Fish Passage from the Tidewater to the Sierras Workshop

A Workshop at the 35th Annual Salmonid Restoration Conference held in Davis, CA from March 29 – April 1, 2017.

Session Overview

- Session Coordinators:
  - Michael Love, P.E., Michael Love & Associates, Inc.
  - Mike Garello, HDR Engineering, Inc.
  - Ross Taylor, Ross Taylor & Associates

This workshop was a day-long course and discussion focused on taking a broad perspective to address stream and downstream fish passage challenges. This involved the examination of migration barriers from a watershed perspective and understanding how they are inter-related rather than focusing on one barrier at a time. The workshop also discussed the various technologies and approaches available to address barriers, lessons learned from previous projects, and future challenges ahead.

The morning focused on a range of fish migration challenges that arise at road-stream crossings, lowhead dams, and other infrastructure that impede movement of fish. These included inventory and ranking of barriers for remediation while working with multiple ownerships, identifying channel incision that creates fish barriers, conducting geomorphic risk assessments to avoid creating new upstream barriers, and how to select the best fish passage solution for a site.

In the afternoon the workshop focused on upstream and downstream passage over high-head dams. Here, we examined what has worked in the Pacific Northwest, lessons learned, and the similarities and differences in the challenges we face in California. Topics included volitional versus non-volitional upstream passage, guidance and collection systems for out-migrants, thermal barriers and temperature control, and the successes and failures of reservoir transit, among others.

Two interactive panel discussions presented various viewpoints on the use of volitional and non-volitional passage at high head dams as well as on the applicability of lessons generated in the Pacific Northwest for use in California.

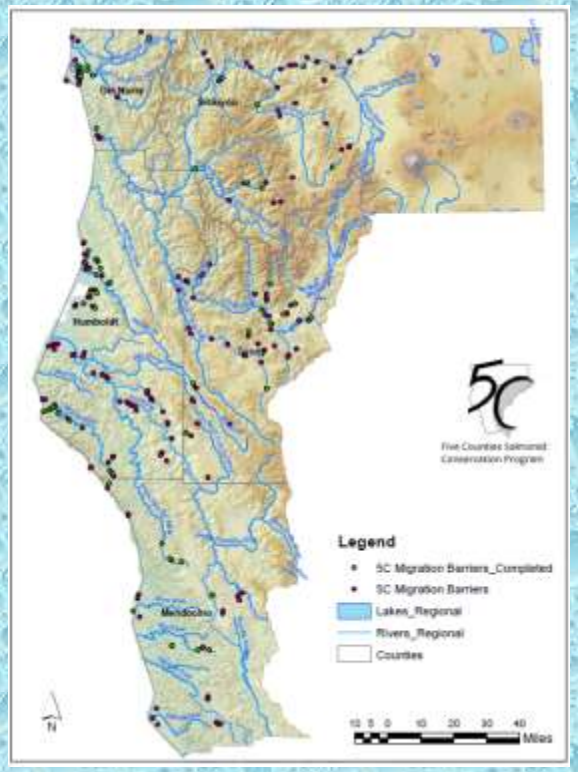
Presentations

(1) Status of Fish Passage Assessments and Prioritization in California, Ross Taylor, Ross Taylor and Associates and Anne Elston, PSMFC

(2) The Need to Address Watershed Scale Channel Incision in our Passage Projects, Michael Love, P.E., Michael Love & Associates, Inc.

(3) One Size Does Not Fit All—Tools and Approaches to Addressing Stream Crossing Barriers, Michael Love, P.E, Michael Love & Associates, Inc.

Status of Fish Passage Assessments and Prioritization in California



Anne Elston – Pacific States Marine Fisheries Commission
Ross Taylor – Ross Taylor and Associates (RTA)

Passage Assessment Methodologies

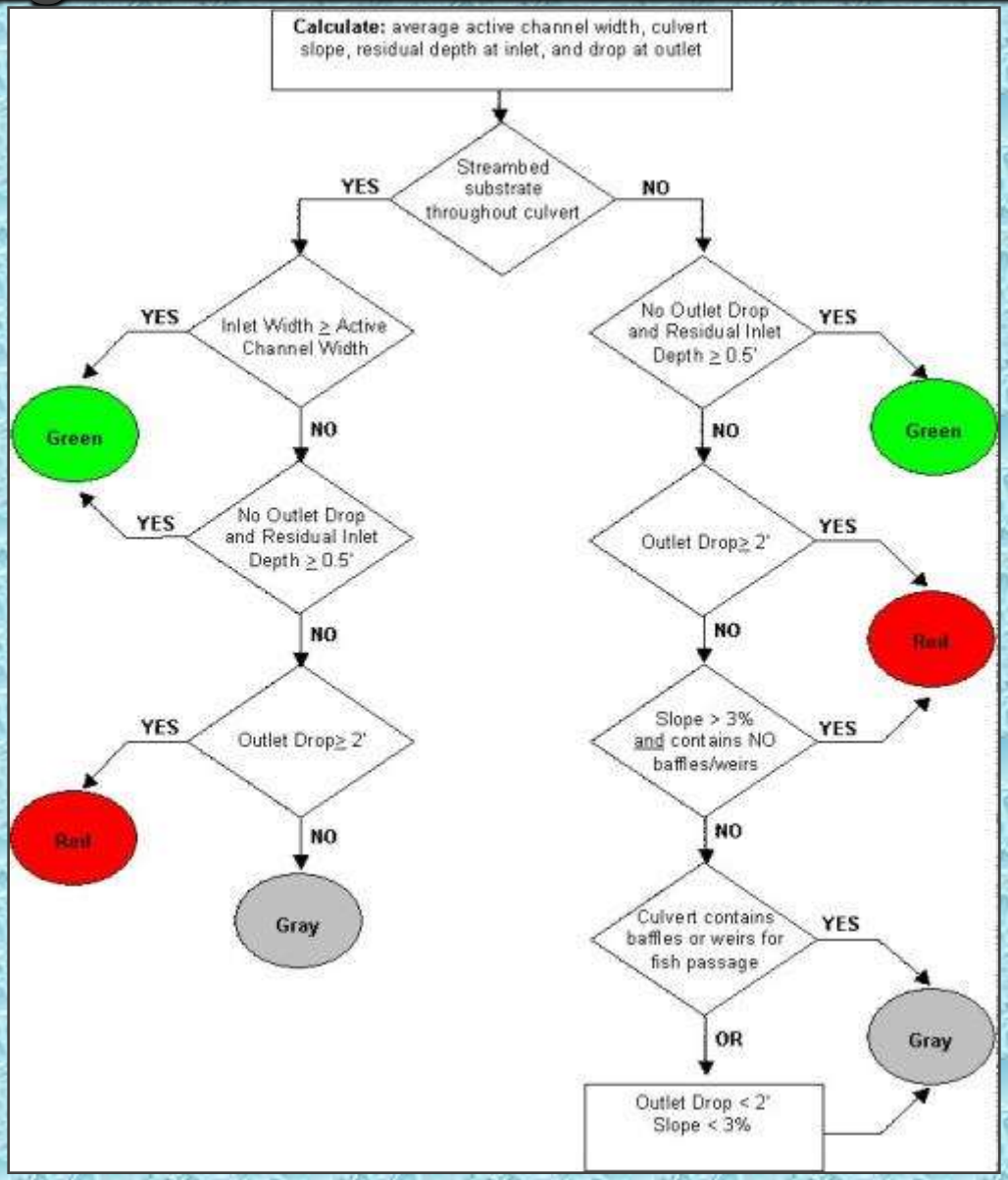
CDFW – Section 9

- Road/stream crossing based, but functional in other select cases.
- Relies on survey data, swimming and leaping abilities of focal species and hydrologic data.

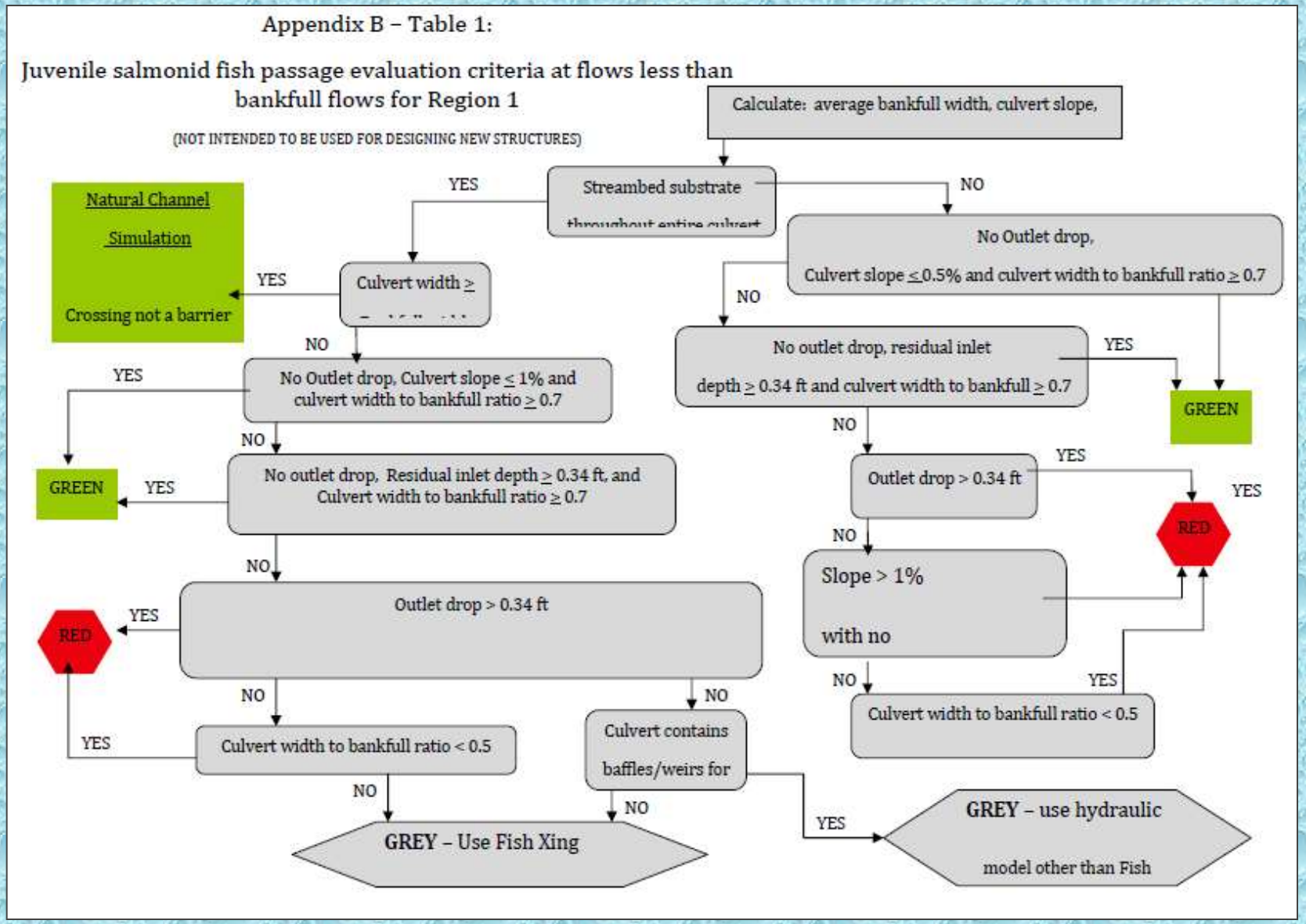
CalTrans – Two pass

- First pass surveys – determine crossing type and inspect habitat suitability of adjacent channel.
- Second pass surveys – requires access for channel and crossing survey. Follow CDFW first-phase evaluation filter and run FishXing on "Grey" subset.

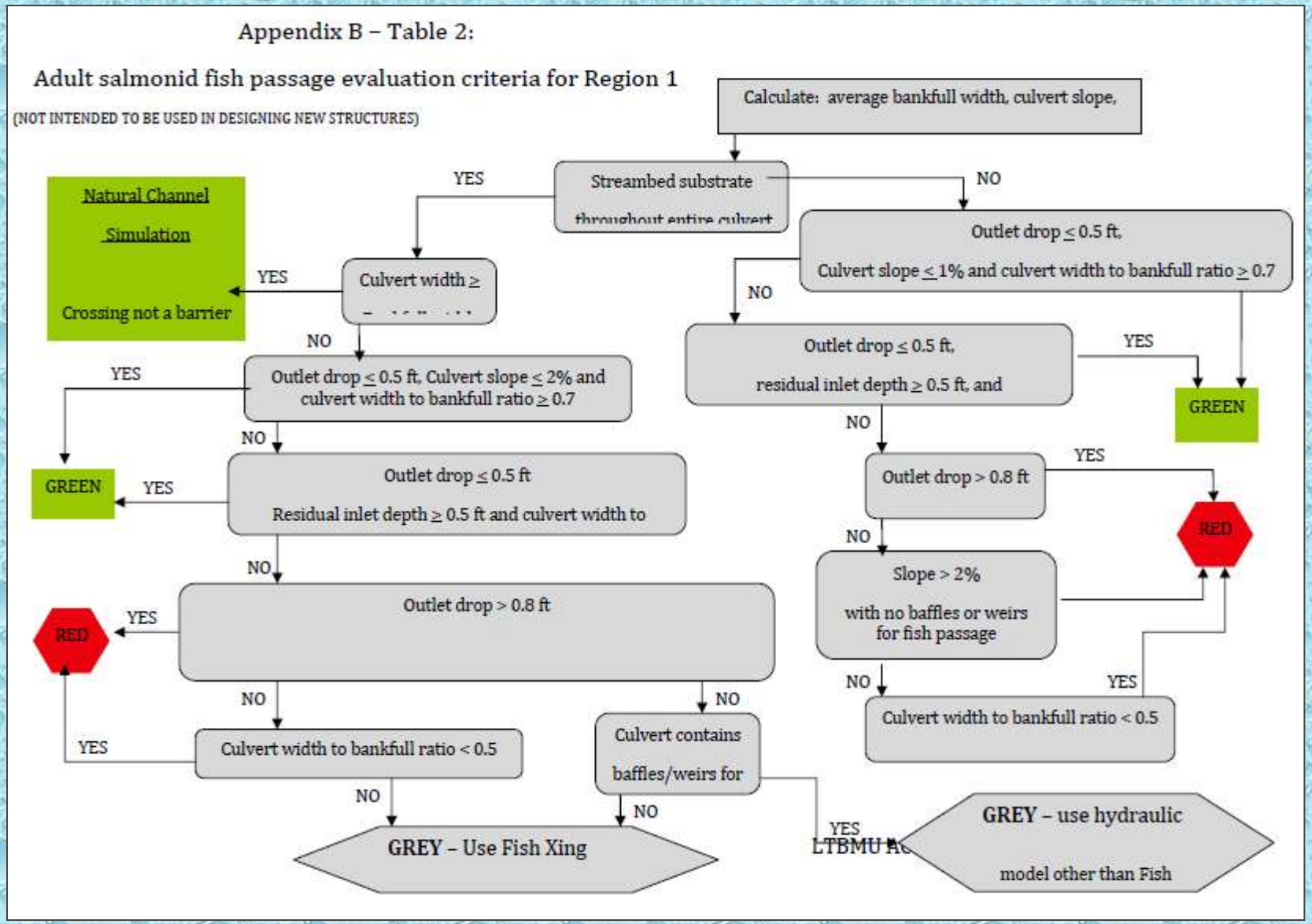
Passage Assessment Methodologies



Passage Assessment Methodologies



Passage Assessment Methodologies



Status of Assessments

Coastal State-maintained (CalTrans)

- On-going and access continues to be an issue.

Sacramento-San Joaquin (DWR)

- On-going, as of 2012 about 95 sites unassessed.

Coastal County-maintained

- Relatively complete. Occasional missed sites.

Coastal City-maintained

- Inconsistent – complete, partial or unassessed.

Coastal Private-maintained

- Inconsistent w/unknown status in many locations.

Status of Assessments – CalTrans

2015 Accomplishments

- 455 new assessments completed (425 first-pass and 30 second-pass surveys).

Existing Barrier Locations as of 2015

District 1 (Eureka) – 286 locations.

District 2 (Redding) – 47 locations.

District 4 (Oakland) – 70 locations.

District 5 (San Luis Obispo) – 84 locations.

District 7 (Los Angeles) – 21 locations.

District 11 (San Diego) – 2 locations.

District 12 (Orange) – 1 location.

Status of Assessments – CalTrans

2015 Accomplishments

- Seven fish passage remediation projects completed.
- 37 active fish passage remediation locations (programmed).
- 22 fish barrier locations funded for project delivery – 18 sites identified high-priority CalTrans and CDFW.

Status of Assessments – DWR

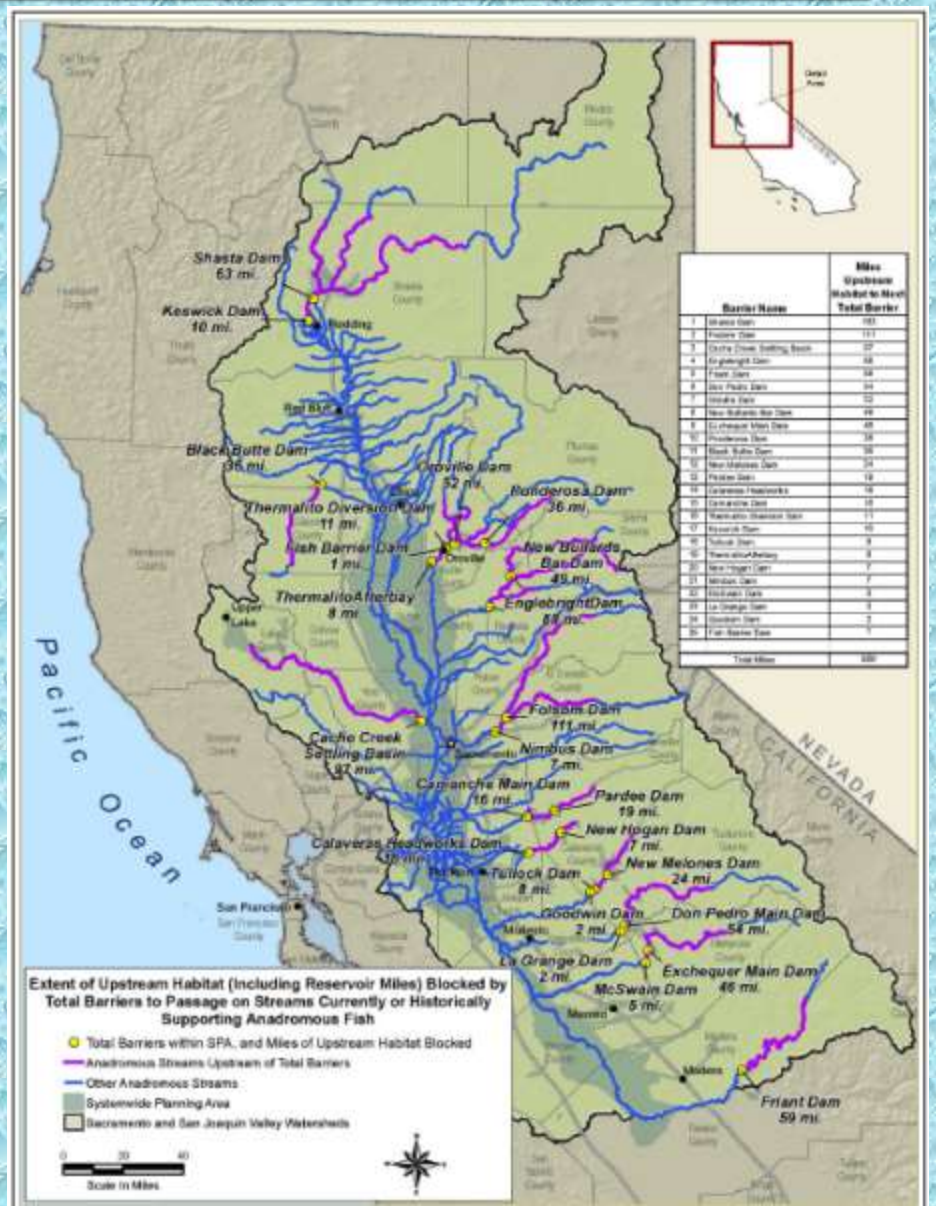
2012 Report Summary

- 189 barrier sites identified in the Systemwide Planning Area.
- 45 DWR diversions added due to entrainment potential.
- Total barriers – 25 sites.
- Partial barriers – 23 sites.
- Temporal barriers – 46 sites.
- Need assessment – 95 sites.
- Screened and unscreened diversions – 45 sites.

Status of Assessments – DWR

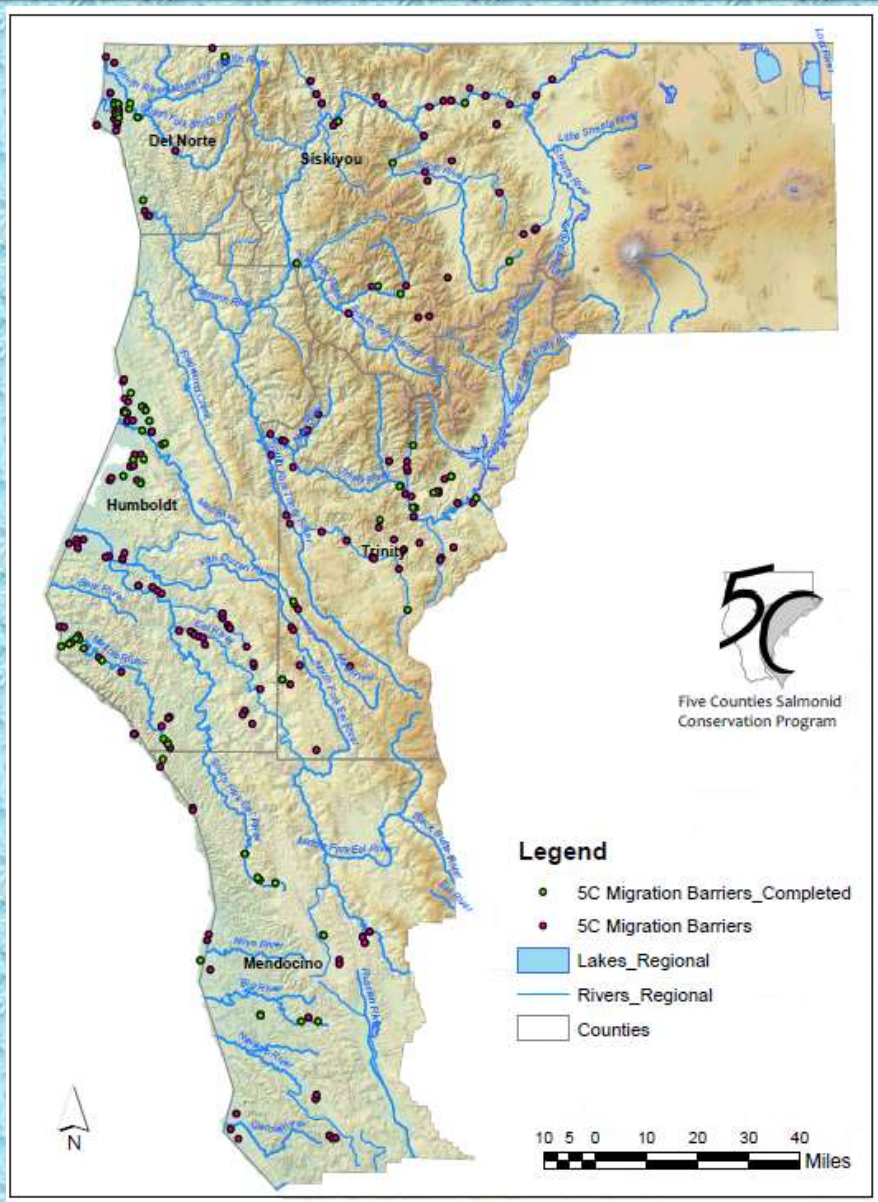
2012 Summary

- 25 total barrier sites = 900 miles blocked.
- Addition of partial and temporal = 3,000 miles.



