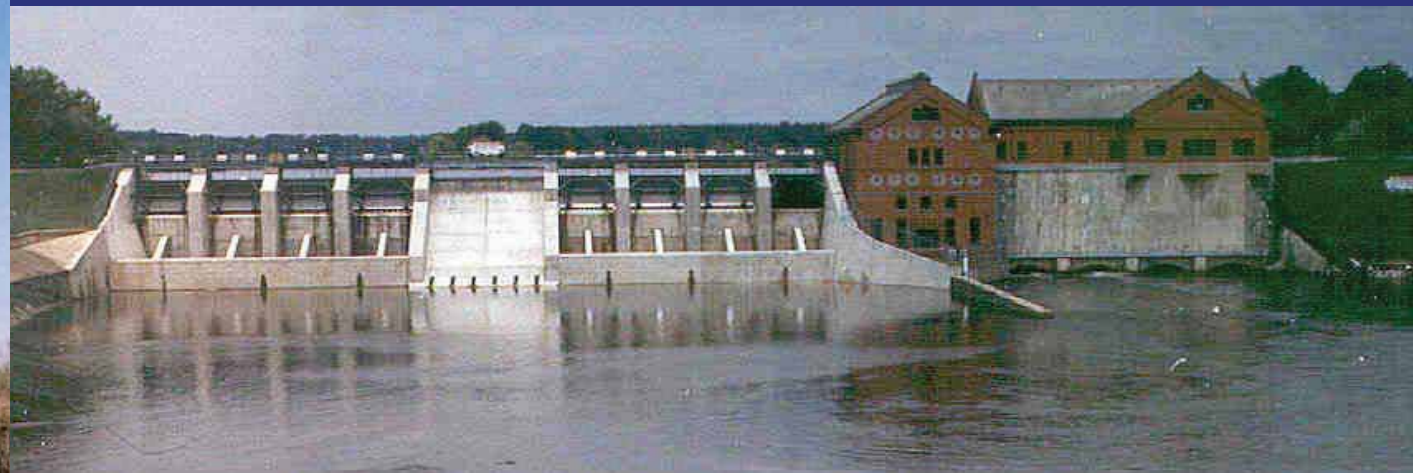
The Habitat Management Unit

Michigan Department of Natural Resources

Fisheries Division



- **Most culverts were placed and designed with the objective of moving water across a road alignment**
- **Little consideration given to ecosystem processes (hydrology, sediment transport, fish and wildlife passage or movement of woody debris)**
- **Not surprising then - that many culverts significantly disrupt movement of aquatic organisms and normal stream function**

Hotchkiss, R.S. and Frei, C.M. 2007. Design for Fish Passage At Roadway Stream Crossings: Synthesis Report. U.S Department of Transportation, Federal Highway Administration, Office of Highway Infrastructure and Research. FHWA-HIM-07-033

Stream simulation

Is an approach to culvert design:

- **that avoids flow constriction during normal conditions**
- **maintains appropriate channel conditions with structure**

and is an effective approach for accommodating and preserving or restoring ecosystem function that maintains habitats and aquatic animal populations

Road networks and river systems are similar in that:

- **long, linear features of the landscape**
- **transporting materials and organisms is fundamental to how they function**
- **connectivity is key to continued functioning of both**

Our goal should be to create a transportation infrastructure that does not fragment or undermine the essential ecological infrastructure of the land

Fish swimming abilities:

- are highly variable among species
- the danger with using swimming abilities to design crossings is that most information we have is on strong swimmers
- very little is known about the majority of fish species particularly juvenile and non-sport fish species

-even less is known about non-fish species

soft shell and musk turtles rarely travel overland and are not strong swimmers but continuity is essential for survival this is also true for many species of crayfish and most salamanders

mussels are also dependent on fish movement however most use small, sedentary host fish that are typically weak swimmers and highly vulnerable to movement barriers

Given the large number of species that make up river communities

lack of information on swimming abilities

and, passage requirements for most species *a species based approach should not be used* for designing road stream crossings

An ecosystem approach is the practical approach to maintain viable populations and maintain the essential ecological processes that shape and maintain ecosystems over time.

