Site Assessment and Field Data Collection for Stream Simulation Design

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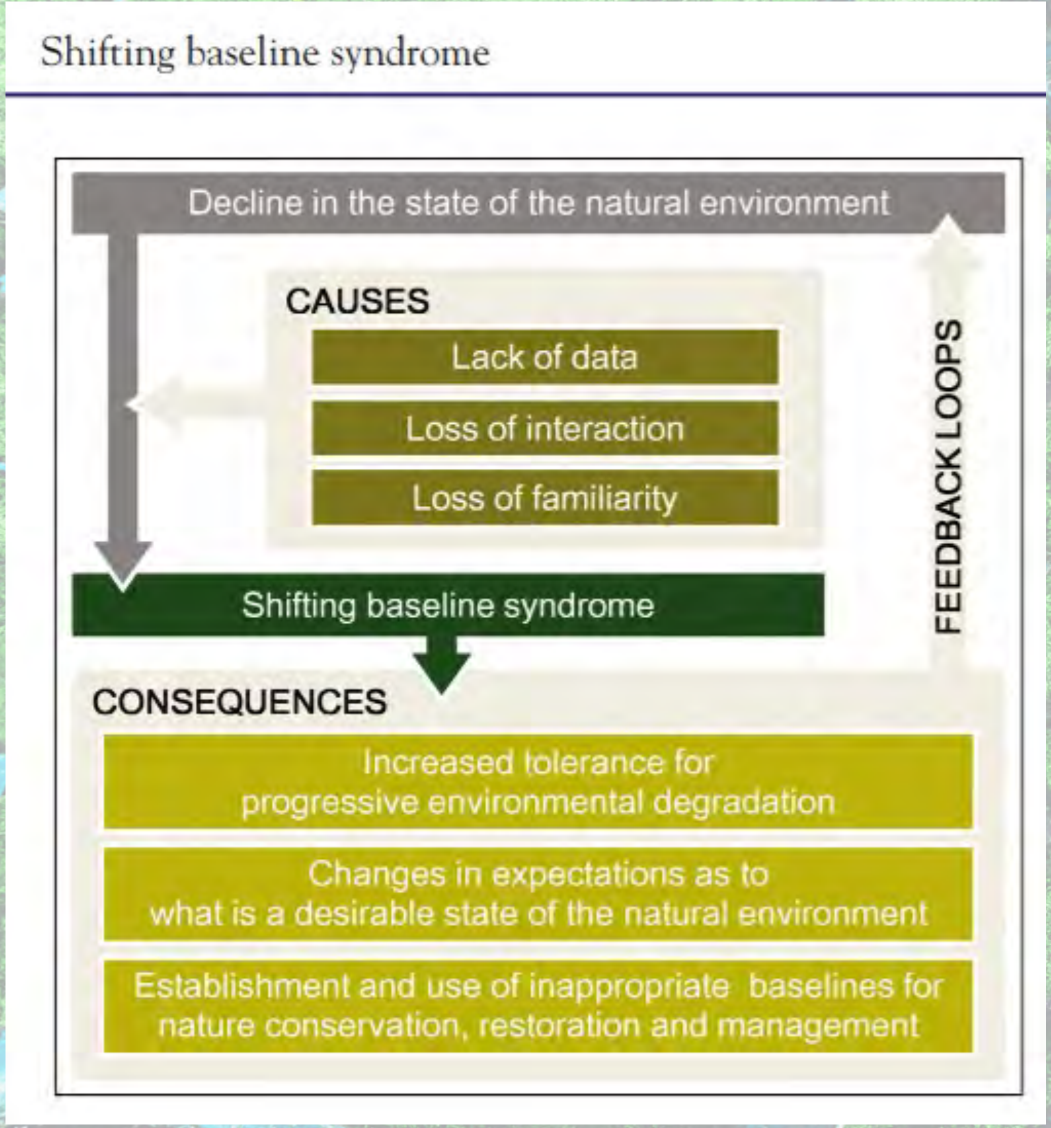
Presentation Outline

- Conservation Goals and Shifting Baseline Syndrome
- Overview of Stream Simulation Design Methodology
- Site Assessment
- Reference Reach
- Available Guidelines and Resources



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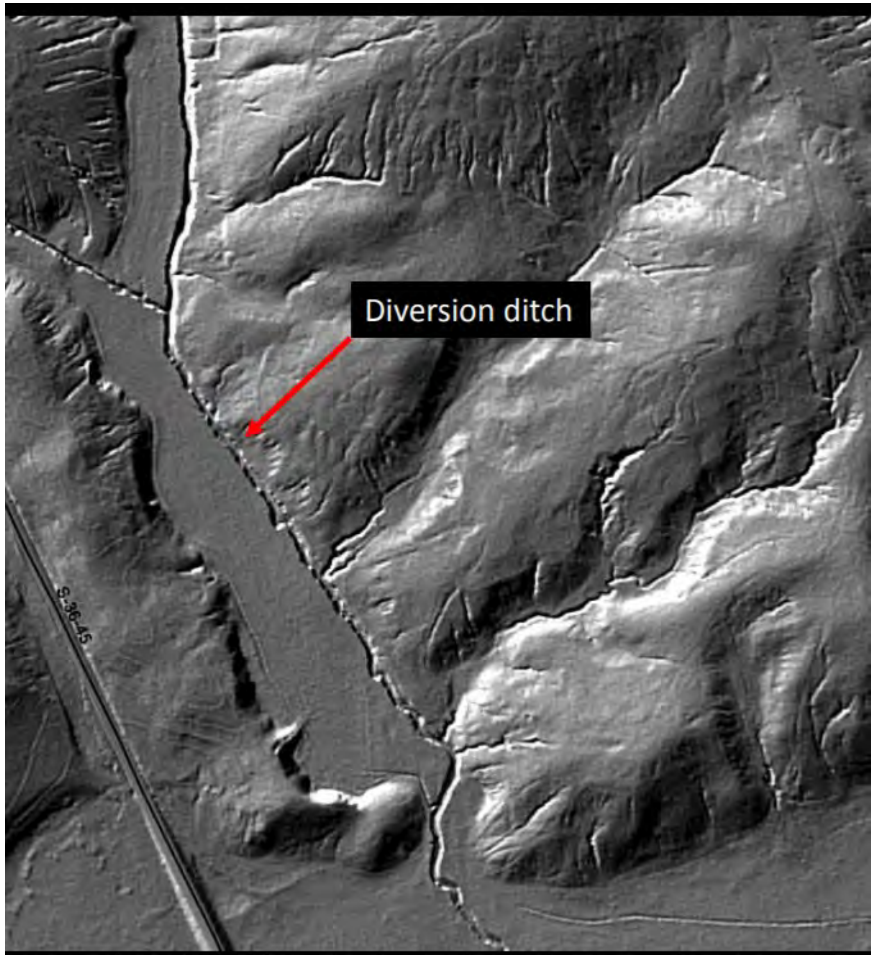
Shifting baseline syndrome: causes, consequences, and implications

Masashi Soga[1*] and Kevin J Gaston[2]

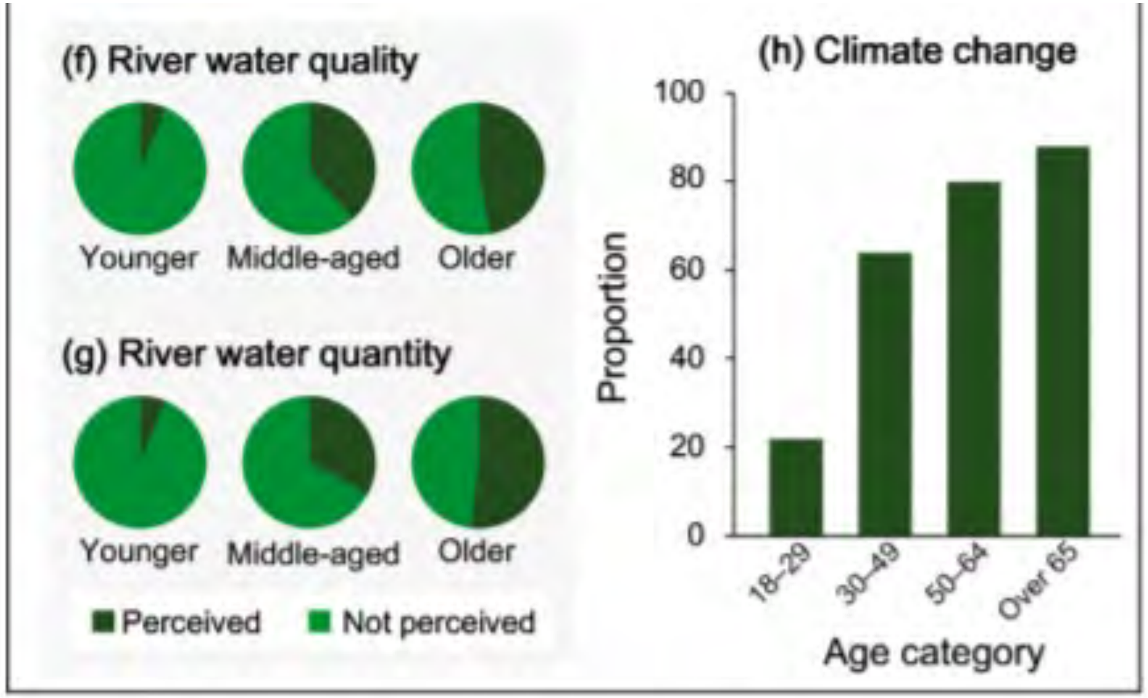
With ongoing environmental degradation at local, regional, and global scales, people's accepted thresholds for environmental conditions are continually being lowered. In the absence of past information or experience with historical conditions, members of each new generation accept the situation in which they were raised as being normal. This psychological and sociological phenomenon is termed shifting baseline syndrome (SBS), which is increasingly recognized as one of the fundamental obstacles to addressing a wide range of today's global environmental issues. Yet our understanding of this phenomenon remains incomplete. We provide an overview of the nature and extent of SBS and propose a conceptual framework for understanding its causes, consequences, and implications. We suggest that there are several self-reinforcing feedback loops that allow the consequences of SBS to further accelerate SBS through progressive environmental degradation. Such negative implications highlight the urgent need to dedicate considerable effort to preventing and ultimately reversing SBS.

Front Ecol Environ 2018; 16(4): 222–230, doi: 10.1002/fee.1794

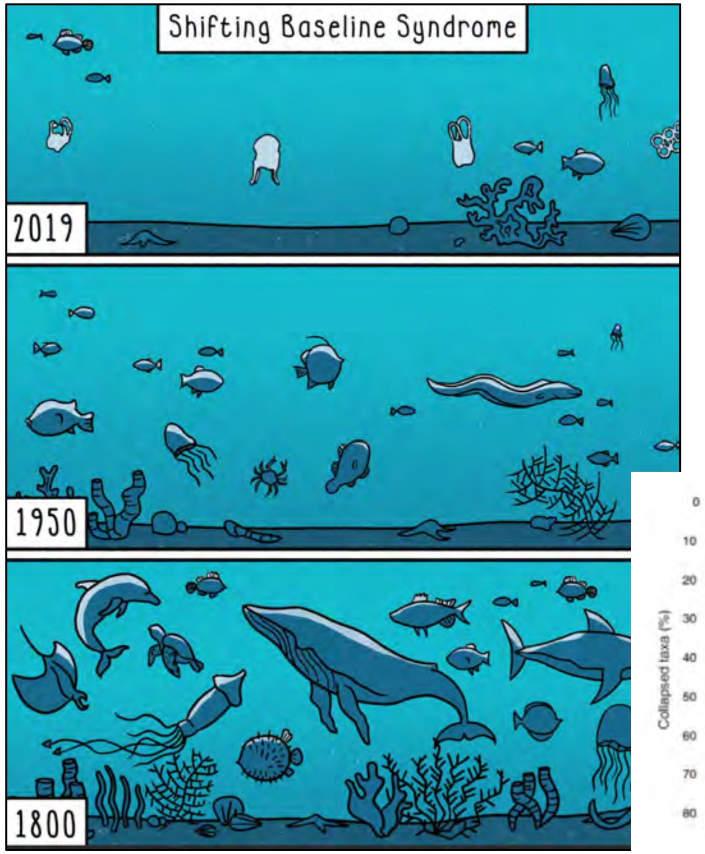


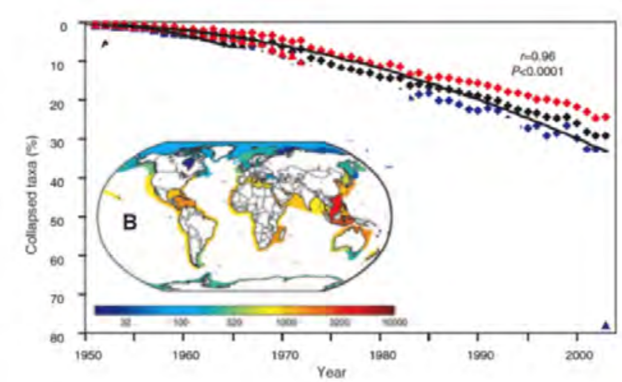
"Shifting baseline syndrome (SBS) is a psychological and sociological phenomenon whereby each new human generation accepts as natural or normal the situation in which it was raised"

SBS occurs when conditions of the natural environment gradually degrade over time, yet people (local citizens, natural resource users, policy makers) falsely perceive less change because they are not aware of, or fail to recall accurately, what the natural environment was like in the past.



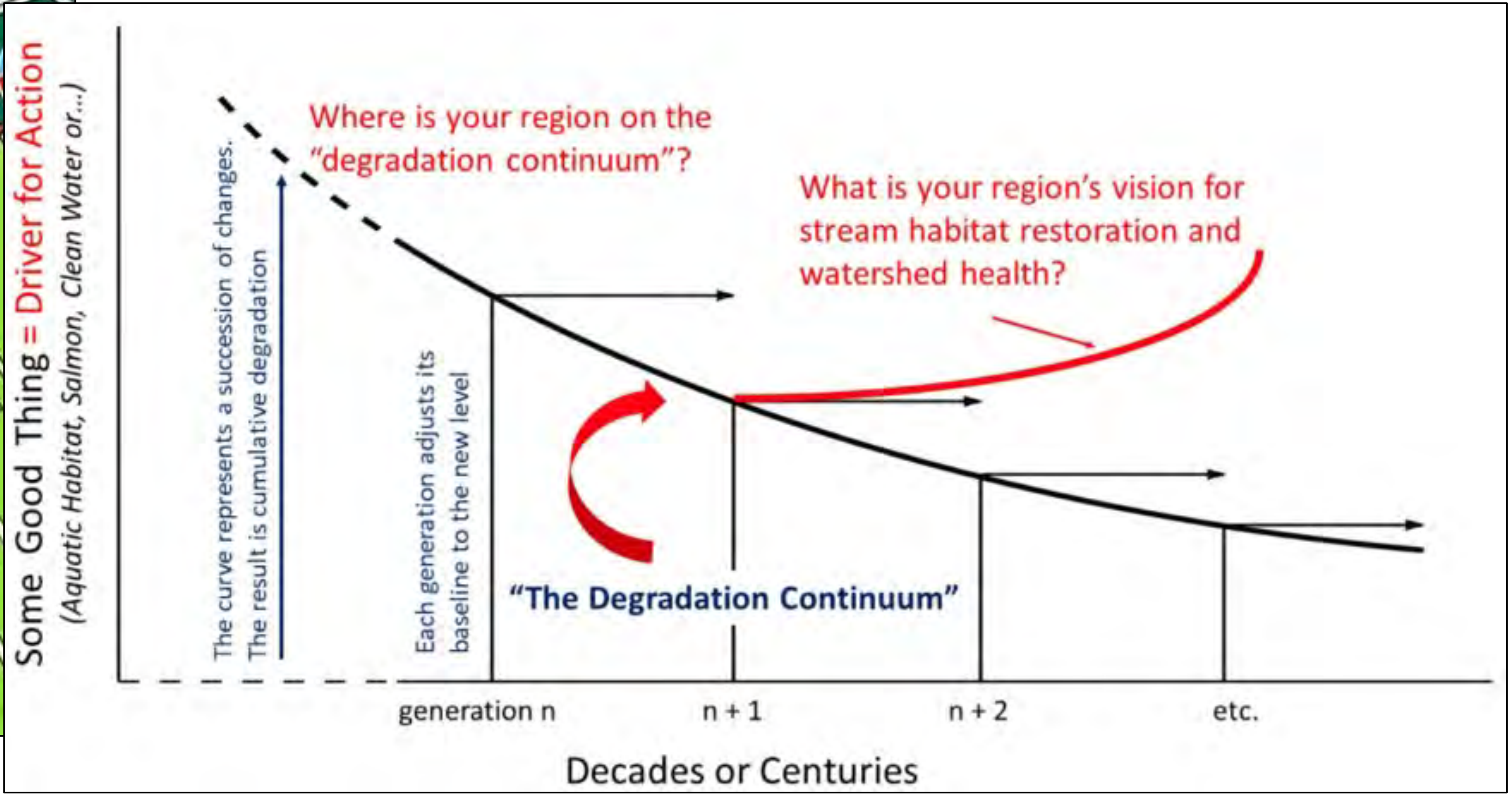
Younger residents, compared to older ones, perceived a lesser degree of change in the availability of local water resources and water quality.





The first documented cases of SBS are in fisheries stock reports.

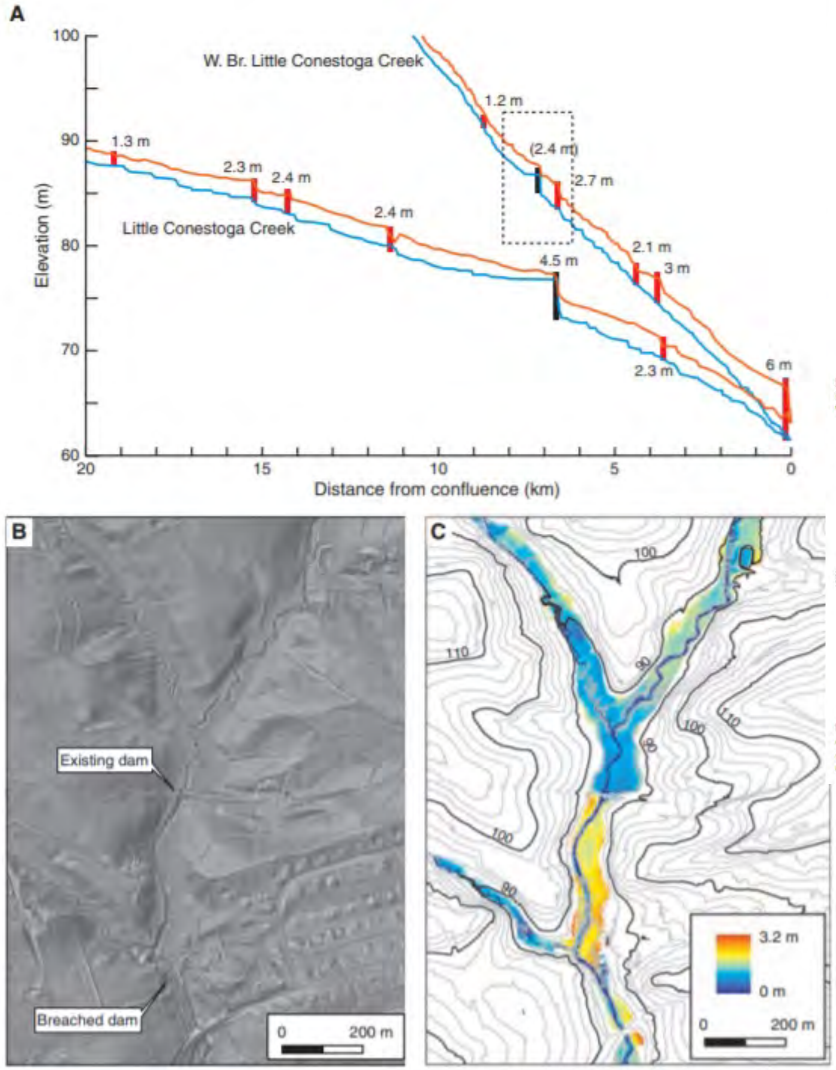
Each generation of managers set lower *sustainable* harvest targets as stocks progressively diminished.