Status of Assessments – Five Counties

- 245 sites ranked for treatment.
- As of 2014, 65 projects completed.
- Reconnected 150 miles of channel.
- Ongoing projects.



Accessing Assessments & Assessment Data

- Information from Fish Passage Assessments are housed in the Fish Passage Assessment Database (PAD), a California State-wide inventory of known and potential barriers to fish passage.
- Assessment focus in California has been mostly on evaluating passage for salmonids; therefore, most information in the PAD is salmonid focused. There is incidental information on passage for other species (i.e., lamprey, sturgeon, resident trout, etc.).

Nature of Assessments

Fish Passage Assessments include

- Single assessments conducted at a structure
- Assessments based on structure ownership (e.g., Highway and County Road System) due to source of funding
- Watershed-scale assessments

Nature of Assessments (Cont.)

Protocols vary and include

- Rapid Assessment Protocols
- CDFW Restoration Manual – Green Gray Red Filter
- USFS Green-Gray-Red Filter
- Hydraulic modeling (FishXing and HEC-RAS)
- Professional Judgment

Accessibility

PAD Program Page on Calfish.org
www.calfish.org/pad/ > Data Access

Data Portal

Table view of assessment data for California providing links to photos, map links to individual barriers, and access to fish passage assessment reports and other documents tied to individual barrier records. Hosted by CDFW.

Map Viewer - PAD Layer

Spatial view of assessment data for California. This is a layer on CDFW BIOS (Map Viewer).

Accessibility (Cont.)

PAD Program Page on Calfish.org
www.calfish.org/pad/ > Data Access Tab

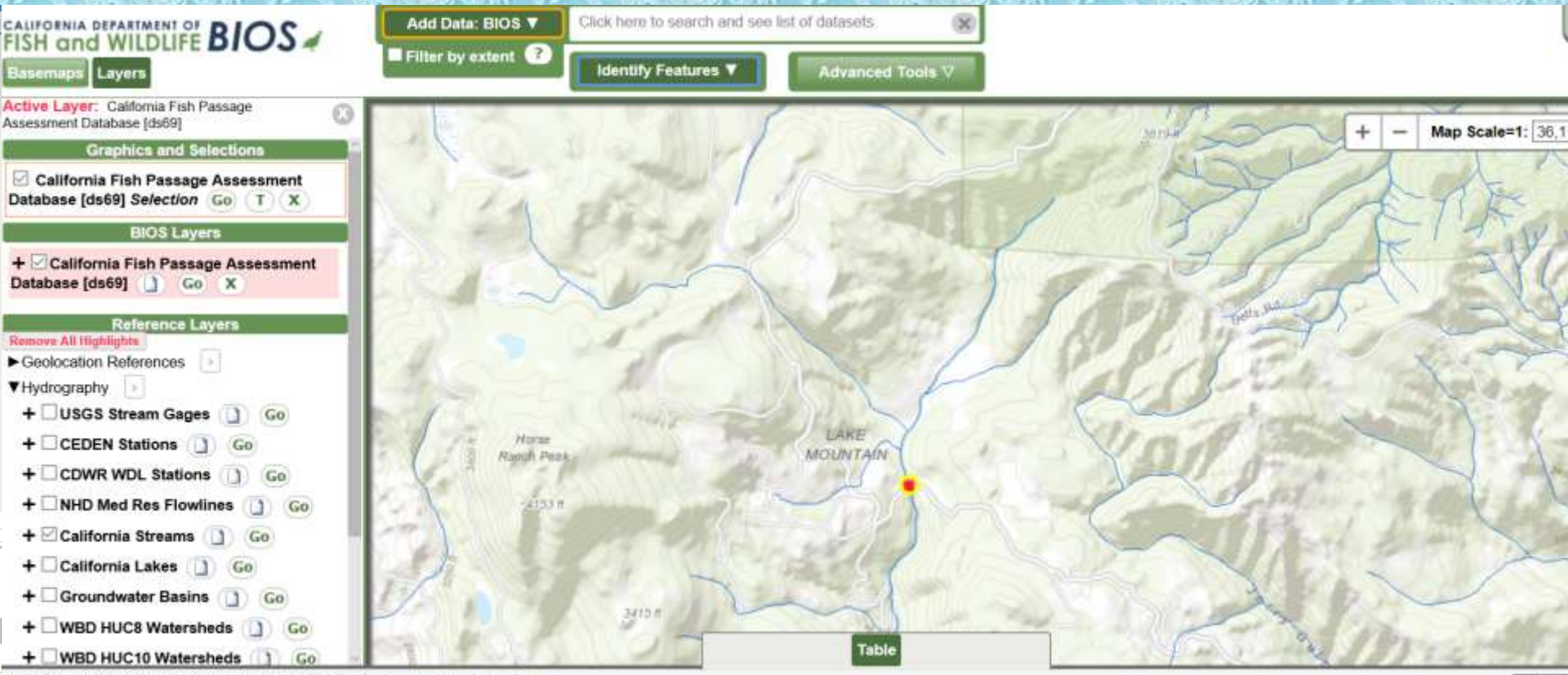
Downloads

Compatible with Google Earth and other GIS applications (ArcGIS, QGIS).

Document Library

Provides direct access to fish passage assessment reports and other documentation with passage information provided to the PAD. This is hosted by the CDFW Document Library.

PAD Data Portal - Lower Eel Sub-Basin Example



California Fish Passage Assessment Database [ds69] Selected features: 1

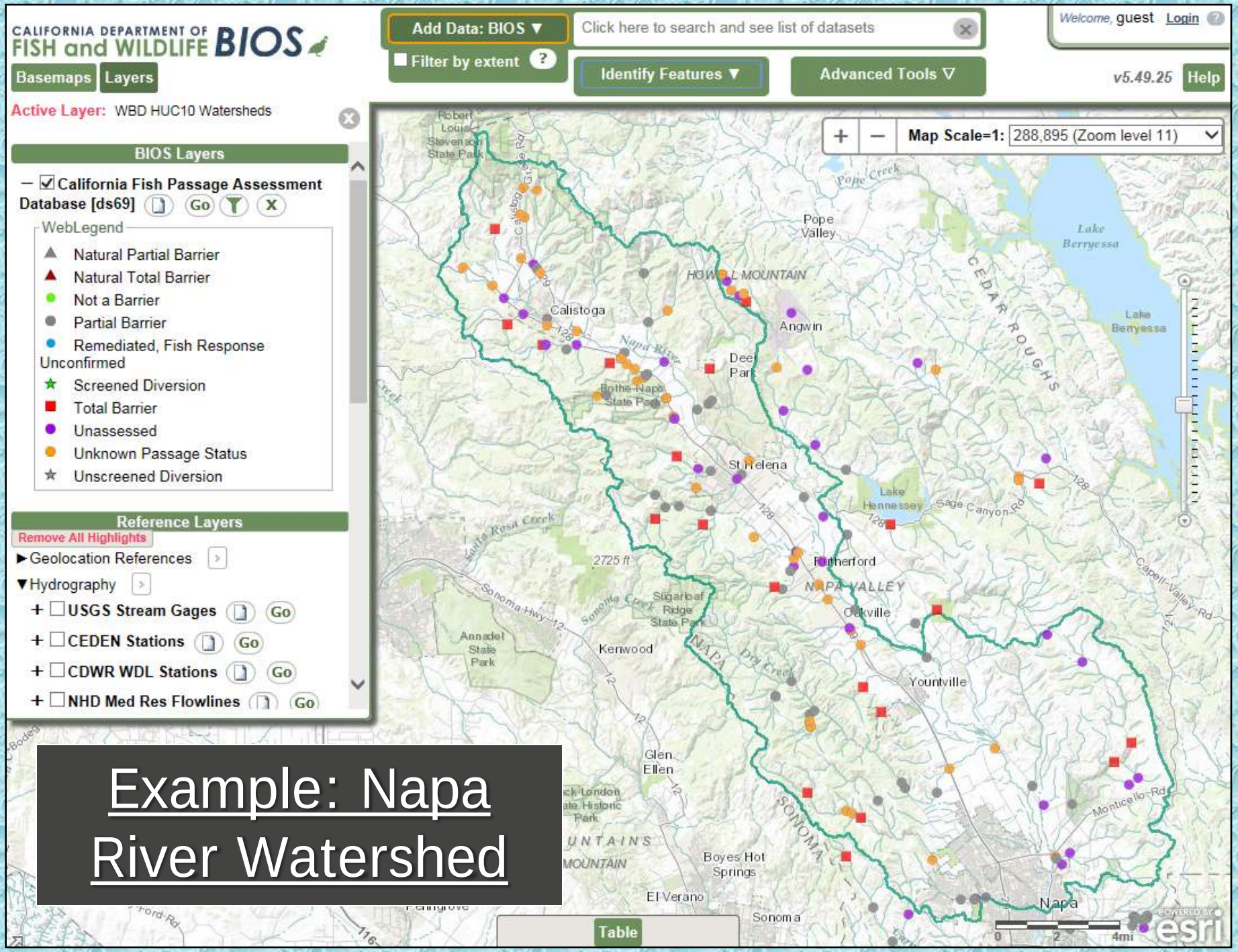
Print Pr

Zoom	Photo	PAD_ID	PassageID	StreamName	TributaryT	SiteName	SiteType	BarStatus	SpeciesBlocked	NumStructures	Protocol	AssessedBy	SurveyDate
1 Go	Link	705990	7324	Wilson Creek	North Fork Eel-Eel River	Zenia Lake Mountain Road	Road crossing	Total	Multiple Andromous Salmonids		DFG Restoration Manual	Ross Taylor and Associates	2002

	Burgess Ranch Road	Total	Road crossing...	Trinity County	Burgess Creek	Hembry Cr-South...	Ross Taylor and ...	Barrier Status: RED: the Green-Gray-Red filter...	-123.488482175835	40.18968949030
	Zenia Lake Mountain ...	Total	Road crossing...	Trinity County	Wilson Creek	North Fork Eel-E...	Ross Taylor and ...	Barrier Status: RED: the Green-Gray-Red filter...	-123.390451189537	40.00432045793
	Ruth Zenia Road	Total	Road crossing...	Trinity County	Panther Creek#2	Bar Cr-West For...	Ross Taylor and ...	Barrier Status: RED: the Green-Gray-Red filter...	-123.452820937771	40.24305868308
	rock falls	Partial	Non-structural ...	Private landowne...	Burger Creek	Eel River	California Depart...	ROCK FALLS.22 MI UPSTREAM, 12 feet high...	-123.368852972929	39.71907526384
	Culvert Hwy 101	Partial	Road crossing...	California Depart...			Humboldt State ...		-124.177712630433	40.60486625217
	Culvert Hwy 36	Total	Road crossing...	California Depart...	Fox Creek	Van Duzen River	Humboldt State ...		-123.999592294238	40.51073856876
	Bridge	Unknown	Road crossing...	U.S. Forest Serv...	Black Lassic Creek	Van Duzen River	U.S. Forest Servi...	Bridge	-123.493540779453	40.34998826536

Map Viewer – PAD Layer

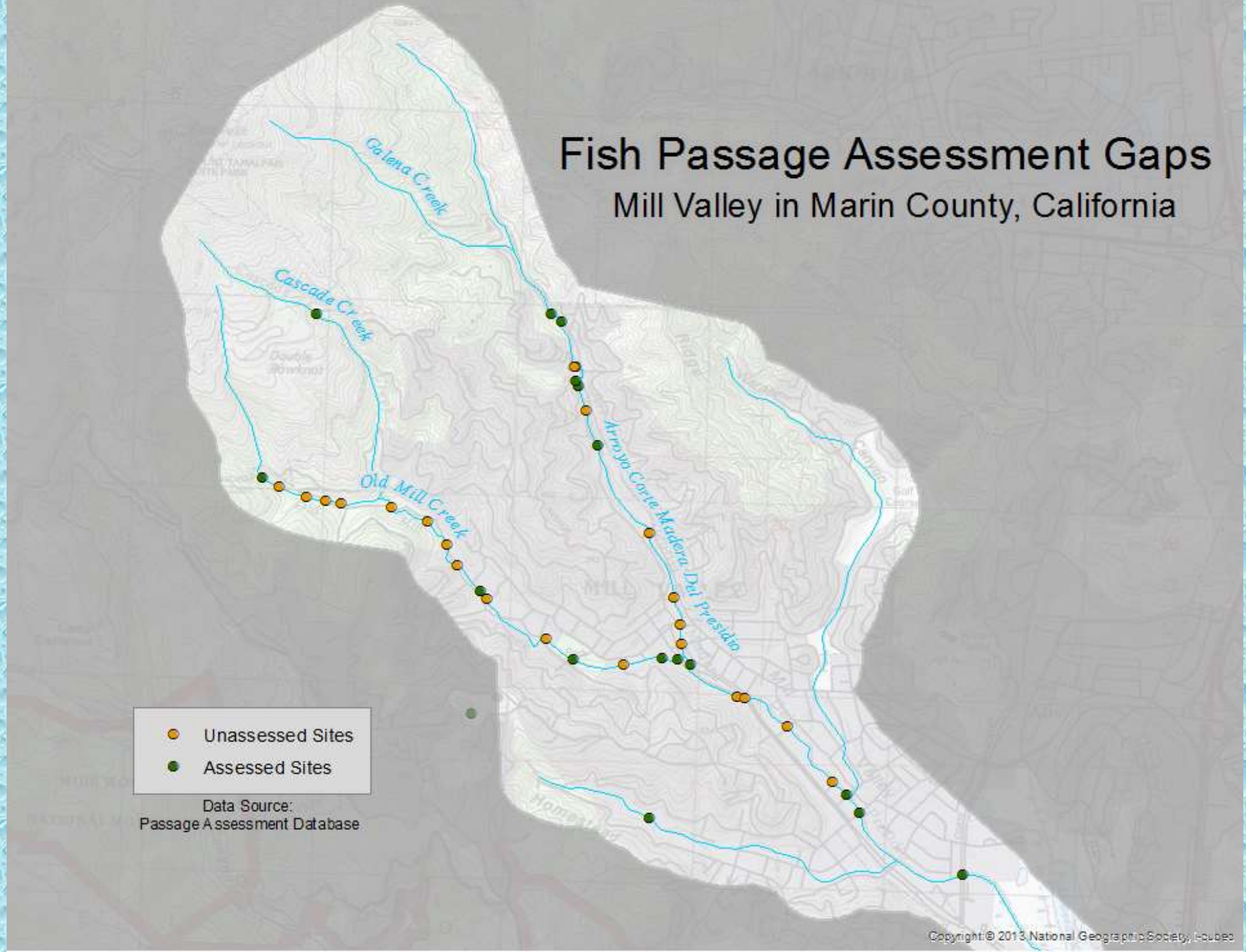
- Spatially view and export tables of known and potential barriers in a watershed.
- Obtain information about the barrier including structure type, barrier status, a description of the structure and impediment, photos, etc.
- See where gaps exist.
- Add anadromous species "observed distribution" layers.
- Print pdf maps of barriers and/or sites needing assessments.



Example: Napa River Watershed

Gaps in Assessments

- Several gaps exist within watersheds
  - >5,000 unassessed sites recorded in the PAD.
  - Currently an unknown number of sites not inventoried in the PAD and not assessed.
- Why do gaps exist?
  - Site access issues due to land owner permission issues, nature of terrain and etc.
  - Funding sources


Fish Passage Assessment Gaps
Mill Valley in Marin County, California
Galena Creek
Cascade Creek
Old Mill Creek
Arroyo Corte Madera Del Presidio
Unassessed Sites
Assessed Sites
Data Source:
Passage Assessment Database
Copyright © 2013 National Geographic Society, i-cubed

Closing Existing Gaps

1) **Identify** Locations needing assessments (gaps). These include

   a) unassessed and unknown passage status sites in the PAD, and

   b) road and railroad crossings not identified in the PAD.

2) **Assess** these sites for fish passage.

Resources: NOAA Fisheries Veterans Program, Grant Funding.

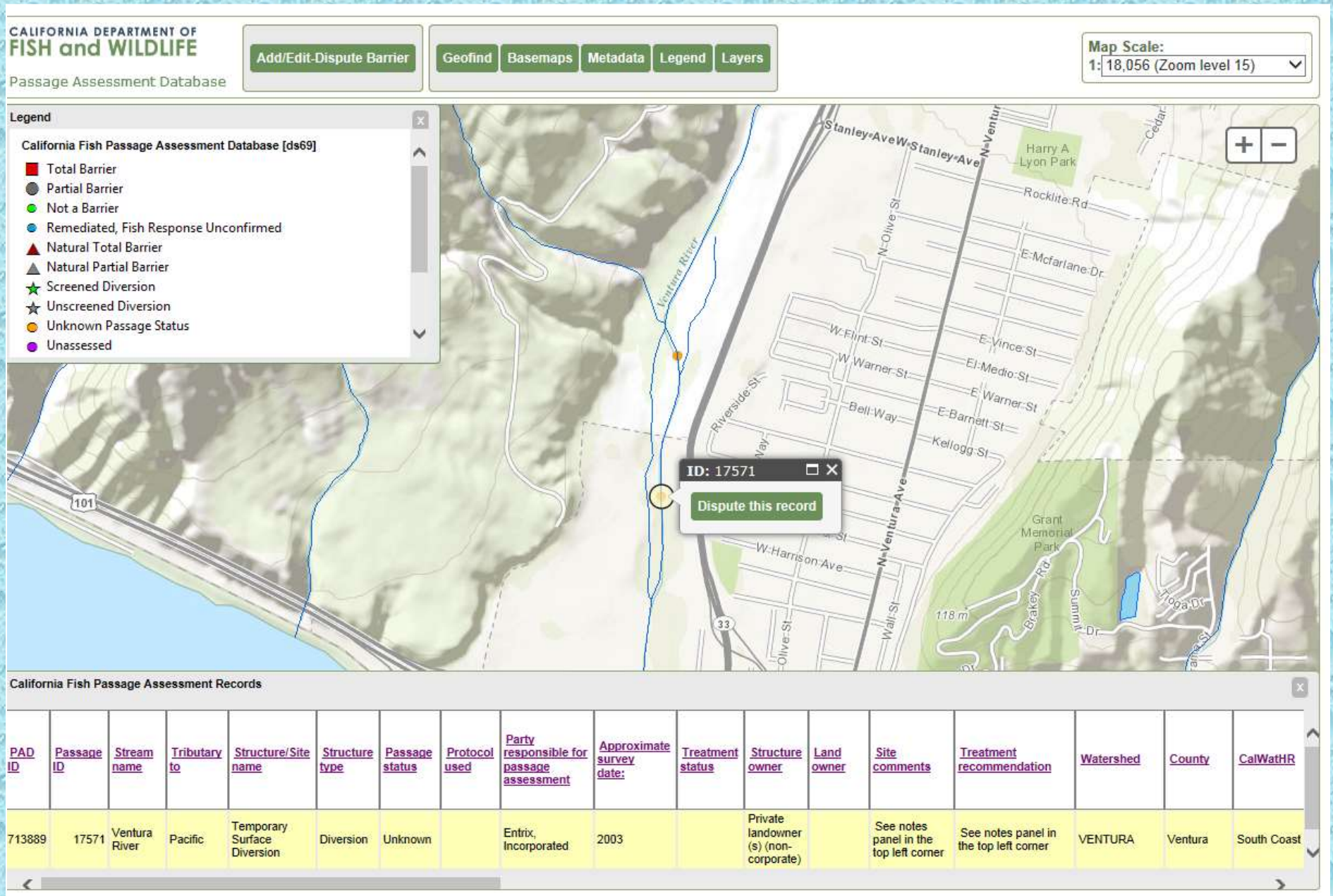
Closing Existing Gaps (Cont.)

3) **Update** the PAD.

Option(s): Utilize the PAD Review Tool or provide updates directly to the PAD Administrator at Anne.Elston@wildlife.ca.gov. Contact information is available on Calfish.org.

Example: San Mateo RCD effort for entire County funded by USFWS and CDFW's FRGP.

PAD Mapping Review Tool (www.calfish.org > data access)



PAD ID	Passage ID	Stream name	Tributary to	Structure/Site name	Structure type	Passage status	Protocol used	Party responsible for passage assessment	Approximate survey date:	Treatment status	Structure owner	Land owner	Site comments	Treatment recommendation	Watershed	County	CalWatHR
713889	17571	Ventura River	Pacific	Temporary Surface Diversion	Diversion	Unknown		Entrix, Incorporated	2003		Private landowner (s) (non-corporate)		See notes panel in the top left corner	See notes panel in the top left corner	VENTURA	Ventura	South Coast

Recent Updates

- HDR 2014-2016 Detailed Surveys at Highway Xings (North Coast, Bay Area and Inland) and H.T. Harvey & Associates Cow Creek Watershed Assessment.

When is PAD Updated?

- PAD is updated as information is provided to the PAD. The day after changes are made, this can be seen in the PAD Data Portal.
- PAD Layer on BIOS and Spatial Downloads are updated less frequently (last updated on November 2016). Next update is planned for April 2017.

Why is it critical to close gaps and update the statewide inventory?

Comprehensive assessment information is necessary for watershed-scale fish passage restoration and effective aquatic habitat connectivity.

The statewide inventory (PAD) collects information from multiple sources regardless of jurisdiction and ownership. It is a tool for identifying strategic barrier removal projects.

Prioritization Methodologies

CDFW (2003) – Section 9 of Restoration Manual

- First-cut ranking by scoring five criteria.
- Barrier score for three age-classes of salmonids, for a total barrier score.
- Species diversity and listing status – more diverse and listing severity raises score.
- Crossing condition and flow capacity – higher scores for poorer condition and limited storm flow capacity.
- Habitat quantity and quality – length modified by a qualitative assessment of quality.
- Professional judgement and other factors considered.

Prioritization Methodologies

CDFW (2003) – Use of Section 9 Prioritization

- Five Counties Salmonid Conservation Group.
- CalTrans District 1.
- FishNet 4C Counties.
- City of Arcata, Humboldt County.
- Strawberry Creek watershed, Humboldt County.
- Corte Madera Creek watershed, Marin County.
- Chorro Creek watershed, SLO County.
- San Luis Obispo County.
- CA State Parks – North Coast and Mendocino Redwoods.
- Northwest Railroad – Eel River watershed.