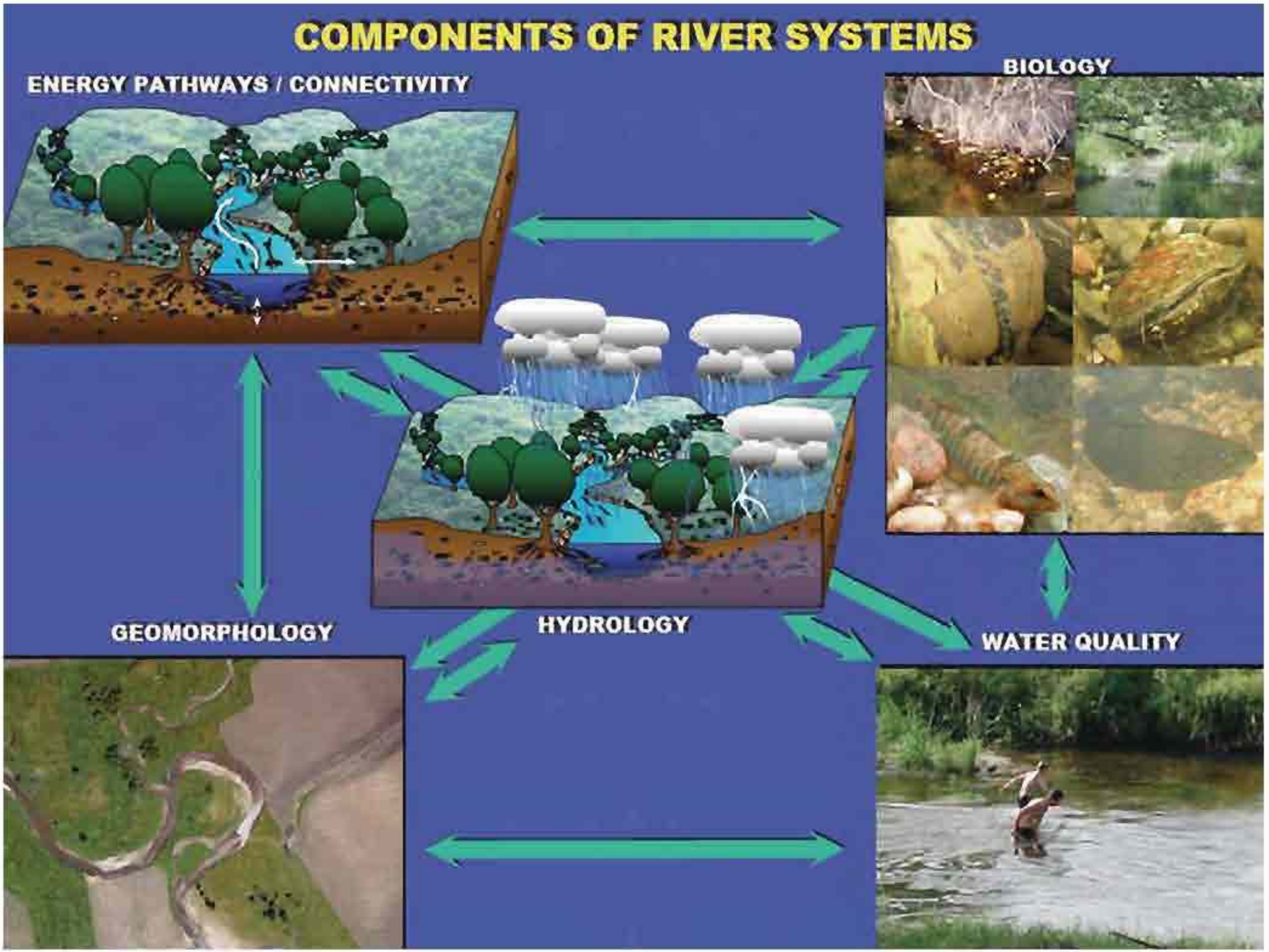
Maintaining un-fragmented stream bottom and bank edge habitat is the best strategy for providing continuous and interconnected populations for these species.

We have focused on fish passage historically and presently however, we should focus on stream function;

fish passage does not mean stream stability but stream stability and function allows for fish passage

In addition other wildlife use these travel corridors including muskrat, mink, otter, frogs and snakes.