SBS feedback loop:

- **Progressively diminishing perception of "natural" and good**
- **Leads to insufficient restoration targets**

Example of SBS in River Management



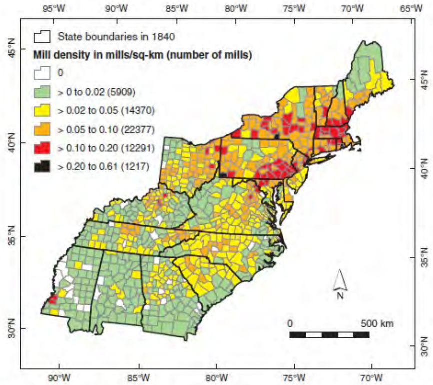


Fig. 1. Density of water-powered mills along eastern U.S. streams by 1840 by county (872 county boundaries are shown for 1840). The highest densities are in the Piedmont and the Ridge-and-Valley physiographic provinces of Maryland, Pennsylvania, New York, and central New England.

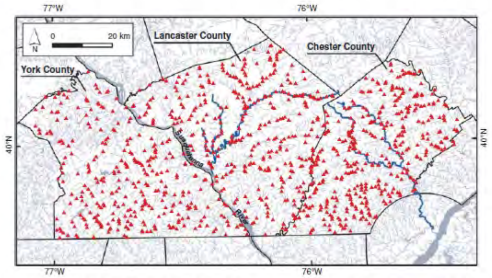
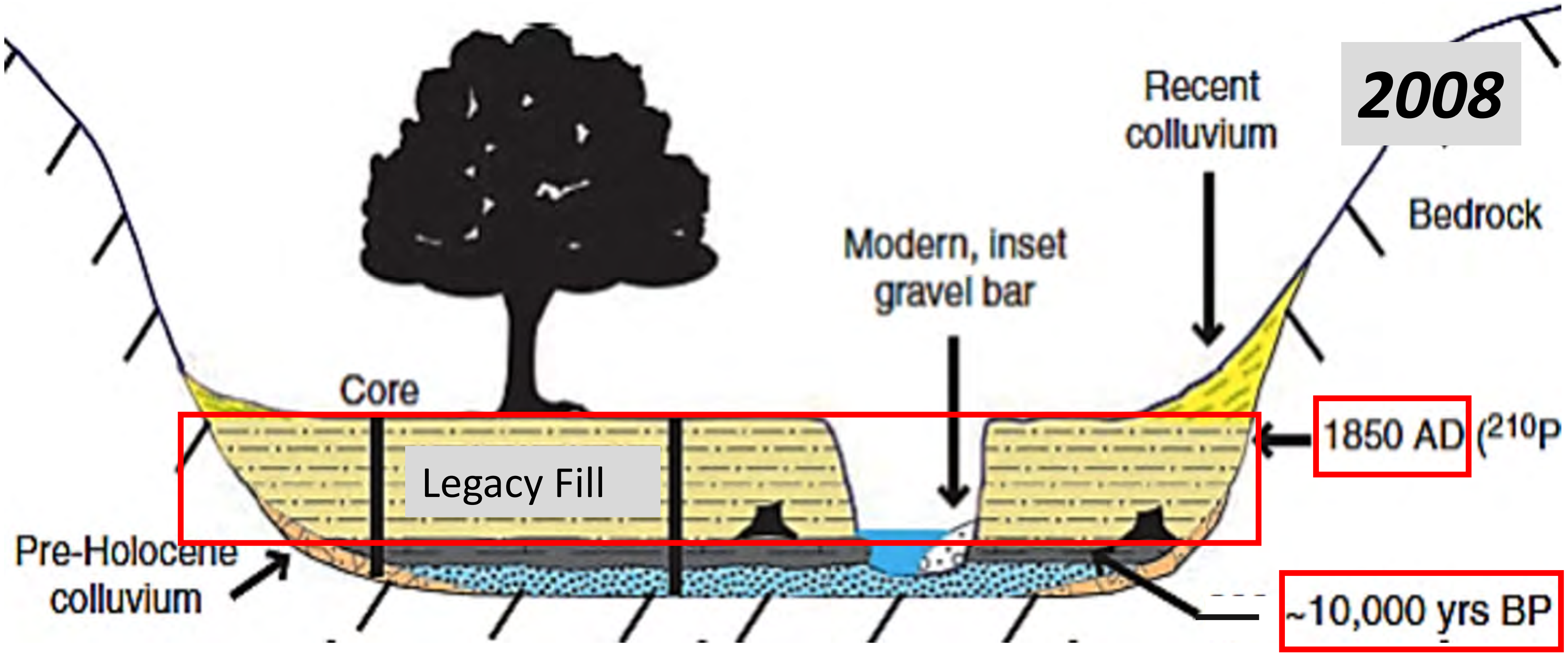


Fig. 2. Historic 19th-century milldams (triangles) on Piedmont streams in York, Lancaster, and Chester counties, southeastern Pennsylvania, located from >100 large-scale township maps dating to 1876 (York), 1875 (Lancaster), and 1847 (Chester). The total number of dams shown is 1025. Main stems of Conestoga (Lancaster) and Brandywine (Chester) rivers are highlighted in dark blue.

"Valley bottoms along eastern streams were characterized by laterally extensive, wetland-dominated systems of forested meadows with stable vegetated islands and multiple small channels during the Holocene epoch.

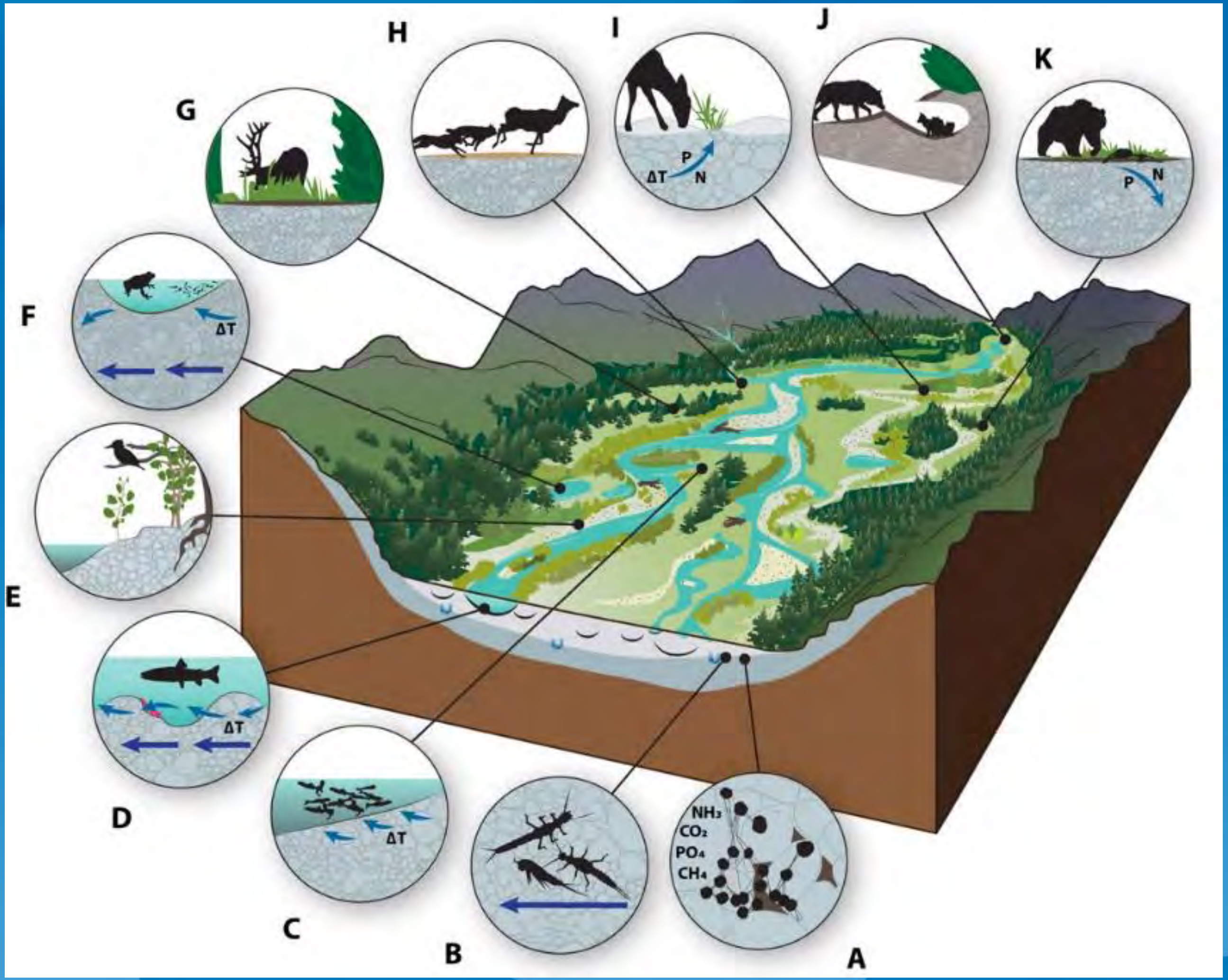
The modern, incised, meandering stream is an artifact of the rise and fall of mid-Atlantic streams in response to human manipulation of stream valleys for waterpower."

Walter, R.C. and Merritts, D.J., 2008. Natural streams and the legacy of water-powered mills. *Science*, *319*(5861), pp.299-304.

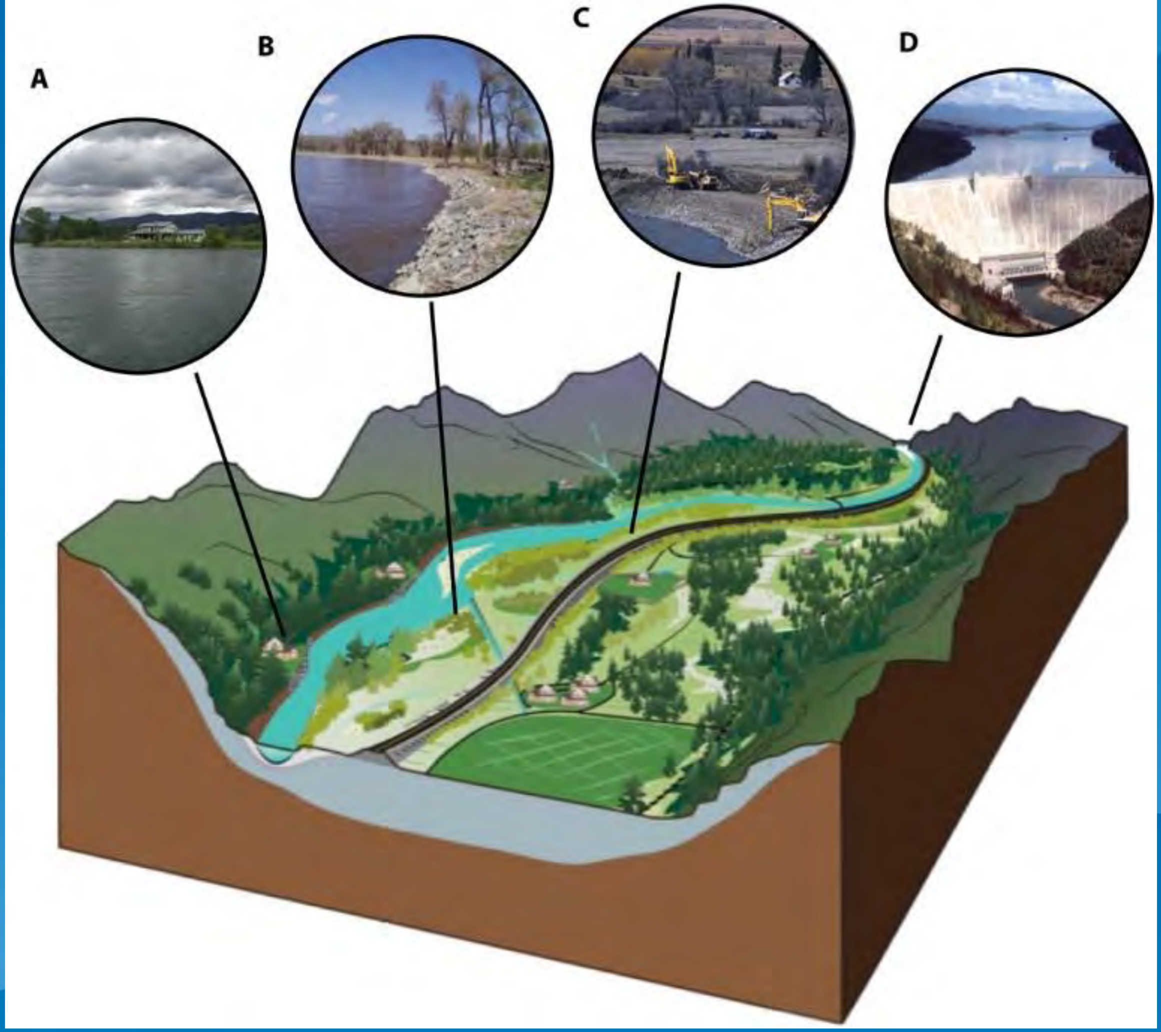


This is important because these same streams are where the concept of the naturally formed 1.5 to 2-yr capacity meandering “bankfull” channel was derived in the 1950-60’s

Floodplain is the ecological nexus of regional biodiversity.



Floodplain as affected by human structures.



F. Richard Hauer et al. Sci Adv 2016

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TWO OVERARCHING AND DISTINCT METHODOLOGIES EXIST FOR ACCOMPLISHING VARIOUS LEVELS OF STREAM RESTORATION AT A SITE

STREAM SIMULATION DESIGN METHOD (SSDM)

BENEFITS:
- **FULL ECOLOGICAL LIFT**
- **AQUATIC ORGANISM PASSAGE FOR ALL NATIVE SPECIES**
- **FREE SEDIMENT AND NUTRIENT MOVEMENT**
- **FLOOD RISK REDUCTION**
- **FLOODPLAIN AND RIPARIAN CONNECTIVITY**

HYDRAULIC DESIGN METHOD (HDM)

BENEFITS:
- **FISH PASSAGE FOR A SELECTED FISH SPECIES**

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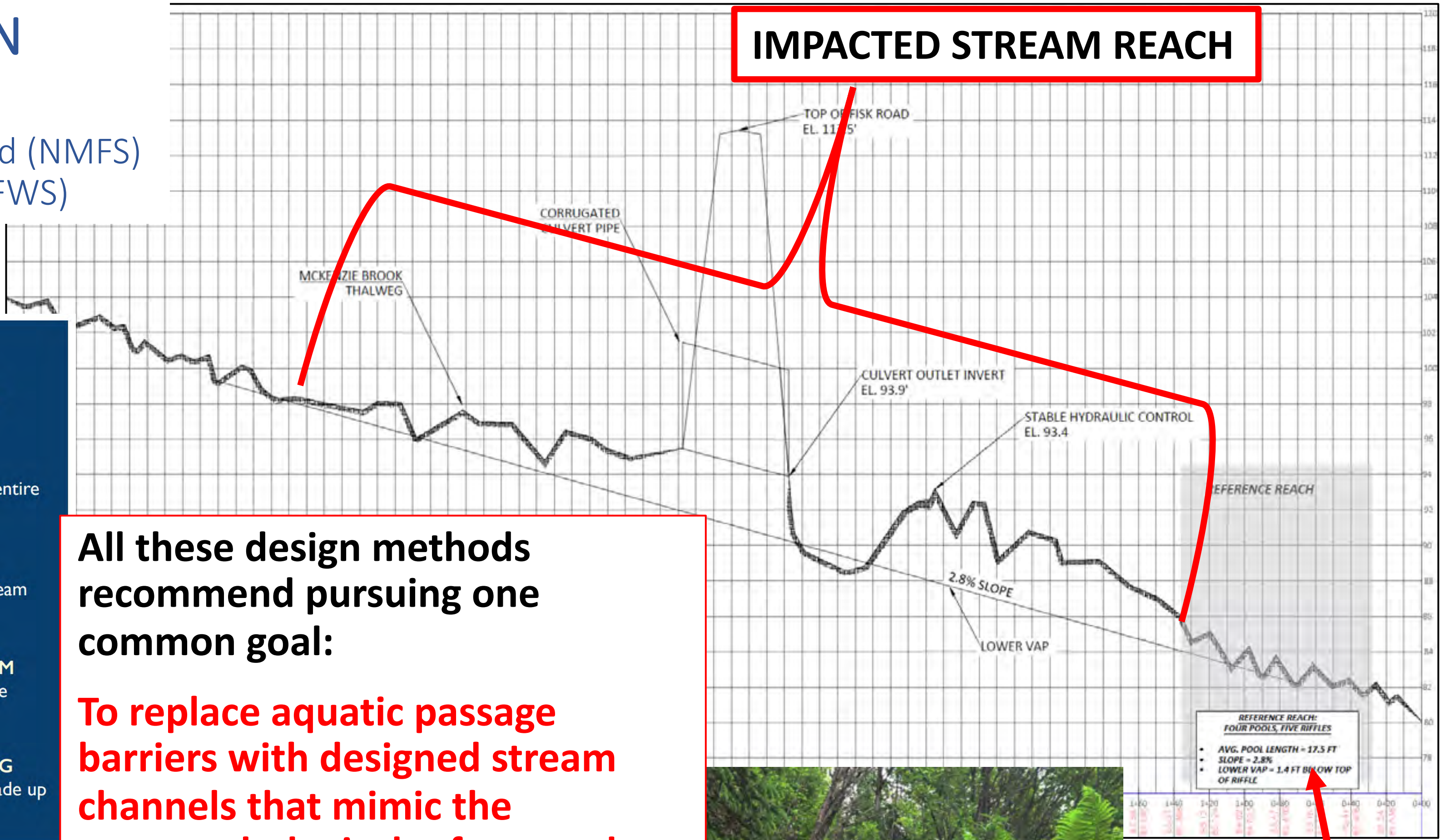
STREAM SIMULATION DESIGN METHODOLOGY (USFS)

a.k.a. Streambed Simulation Design Method (NMFS) or Geomorphic Analog Design Method (USFWS)

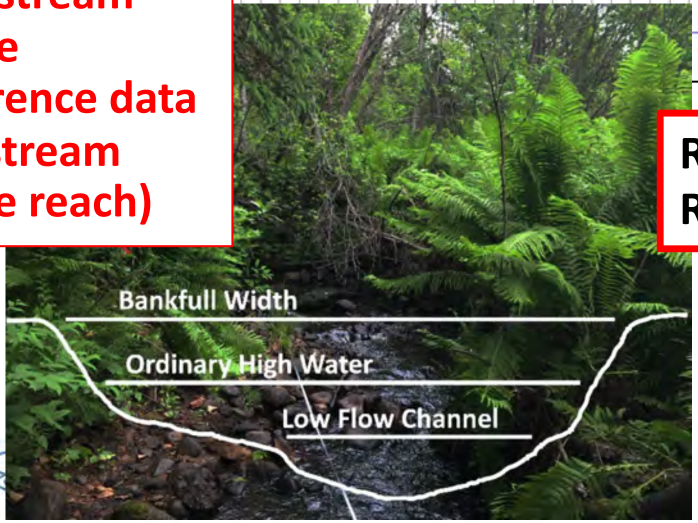
4 Stream Smart **RULES OF THUMB**

1. **SPAN THE STREAM**
   Crossing should at least span the entire width of the natural stream.
2. **SET THE ELEVATION RIGHT**
   Crossing should match natural stream elevation.
3. **SLOPE MATCHES THE STREAM**
   Crossing should match slope of the natural stream.
4. **SUBSTRATE IN THE CROSSING**
   Crossing stream bed should be made up of natural stream bed materials.