Prioritization Methodologies

CDFW (2012) – Memorandum: Priority Barriers

- CDFW and CalTrans would develop mutual list of priority sites along transportation corridors.
- CDFW would also develop a list based on significance to fish migration, regardless of stream crossing ownership.
- List would also identify completed projects.
- The 2012 list included 68 high-priority sites located in 24 coastal and central CA watercourses.
- The 2012 list included 11 sites removed from 2011 list – five barriers treated and six lowered priority.

Prioritization Methodologies

CDFW (2012) – Memorandum Priority Criteria

- High likelihood to improve migration for anad. species
- Availability of recent fish and habitat data.
- Willing partners and land access.
- Known political support at local, state or national levels.
- Site is identified as a barrier in federal recovery plan "core" population.
- Watercourse has eco-regional significance.
- CDFW is committed to project monitoring.
- Site is keystone barrier – lowermost in river/stream.

Prioritization Methodologies

DWR (2012) – Prioritization Criteria

- Signed MOU with Fish Passage Forum in 2006.
- Will utilize prioritization methods developed by the Forum when completed and supported by the 14 federal, state, and local participating entities.
- Interim prioritization process:
  - Biological importance based on NOAA recovery actions.
  - Linkage to State Plan Flood Control facilities.
  - Geographic location.
  - Urgency – three time frames: short, moderate and long term.

Prioritization Methodologies

DWR (2016) – CVFPP Conservation Strategy

- Appendix K – Synthesis of Fish Migration Opportunities in the Central Valley Flood System.
- Barriers ranked relative to each other with a score-and-rank methodology.
- Criteria included:
  - Impediment frequency – hydrology versus target fish swimming and leaping criteria.
  - Barrier intensity – impact on movement, barrier location.
  - Upstream habitat – quantity and quality.

Prioritization Methodologies

CalTrans/FishPac – Prioritization Criteria

- District 1 HSU/Lang report used CDFW (2003) criteria for ranking sites.
- CalTrans/FishPac – prioritization methods in draft form and not available.
- CalTrans/FishPac – species diversity, barrier severity, upstream habitat potential and expert judgement.

Prioritization Methodologies

USFS Tahoe District – Priority Considerations

- Is crossing located in priority watershed for Lahontan Cutthroat recovery?
- Will non-game, native fish and aquatic species also benefit from treatment of barrier?
- How much upstream habitat will be made accessible?
- Are there other stream restoration activities planned in the barrier's general location?
- Is the stream crossing currently a sediment contributor to Lake Tahoe?

Prioritization Methodologies

CA. Fish Passage Forum – Optimization Model

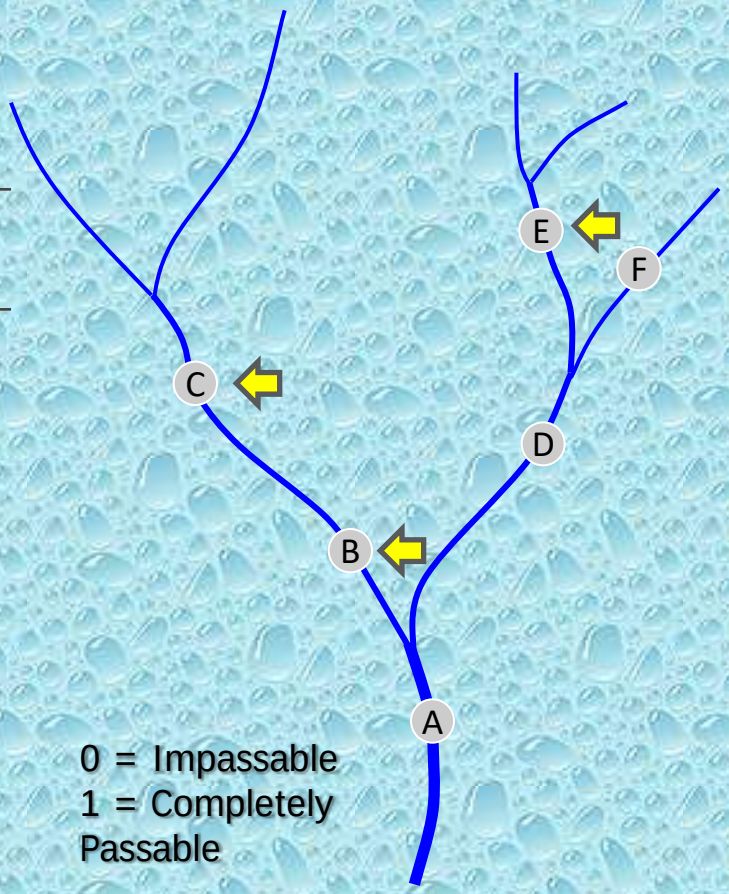
- In process of developing and testing an optimization model (FISHPass). It is a decision support tool for optimizing barrier mitigation.
- Integrates information on
  - Barrier passability
  - Potential habitat
  - Estimated mitigation cost
- Crucially, accounts for:
  - Spatial structure of barrier networks
  - Interactive effects of mitigation decisions on longitudinal connectivity

Barrier Optimization in Action

Barrier Inputs

BARID	PREPASS	COST	USHAB
A	0.4	$250K	2.1
B	0	$120K	0.9
C	0.3	$70K	4.3
D	0.5	NA *	1.7
E	0.2	$300K	0.1
F	0.1	$400K	0.2

* : Natural Barrier



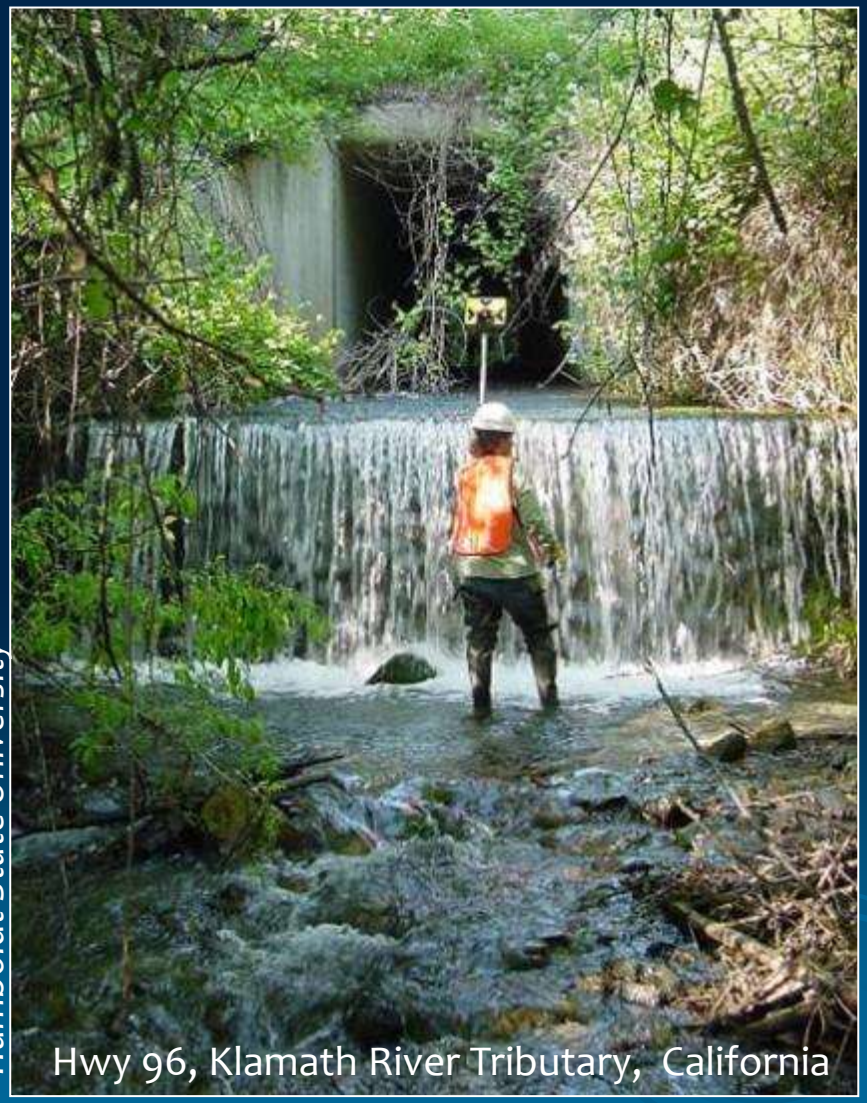
0 = Impassable
1 = Completely Passable

Optimal Solution

Budget	Soln	Gain
$50K	F	0.090
$100K	E	0.192
$150K	B	0.876
$200K	B, C	2.080
$300K	B, C, E	2.272
$400K	A, B	4.047

Note the lack of "nestedness" among solutions (i.e., barriers removed given a certain budget amount may not be removed when the budget is increased)

The Need to Consider Watershed Scale Channel Incision in our Passage Projects

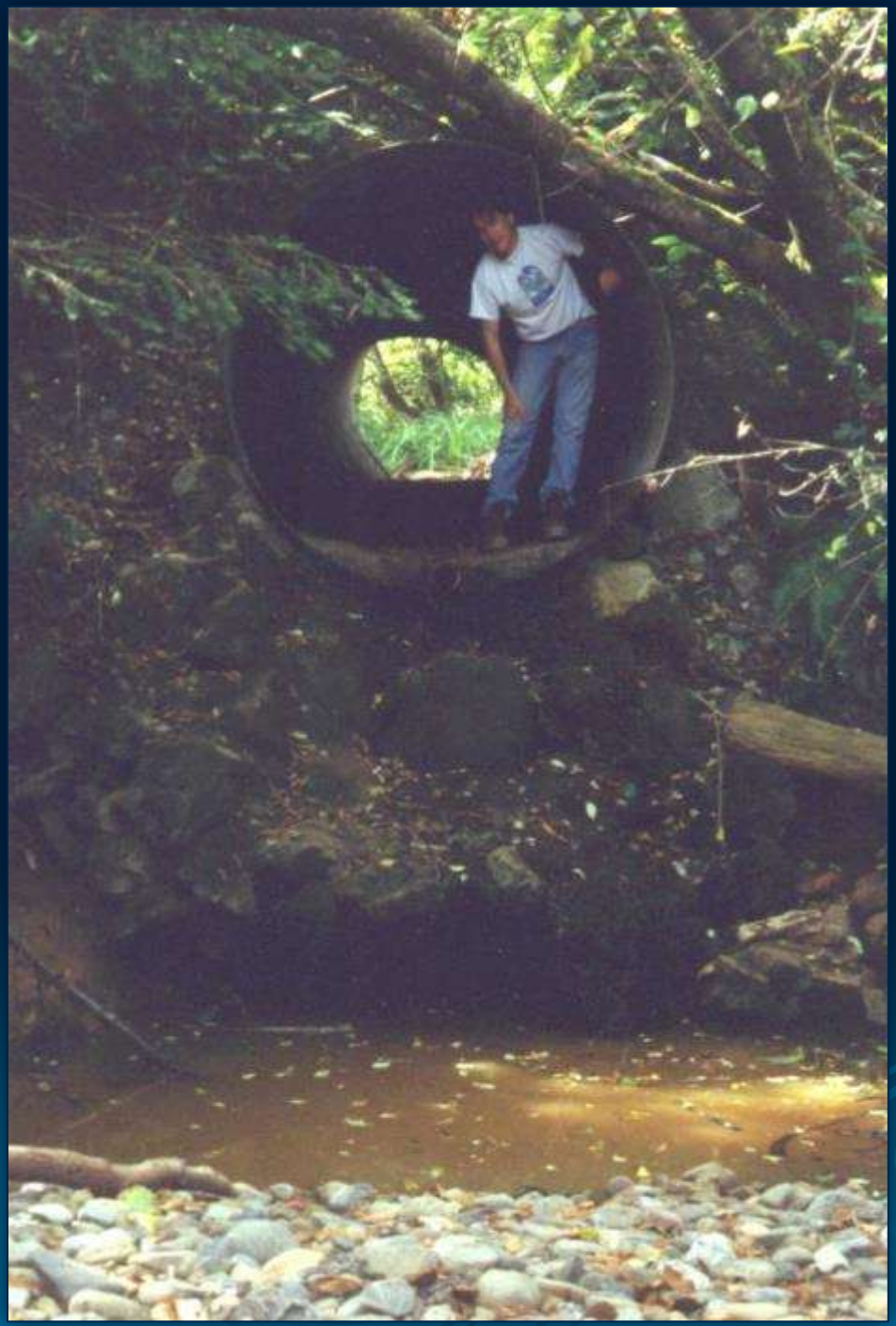


Hwy 96, Klamath River Tributary, California

Humboldt State University

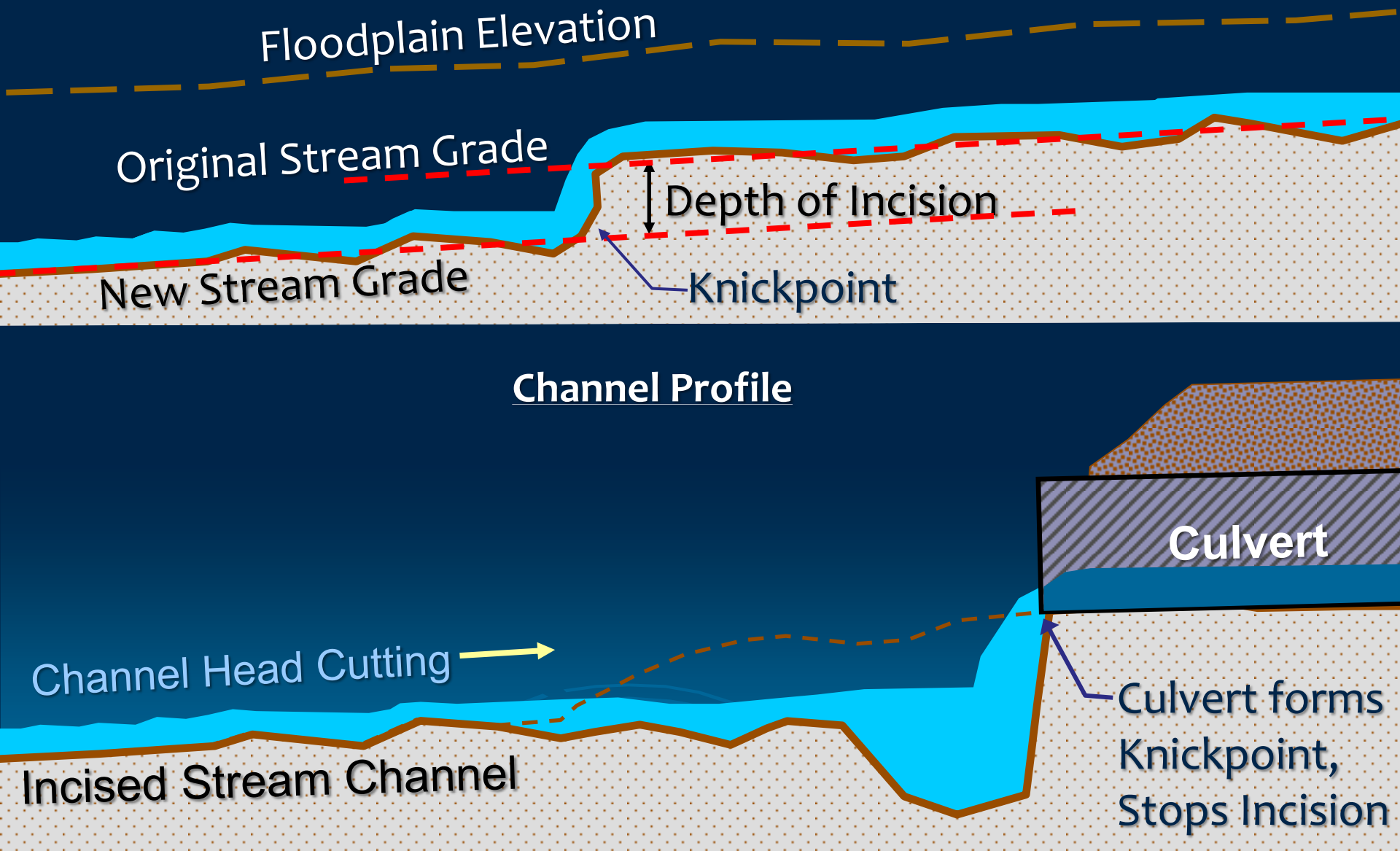
Michael Love P.E.
Arcata, California
mlove@h2odesigns.com

Michael Love & Associates
Hydrologic Solutions



Photos: Ross Taylor

Process of Incision: Headwater Migration



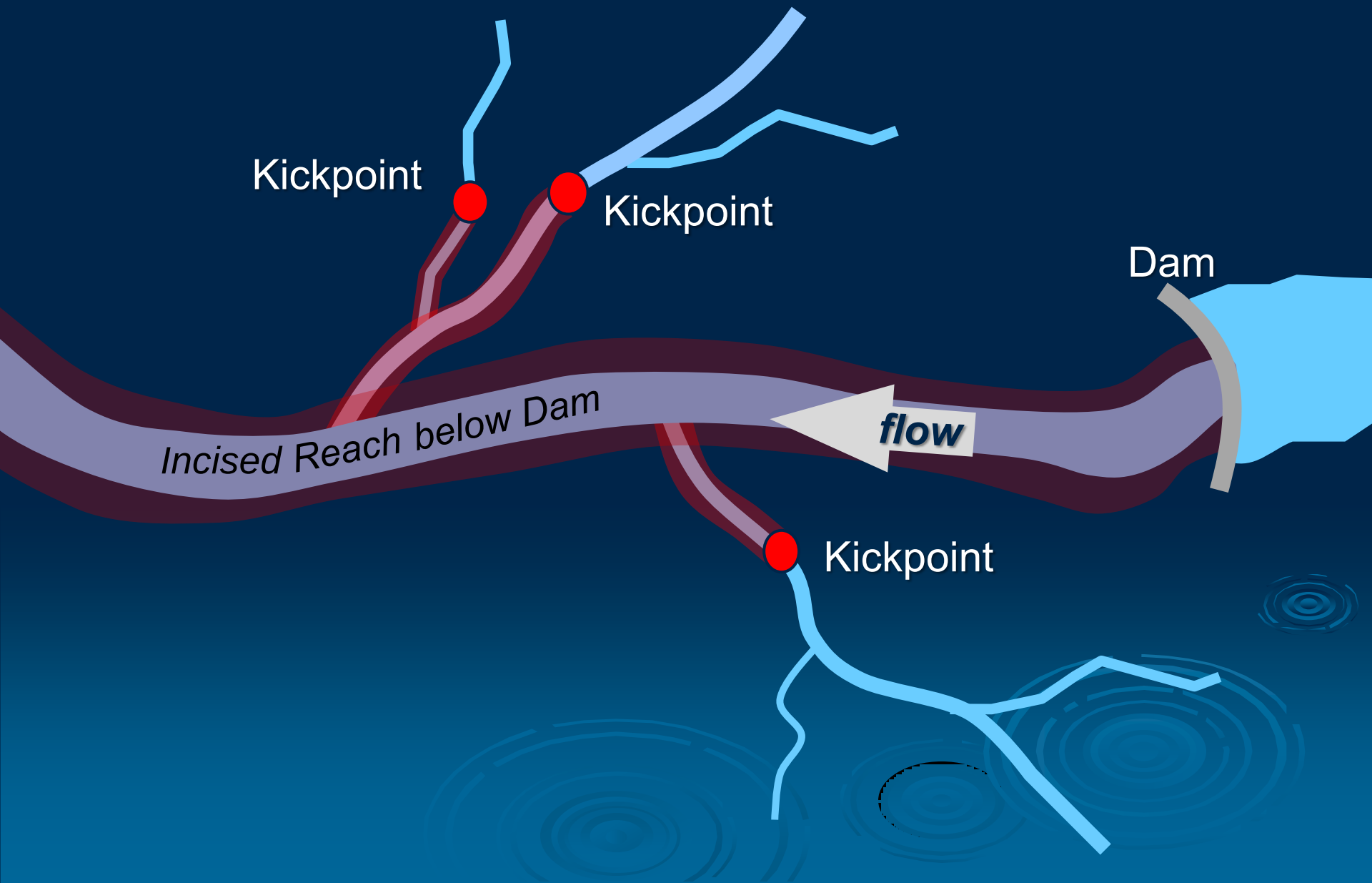
Channel Incision is a Natural Process, but…

Photo: Ujjwal Kumar

We Initiate of the Incision More often then Not

Photo from US Army Corps of Engineers

Incision Often Moves Headward into Tributaries



Knickpoints that Stop Incision but Create Fish Barriers

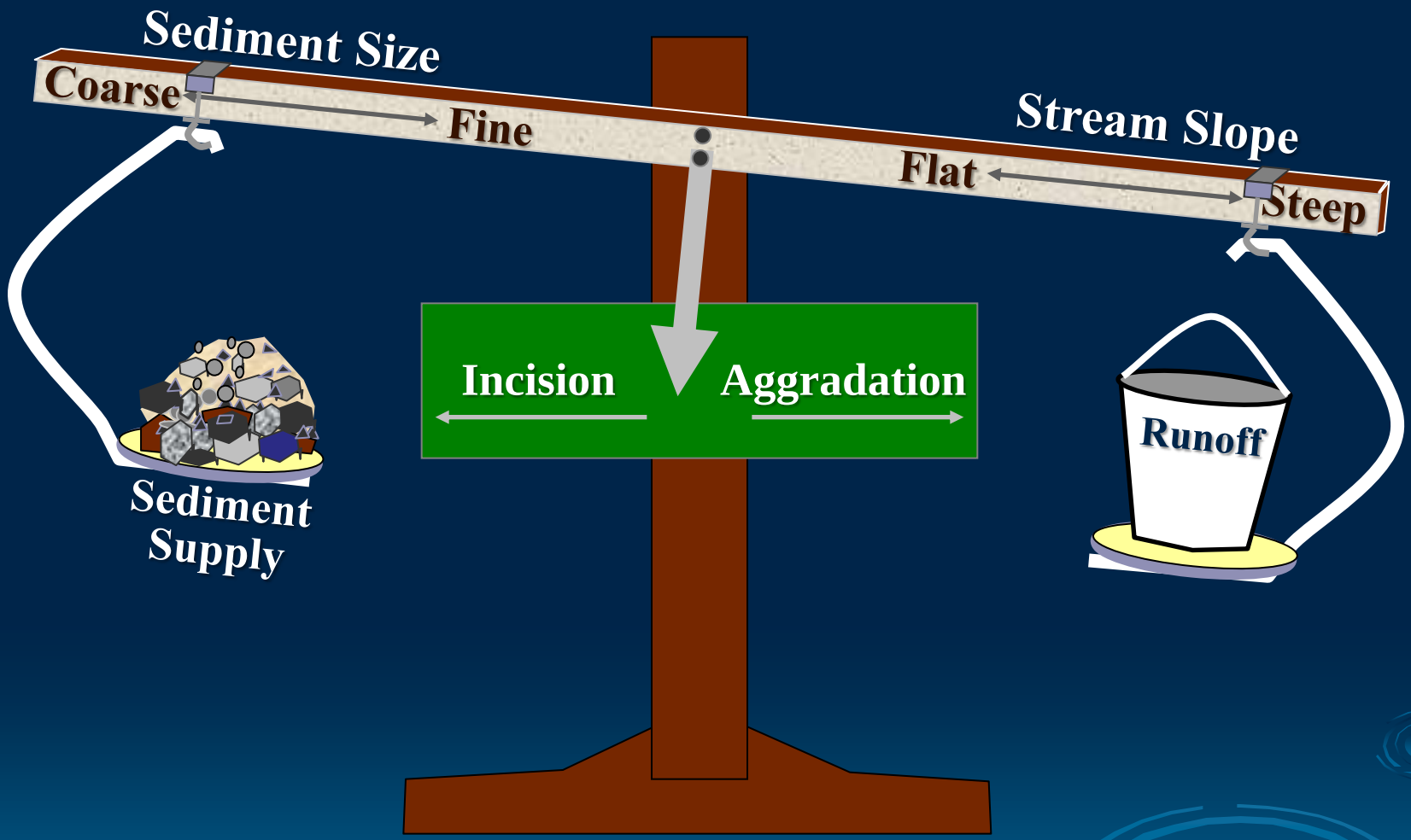
Perched Culverts

Armored Utility Crossings

Perched Bridge Aprons

Perched Fishway Entrances

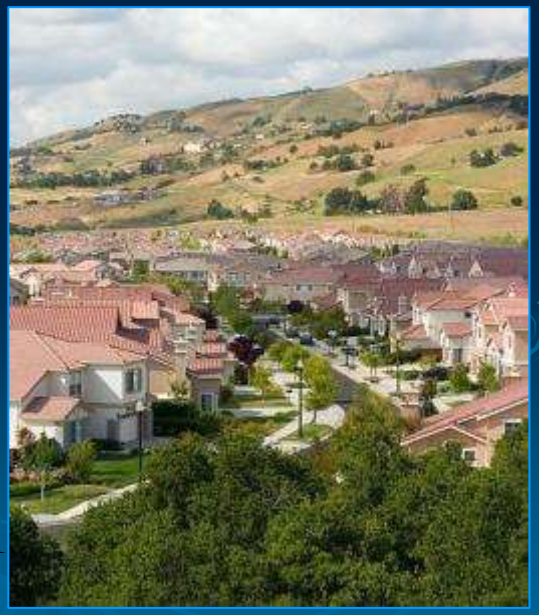
Dynamic Equilibrium and Causes of Incision