COMPONENTS OF RIVER SYSTEMS



Headwater streams:

- **Accumulatively provide much more habitat for aquatic organisms than large rivers**
- **Highly productive due to their relationship with adjacent upland habitat**
- **Provide cooler water temperatures due to shading and groundwater inputs**

-Account for most of the total stream miles

The Problem

- Culverts Can Act As Barriers to Fish!
  - Drop or perched outlets
  - Excessive barrel velocity
  - Insufficient depth
  - Excessive turbulence
  - Behavioral considerations
  - Debris accumulation

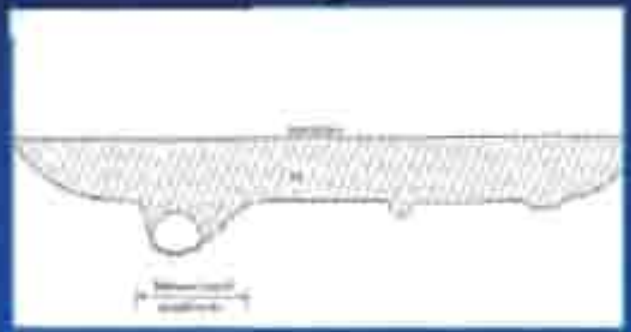
Drop or Perched Outlets

- Caused by
  - Scour at outlet
  - Downstream degradation/incision
- Most common barrier

Furniss, MJ, Cabrara, N, Llanos, A., Firor, S., Love, M., and Guntle, J. (In Review). How culverts can impair and block fish movement: A Primer. Fish Passage Fact Sheet: USDA-Forest Service Pacific Northwest Research Station, Portland OR. URI: www.stream.fs.fed.us/fishxing/fs1

Excessive Barrel Velocity

- Culverts often constrict flow area
- Velocity increases within barrel



Movement Type	Description	Muscle System	Period
Sustained	Used for long periods of travel at low speeds.	Red (purely aerobic)	Hours
Prolonged	Short periods of travel at high speeds	Red and White	Minutes
Burst	Maximum swimming speed or jumping, inducing fatigue	White (purely anaerobic)	Seconds

Depth and Velocity Barrier

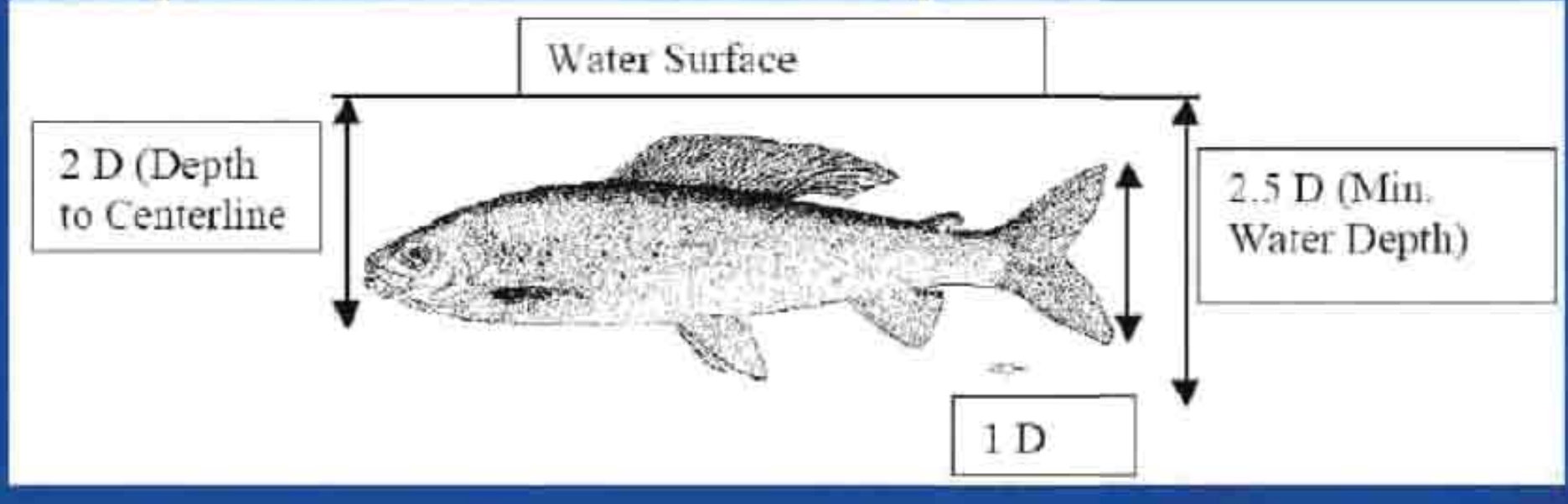
http://www.stream.fs.fed.us/fishxing/529.html

Where do Fish Swim Data Come From?