All these design methods recommend pursuing one common goal:

To replace aquatic passage barriers with designed stream channels that mimic the geomorphological reference data from a representative stream section (i.e., a reference reach)



SSDM ECOLOGICAL BENEFITS

When designed correctly, all native aquatic organisms, even the small-bodied, weak-swimming ones should be able to swim through the restored stream section

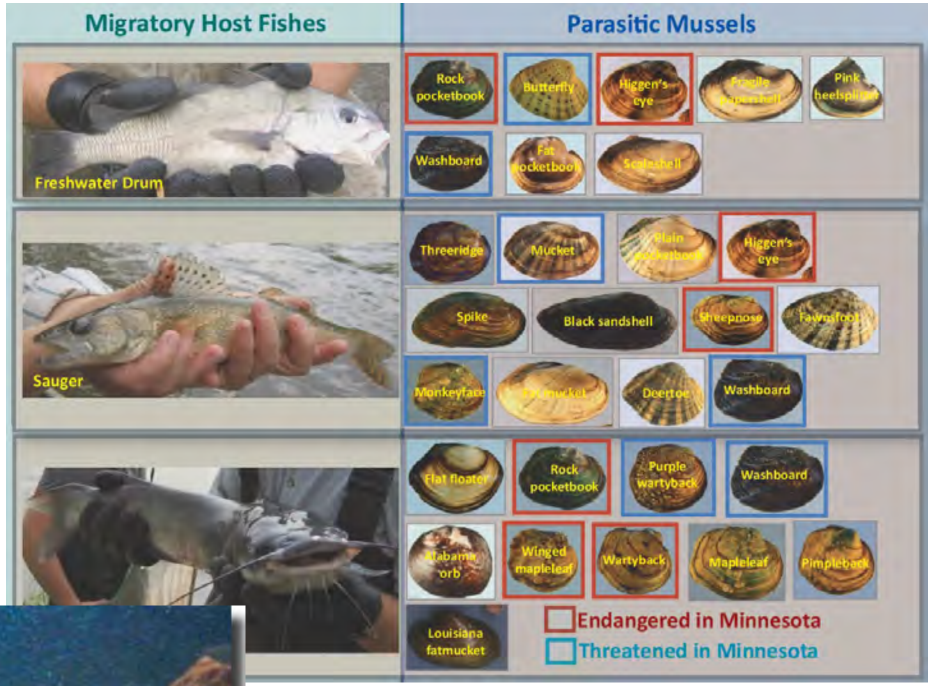
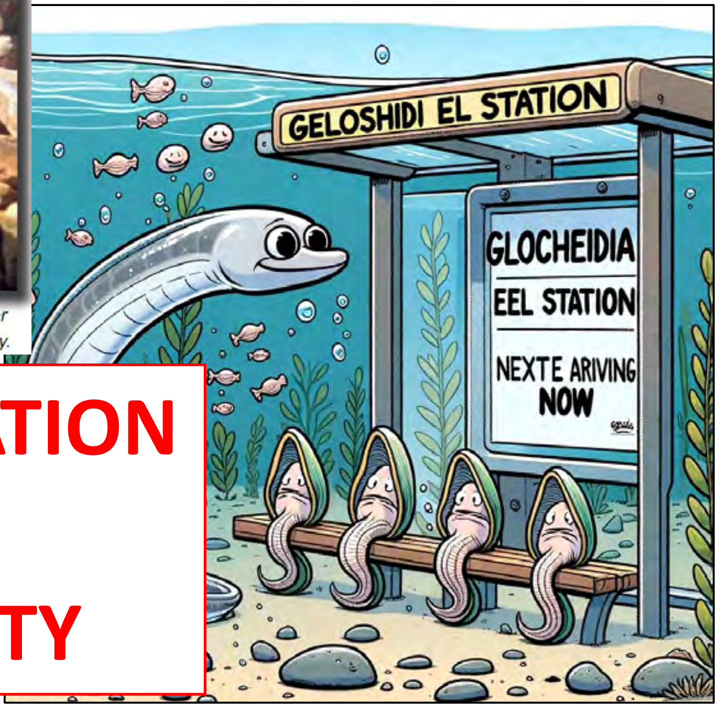


Figure 1.3—A broken-rays mussel uses a mantle-flap lure to attract host darter that it will infect with glochidia. Photo: Chris Barnhart, Missouri State University.



SMALL-BODIED FISH ALSO NEED TO MOVE!

LOGPERCH

DARTER

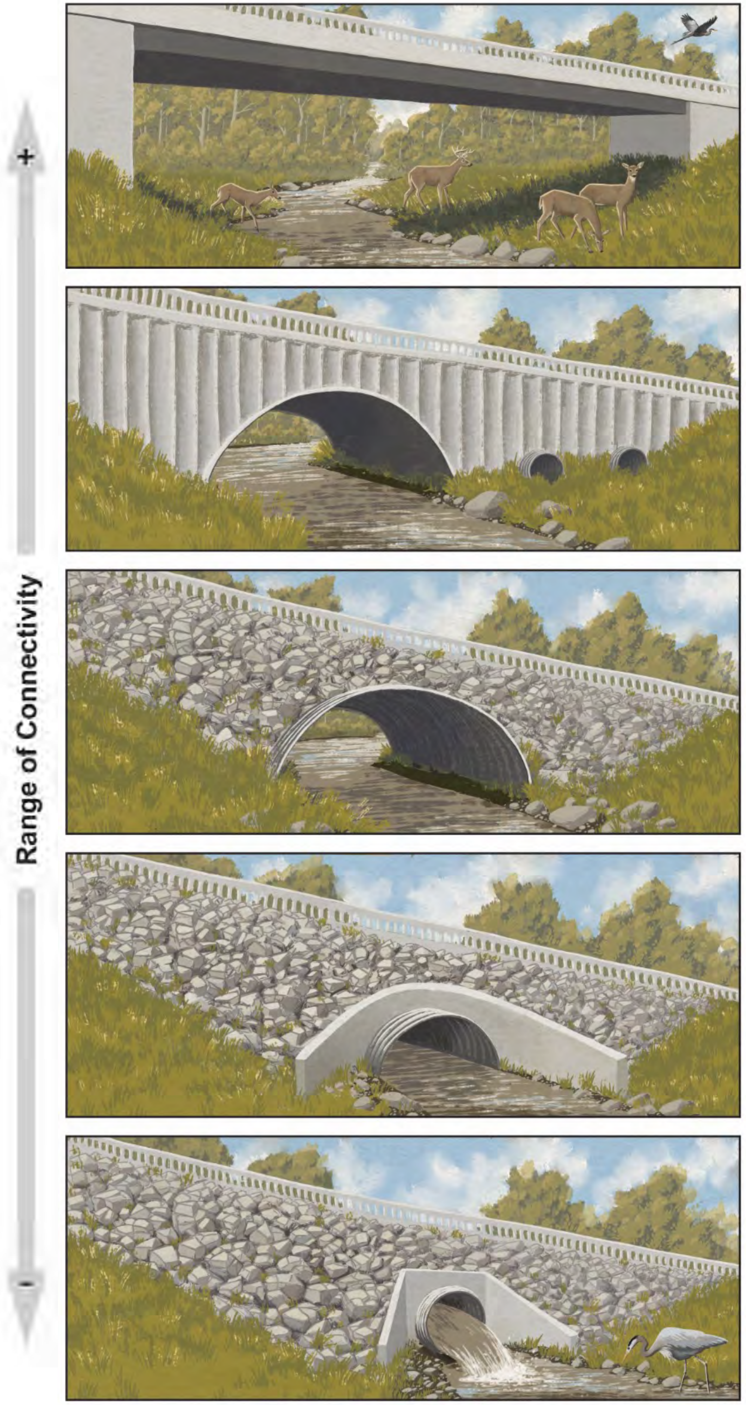
CRAYFISH

↑MUSSEL POPULATION = ↑WATER QUALITY

STREAM SIMULATION DESIGN METHODOLOGY

LET THE STREAM BE THE STREAM!

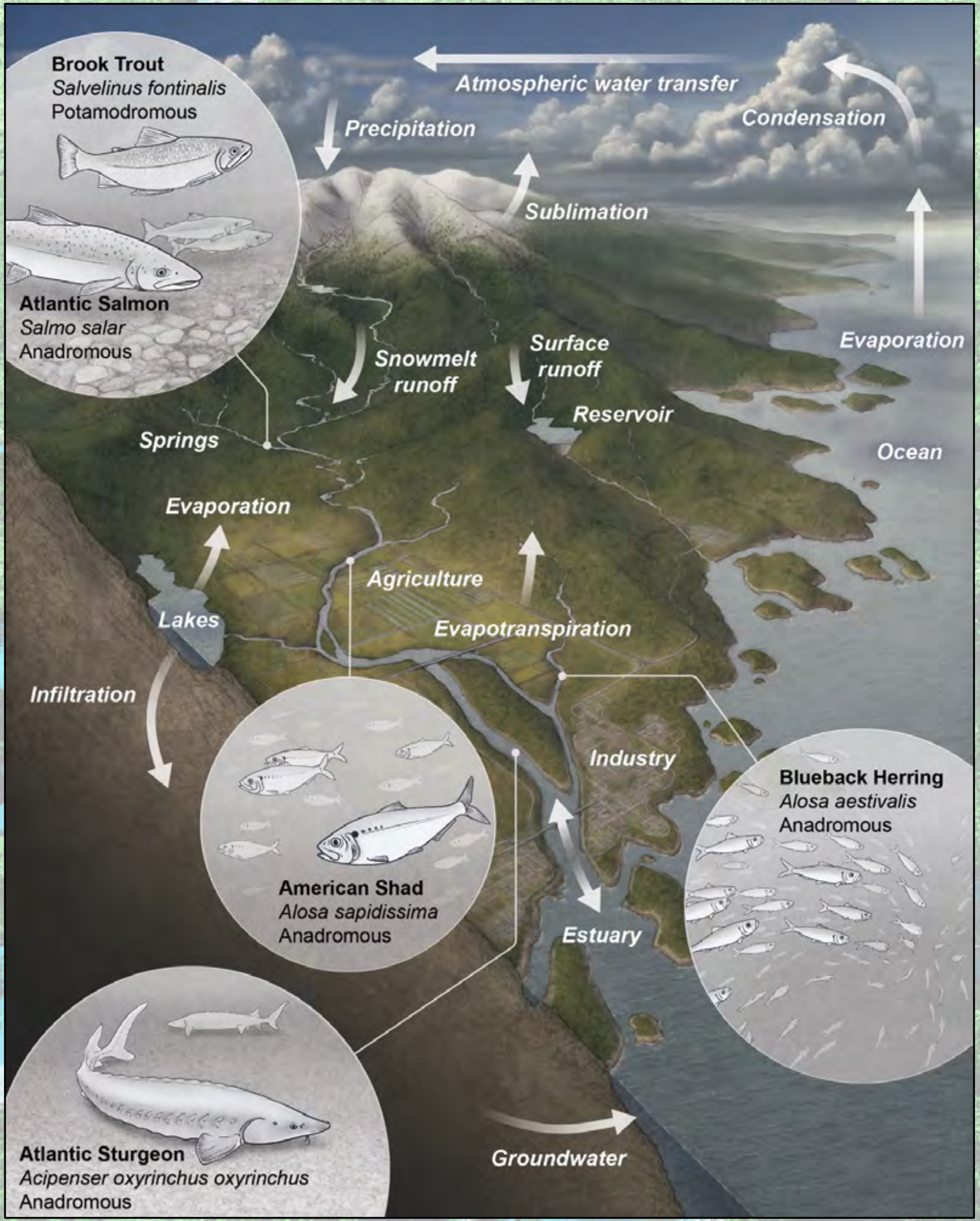
If you were a fish, which would you choose?



STREAM SIMULATION DESIGN PROCESS

- USFS 2008

SITE ASSESSMENTS AND FIELD SURVEYS SHOULD BE TREATED AS FORENSIC INVESTIGATIONS



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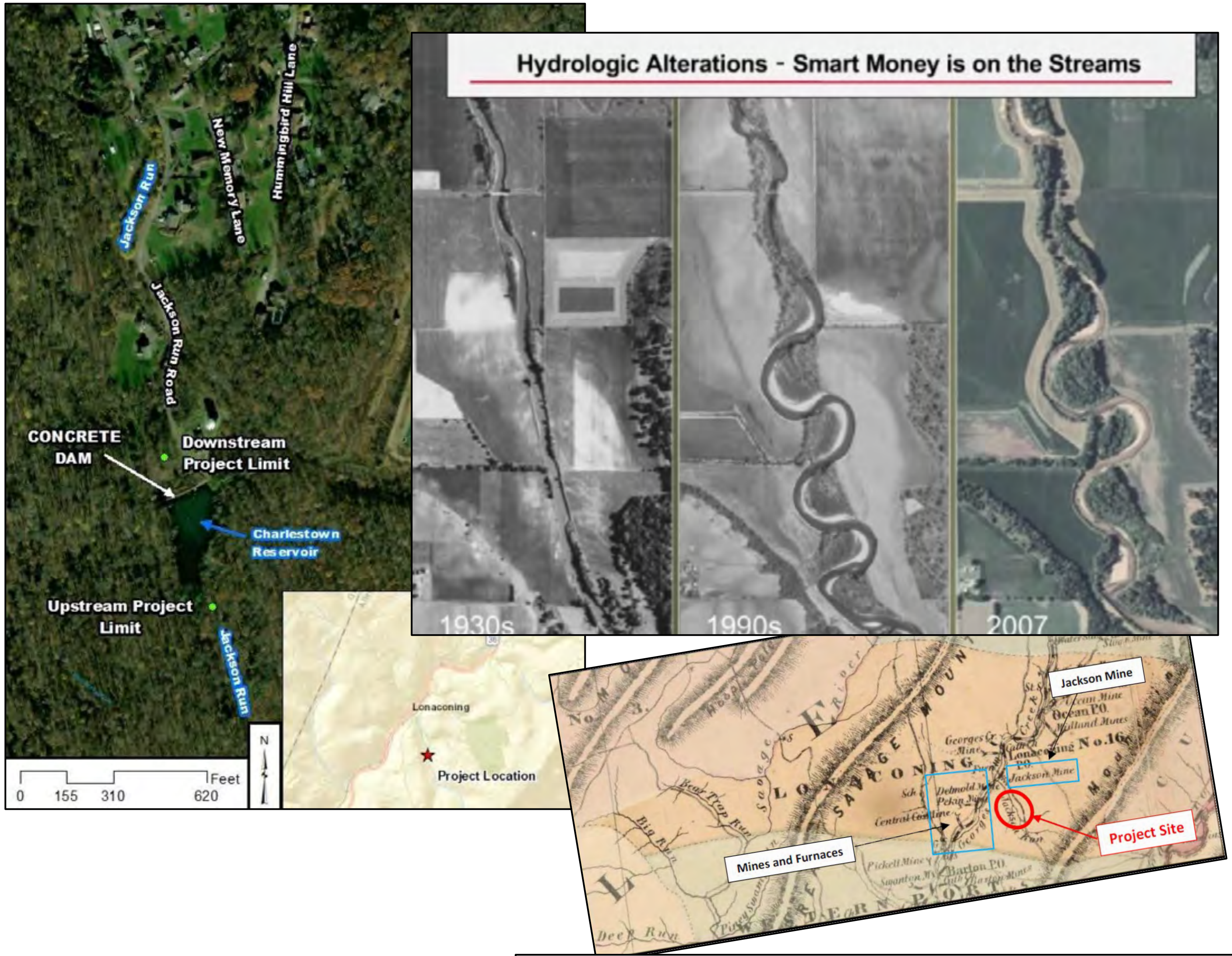

Maps and satellite imagery can reveal significant information about a stream's history and possible anthropogenic impacts