The Lane Relationship (from Lane, 1955)

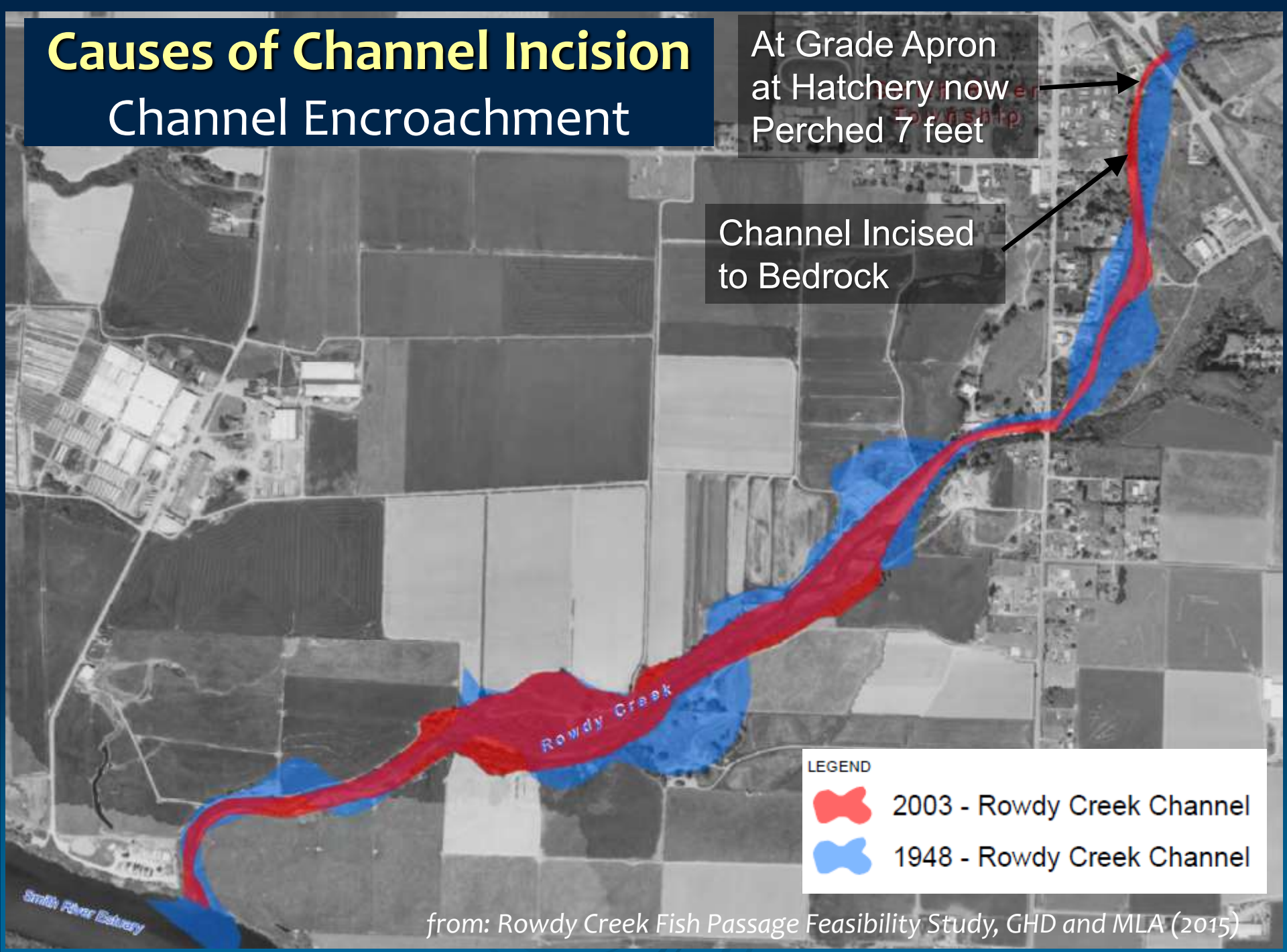
Causes of Channel Incision

- ✓ Channelization
  (shortening/steepening the channel)
- ✓ Channel encroachment
  (Increase depth of flow, bed & bank shear)
- ✓ Increase in runoff
  (urbanization, agriculture, road density)
- ✓ Decrease in sediment supply
  (dams, gravel extraction, urbanization)
- ✓ Loss of wood in streams
  (removal of large wood, beaver dams)
- ✓ Climate change/extreme weather



Causes of Channel Incision

Channel Encroachment



from: Rowdy Creek Fish Passage Feasibility Study, GHD and MLA (2015)

Causes of Channel Incision

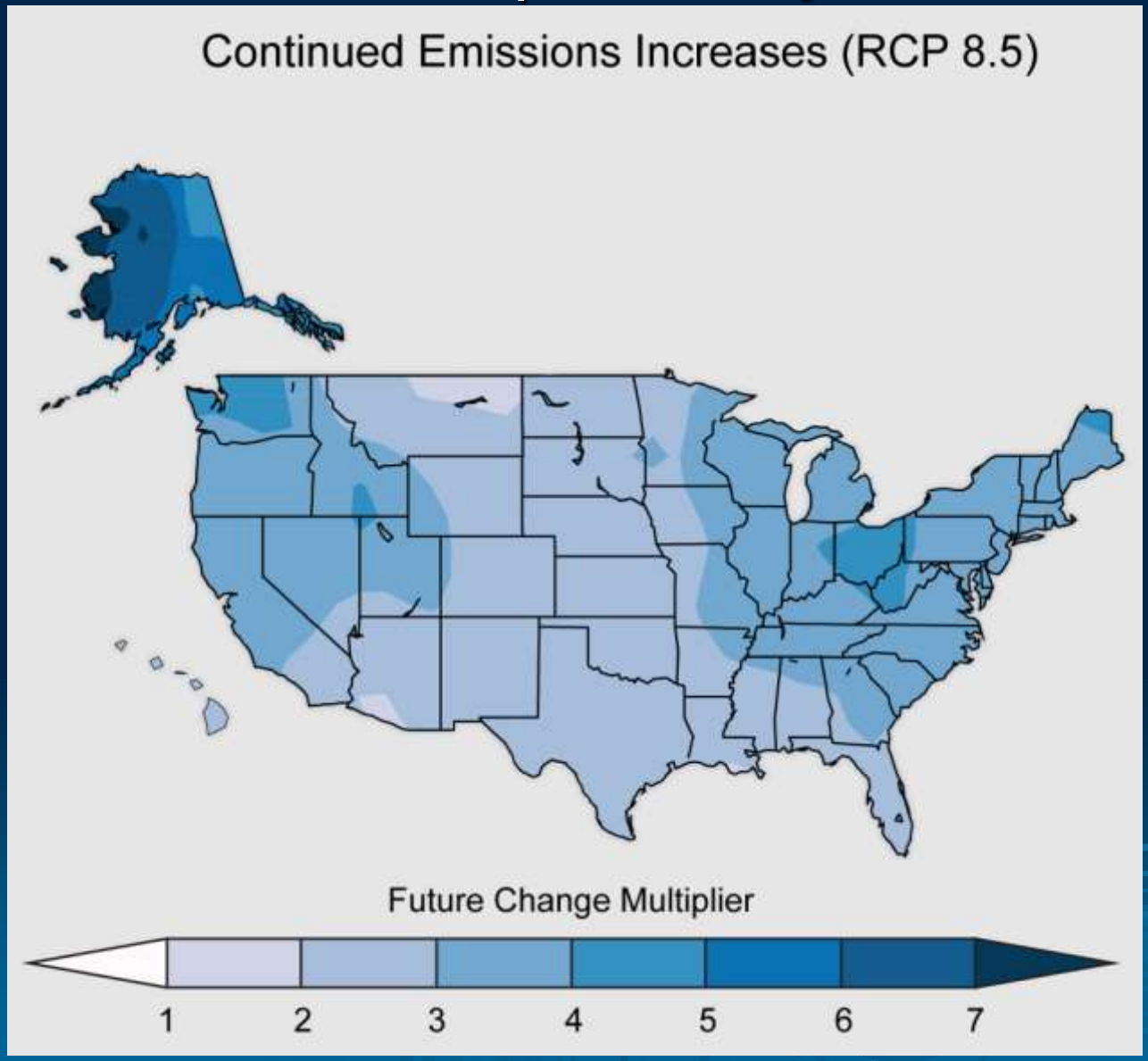
Dams and Debris Basins

Debris Basin Catches all Sediment

Downstream Channel Incised 8 feet

Projected Increase in Heavy Precipitation Events

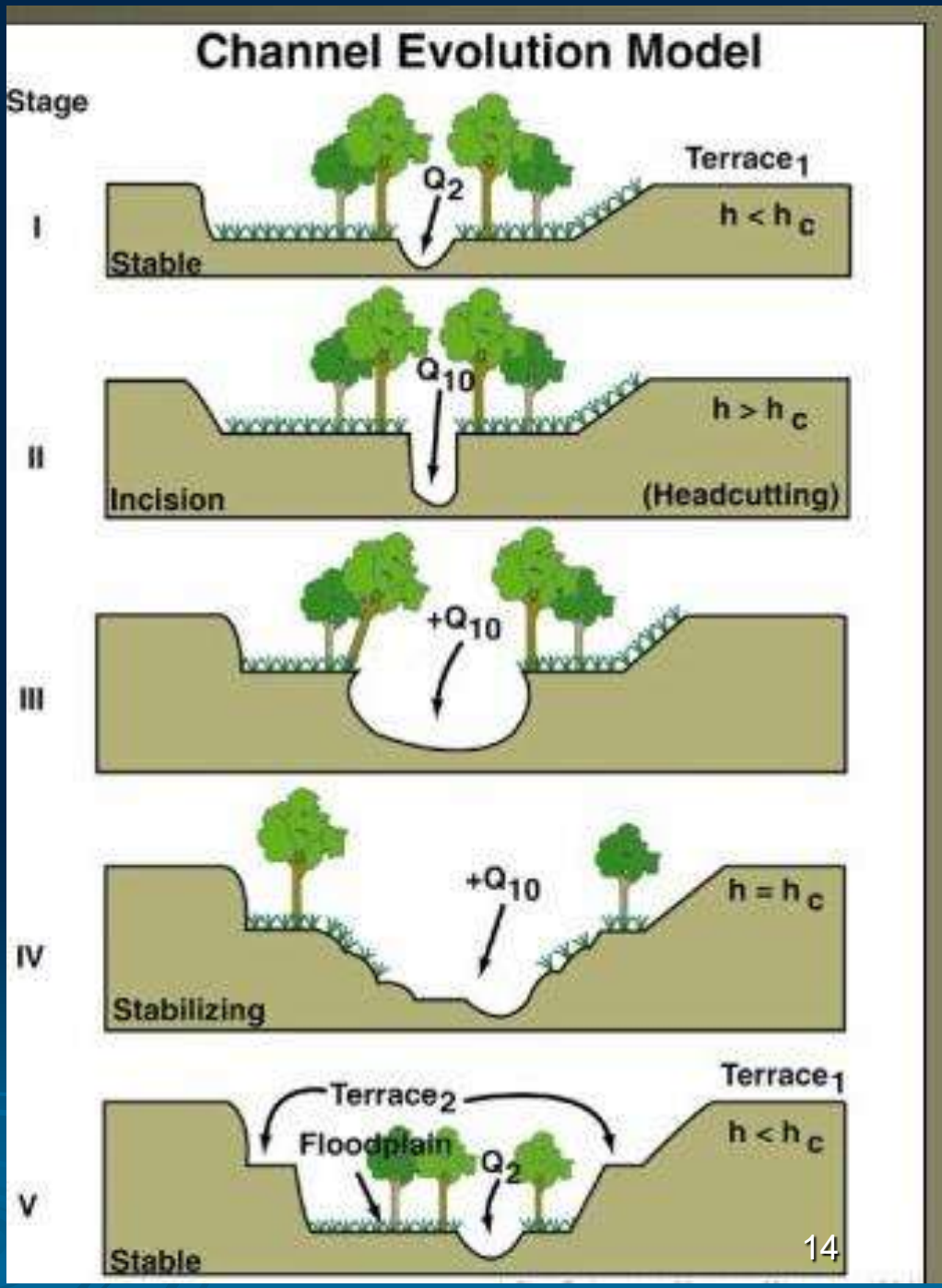
2081-2100 compared to 1981-2000



from U.S. National Climate Assessment, 2014

Channel Evolution Model (CEM)

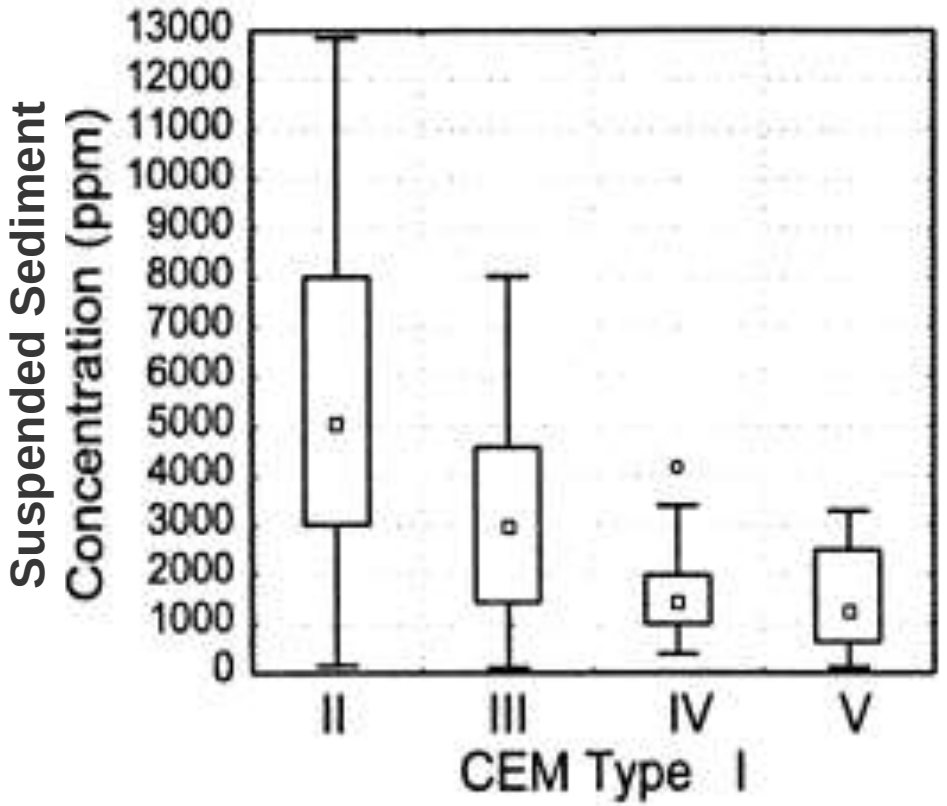
Stage II Incision

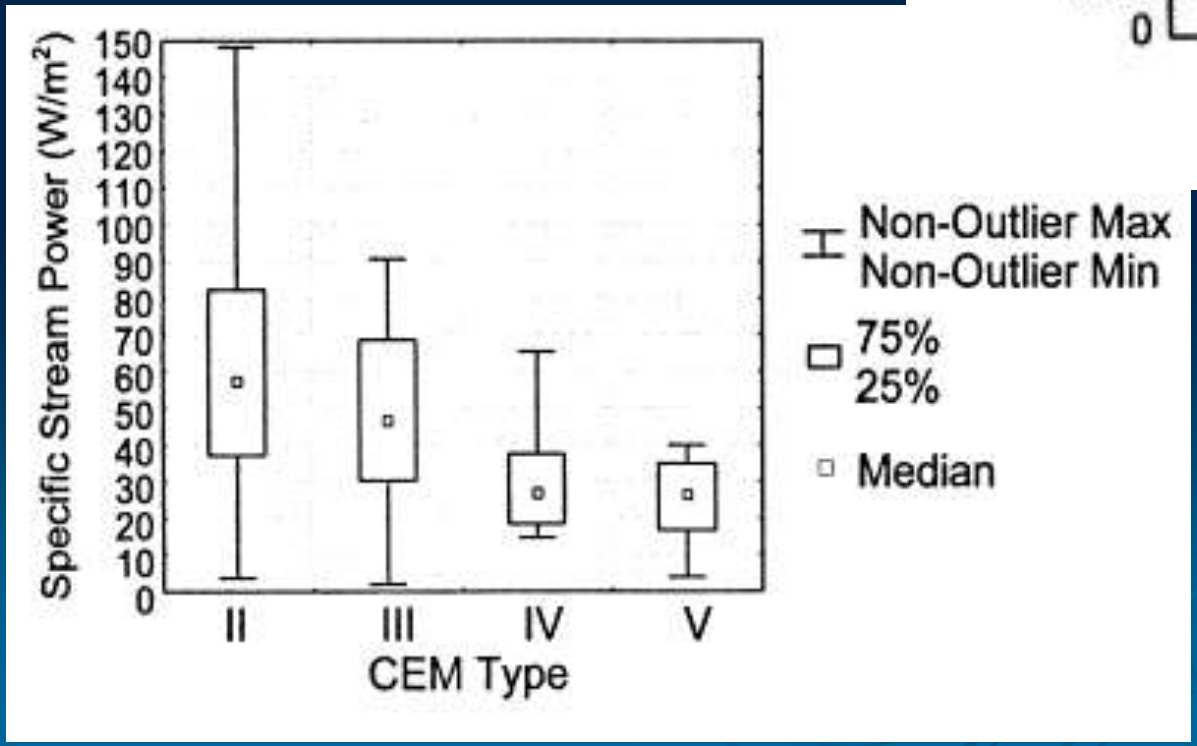


from Schumm, Harvey, and Watson. 1984.