- Controlled laboratory tests
- Example, Longnosed dace
  - Tested at Brigham Young University
  - Fish demonstrate remarkable adaptations

Insufficient Depth

- Culvert can present a uniform cross section
- Spreads flows to shallow depths



From Alaska Department of Fish and Game

Excessive Turbulence

- Potential for high turbulence
  - Inlet
  - Within barrel
- Fish will avoid excessive levels

Behavioral Considerations

- Long culverts
- Darkness
- Confined culverts

Not much known and not much agreement on these issues

Debris Accumulation

- Restricted access
- More significant with smaller barrels

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

Implications

- Independent groups
  - Less robust gene pool
  - Susceptible to disasters
- Excellent habitat may be blocked!

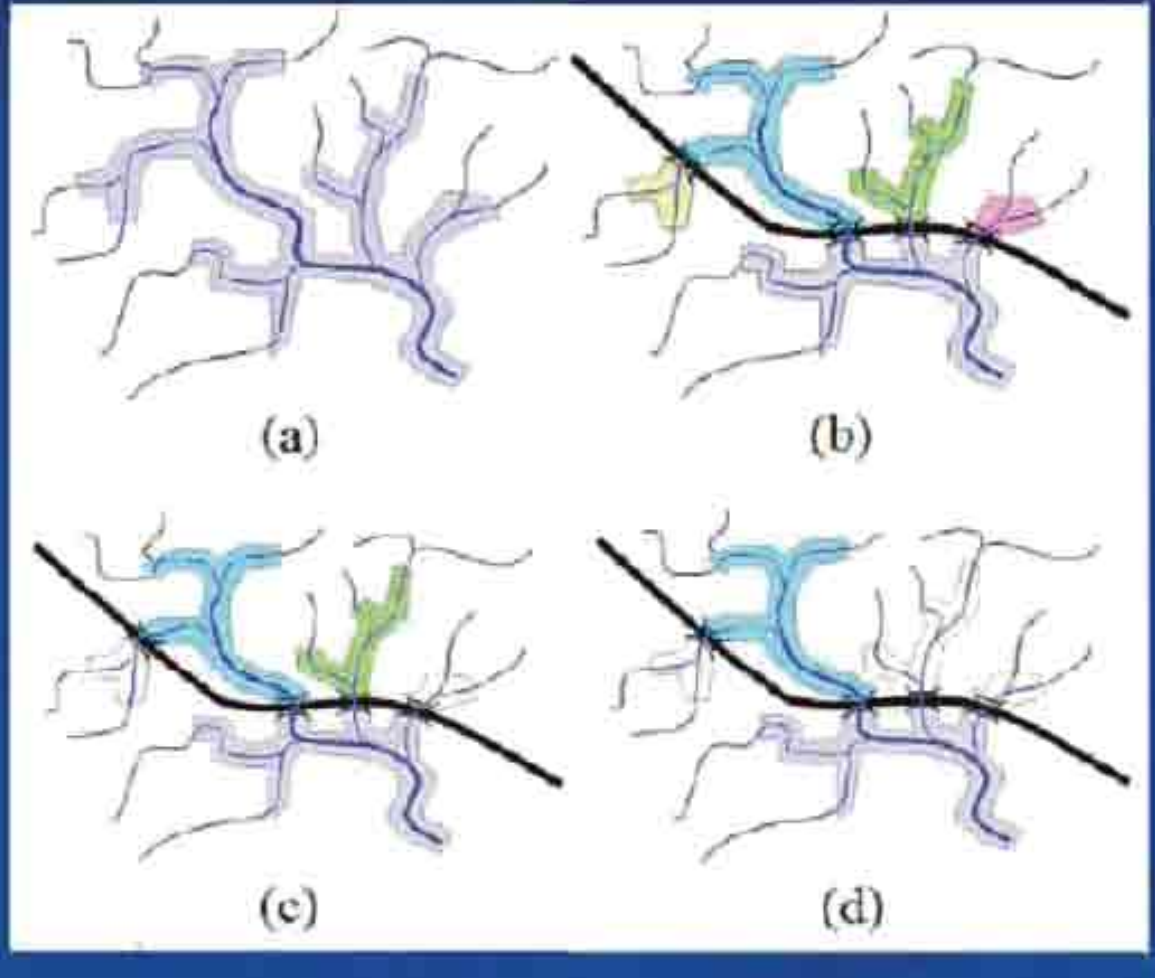
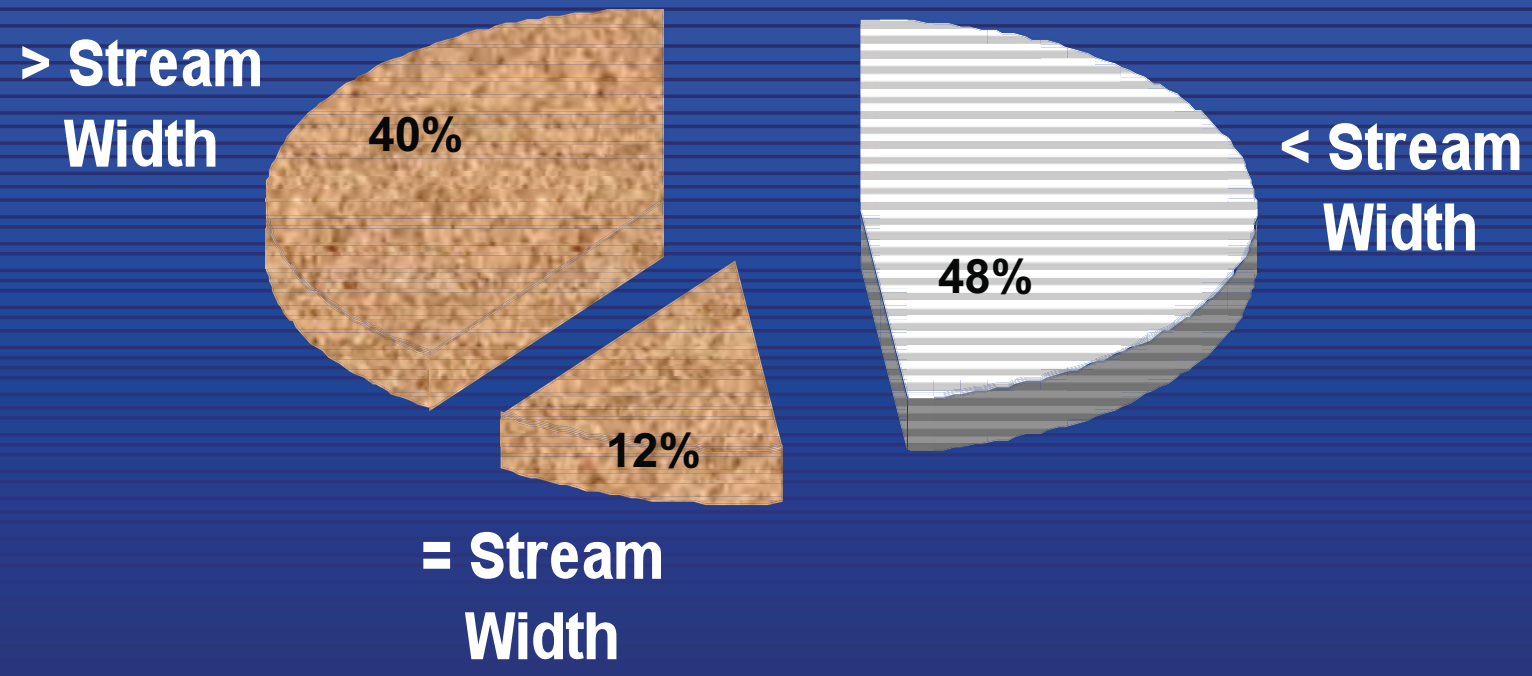