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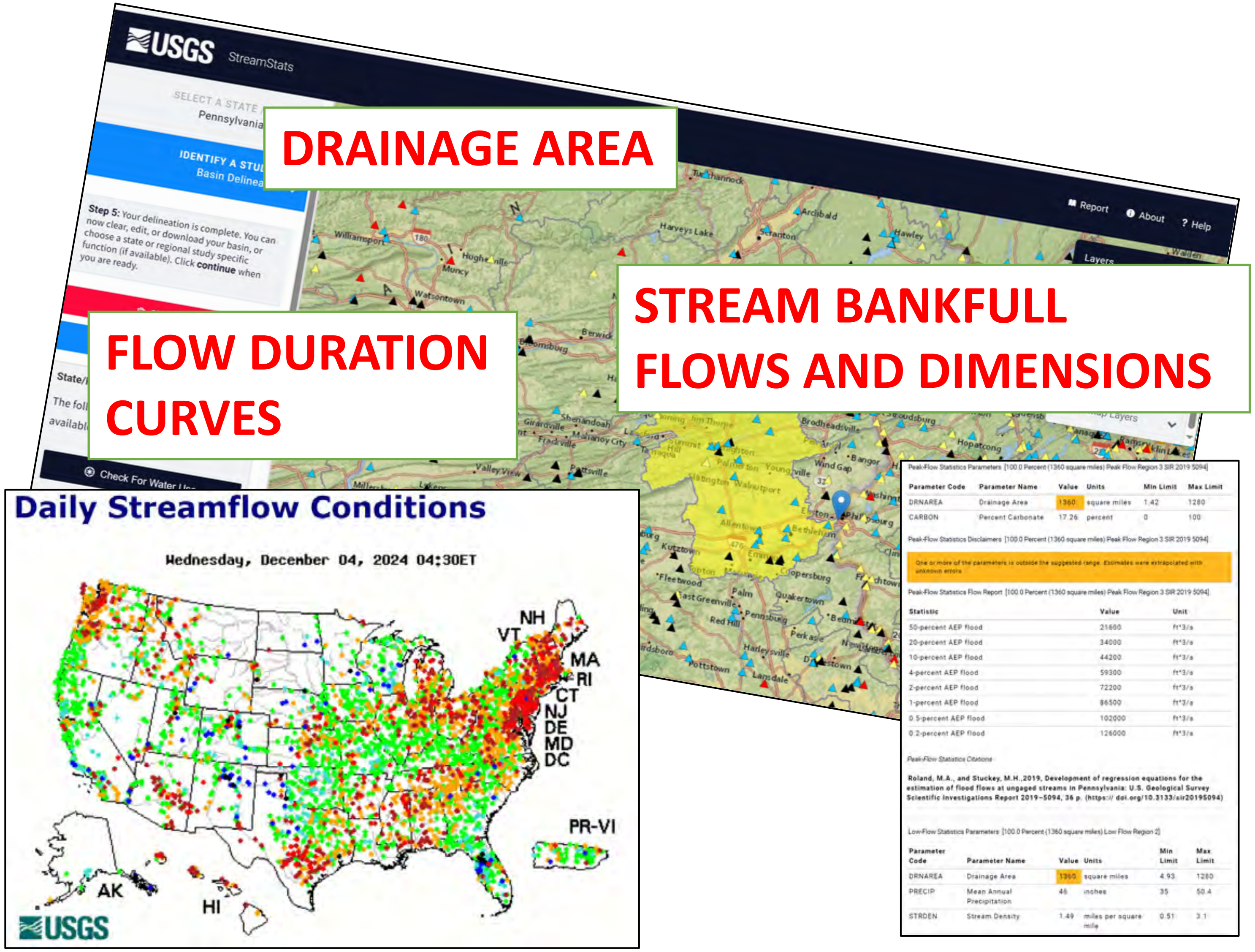

Regional regression curves (e.g., USGS StreamStats) and stream gauges are great tools for assessing your site remotely in preparation for field visits

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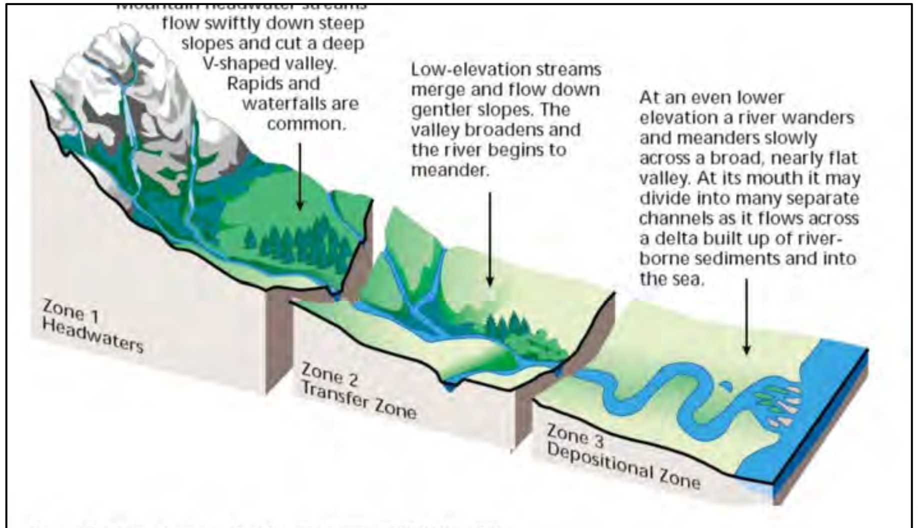
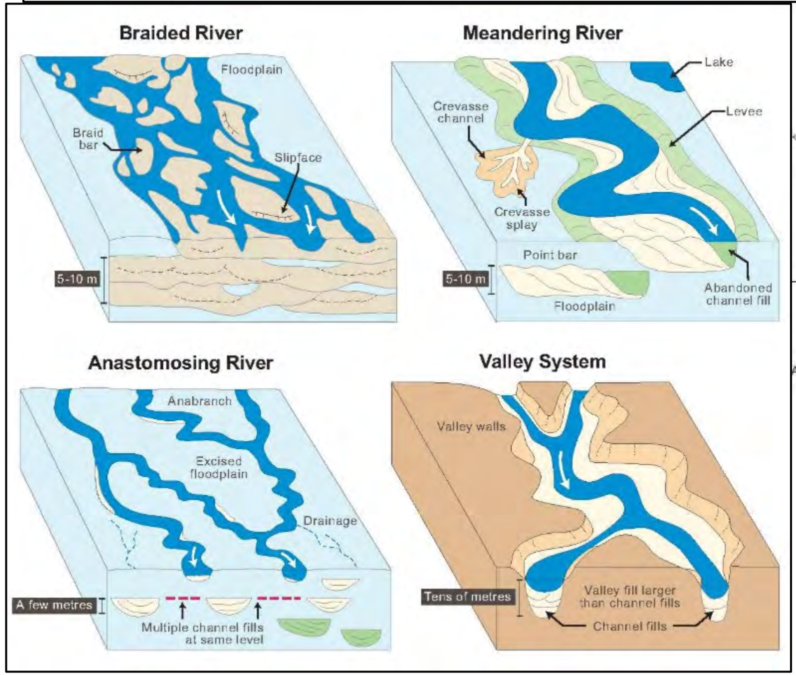


Figure 2.4 Three Longitudinal Profile Zones (FISRWG, 1998)



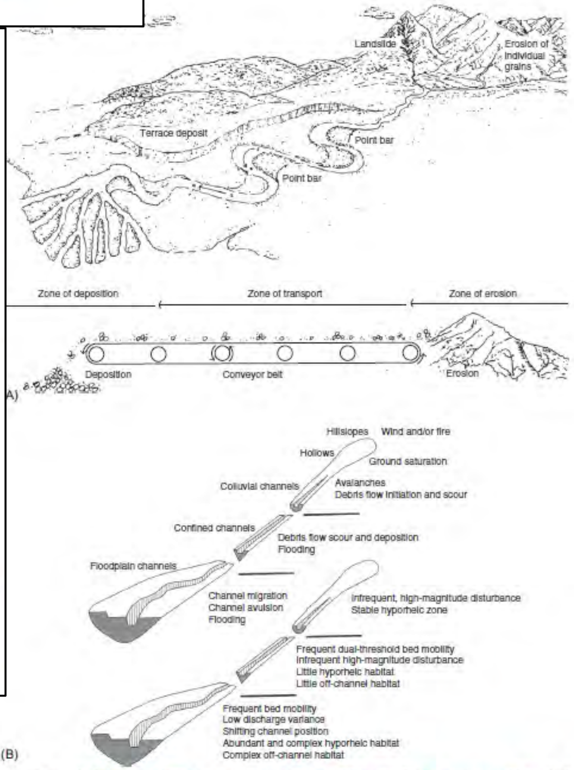


Fig. 2 Process domains defined by (A) Schumm (1977) (as depicted by Kondolf, 1994) and (B) Montgomery (1999). (A) Reprinted with permission from Kondolf GM (1994) Geomorphic and environmental effects of instream gravel mining. *Landscape and Urban Planning* 28: 225–243. (B) Reproduced from Montgomery DR (1999) Process domains and the river continuum. *Journal of the American Water Resources Association* 35: 397–410.

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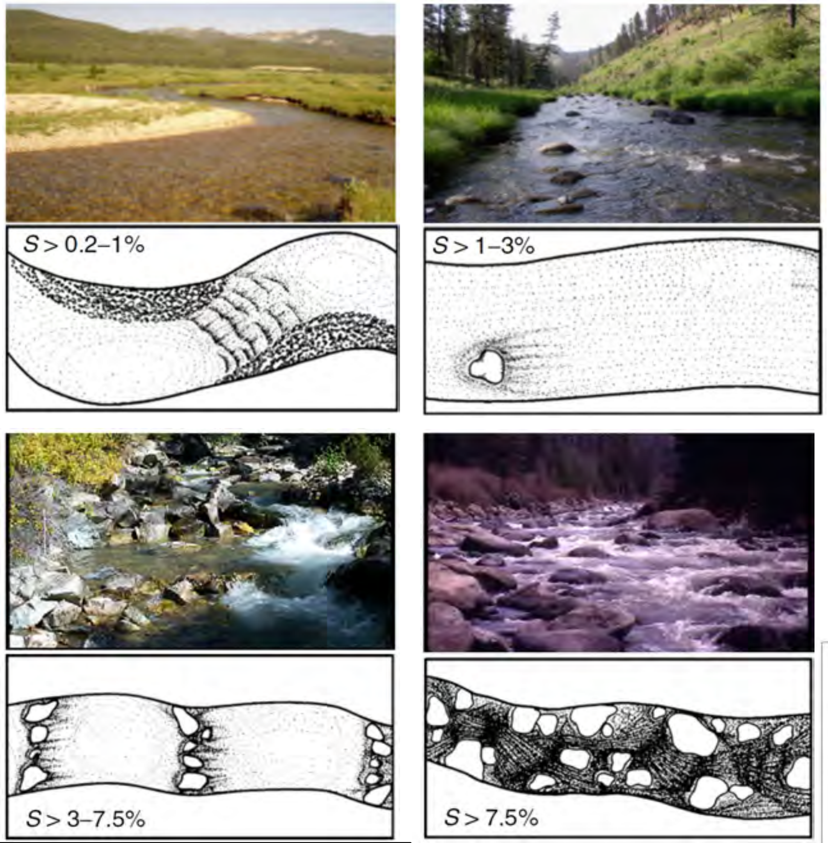
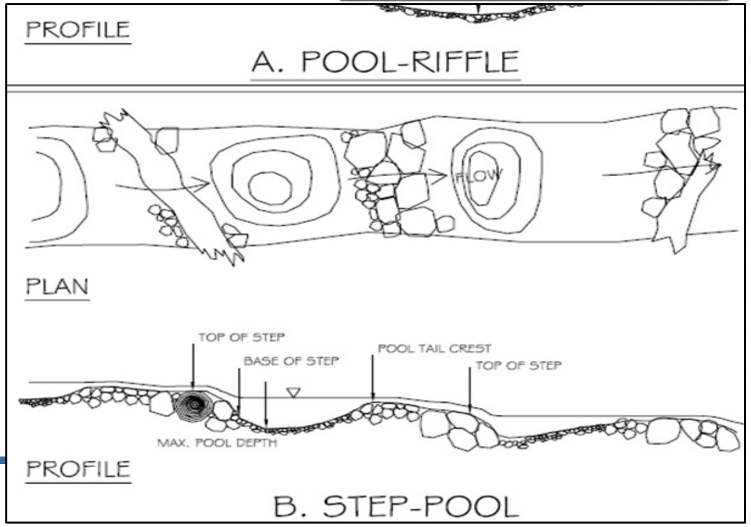
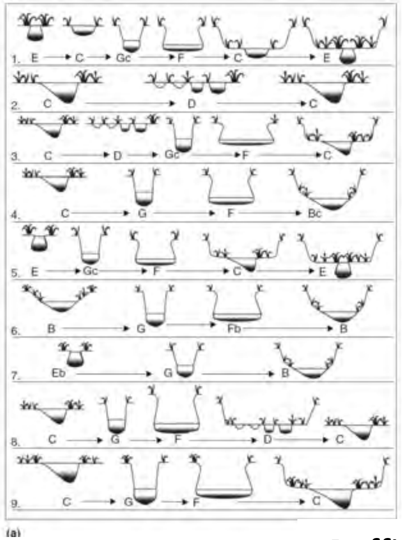
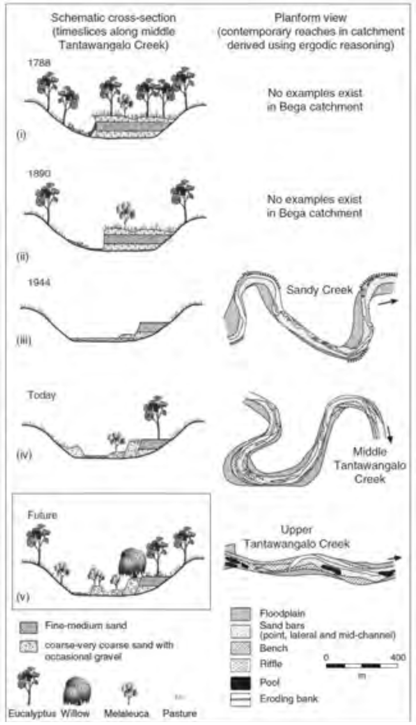


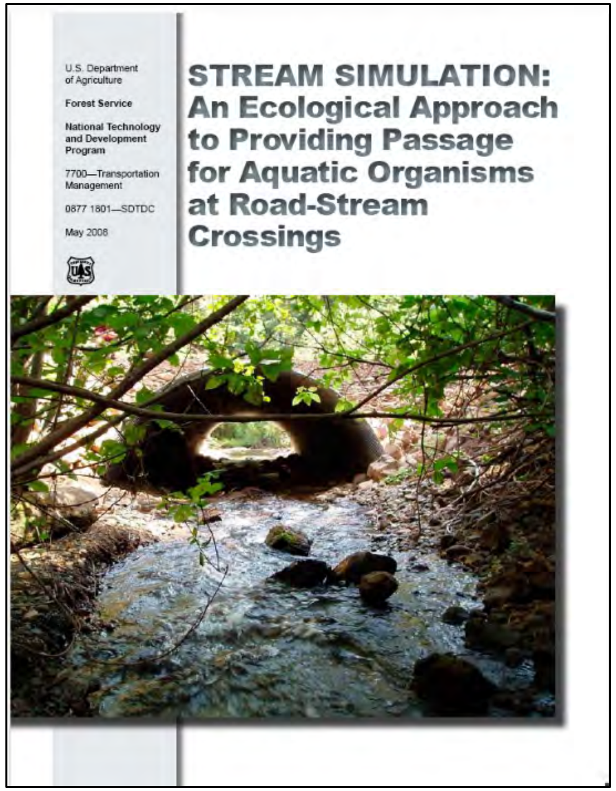






-Buffington & Montgomery 2013

Bed Variability and Channel Bed Features
GEOMORPHIC SITE ASSESSMENT



USFS (2008) Stream Simulation Design Manual

Chapter 5—Site Assessment

GEOMORPHIC SITE ASSESSMENT
Cross Section

Bankfull dimensions
Regional Regression Curves vs Field Measurements

Bankfull Statistics Parameters

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	44.1	square miles	2.92	298

Bankfull Statistics Flow Report

Statistic	Value	Unit
Bankfull Streamflow	277	ft^3/s
Bankfull Width	54.9	ft
Bankfull Depth	2.15	ft
Bankfull Area	118	ft^2

Bankfull Statistics Citations

Dudley, R.W.,2004, Hydraulic-Geometry Relations for Rivers in Coastal and Central Maine: U.S. Geological Survey Scientific Investigations Report 2004-5042, 30 p.

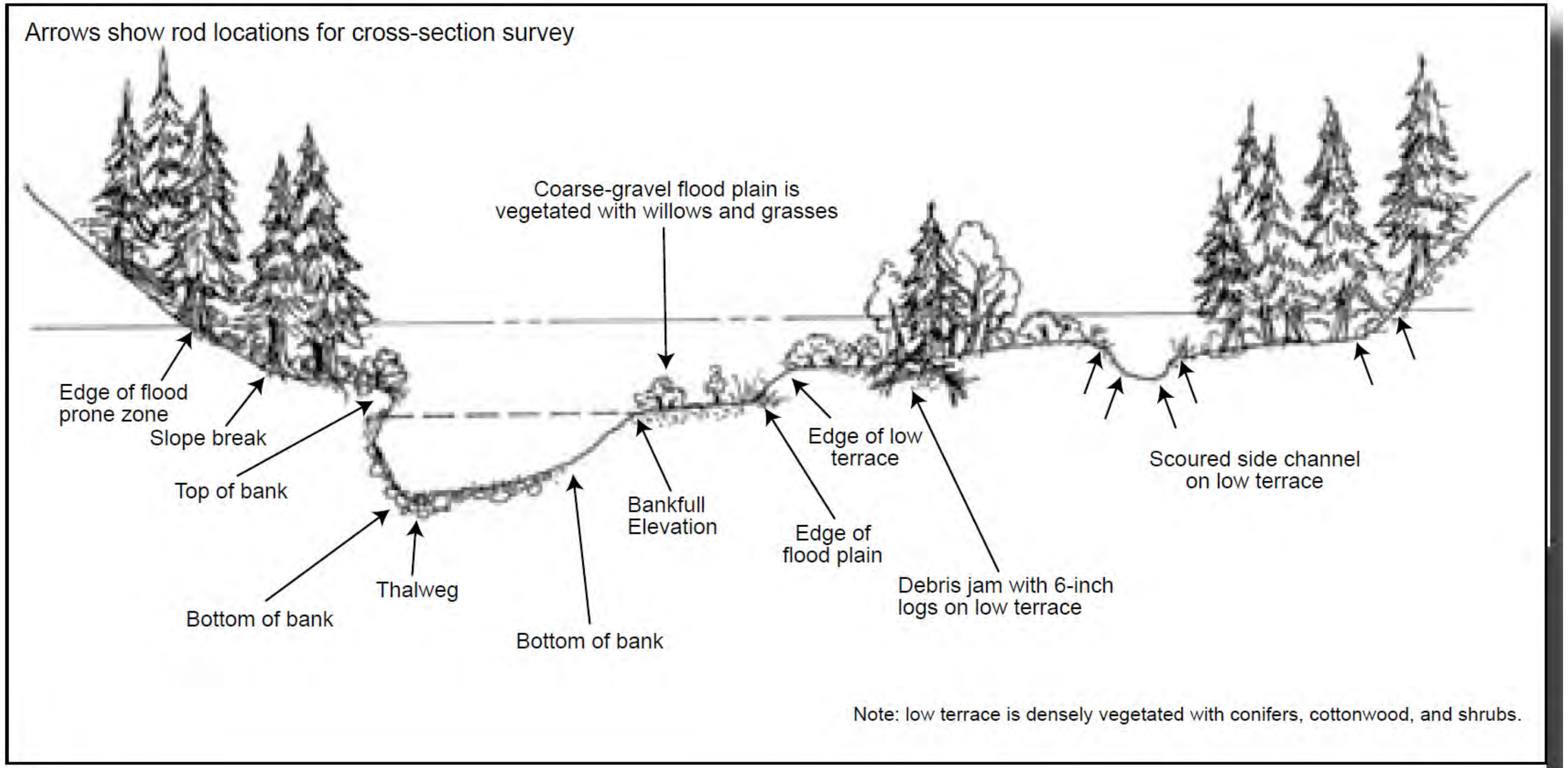
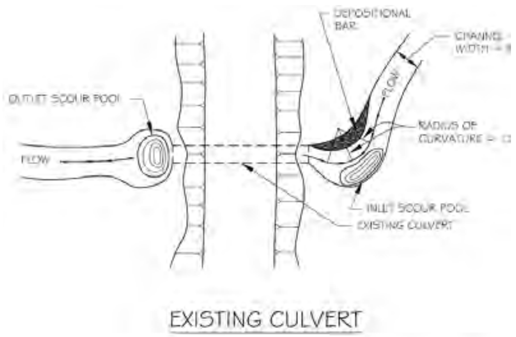


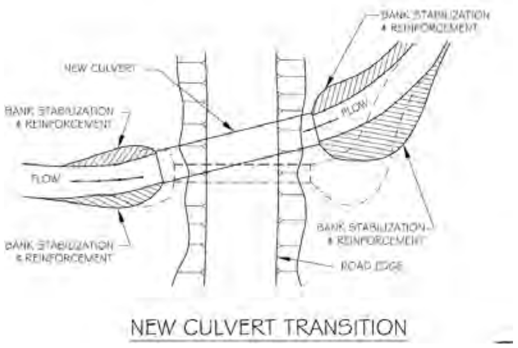
Figure 5.4—Schematic channel cross section showing recommended survey points.