Incising Channel, Toby Tubby Creek Watershed, Mississippi

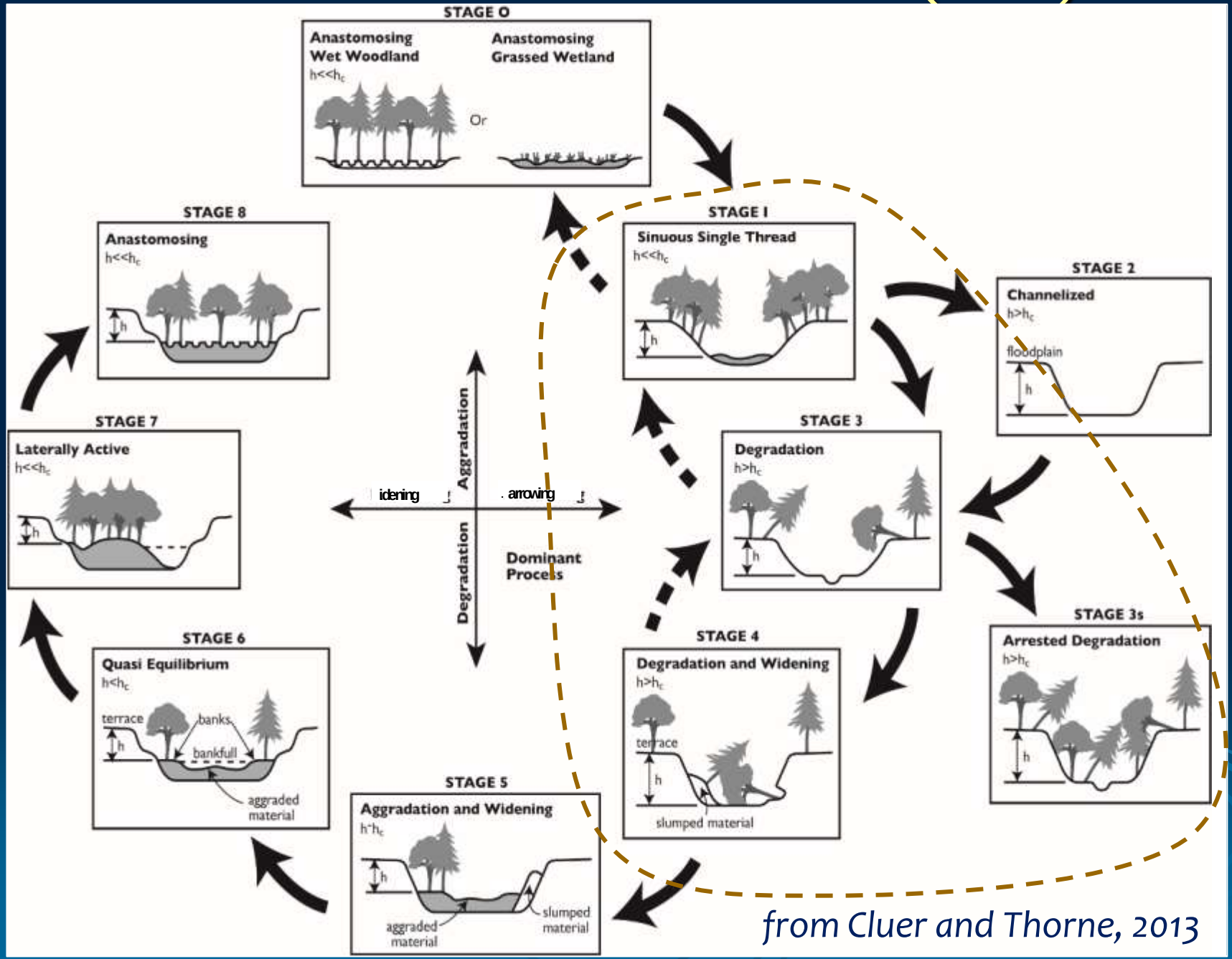
Water Quality and Stream Power vs. CEM Channel Type





from: Bledsoe et al., 2002

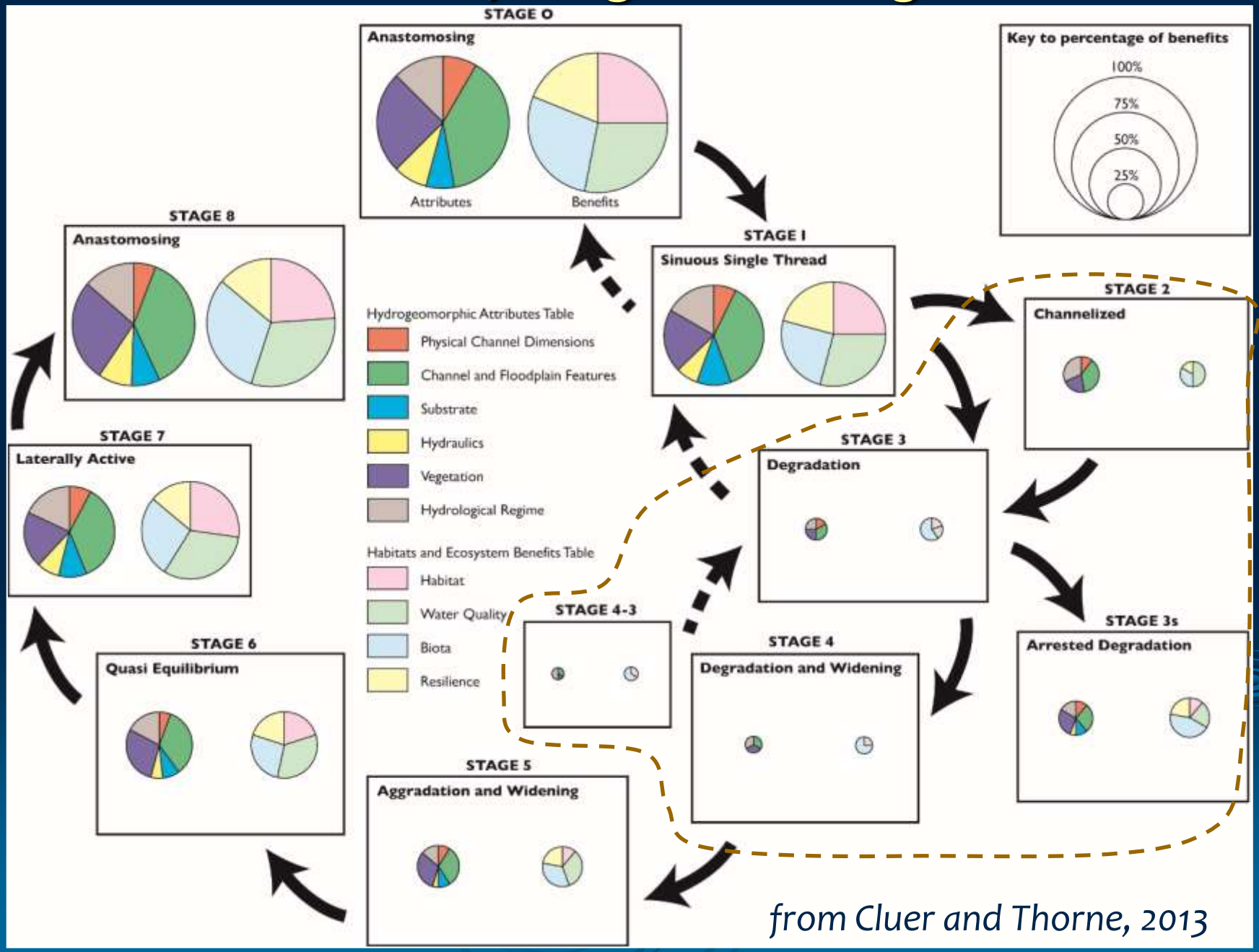
Stream Evolution Model (SEM)



Multiple Paths
Dead Ends

from Cluer and Thorne, 2013

Stream Evolutionary Stage vs. Ecological Benefits



from Cluer and Thorne, 2013

The Stream Channel Incision Syndrome
Loss of Habitat and Ecosystem Benefits

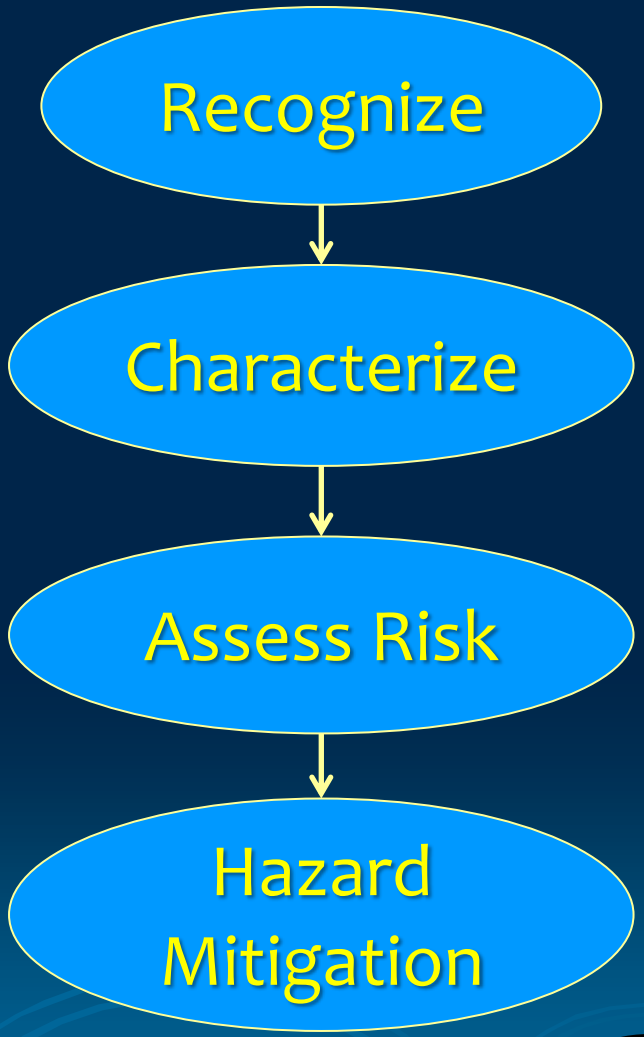
"We conclude channel incision presents a syndrome that is characterized by perturbed hydrology, degraded physical habitat, elevated nonpoint source pollution, and depleted fish species richness and that is extremely deleterious to instream ecosystem services."

Shields et al. 2010. *The stream channel incision syndrome and water quality.* Journal of Ecological Engineering

Allowing Incision to Migrate Upstream without Considering Risk

Jordan Creek at Parkway Drive

Incorporating Incision Risk Assessments into Passage Projects



Resource: Castro, Janine. 2003. *Geomorphic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision*. USFWS

Step 1 - Recognition: Incision or Local Scour?

photo: Kozmo Bates

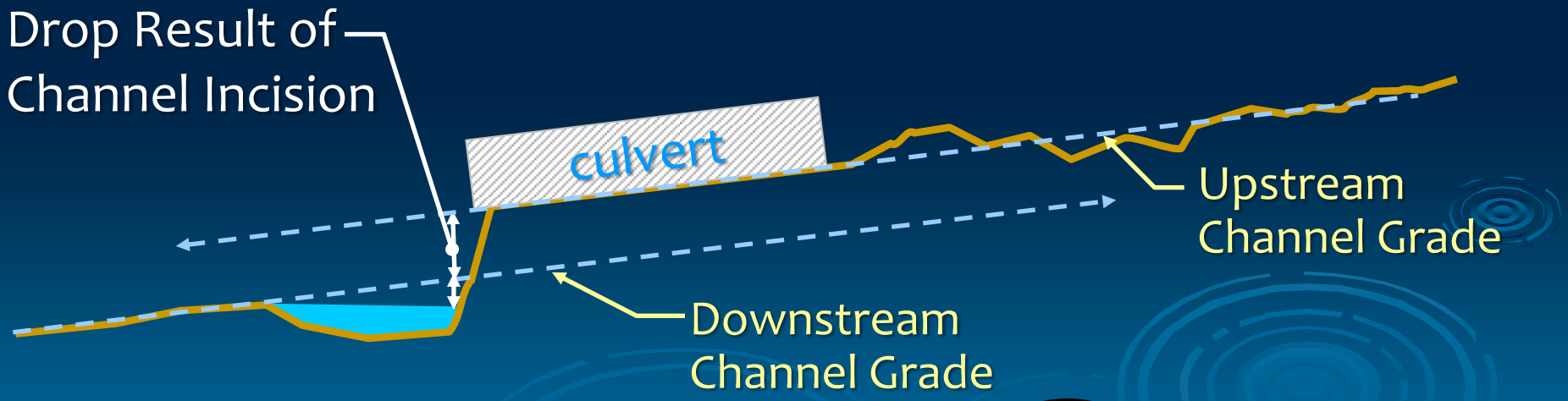
From further downstream – Pipe at Stream Grade

photo: Kozmo Bates

Recognize Local Scour vs. Incision

Drop formed by Plunge Pool

(Localized Scour)

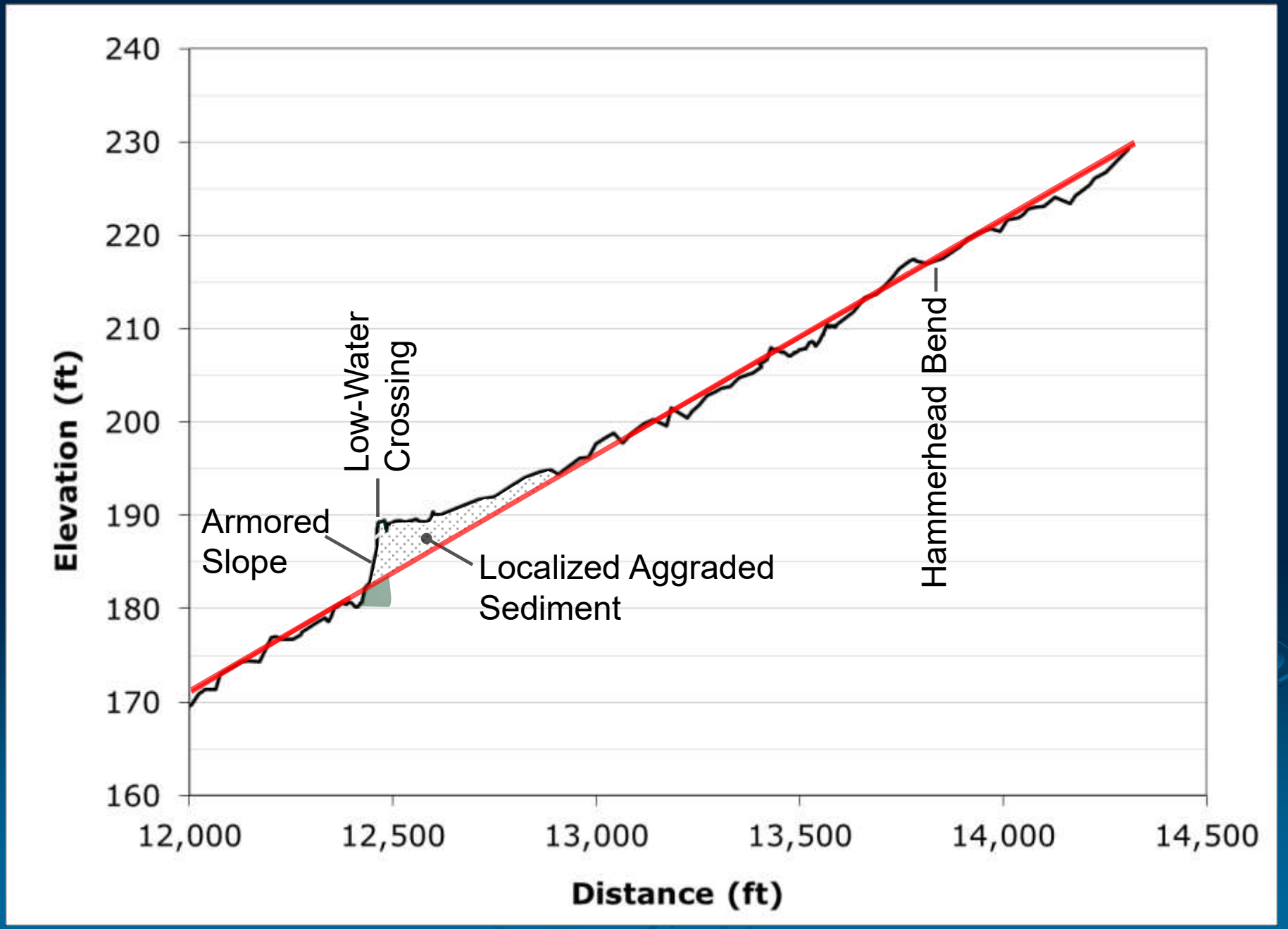


Channel Profile Interpretation

Incision Knickpoint or Not?

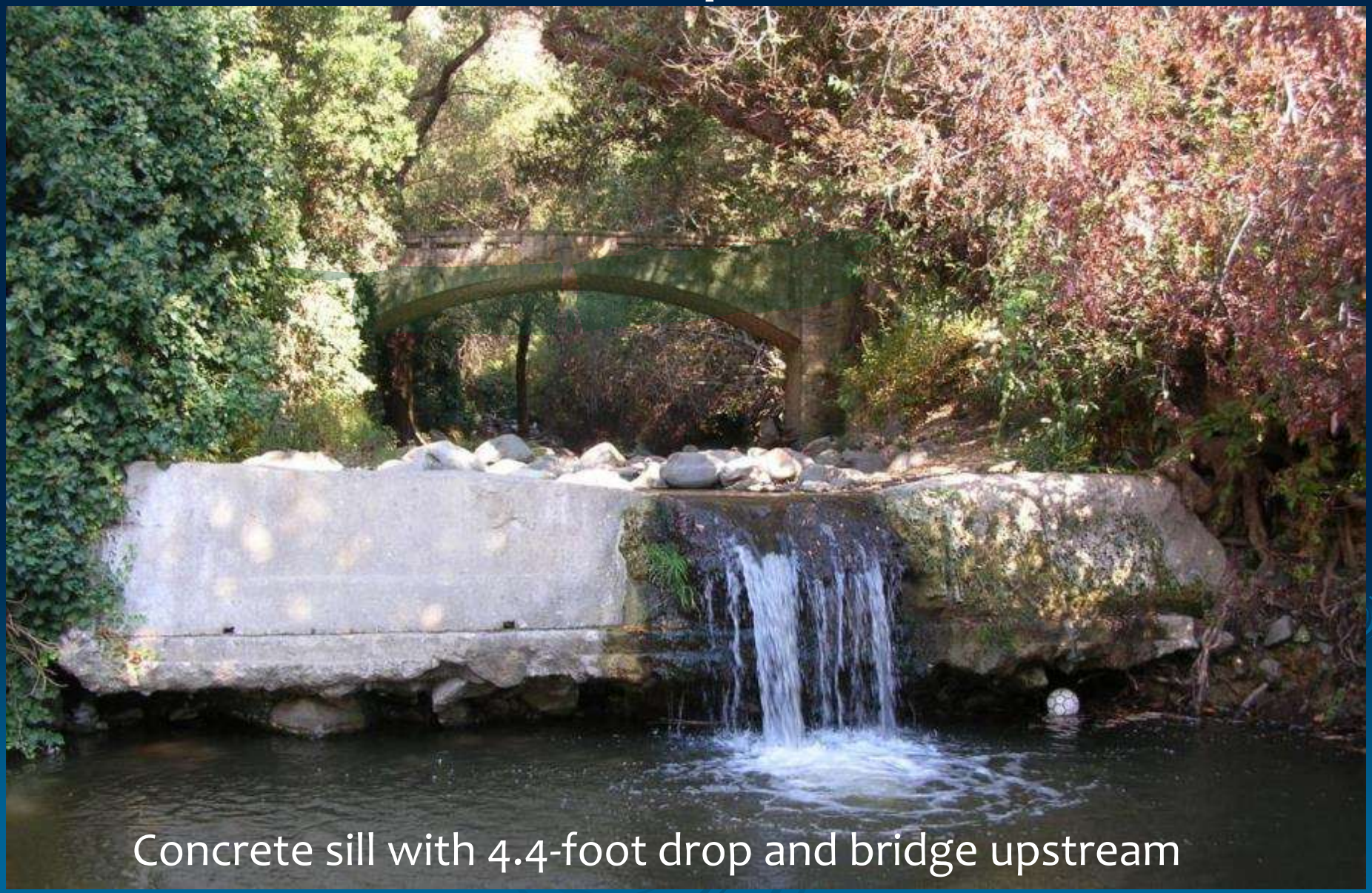
Vented low-water crossing (ford) with 8.7 feet of drop.

Channel Profile Interpretation



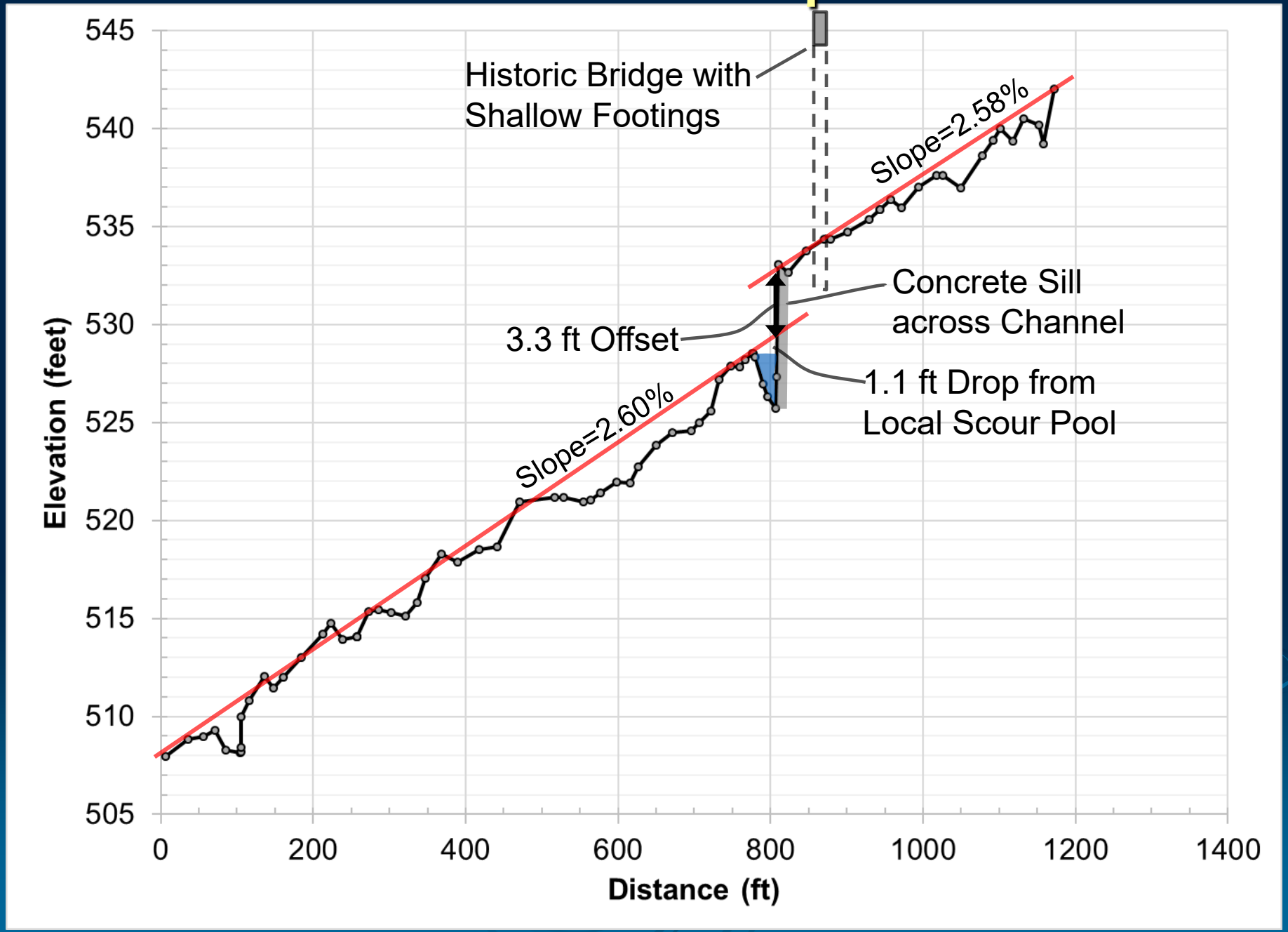
Channel Profile Interpretation

Incision Knickpoint or Not?



Concrete sill with 4.4-foot drop and bridge upstream

Channel Profile Interpretation



Other Channel Incision Indicators

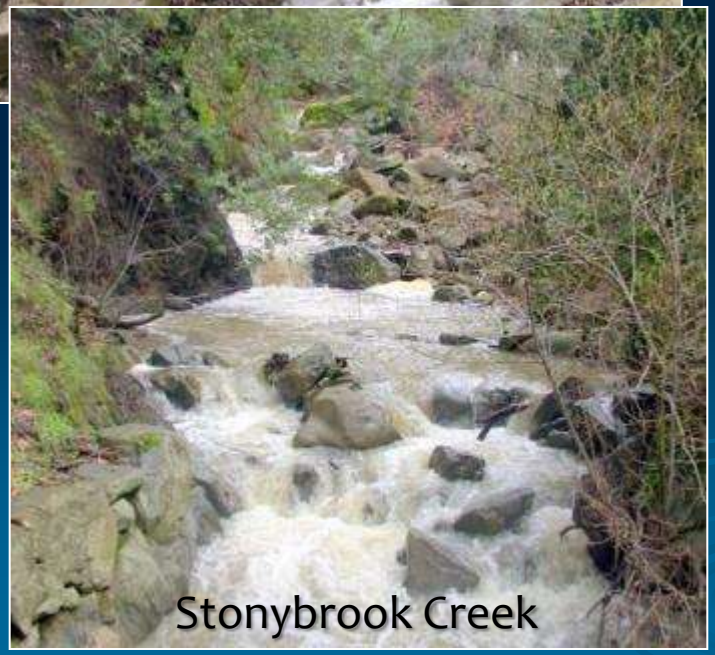
- **Lack of Sediment Deposition**
  Erosion of channel bed down to bedrock or other resistant soil layers
- **Toe of Bank is Vertical**
  Exposed roots, lack of sediment layering at streambed-banks interface
- **Actively Widening (Stage III)**
  Active bank failures, low depositional bars
- **Lack of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

List adapted from J. Castro, 2003

Risk Assessment - Rate of Headward Incision

More mobile the bed material, more rapid the channel regrades.