Figure 3.1 in Synthesis Report, page 3-2

Waterbody	$Culvert_W < BKF_W$	Culvert > Stream Slope	Not Buried	Perched	M/NM	Fish Xing
Denomie		**X**		X	***S/M***	Barrier
Pekkala	**X**	**X**	**X**		***S/M*** @ BKF	Barrier
Dickerson	**X**	**X**	**X**	X	S/NM	Partial
Quaker Brook		**X**	**X**		S/NM	Barrier
McBride		**X**	**X**		***S/M***	Partial
Sweet S'Mine		**X**	**X**		S/NM	Partial
Evans	**X**	**X**	**X**		S/NM	Barrier
Indian		**X**			***S/M***	Partial
McIntyre					N/A	
Arner	**X**	**X**	**X**		S/NM	Barrier
Second	**X**				***S/M*** Passable	Barrier
Larson	**X**	**X**	**X**		N/A	
Gomanche	**X**				N/A	
Perch					N/A	
% of Total	**50%**	**71%**	**64%**	**14%**	**60% (6/10)** N/A	**91% (10/11)**
					N/A	
					N/A	

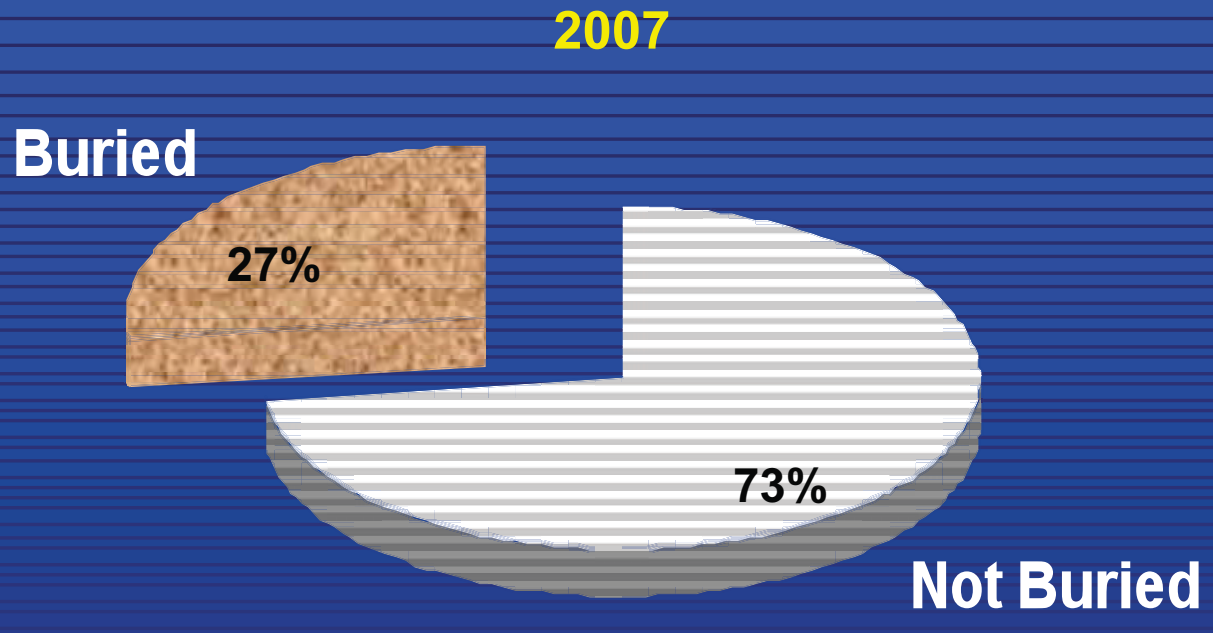
Michigan Department of Natural Resources and Michigan Department of Environmental Quality 2007 Culvert Application Inventory