-USFS 2008

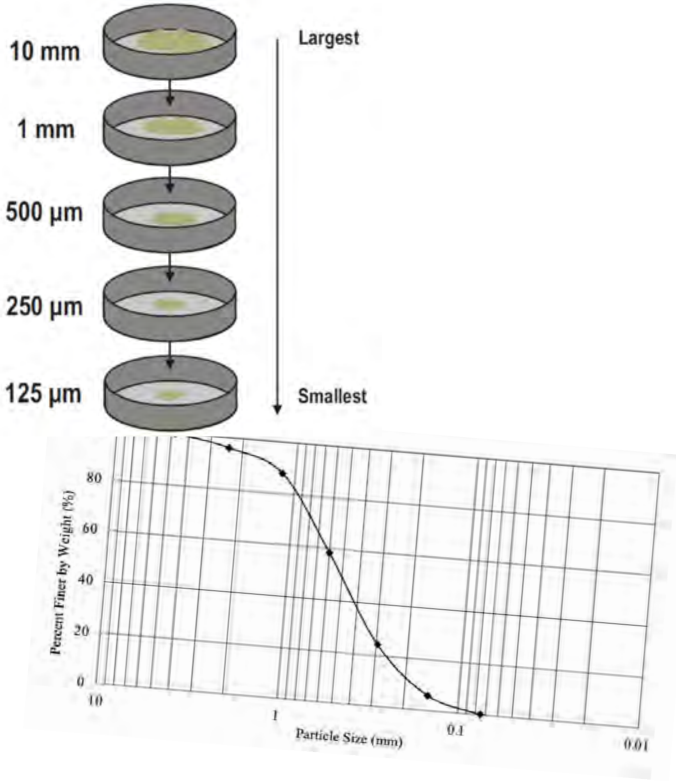
GEOMORPHIC SITE ASSESSMENT

Channel Alignment

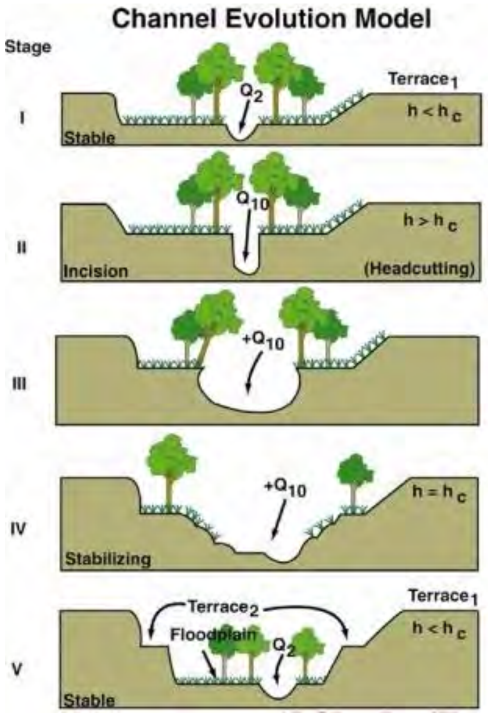




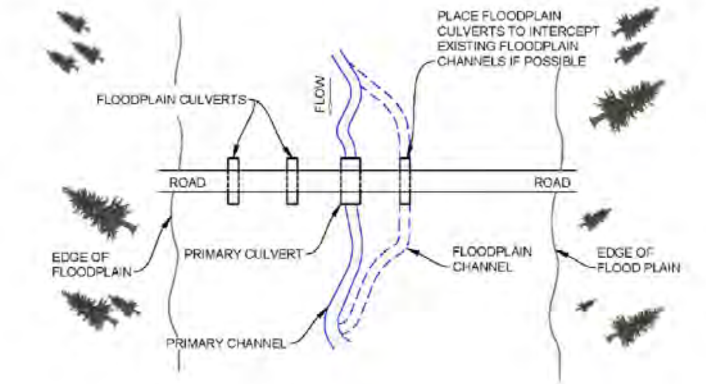
Streambed Material Composition

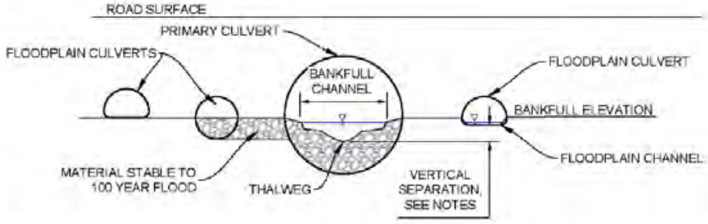


Channel Stability and Geotechnical Analysis



Floodplain Conveyance

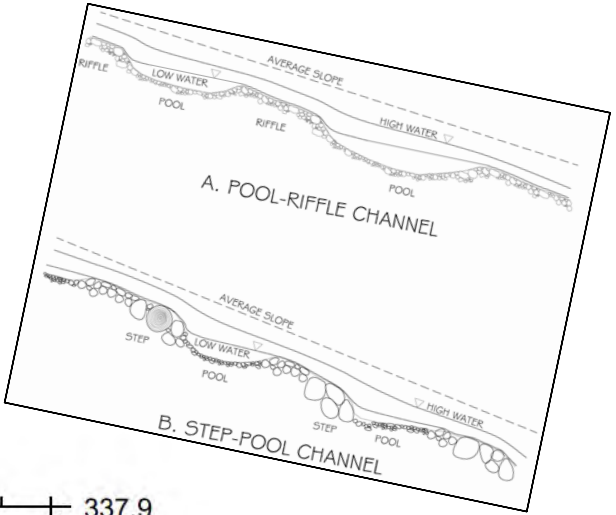


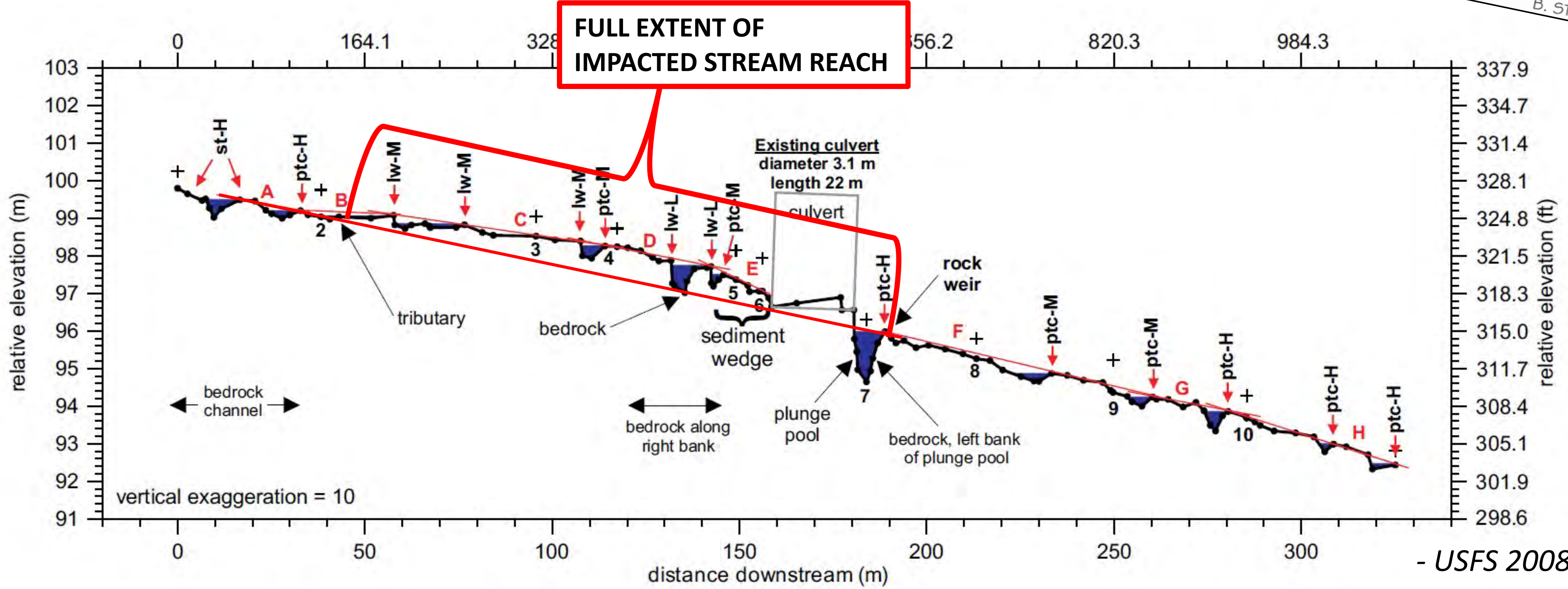


GEOMORPHIC SITE ASSESSMENT
Longitudinal Profile

“The longitudinal profile is perhaps the single most valuable tool in a stream-simulation design process”

– USFS 2008

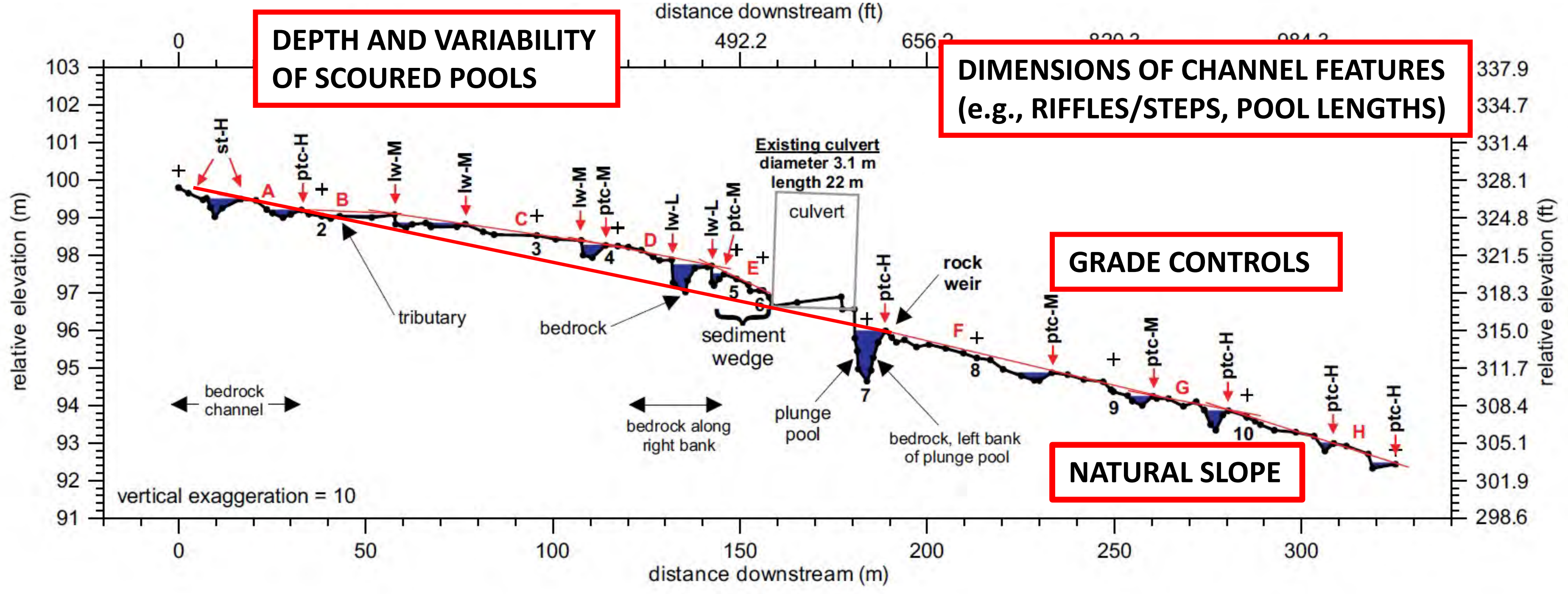




- USFS 2008

APPROPRIATELY SURVEYED LONGITUDINAL PROFILES SHOULD BE AT LEAST 40 TO 60 TIMES LONGER THAN THE ESTIMATED BANKFULL WIDTH

GEOMORPHIC SITE ASSESSMENT
Longitudinal Profile



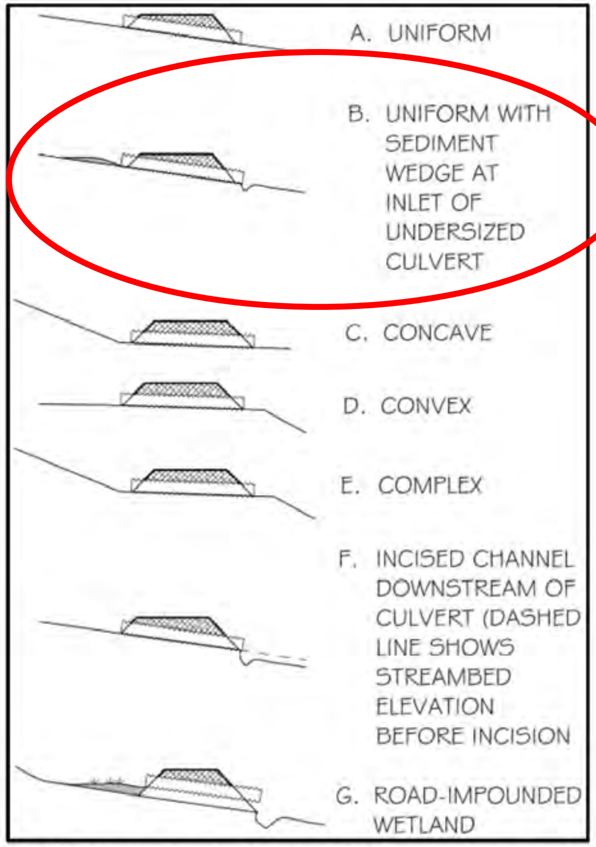


Image taken from *U.S. Forest Service.2008.Stream Simulation: An Ecological Approach to Providing Passage of Aquatic Organisms at Road Crossings*

INFORMATION IN THE LONGITUDINAL PROFILES SHOULD BE DETAILED ENOUGH FOR THE DESIGN TEAM TO CONFIDENTLY DIAGNOSE THE GEOMORPHIC IMPACTS ON THE STREAM

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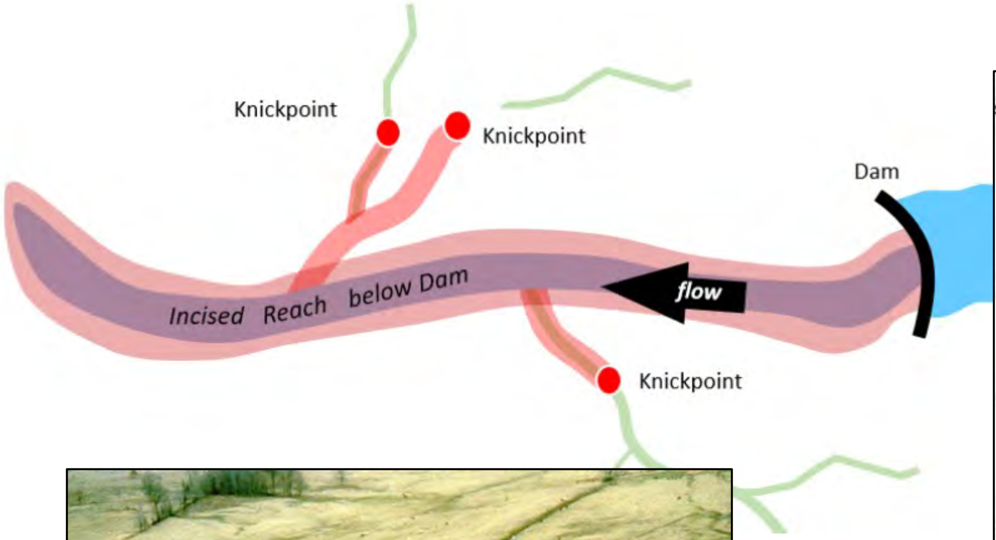
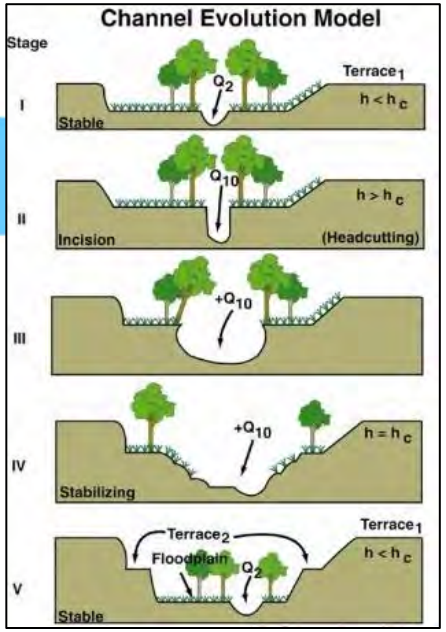
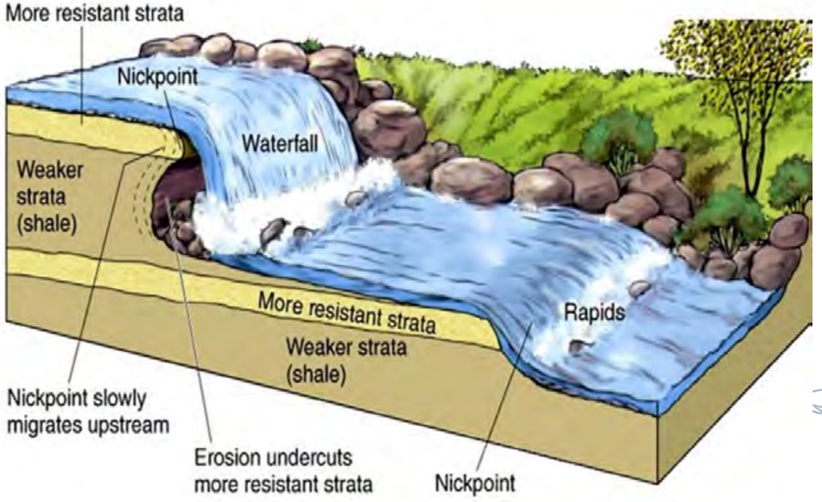