Boulder Channel

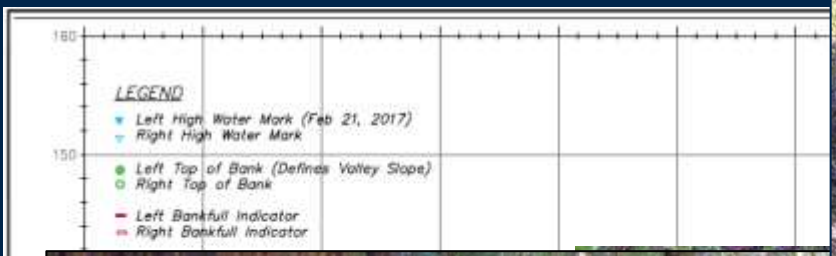


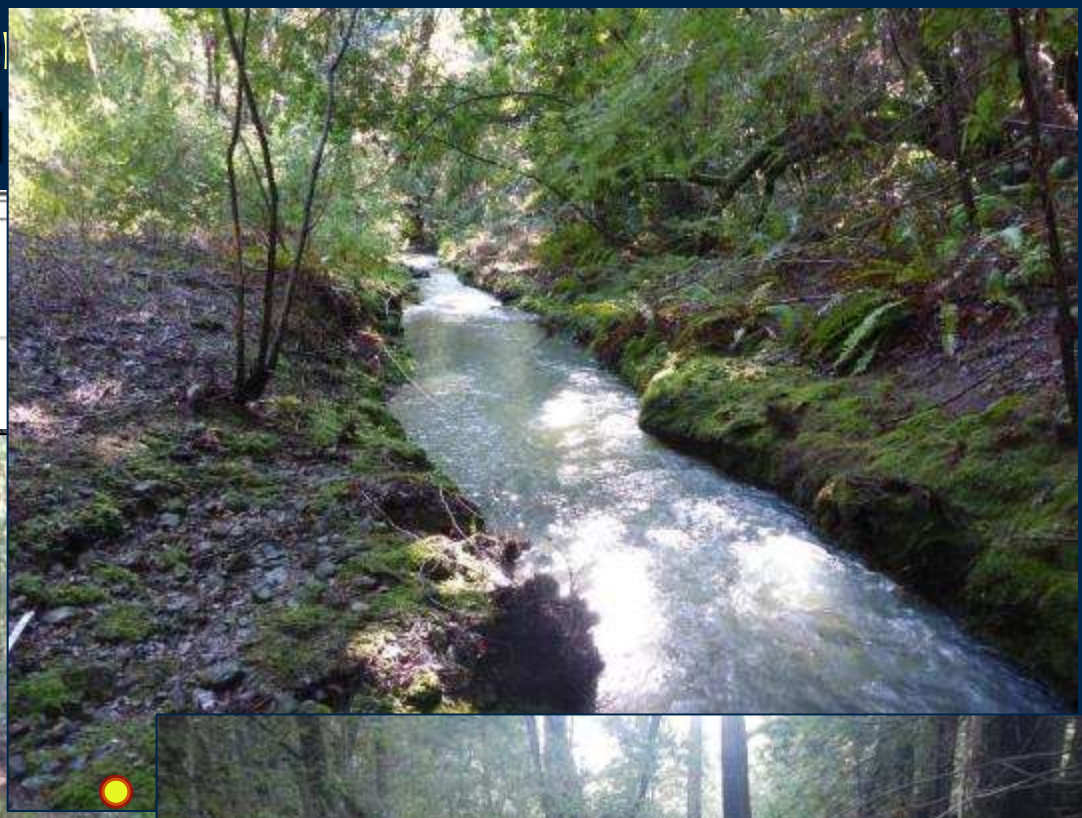
Fine Grain Bed and Banks

Risk Assessment for Removing Kickpoints in Incised Channels

- **Anticipated magnitude and extent**
  Depth of incision and length of channel at risk
- **Risk to upstream property and infrastructure**
- **Impact to existing riparian vegetation**
  Will water table lower with incision and rootzone become dry?
- **Change in connectivity to side-channels and floodplain**
- **Rate of incision, bank widening, and sediment release**
  Mobility of bed, erosivity if banks, wood controls, bedrock
- **Ability of channel to recover**
  Will bank material and land-use permit channel evolution (widening)?

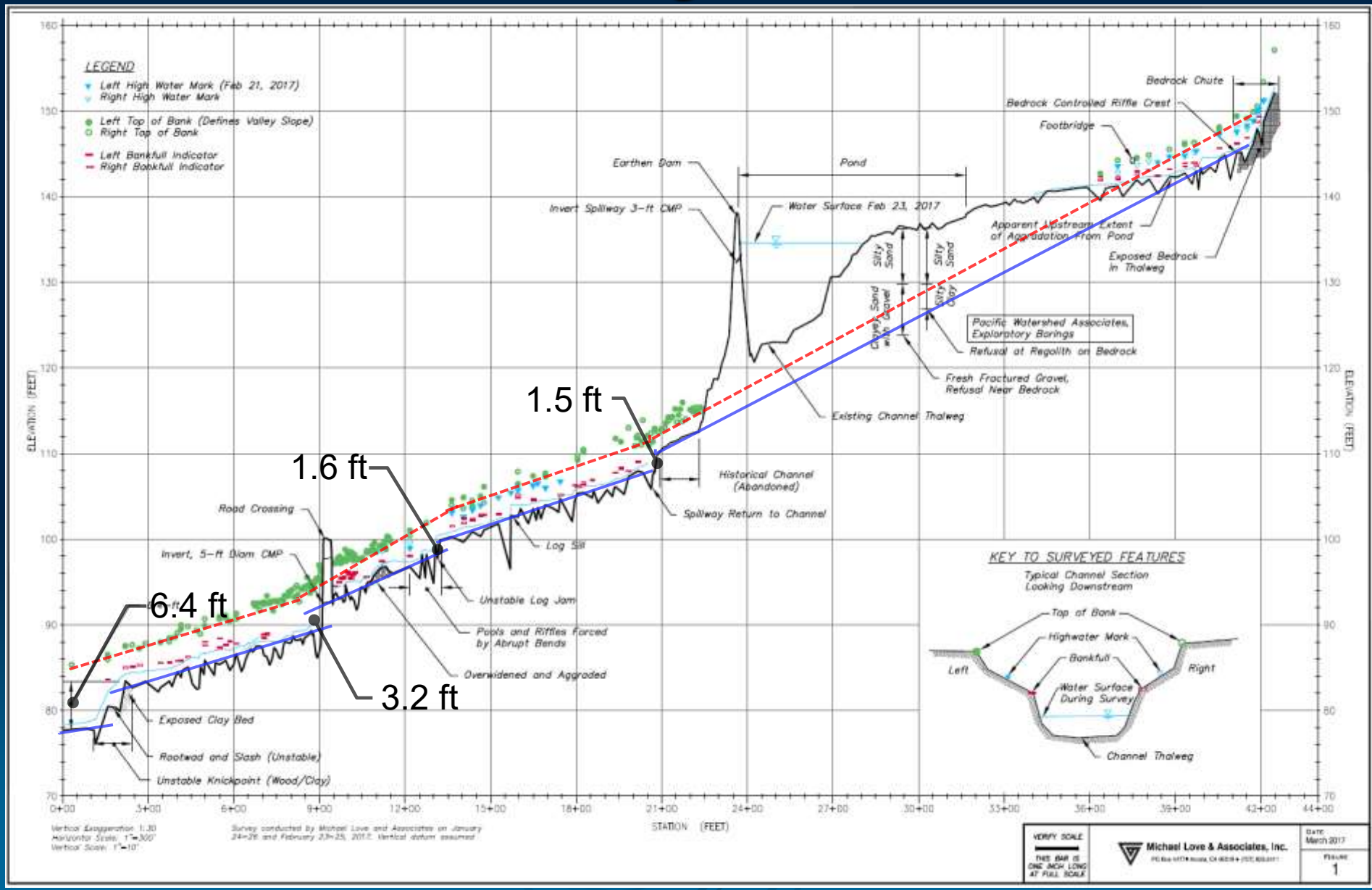
Thalweg Profile Inte
Chal





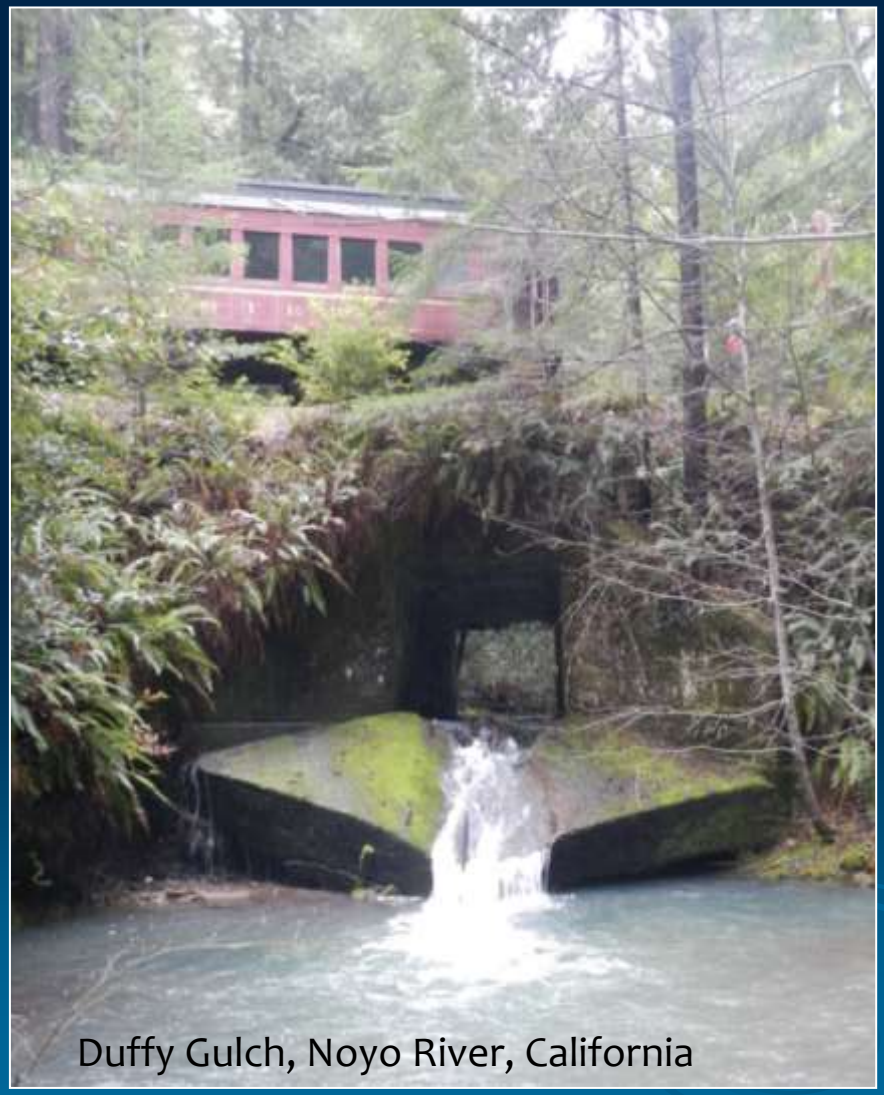
Thalweg Profile Interpretation – Group Exercise

Challenge Creek



One Size Does Not Fit All

Contemporary Design Approaches to Address Fish Passage at Stream Crossings



Duffy Gulch, Noyo River, California

Michael Love P.E.
Arcata, California
mlove@h2odesigns.com
707-822-2411

Michael Love & Associates
Hydrologic Solutions

California Department of Fish & Wildlife

California Salmonid Stream Habitat Restoration Manual

Part XII: Fish Passage Design and Implementation (2009)

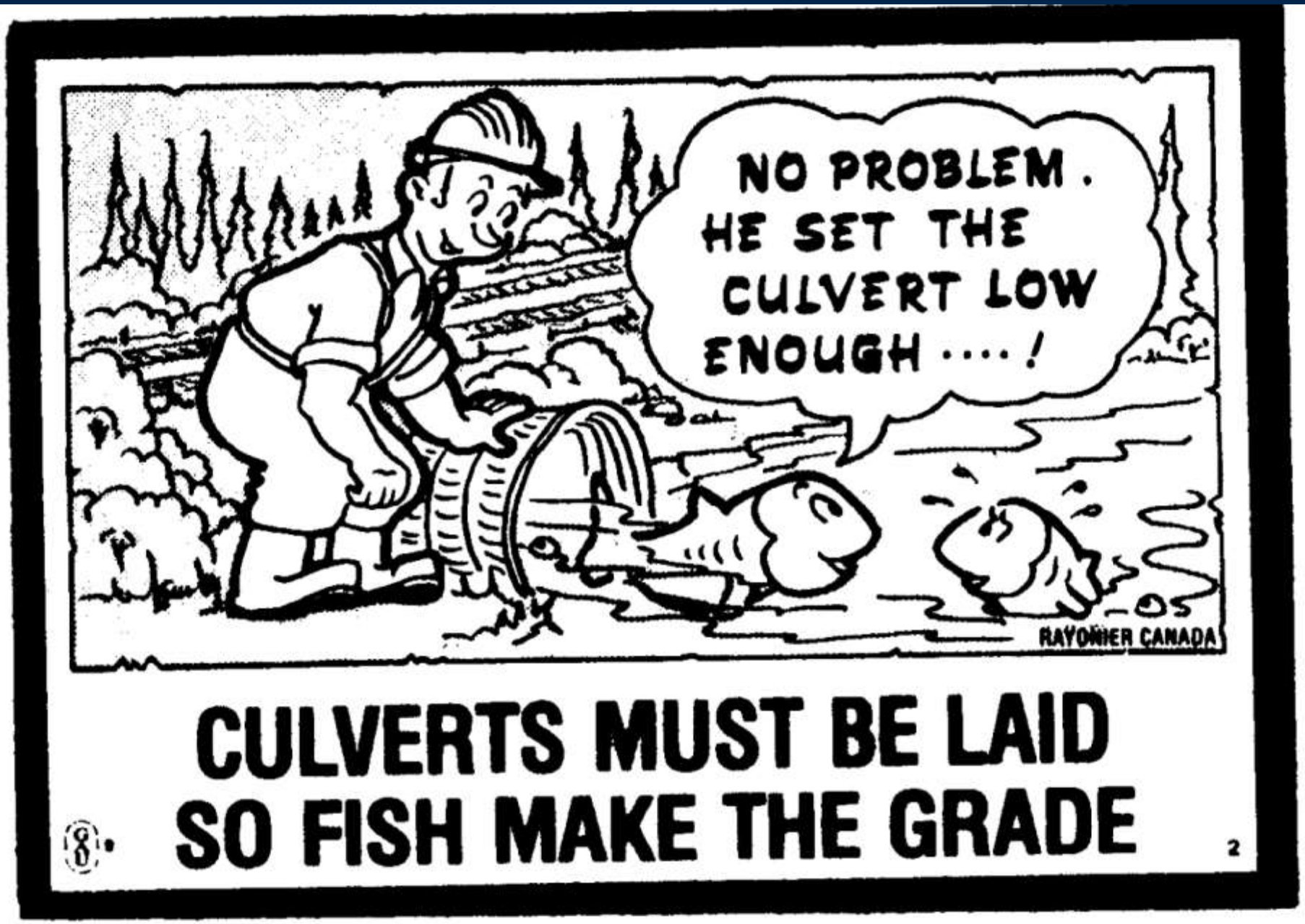
Available at:

http://www.dfg.ca.gov/fish/resources/habitatmanual.asp

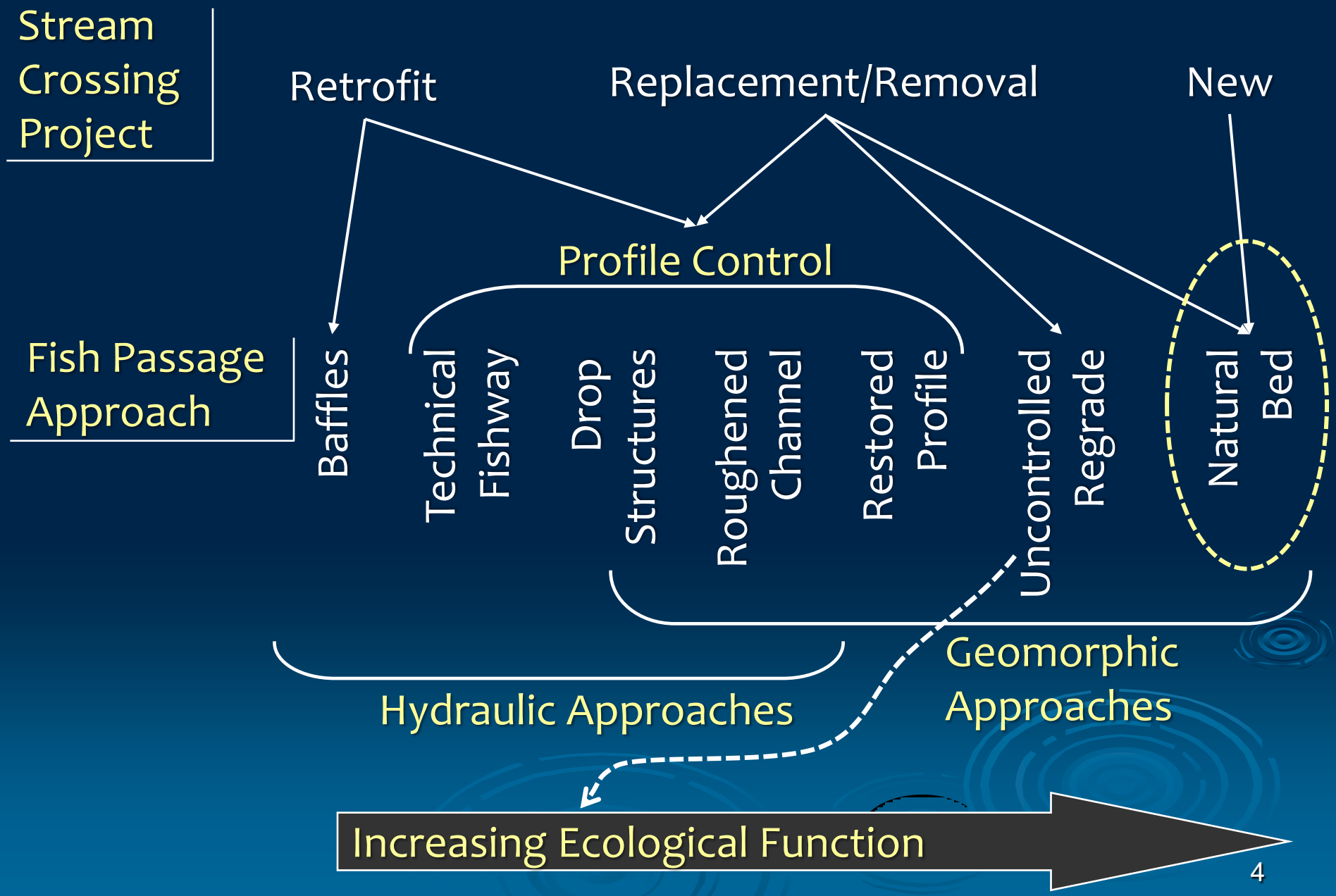
Primary Authors:

Michael Love P.E.
Michael Love & Associates, Inc.

Kozmo Bates P.E.
Olympia, WA


NO PROBLEM. HE SET THE CULVERT LOW ENOUGH ....!
RAYONIER CANADA
CULVERTS MUST BE LAID SO FISH MAKE THE GRADE
8.
2

Design Approaches for Aquatic Organism Passage



Stream Simulation Design Approach for Passage of Aquatic Organisms

"A channel that simulates characteristics of the natural channel will present no more of a challenge to movement of organisms than the natural channel."

Primary Source:

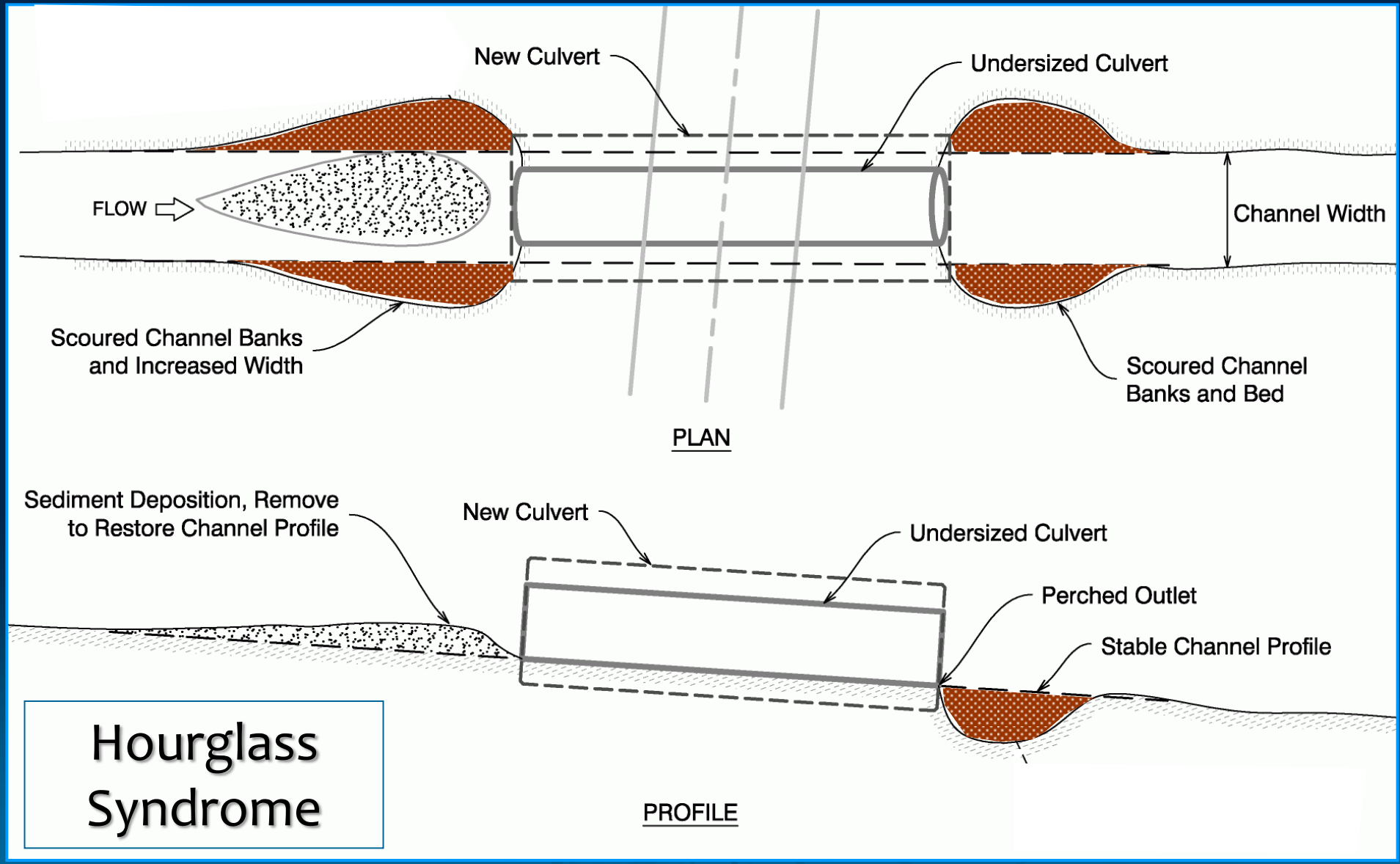
USFS (2008). *Stream simulation: an ecological approach to road stream crossings*

Available at the FishXing website: **FishXing.org**

What is Stream Simulation?