2007

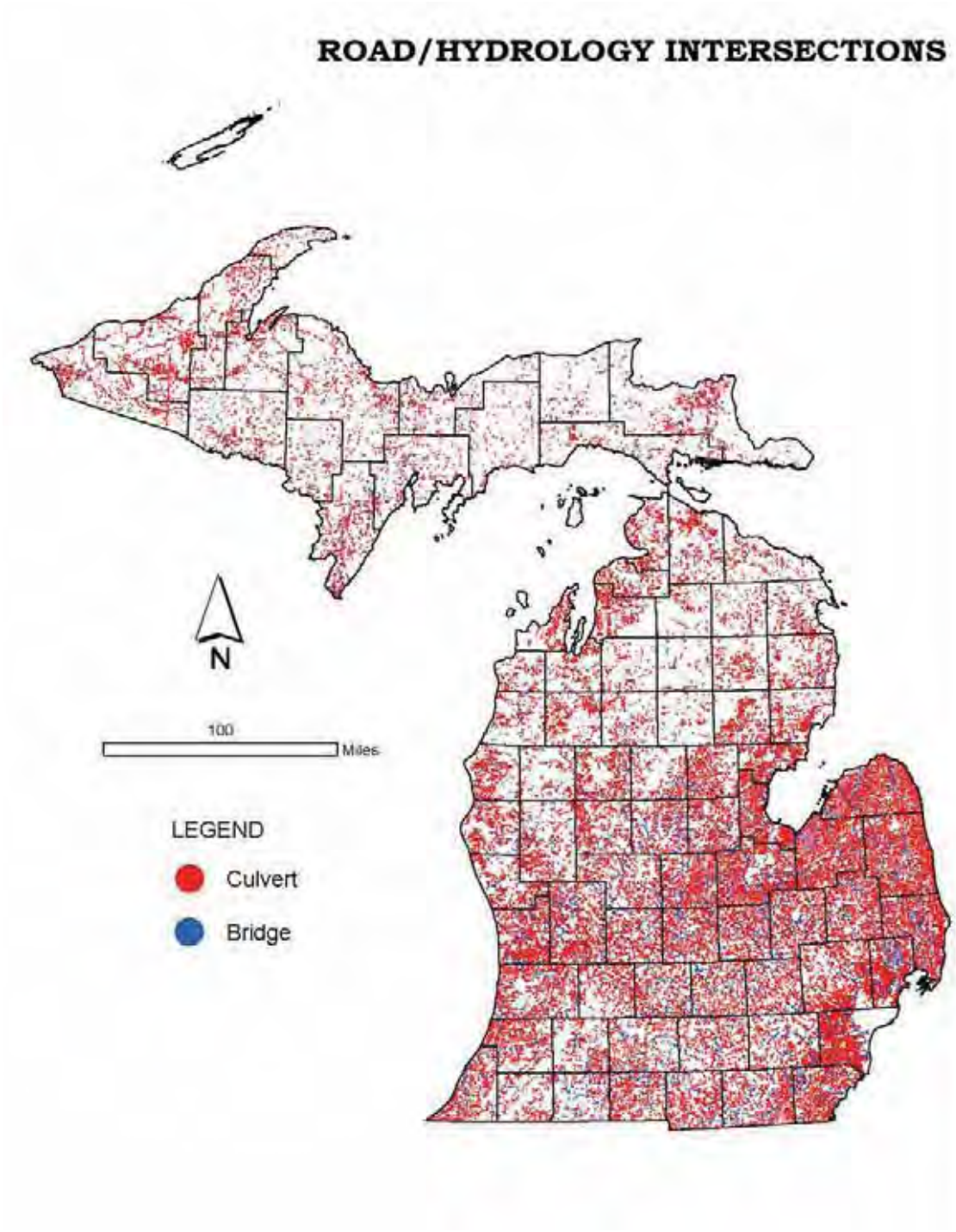


Culvert applications reviewed 240

Michigan Department of Natural Resources and Michigan Department of Environmental Quality 2007 Culvert Application Inventory



Culvert applications reviewed 224



Road Hydro Intersections = 67,511

Culverts = 60,700

Bridges = 6,811

What about the >800 non-migratory fishes and other aquatic species?

http://fishpassage.wsu.edu/pdfs/MarkHudy.pdf

Motivation

- Endangered Species Act
  - Endangered
  - Threatened
  - Proposed or candidate species
  - State or regional additions
- Jurisdiction
  - National Oceanic and Atmospheric Administration (NOAA)
    - National Marine Fisheries Service (NMFS)

Clean Water Act

- If aquatic life is a designated use, culvert installation, operation and maintenance should not cause physical, chemical or biological degradation or otherwise alter fish species composition and demographics, and habitat. The discharge should not impede fish movements, the movements of prey and forage, or symbiotic and commensal species