An **incised channel** is a river or stream channel that has eroded deeply into its bed, cutting downward into the underlying soil or rock layers. This process creates a channel that is significantly deeper than the surrounding floodplain. As a result, the stream sits lower in the landscape, often with steep or near-vertical banks

Incision Often Moves Headward Until Encountering a Knickpoint

Perched Culverts

Dams

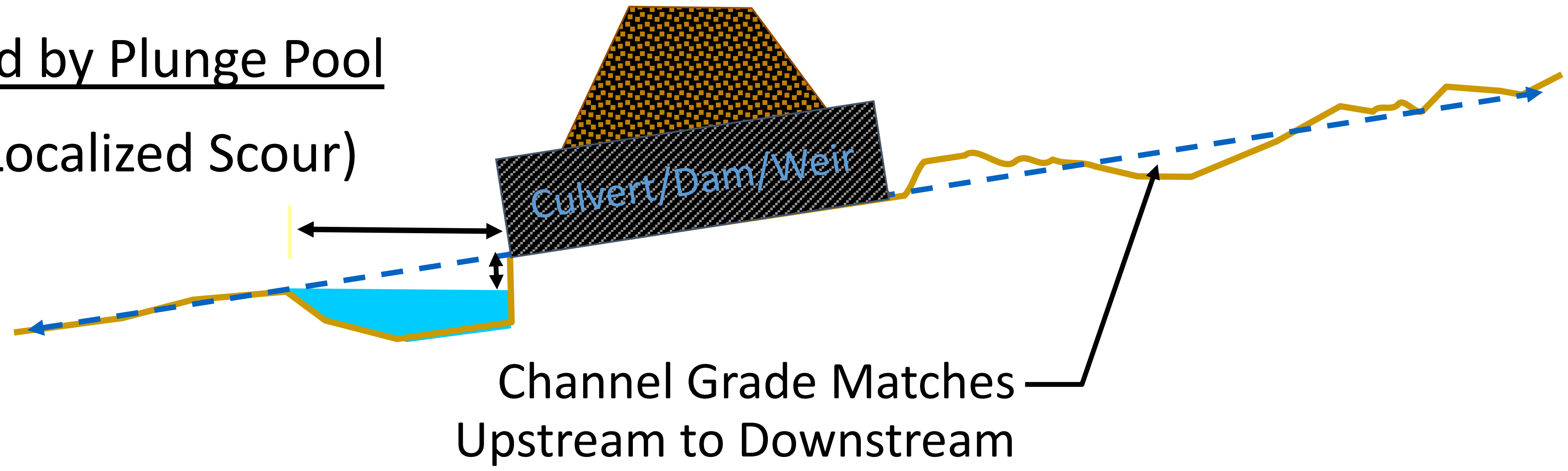
Perched Bridge Aprons

Perched Fishway Entrances

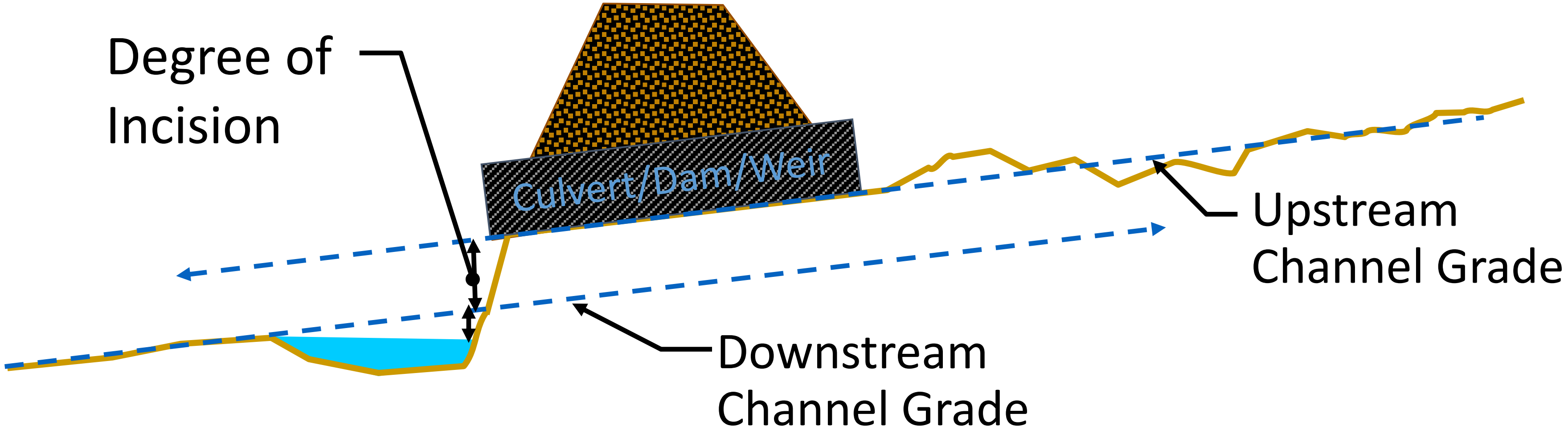
Recognize Local Scour vs. Channel Incision

Drop formed by Plunge Pool

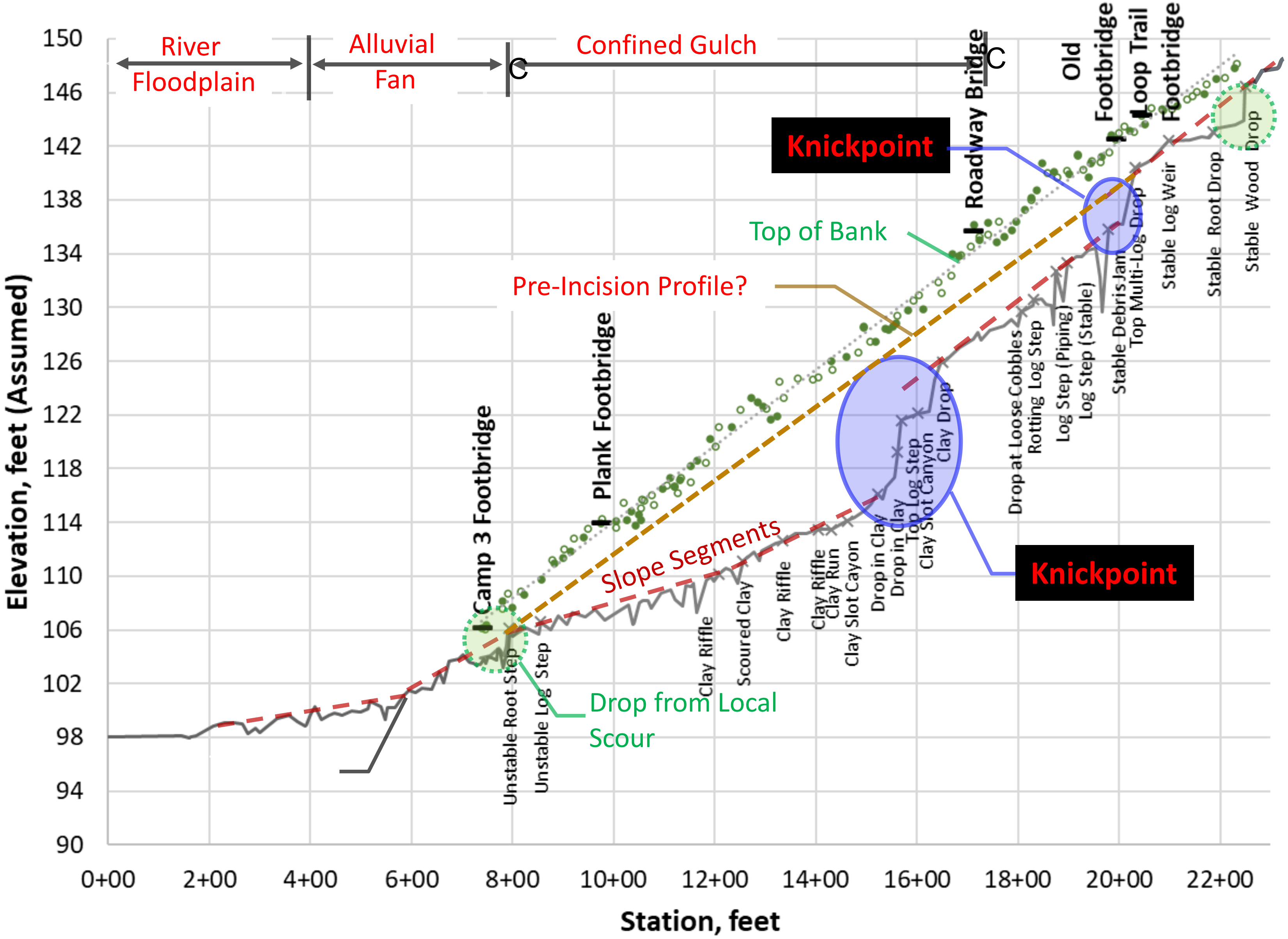
(Localized Scour)



Drop from Channel Incision



Bed Variability and Channel Bed Features
ACITVELY INCISED CHANNEL



Fis
No

Some Channel Incision Indicators

- **Toe of Bank is Vertical**
  Exposed roots, lack of sediment layering at streambed-banks interface
- **Actively Widening (Stage III)**
  Active bank failures, low depositional bars
- **Infrastructure/Cultural Features Exposed**
  Perched culverts, exposed bridge footings and pipelines
- **Lack of Sediment Deposition**
  Erosion of channel bed down to bedrock or other resistant soil layers
- **Lack of Pools**
  Long reaches of riffles/runs without pools

Stage II Incision

Stage III/IV Widening/Stabilizing

Example of Allowing Incision to Migrate Upstream without Considering Risk

Jordan Creek, CA

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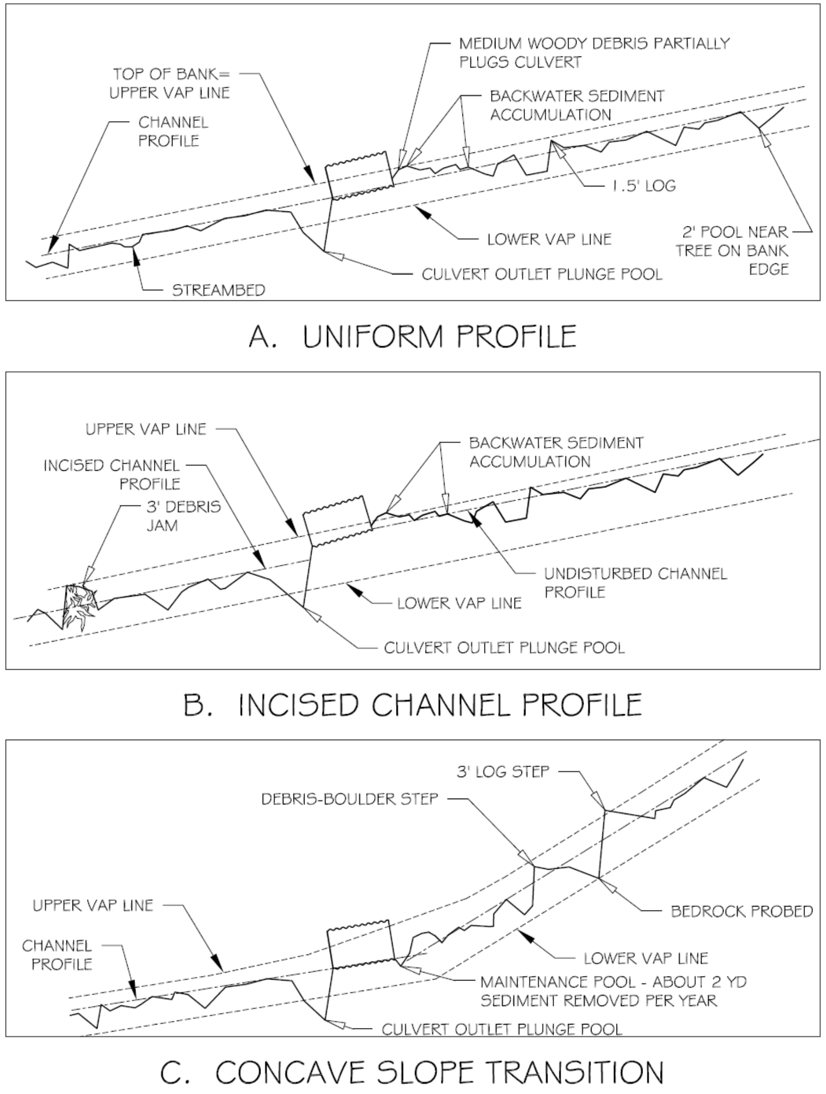
- Watershed Context
- Channel Type (transport channels vs response channels)
- Bed Variability and Channel Bed Features (e.g., pool lengths and depths, riffles/steps, natural and anthropogenic grade controls)
- Channel Incision
- **Vertical Adjustment Potential (VAP)**



THREE CRITICAL GEOMORPHOLOGICAL ATTRIBUTES IN THE LONG-PRO

- **Lower Vertical Adjustment Potential** = estimated line of the lowest likely elevations of any point along the thalweg of the stream channel in the absence of a barrier. It is typically delineated by connecting the bottoms of the natural pools outside the influence of the existing barrier (safety factors might be warranted depending on local geomorphology and type of substrate)
- **Natural Channel Profile** = a delineated line that connects the channel slope segments outside the influence of the existing barrier.
- **Upper Vertical Adjustment Potential** = estimated line of the highest likely elevations, caused by sediment aggradation, of any point along the thalweg of the channel in the absence of a barrier. It is typically delineated by connecting the top of banks along the stream channel (safety factors might be warranted depending on local geomorphology and type of substrate)

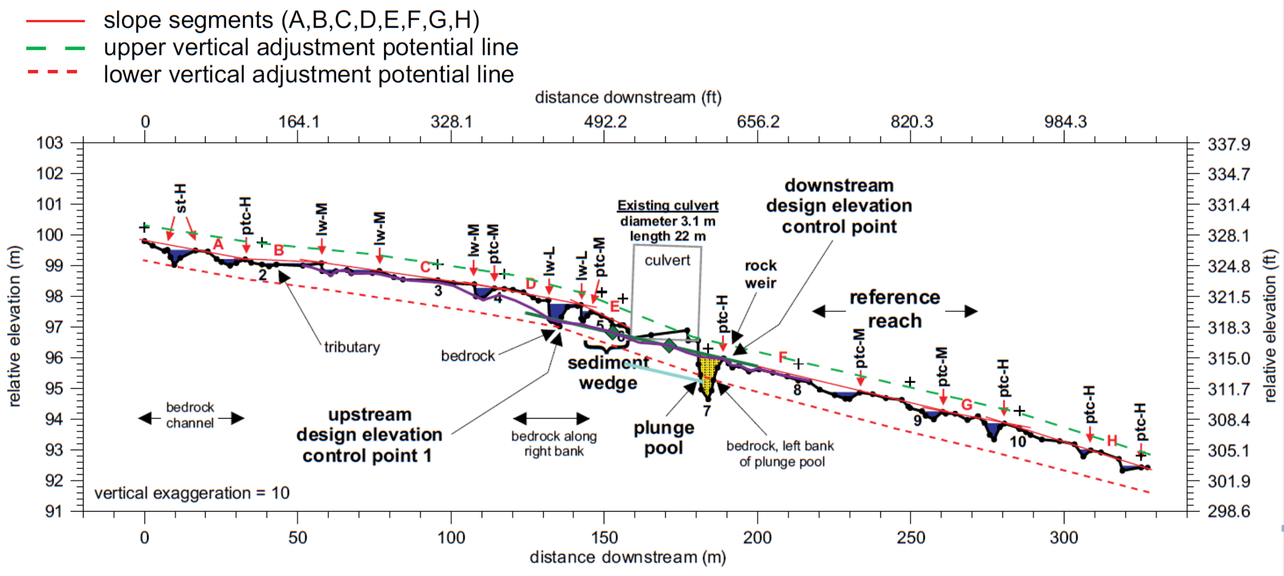
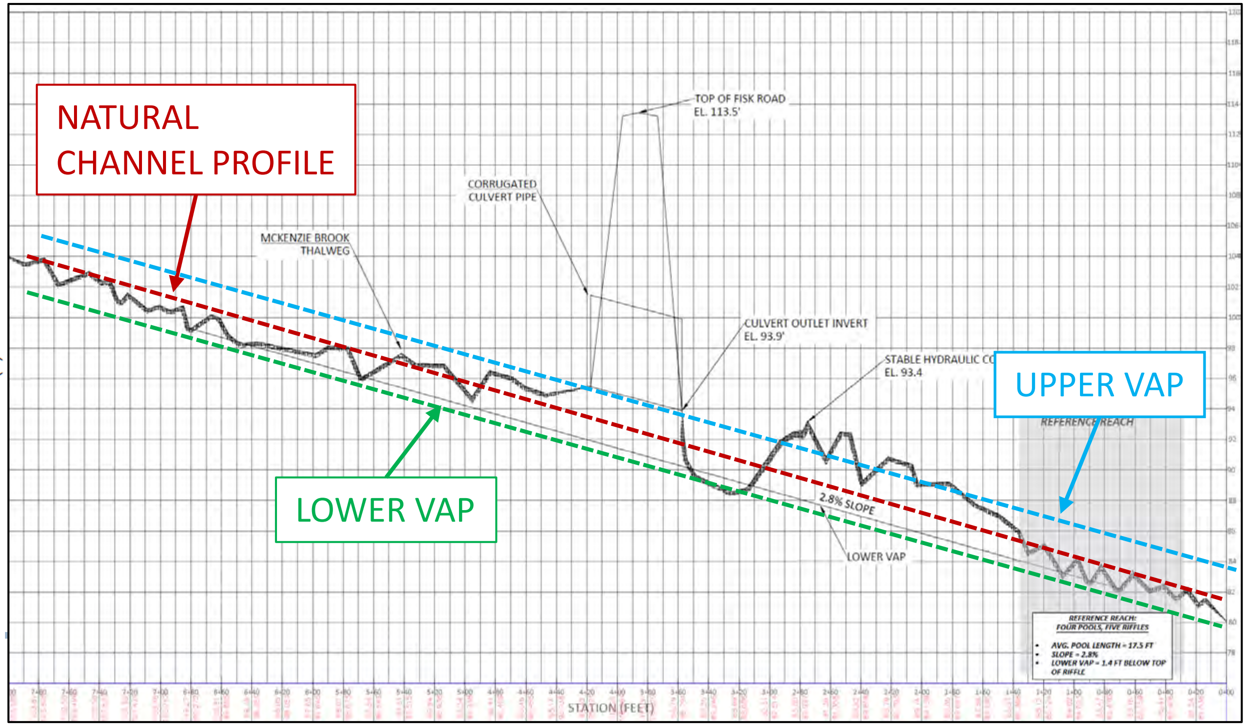


Figure 6.13—Newbury Creek channel profile anticipated after channel response to culvert replacement.



