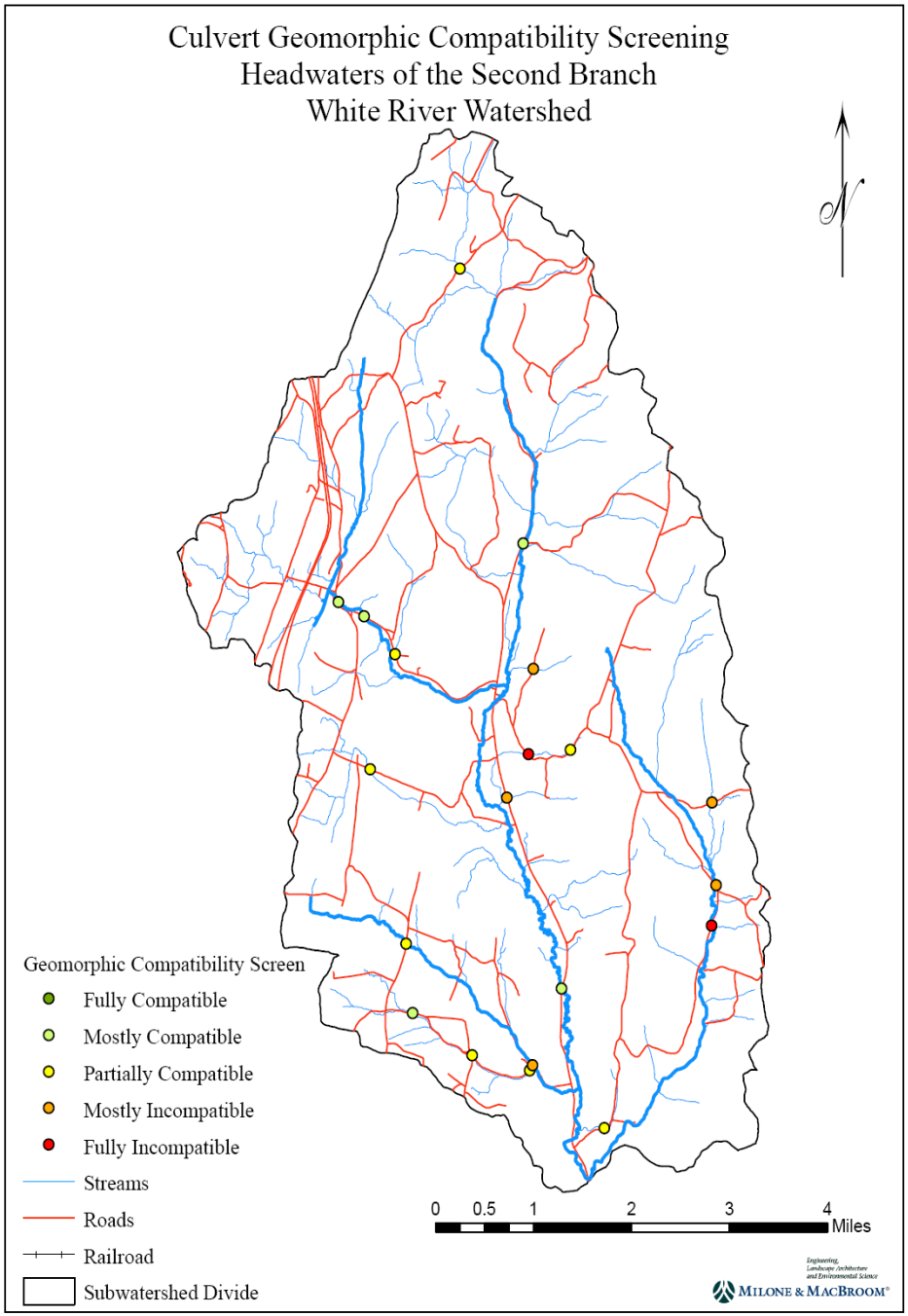
GC Screen Score (%)	Description of geomorphic compatibility between structure and channel	# of structures with this score	% of structures with this score
81 - 100	Structure fully compatible with natural channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. A similar structure is recommended when replacement is needed.	88	5
61 - 80	Structure mostly compatible with current channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. Minor design adjustments recommended when replacement is needed to make fully compatible.	541	32
41 - 60	Structure compatible with either current form or process, but not both. Compatibility likely short term. There is a moderate risk of structure failure and replacement may be needed. Re-design suggested to improve geomorphic compatibility.	704	42
21 - 40	Structure mostly incompatible with current form and process, with a moderate to high risk of structure failure. Re-design and replacement planning should be initiated to improve geomorphic compatibility.	328	19
0 - 20	Structure fully incompatible with channel and high risk of failure. Re-design and replacement should be performed as soon as possible to improve geomorphic compatibility.	26	2

White River Results

4	157	30	135
GREEN	GRAY	ORANGE	RED
1%	48%	9%	41%

5	93	165	145	26
Full Compatibility	Mostly Compatible	Compatible in short term	Mostly incompatible	Incompatible
1%	21%	38%	33%	6%


Vermont Culvert Aquatic Organism Passage (AOP) Screening Tool
Headwaters of the Second Branch Subwatershed White River Watershed
LLL 3.63 miles
MLL 14.13 miles
HHM 13.27 miles
MLL 0.64 miles
MLL 1.4 miles
MLL 0.76 miles
MLL 8.98 miles
LLL 0.84 miles
MLL 1.65 miles
MMM 22.56 miles
LLL 3.18 miles
LLL 4.21 miles
LLL 1.13 miles
AOP Retrofit Potential Screen
(strong-moderate-weak swimmers/leapers)
Upstream reconnection stream length
H High
M Medium
L Low
AOP Coarse Screen
Full AOP
Reduced AOP
No AOP, except Adult Salmonids
No AOP
Roads
Streams
Railroad
Subwatershed Divide
0 0.5 1 2
Miles
Milone & MacBroom