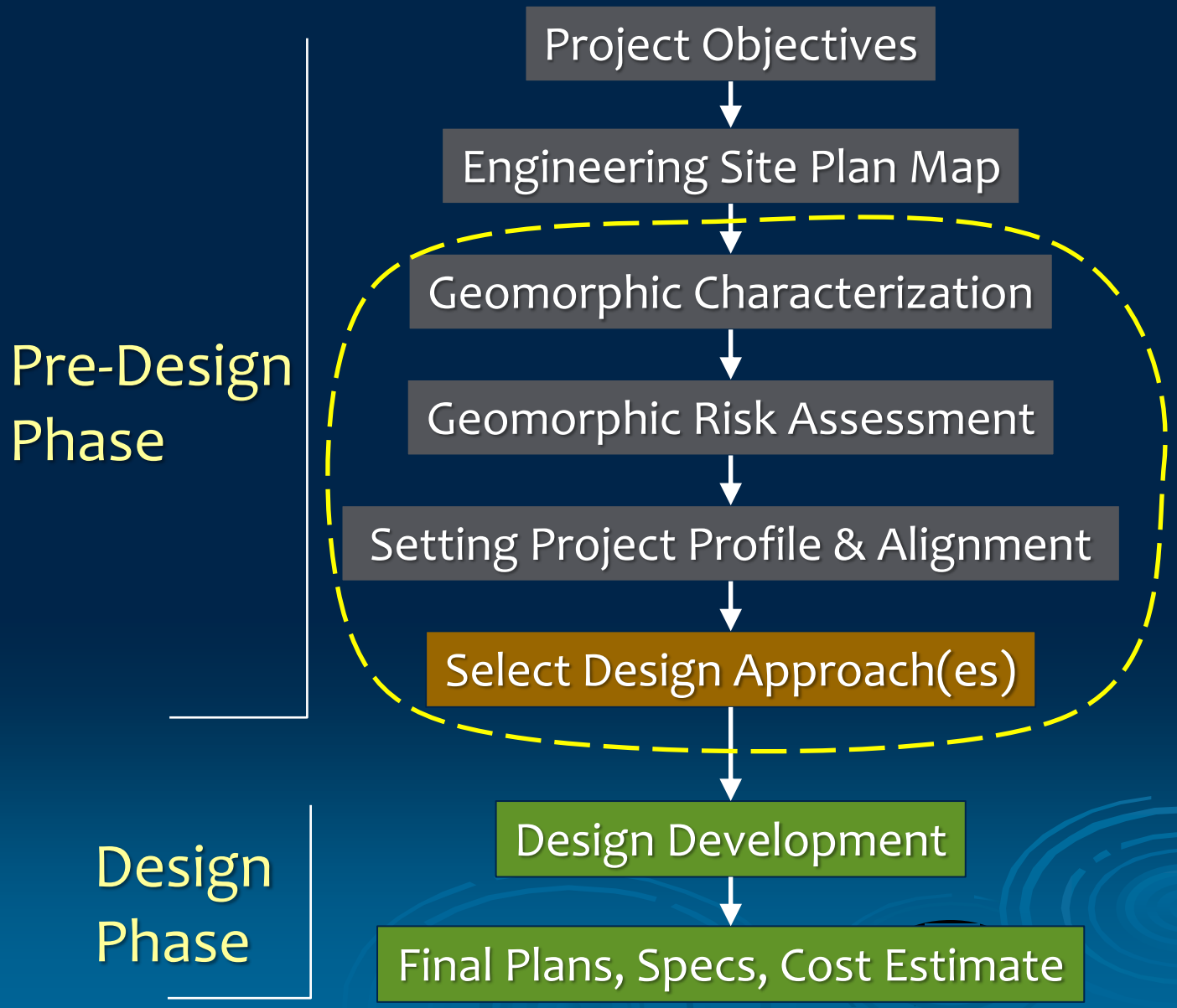
- A Geomorphic Approach to Designing Stream Crossings
- Design Profile Seamlessly Connects Downstream & Upstream Channel Profiles
- Simulate A Natural Channel Reference Reach
  - Channel Slope
  - Bankfull Cross Section Dimensions
  - Channel Structure
    - Channel Bedforms
    - Mobility/Stability
  - Forcing Features
  - Continuous Banks

Restoring Channel Geometry

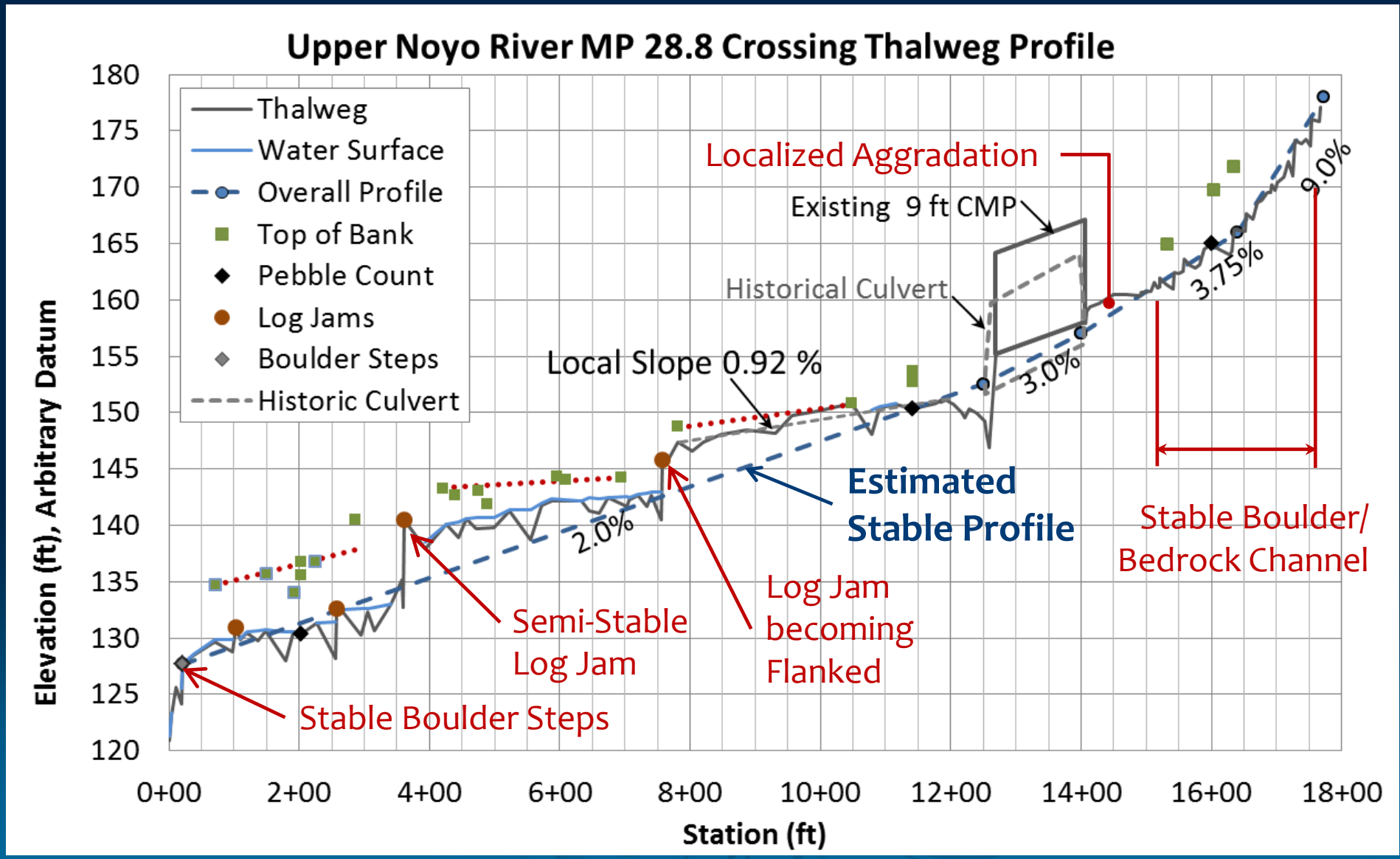


Hourglass Syndrome

Passage Design Process

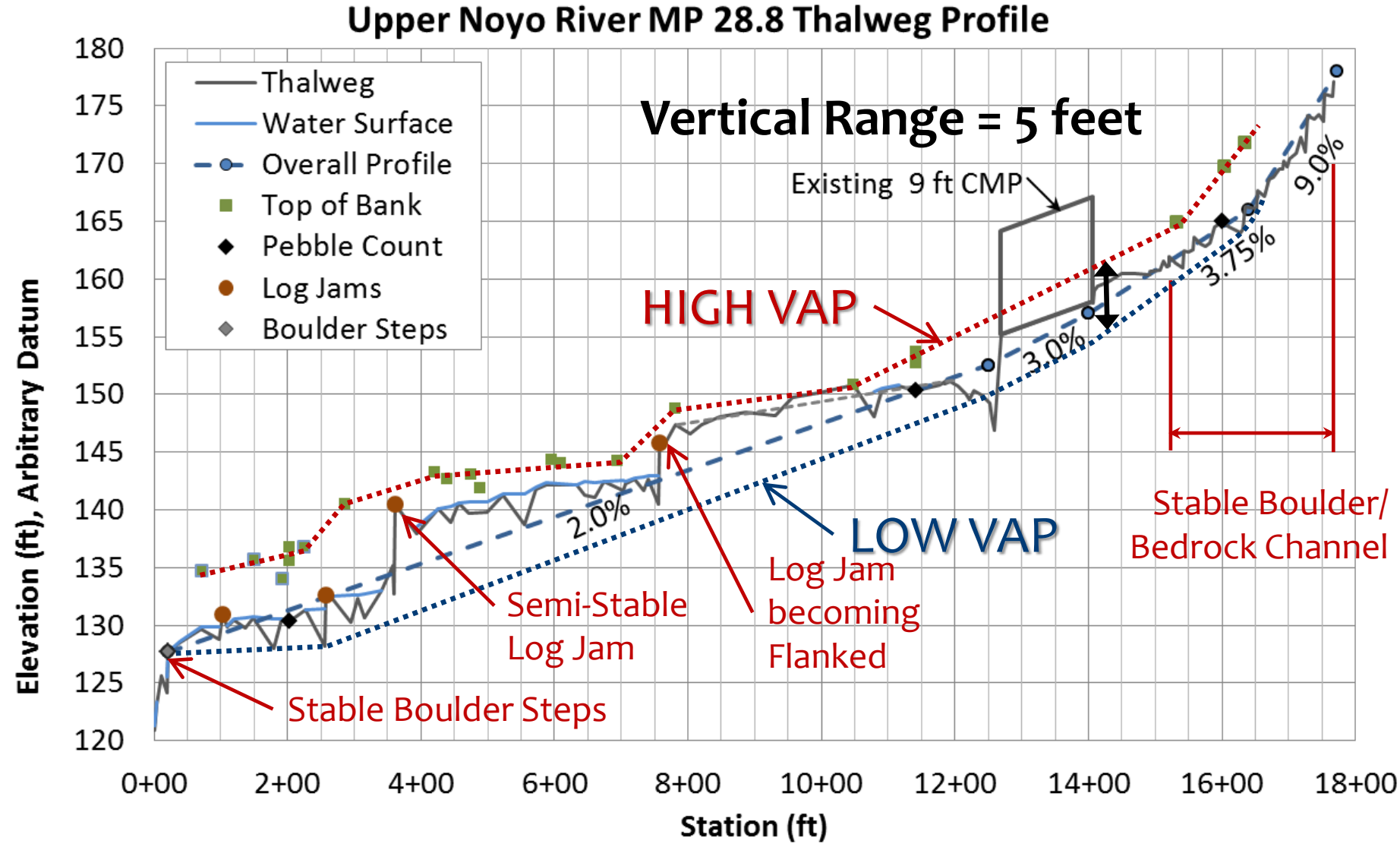


Channel Profile Analysis



Vertical Adjustment Potential (VAP) Profiles

Estimates the range of possible channel profiles for life of project



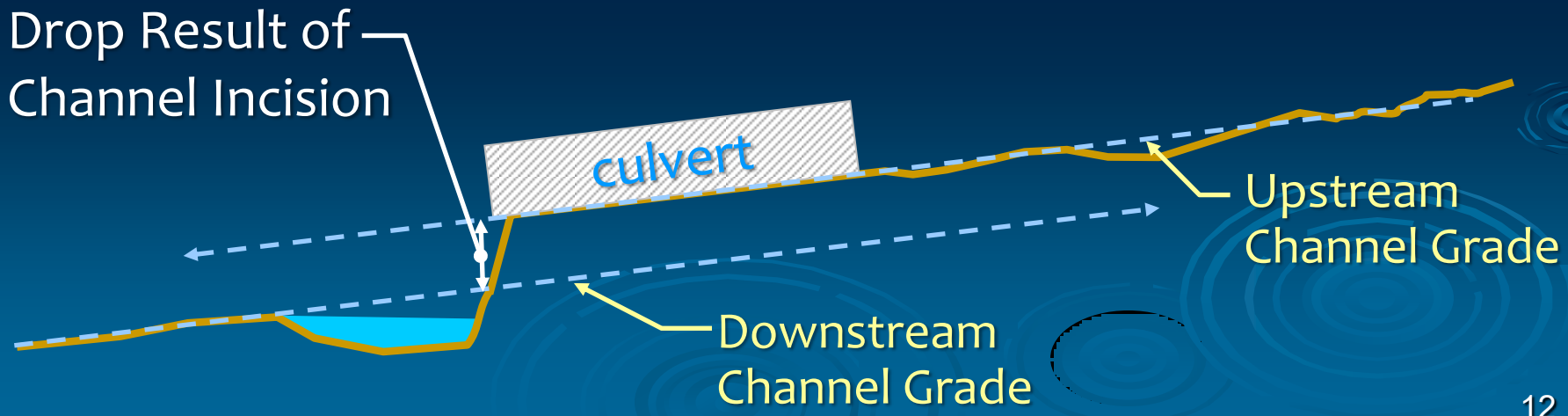
Vertical Adjustment Potential (VAP)

Develop VAP with long profile and field investigations:

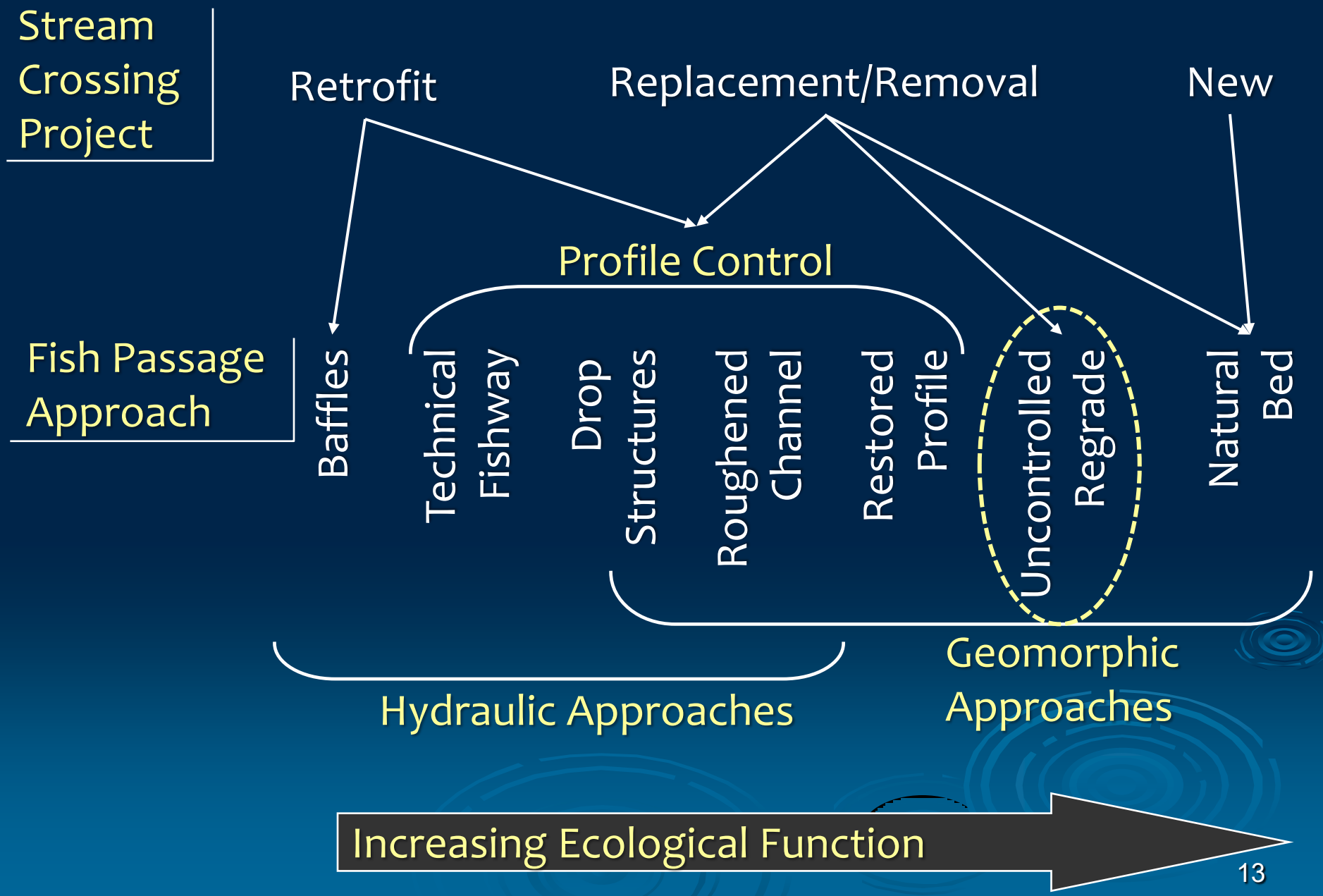
- ✓ Channel slopes
- ✓ Stability/mobility of channel type/material
- ✓ Channel controls and anticipated longevity [bedrock, large wood, colluvium, hard infrastructure]
- ✓ Knickpoints, evidence of active incision (downcutting) or aggradation
- ✓ Pool scour depths (low VAP)
- ✓ Bankfull and floodplain elevations (high VAP)
- ✓ Historical information (existing invert elev. and slope)

Stream Simulation Appropriate

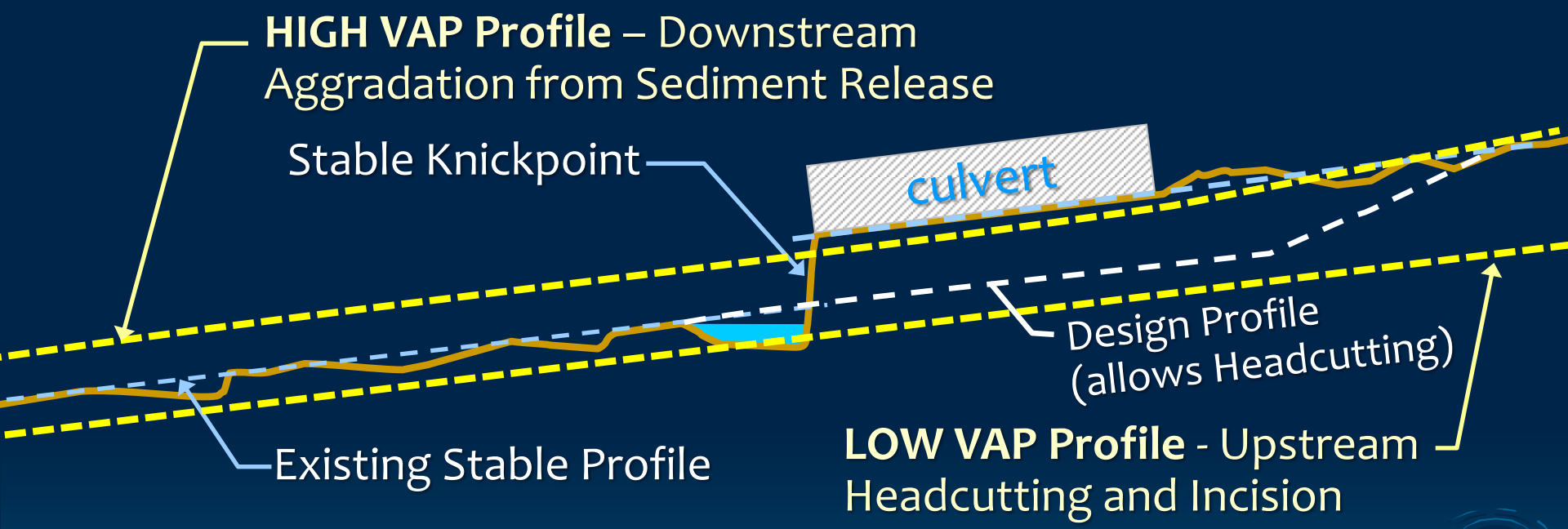
Stream Simulation **Not** Appropriate



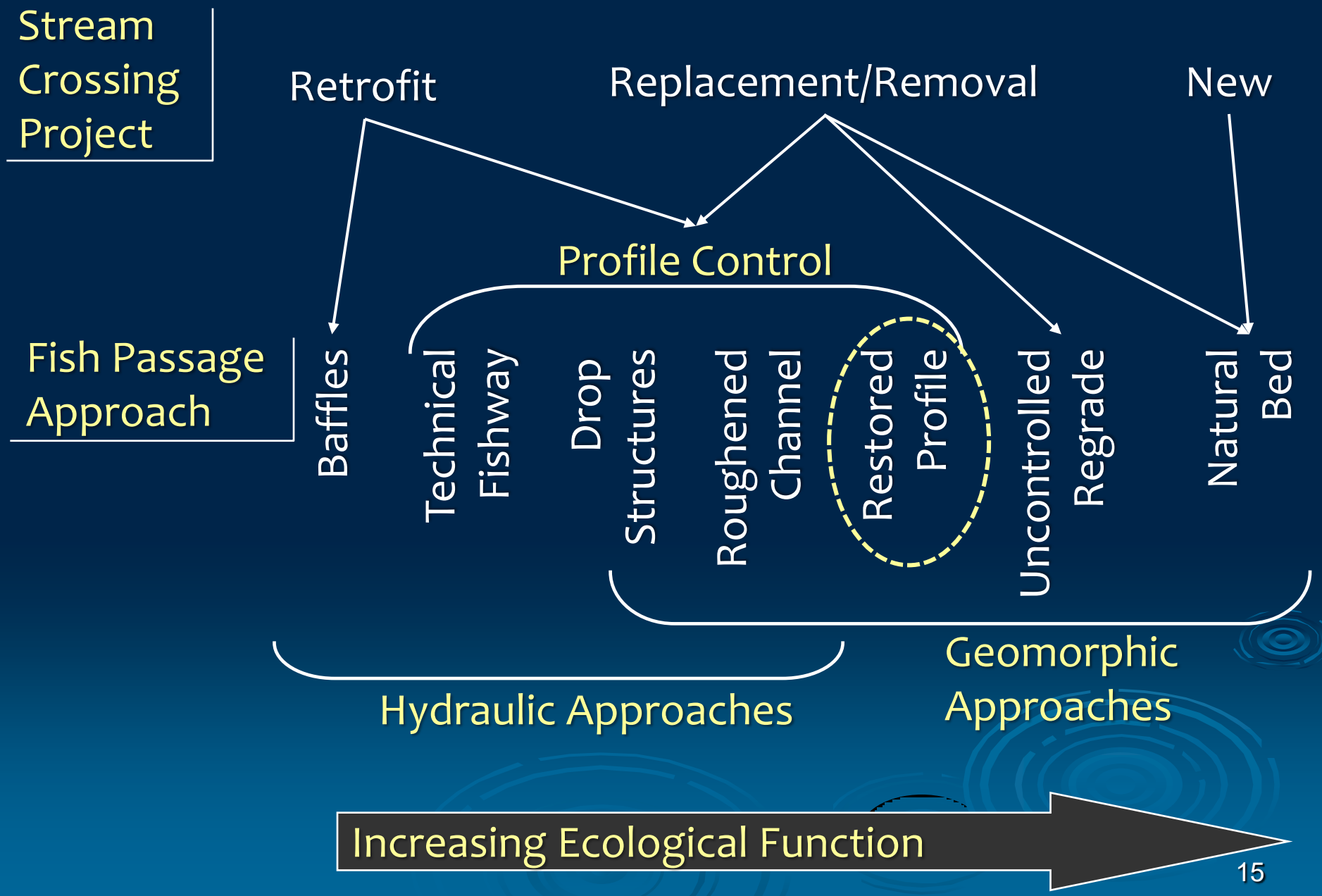
Design Approaches for Aquatic Organism Passage