VERTICAL ADJUSTMENT POTENTIAL

Delineating Upper and Lower VAP lines is essential for anticipating and accommodating the maximum expected vertical changes in the channel's profile. These lines serve as a critical references for designing infrastructure that can withstand potential adjustments in the channel's elevation due to factors like sediment deposition or erosion.

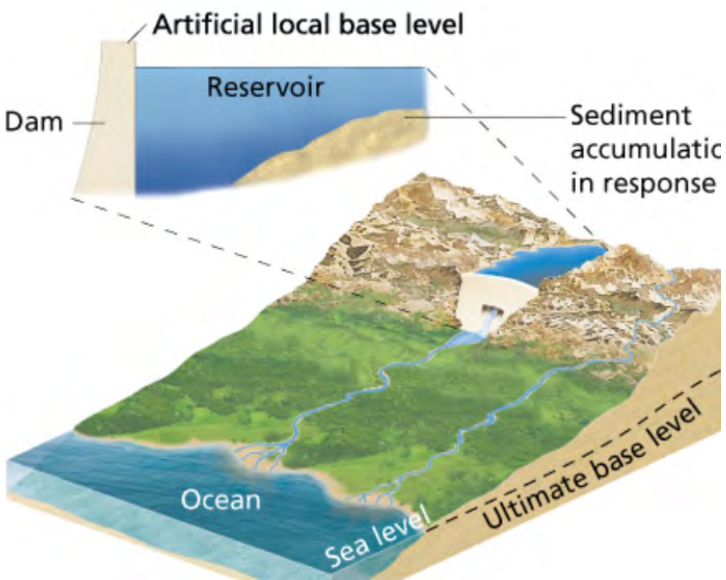
- **Lower Vertical Adjustment Potential:**
  - Adjust the downstream project profile to accommodate Lower VAP.
  - Design fishway entrances based on Lower VAP.
  - Determine the elevation of structural elements (e.g., culvert footings) based on low VAP.

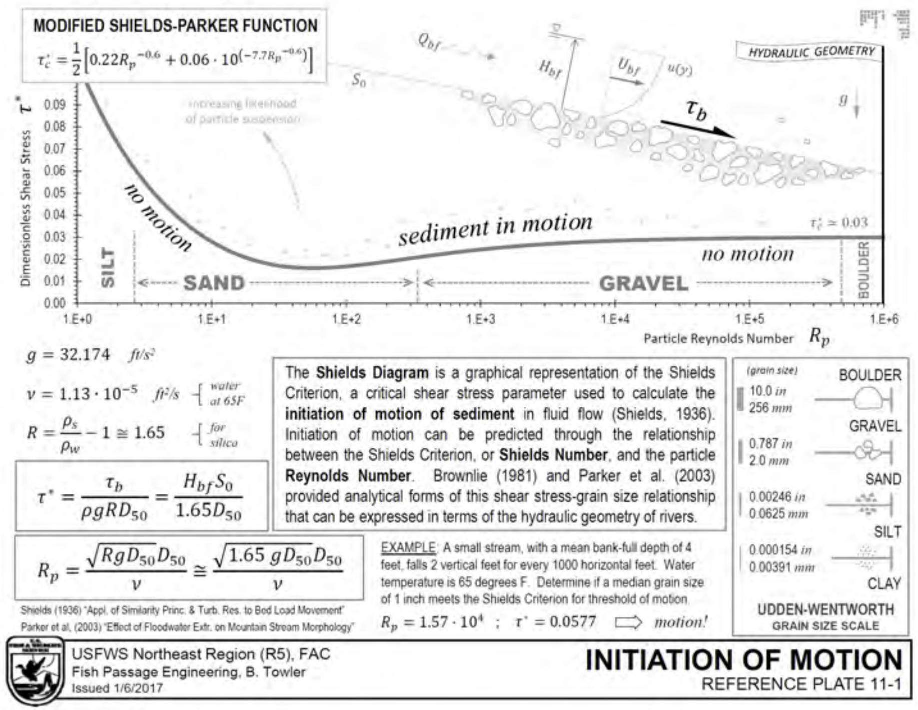
YOU WILL BE FLYING BLIND IF YOU DESIGN A STREAM CROSSING STRUCTURE WITHOUT WELL-DEFINED VAP LINES!

- **Upper Vertical Adjustment Potential:**
  - Ensure Adequate Hydraulic Capacity for High VAP conditions.
  - Mitigate Lateral Migration and Flanking at High VAP.

BOTTOMLINE

The site assessment should be comprehensive and thorough enough to allow the design team to confidently diagnose a barrier’s impact on the stream’s natural geomorphological features and make informed decisions about the management of the accumulated sediment and potential headcutting after restoration





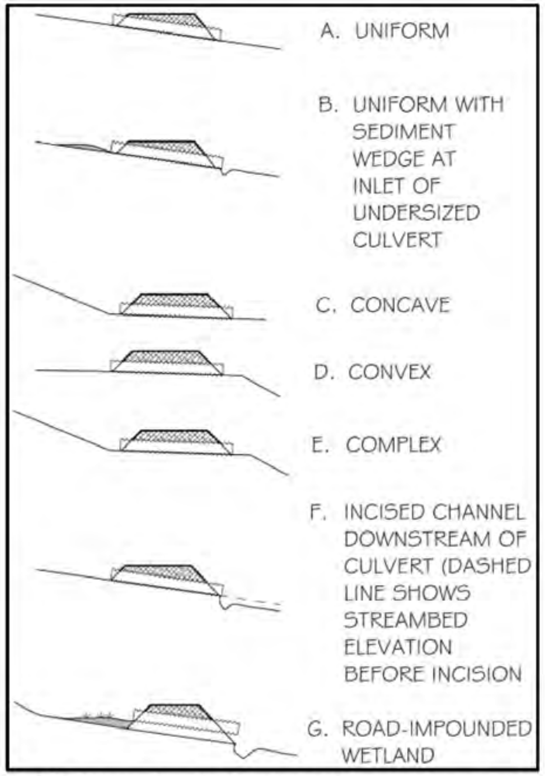
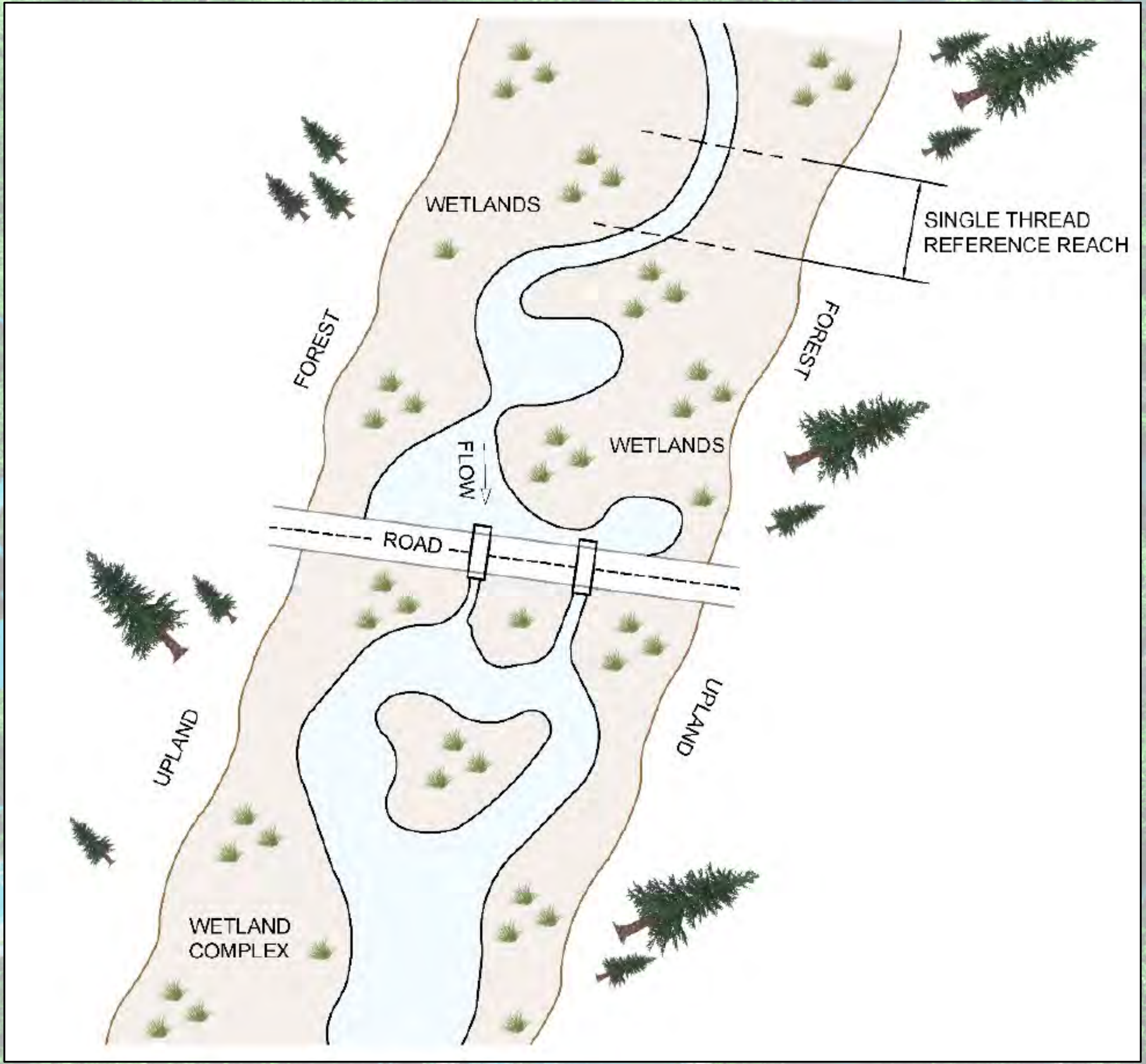


Image taken from *U.S. Forest Service.2008.Stream Simulation: An Ecological Approach to Providing Passage of Aquatic Organisms at Road Crossings*

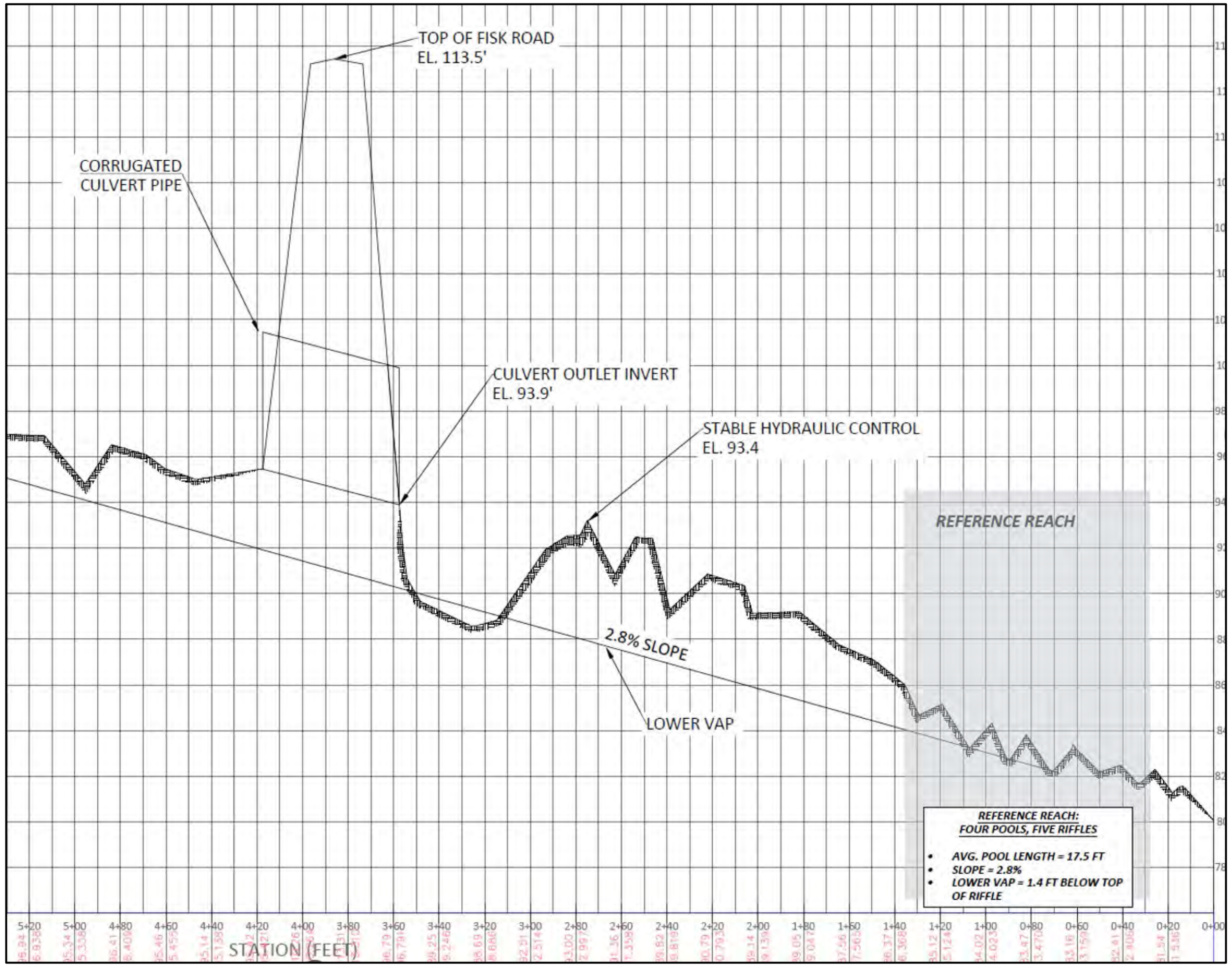


Presentation Outline

- Conservation Goals and Shifting Baseline Syndrome
- Overview of Stream Simulation Design Methodology
- Site Assessment
- **Reference Reach**
- Available Guidelines and Resources

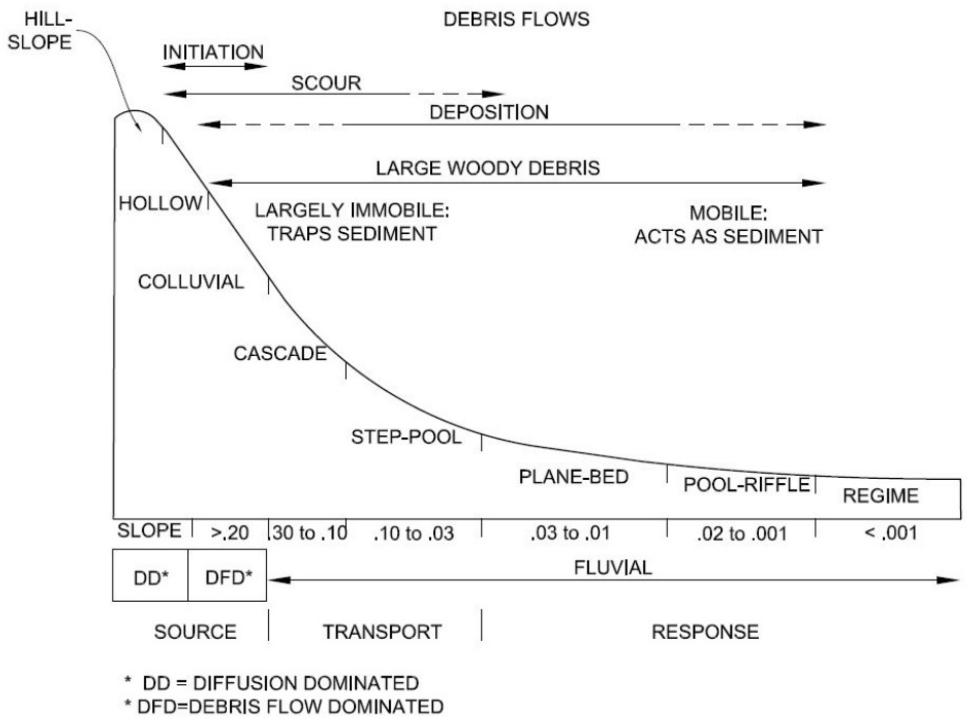
REFERENCE REACH FOR SSDM

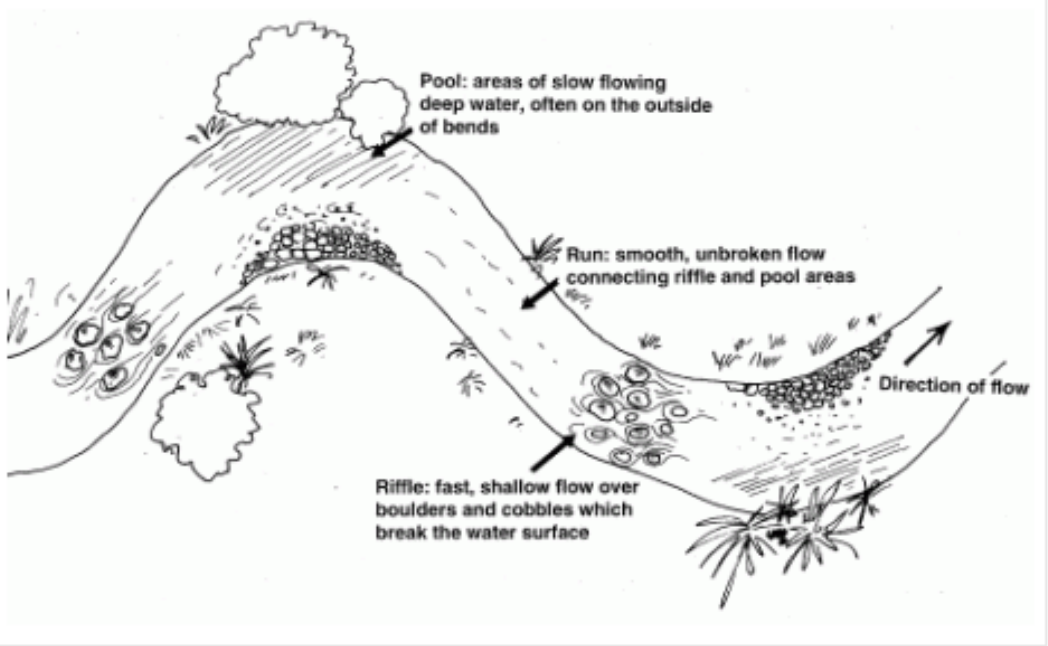
The **reference reach** is a representative section of a natural stream channel that is outside of the influence of the existing aquatic barrier and can be used as a template for designing stream crossing structures, such as culverts or bridges. This reach embodies the natural physical and hydraulic characteristics of the stream, including channel dimensions, substrate composition, flow patterns, and habitat features. By closely mimicking these attributes in the design, the crossing structure aims to simulate natural stream conditions, facilitating unimpeded movement of aquatic organisms and maintaining ecological continuity.