Culvert Geomorphic Compatibility Screening
Headwaters of the Second Branch
White River Watershed
N
Geomorphic Compatibility Screen
Fully Compatible
Mostly Compatible
Partially Compatible
Mostly Incompatible
Fully Incompatible
Streams
Roads
Railroad
Subwatershed Divide
0
0.5
1
2
3
4
Miles
Engineering,
Landscape Architecture
and Environmental Science
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Stream Crossing AOP Guidelines

Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont

Kozmo Ken Bates, P.E., Kozmo, Inc.
Rich Kirn, Vermont Department of Fish and Wildlife

Final Draft-February 2008

VERMONT

Stream Crossing AOP Guidelines
The Process

- Contracted with Kozmo Ken Bates to develop guidelines
  - Chief fish passage engineer for WA F&G (25 years)
  - Primary engineering author for WA F&G Fish Passage Guidelines; assisted other states/agencies
  - Taught fish passage design courses for USFWS, University of Wisconsin, etc.

- AOP Workshop – July 2005, full-week
  - Introduce AOP design concepts
  - Identified issues to address during guideline development
  - Participants included VTrans, VDF&P, VDEC, VTF&W, USFWS, US CofE

- Guideline Review Committee
  - Vtrans (5), VDEC (2), VDFW (1)
  - 50% draft March 2006; 90% draft March 2007
  - Other reviewers: USFS, USFWS, USGS (UVM), TNC, TU, VTF&P, USEPA, US CofE

AOP Guidelines STATEMENT OF PURPOSE

This document is intended to provide technical guidance in the design and construction of stream/road crossings where the need for passage of aquatic organism passage has been identified. This guide is neither a cookbook nor a manual. Each site is unique, and conditions will lead to individual solutions. .....

These guidelines are not intended for use as a regulatory document. They are informative and do not impose any legal or regulatory requirement on the owner/designer of the project.

Ongoing or recent work

- 2007 Workshops for private and public sector structure designers
- 2008 Workshops for private and public sector structure designers
- Continued work with Vtrans on accessing and utilizing coarse screen data
- Continued tech assistance with identifying AOP needs and structure design

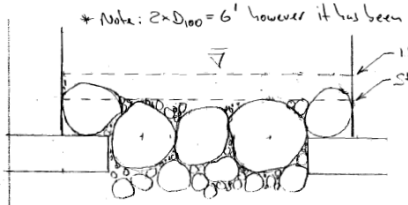
AOP Design

Open Bottom Structure

Rock band design : Cross Section

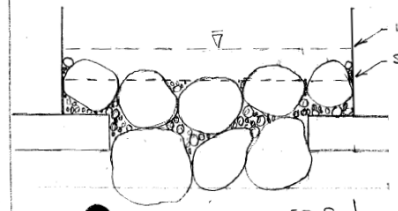
In ideal scenario the rock bands would be constructed with a footer course of 4 ft dia (4'×4'×3') boulders topped with 3 ft. boulders. The goal is for the top course to move over time and the footer course to stay in place. Sizing depicted here follows the draft guidance manual for PDP where non-mobile material should be $2 \times D_{100}$*, and step forming boulders $= D_{100}$

* Note: $2 \times D_{100} = 6'$ however it has been deemed impractical to use anything larger than 4'.



Existing Scenario

- 3-4 ft dia boulders between poured footers.
- 2 ft. boulders set on poured footers

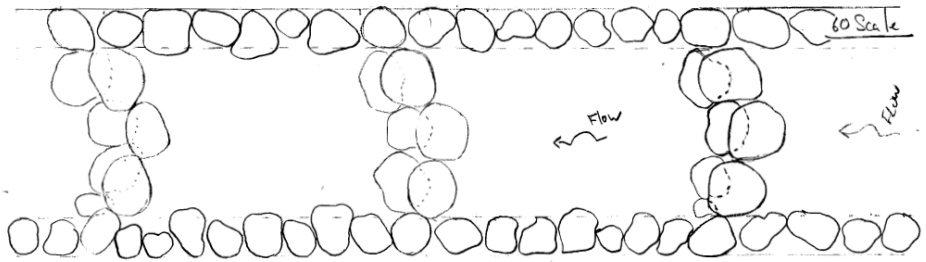


Ideal Design Scenario (requires 2 ft. of excavation below poured footers)

- 4 ft dia (on 2 dimensions) Boulders used in footer course
- 3 ft dia (on 2 dimensions) used in top course

50 Scale

Plan View



- Back lines along edge of the arch walls of 2-3 ft stone. Purpose is to create roughness along margins.
- Rock bands are shown with a footer and top course with the footer course offset slightly downstream to provide energy dissipation. It is recognized that excavation to accomodate the footer course may not be possible
- It is important that the rock bands be constructed curvilinear in plan form such that they are concave in the downstream direction so that the boulders support eachother against the flow and the flow is directed toward the center of the channel as it spills over each rock band.

AOP Design
Embedded Pipe

AOP Design

Box with constructed bed

Potential Retrofit Solutions

Grade control structures to backwater outlet

Baffles or weirs to reduce velocities or increase or depth within structure