US Army Corps of Engineers Nationwide Permits

- Issued 2002 and renewed 2007

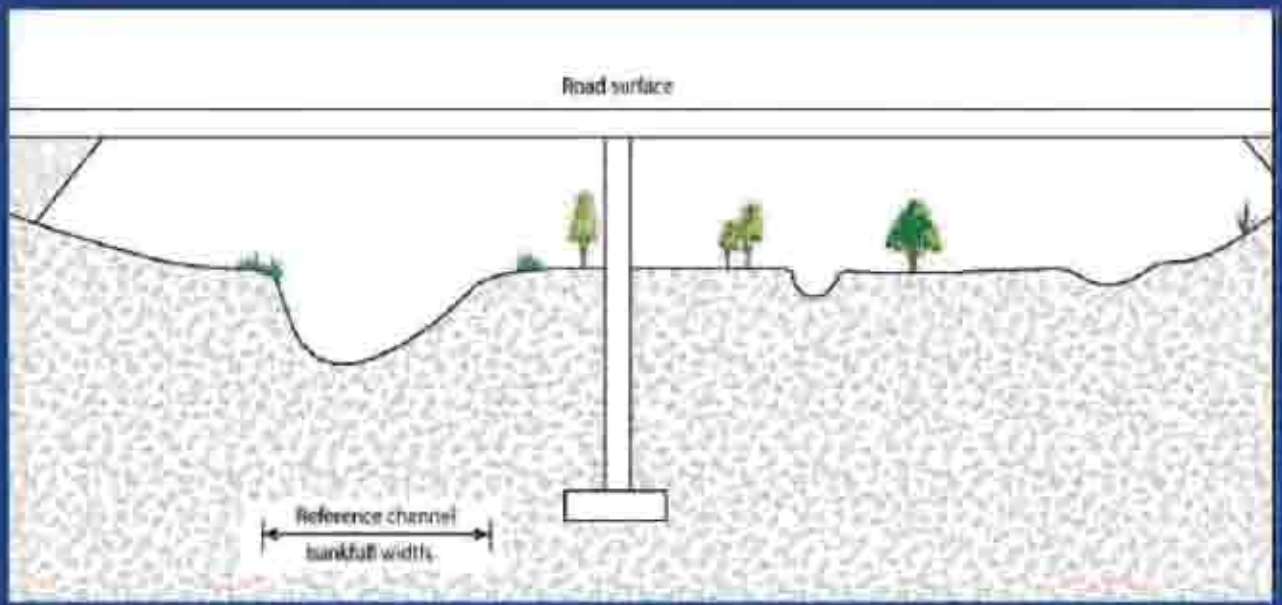
> 2. *Aquatic Life Movements.* No activity may substantially disrupt the necessary life cycle movements of those species of aquatic life indigenous to the waterbody, including those species that normally migrate through the area, unless the activity's primary purpose is to impound water. Culverts placed in streams must be installed to maintain low flow conditions.

Mitigation may be the Motivation

- Stream alteration elsewhere
- Requires restoration
- May do so with fish passage at culverts

- Or….maybe it's just the right thing to do!!

Name	Relative Width	Characteristics		
		Biological	Geomorphic	Hydraulic
No Impedance	≥100-yr floodplain	Pass all fish and aquatic organisms	Unchanged	Q_{100} unconstricted



	Name	Relative Width	Characteristics		
			Biological	Geomorphic	Hydraulic
1	Geomorphic Simulation	≥bankfull	Pass all fish and aquatic organisms	Natural Substrate, Mobile bed, Stability of substrate usually not checked	Unaltered for Q slightly above bankfull; Check Q_{100}

	Name	Relative Width	Characteristics		
			Biological	Geomorphic	Hydraulic
2	Hydraulic Simulation	≤bankfull	Reported to pass all fish and aquatic organisms	Oversized substrate; Stationary bed; Stability of bed usually checked	Similar for Q slightly less than bankfull; Check Q_{100}

Kim Hastings, USFS

	Name	Relative Width	Characteristics		
			Biological	Geomorphic	Hydraulic
3	Hydraulic Design	variable; usually <bankfull	Pass target species at target life stage	Artificial channel	Must meet target species and life stage requirements; Check for Q_{100}

Summary Comments on Design

- Geomorphic Simulation
  - Does not check for fish passage
  - Generally does not check for sediment stability
  - Requires a reference reach for comparison
- Hydraulic Simulation
  - Uses a slightly smaller but still arbitrary span
  - Does not check for fish passage – it's assumed
  - Requires larger substrate and a stability check

Comments, Continued

- Hydraulic Design
  - Requires specific information about fish swimming abilities
  - Requires finding numerical values for "fish passage discharge"
  - Requires baffles or weirs or no slope or other means to decrease velocities to values that are likely lower than those found in stream reach
  - Almost always used as retrofit alternative