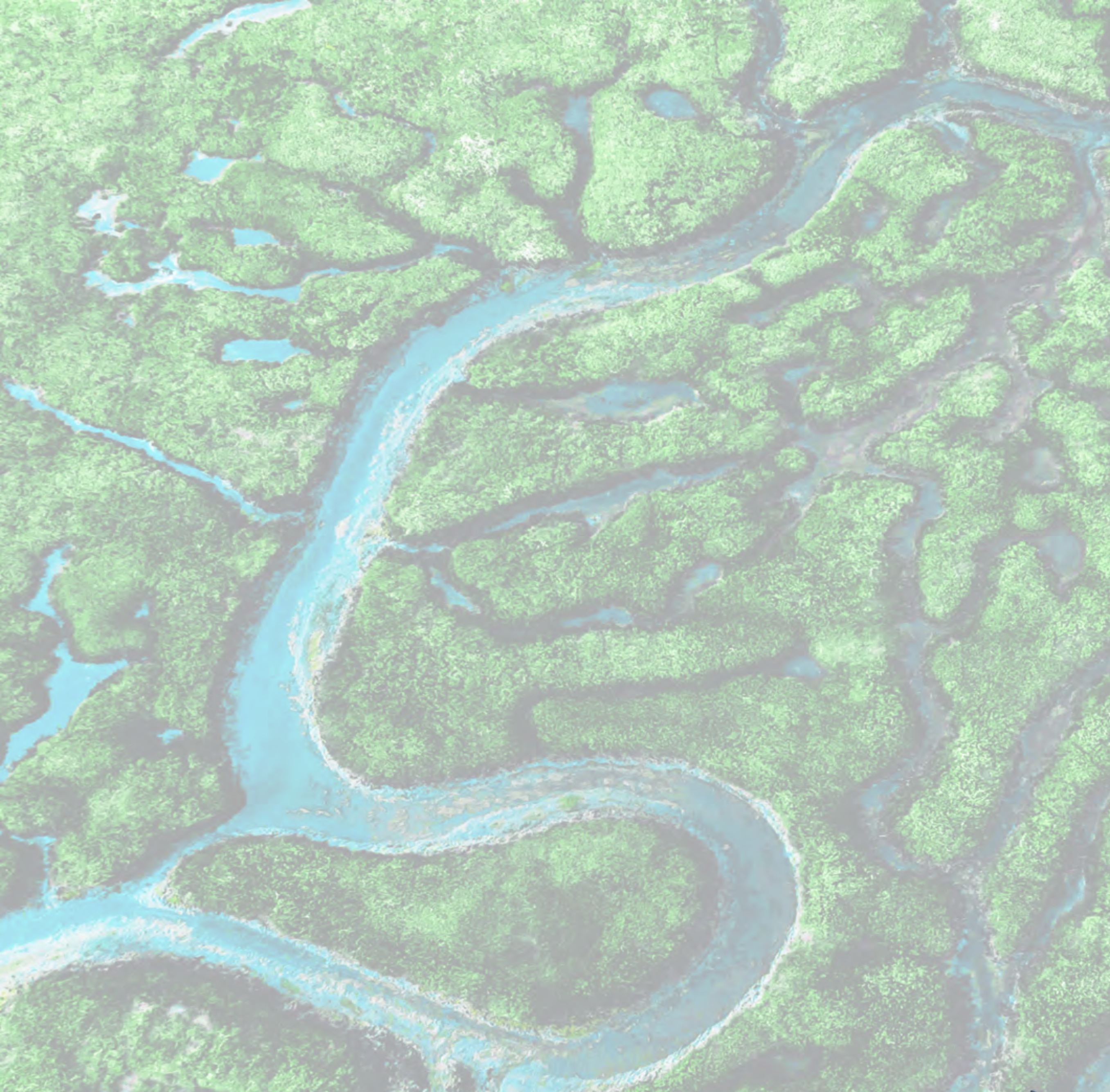


WHAT TO THINK ABOUT WHEN CHOOSING YOUR REFERENCE REACH

- Is the reference reach outside the influence of the culvert (typically 20-30 channel widths from the inlet or outlet)?
- Is it upstream or downstream from the impacted reach?
- Are you sure there are no additional anthropogenic infrastructure impacting the reference reach?
- Is the reference reach representative of the natural conditions for the impacted stream reach based on the watershed context (e.g., channel slope, bankfull dimensions, grade controls, streambed composition, etc.)
- What type of in-stream features need to be reconstructed inside your culvert (pools and riffles, step pools, flat and sandy)?







Presentation Outline

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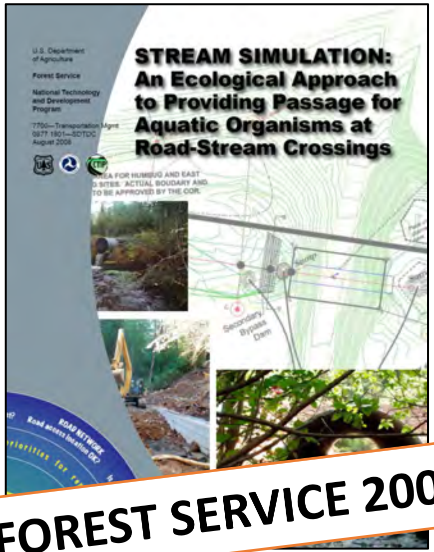
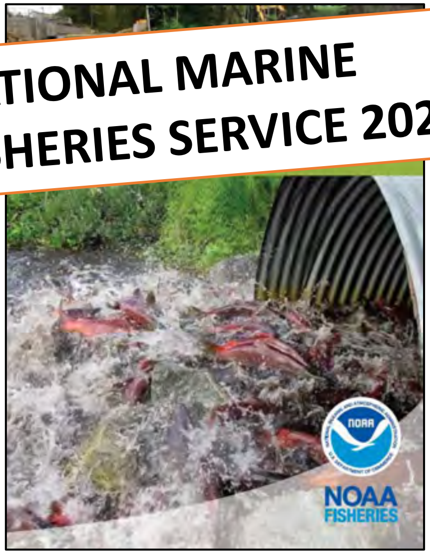
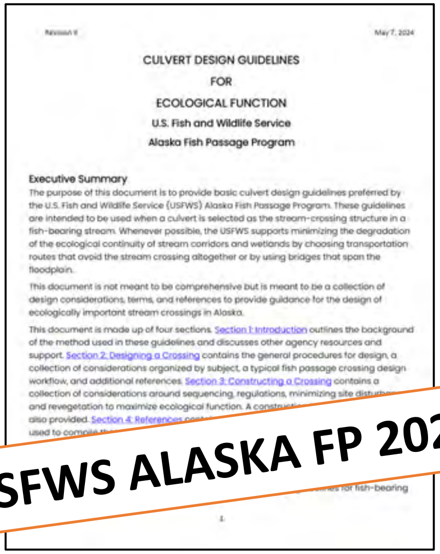
AVAILABLE DESIGN GUIDELINES



US FOREST SERVICE 2008

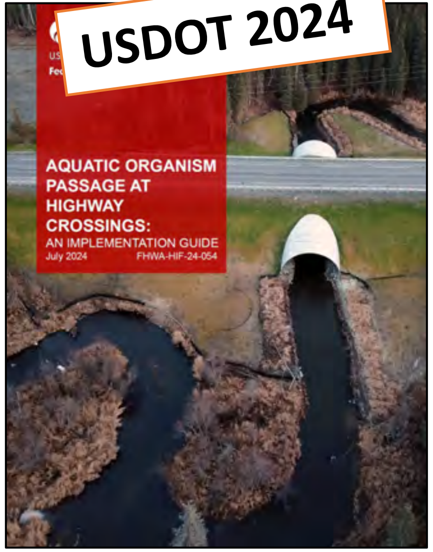
NATIONAL MARINE FISHERIES SERVICE 2022

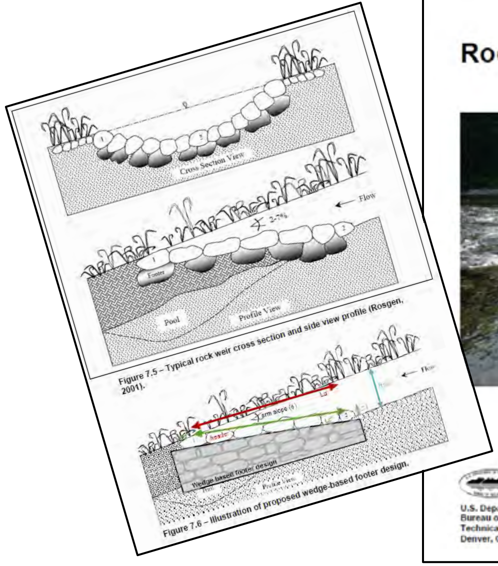


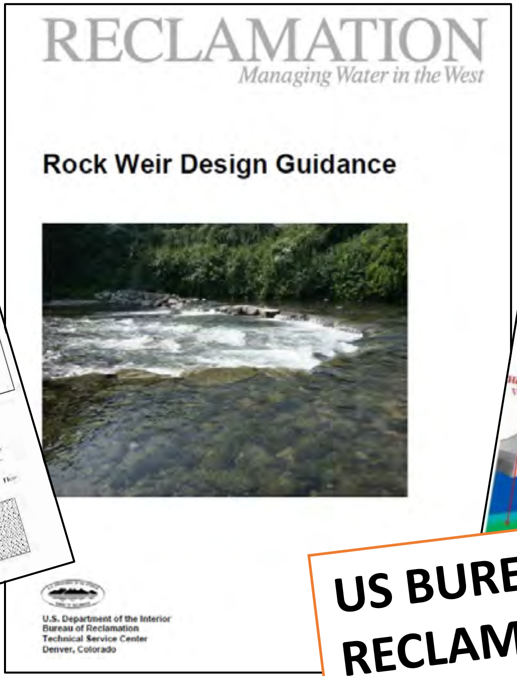


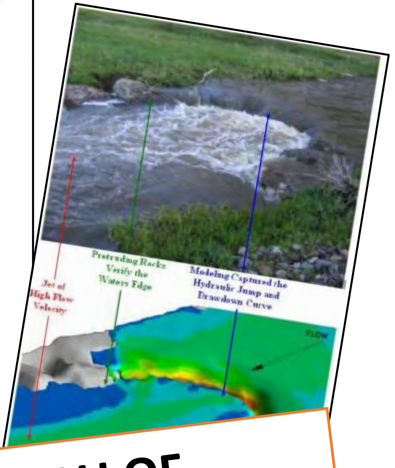
USFWS ALASKA FP 2024

USDOT 2024









US BUREAU OF RECLAMATION 2016

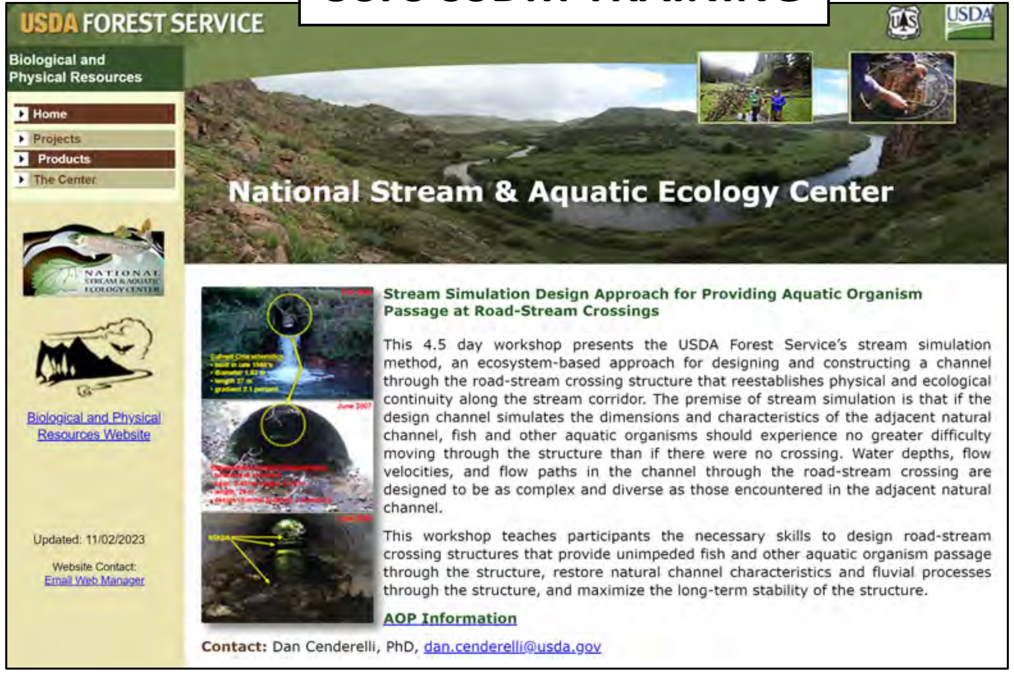
AVAILABLE STATE GUIDELINES

YOUR PROJECT'S STATE MIGHT HAVE ITS OWN DESIGN GUIDELINES!

State	Document Name	Date
	NORTHEAST REGION	
CT	CT Stream Crossing Guidelines	2008
MA	Massachusetts River and Stream Crossing Standards	2012
ME	Stream Smart Road Crossing Pocket Guide	
NH	NH Stream Crossing Guidelines	2009
NY	Stream Crossings: Guidelines and Best Management Practices	
PA	Stream Crossing Culvert Practices for Aquatic Organism Passage	2015
VT	Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont	2007
	SOUTHEAST REGION	
GA	Georgia's Stream Crossing Handbook: Regulations and ecological considerations	2012
VA	Non-anadromous Fish Passage in Highway Culverts - Fitch, 1995	1995
VA	An Analysis of the Impediments to Spawning Migrations of Anadromous Fish in Virginia Culverts - Mudre et al., 1985	1985
	MIDWEST REGION	
KS	Kansas Fish Passage Guide	2015
MN	Minnesota Guide for Stream Connectivity and Aquatic Organism Passage through Culverts	2019
WI	Fish Friendly Culverts	
	WEST REGION	
CA	Culvert Criteria for Fish Passage	2007
WA	Washington DFW Water Crossing Design Guidelines	2013
	SOUTHWEST REGION	
AZ	Guidelines for Culvert Construction to Accommodate Fish and Wildlife Movement and Passage	
NM	Bridge and Culvert Construction Guidelines for Stream, Riparian, and Wetland Habitats	2018
	FEDERAL GUIDELINES	
Federal Highway Administration	Culvert Design for Aquatic Organism Passage	2024

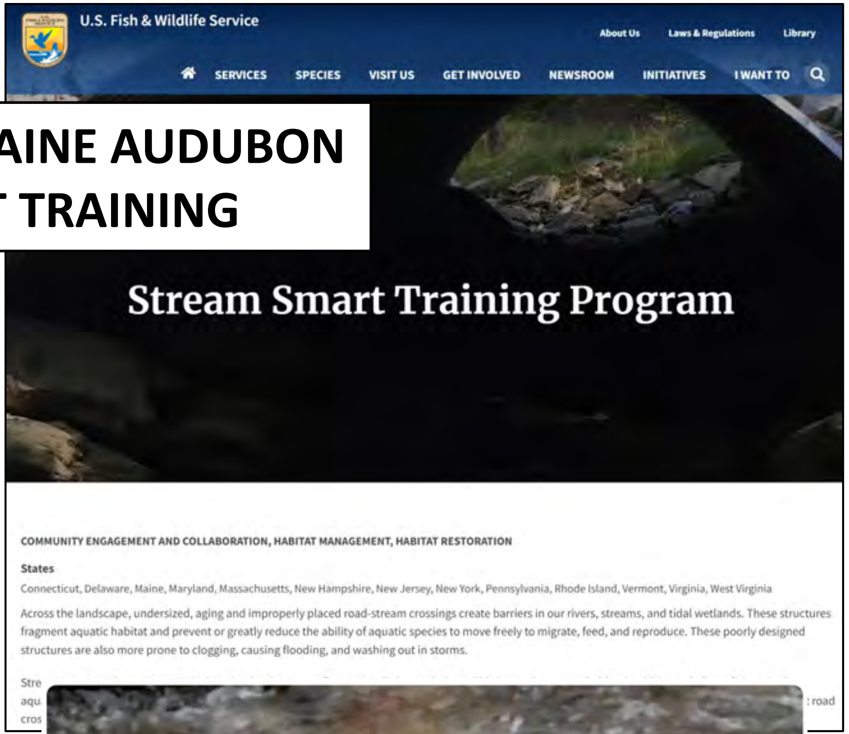
STREAM SIMULATION DESIGN TRAININGS AND VIDEOS

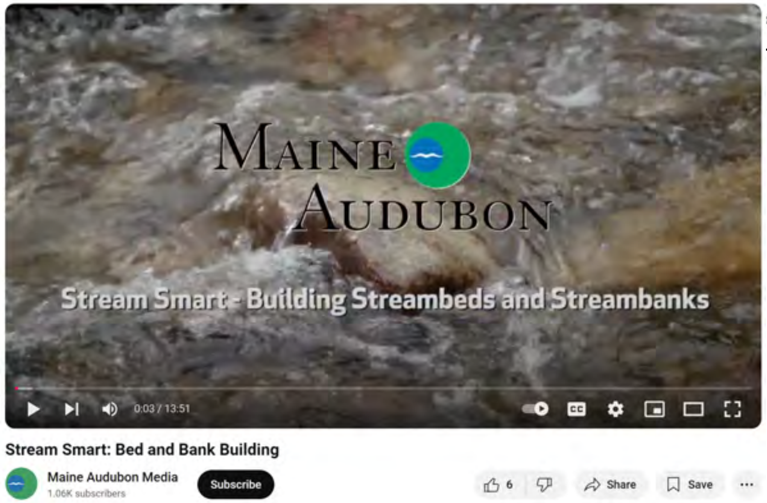
USFS SSDM TRAINING



https://www.youtube.com/watch?v=QS_0m8UkMD4&t=4s

USFWS AND MAINE AUDUBON STREAMSMART TRAINING





https://www.youtube.com/watch?v=8EVqegR8UPg