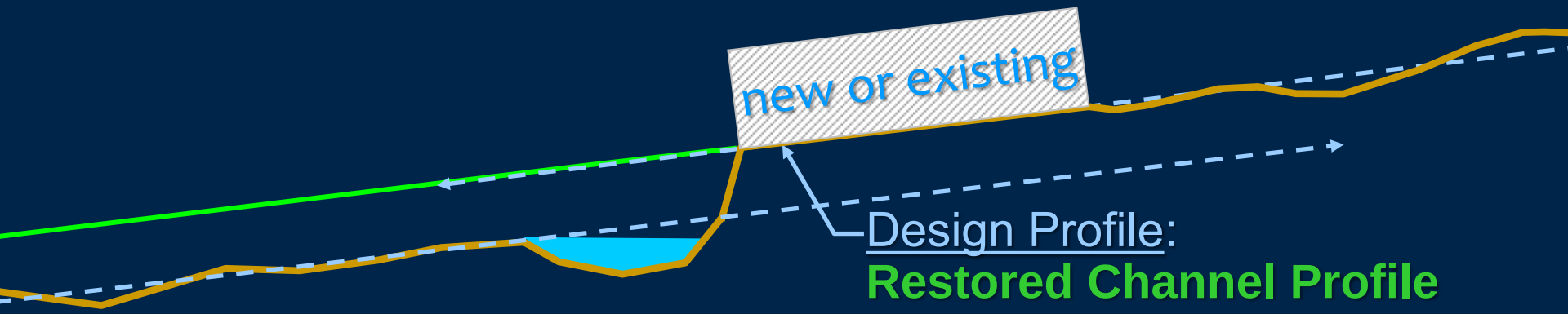
VAP Profiles for Incised Channels
(no grade control – "Uncontrolled Regrade")



Design Approaches for Aquatic Organism Passage



Restored Profile Option



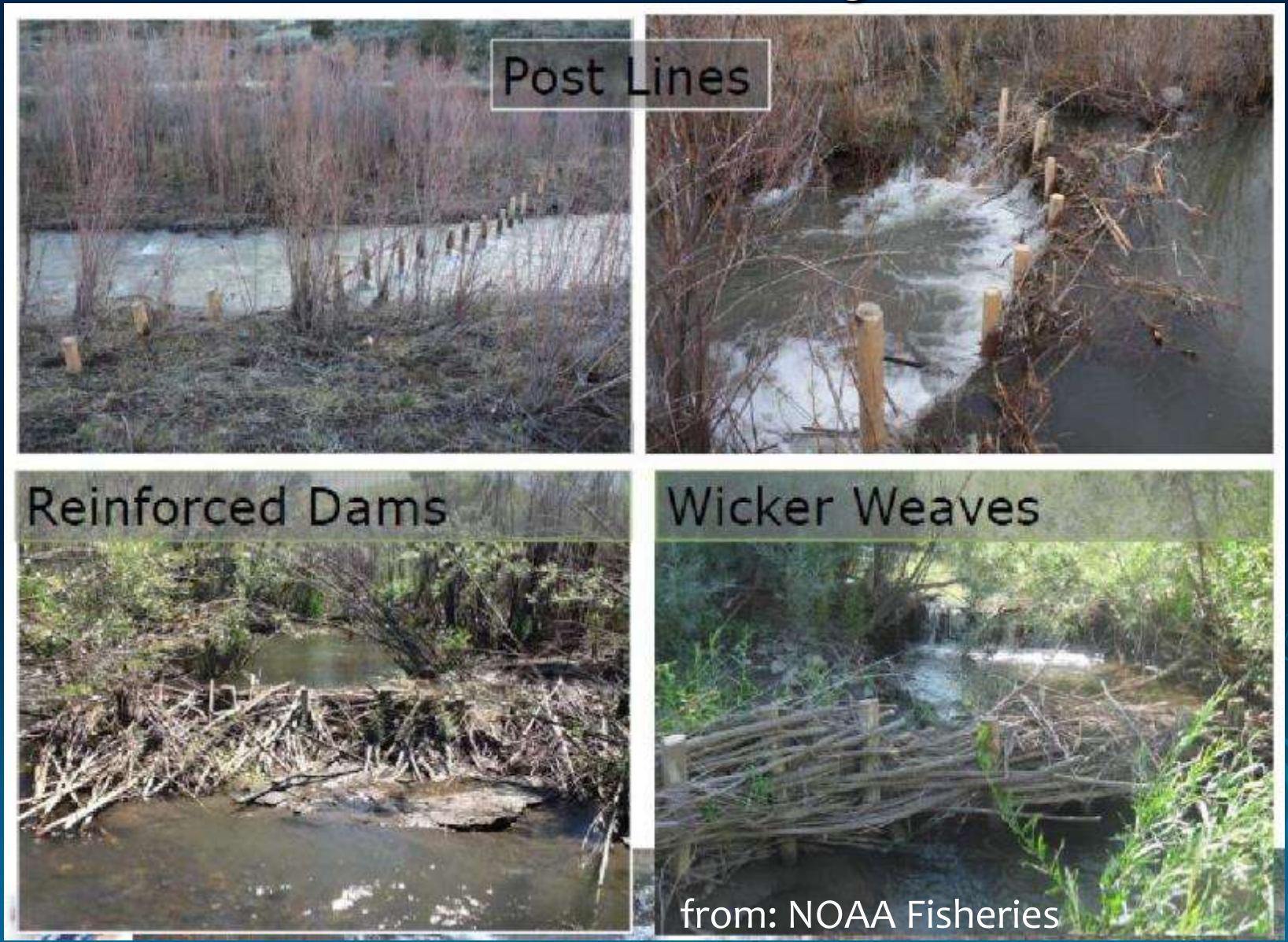
Restoring Incised Channels and Connectivity

Placing Wood - Profile Restoration

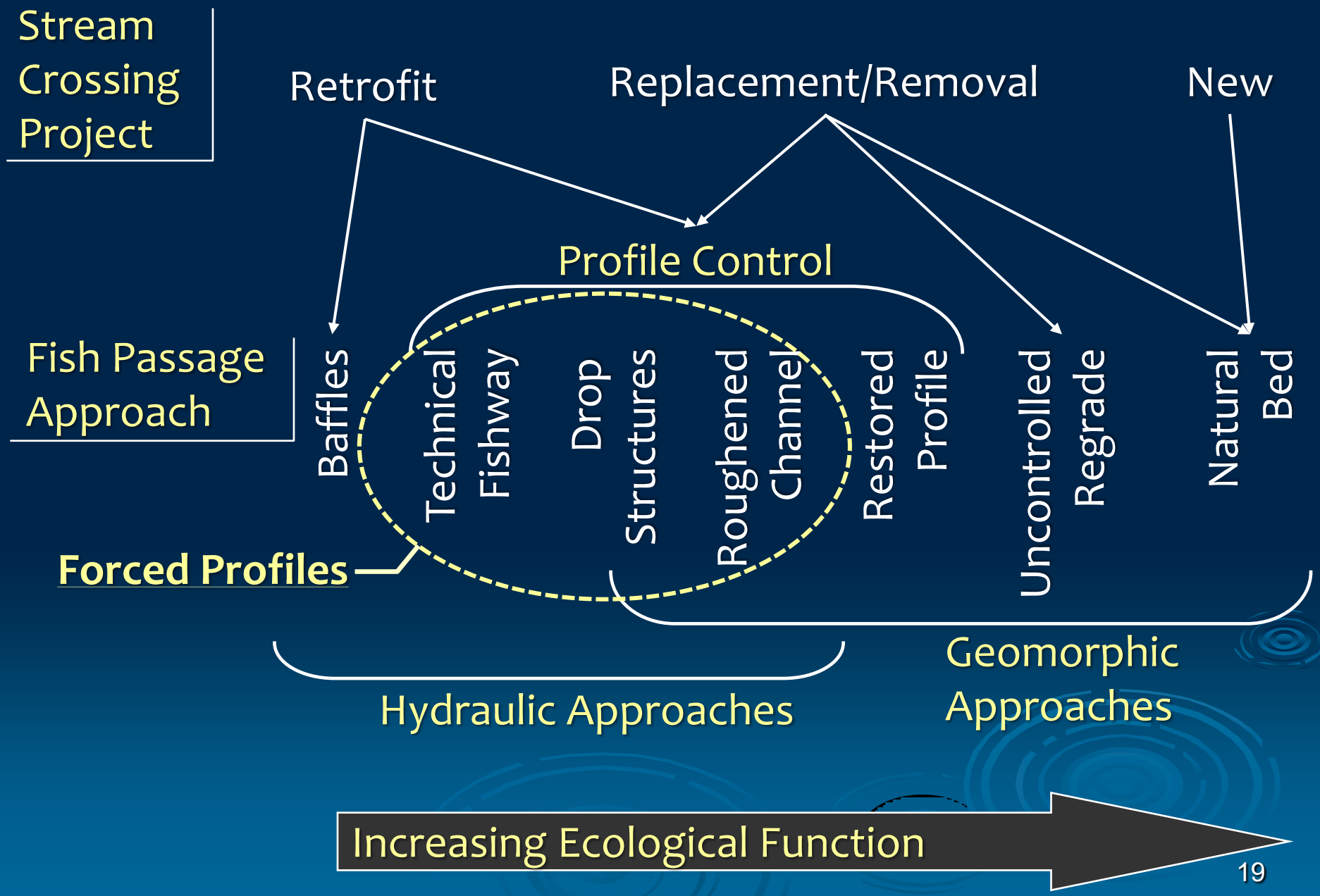
Baker Creek
photos: Sam Flanagan, BLM

Restoring Incised Channels and Connectivity

Beaver Dam Analogs



Design Approaches for Aquatic Organism Passage



Forced Profiles

Profile Control - Downstream Transitions

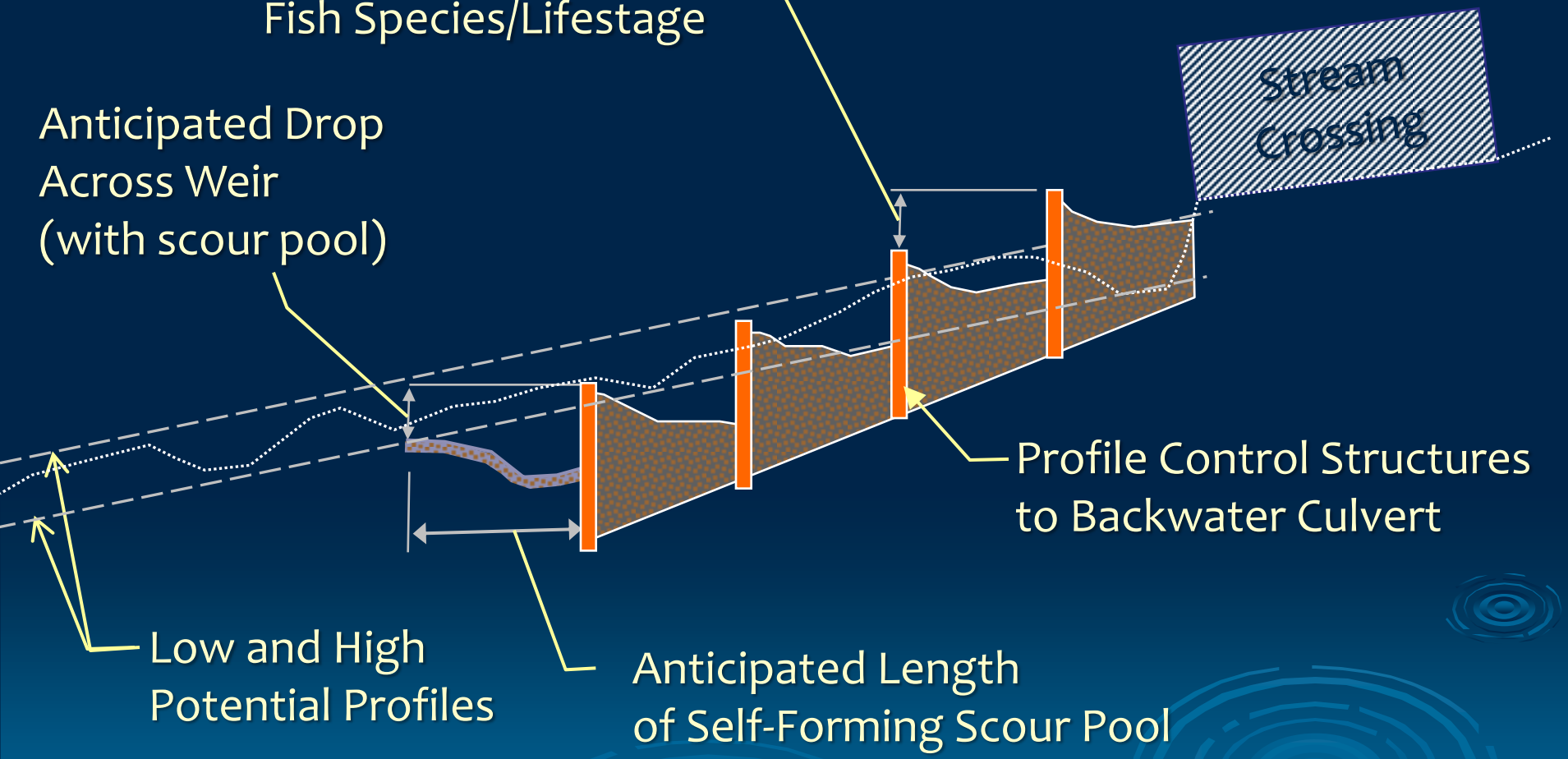
Photo: Glenn Hurlburt

Drop at Fishway Entrance from Downstream Scour

Photo: Mike Garello

Rock Weir Failed from Downstream Scour

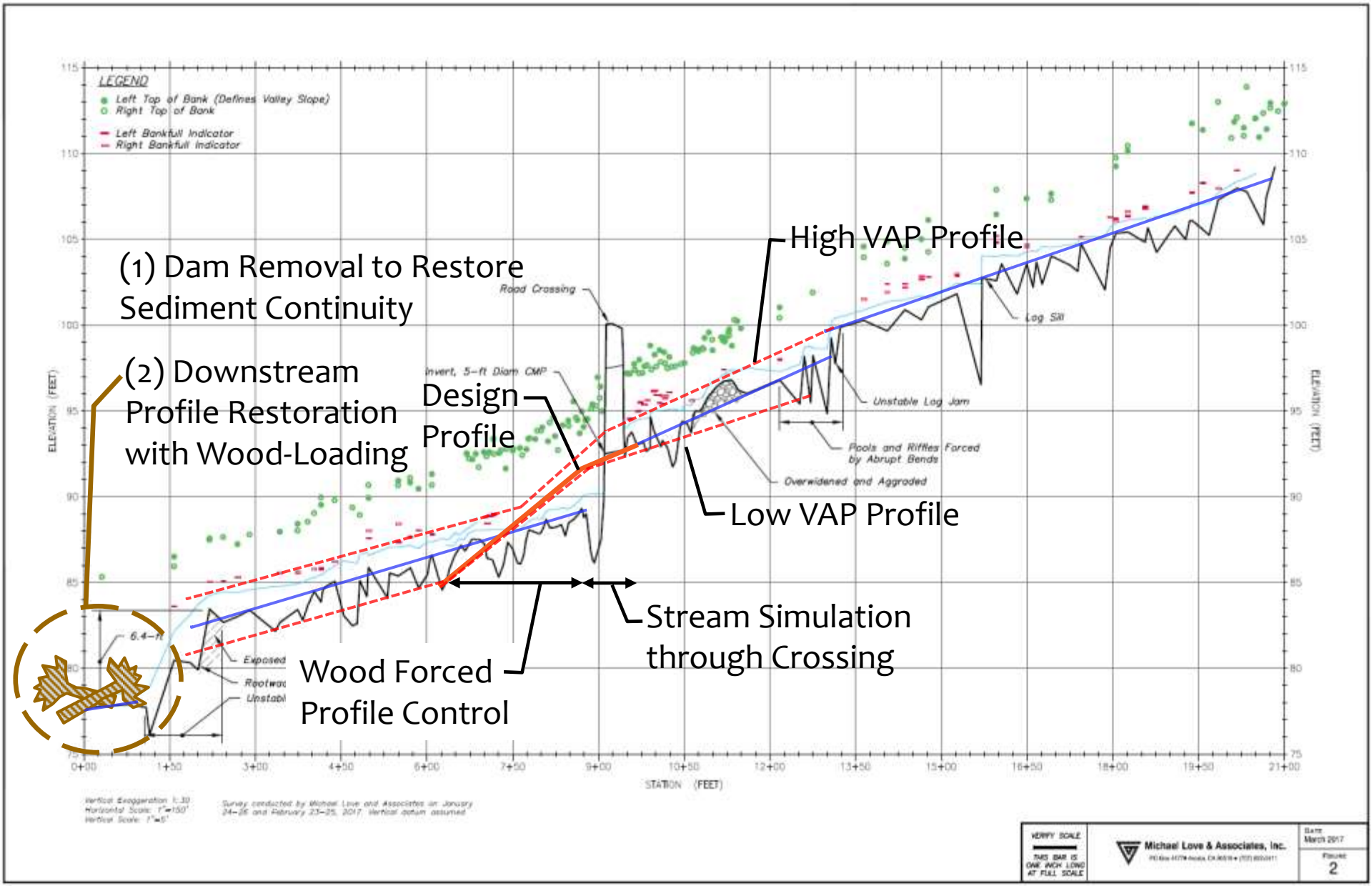
Using Low VAP to Set Profile Control Transition



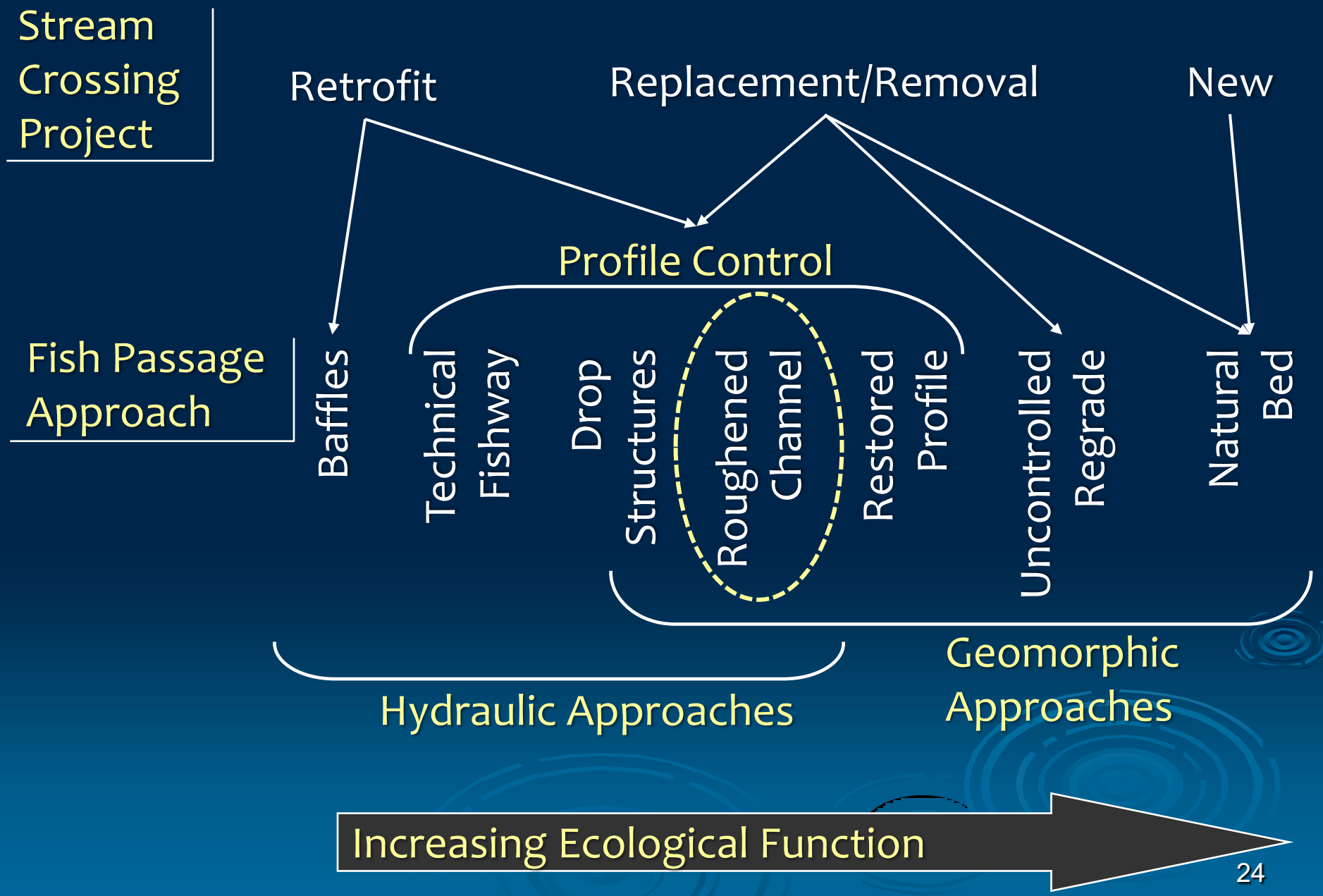
- ✓ Place Downstream End of Profile Control based on Anticipated Scour Pool Length at Low VAP Profile

Challenge Creek

Setting the VAP Profiles and Design Profile

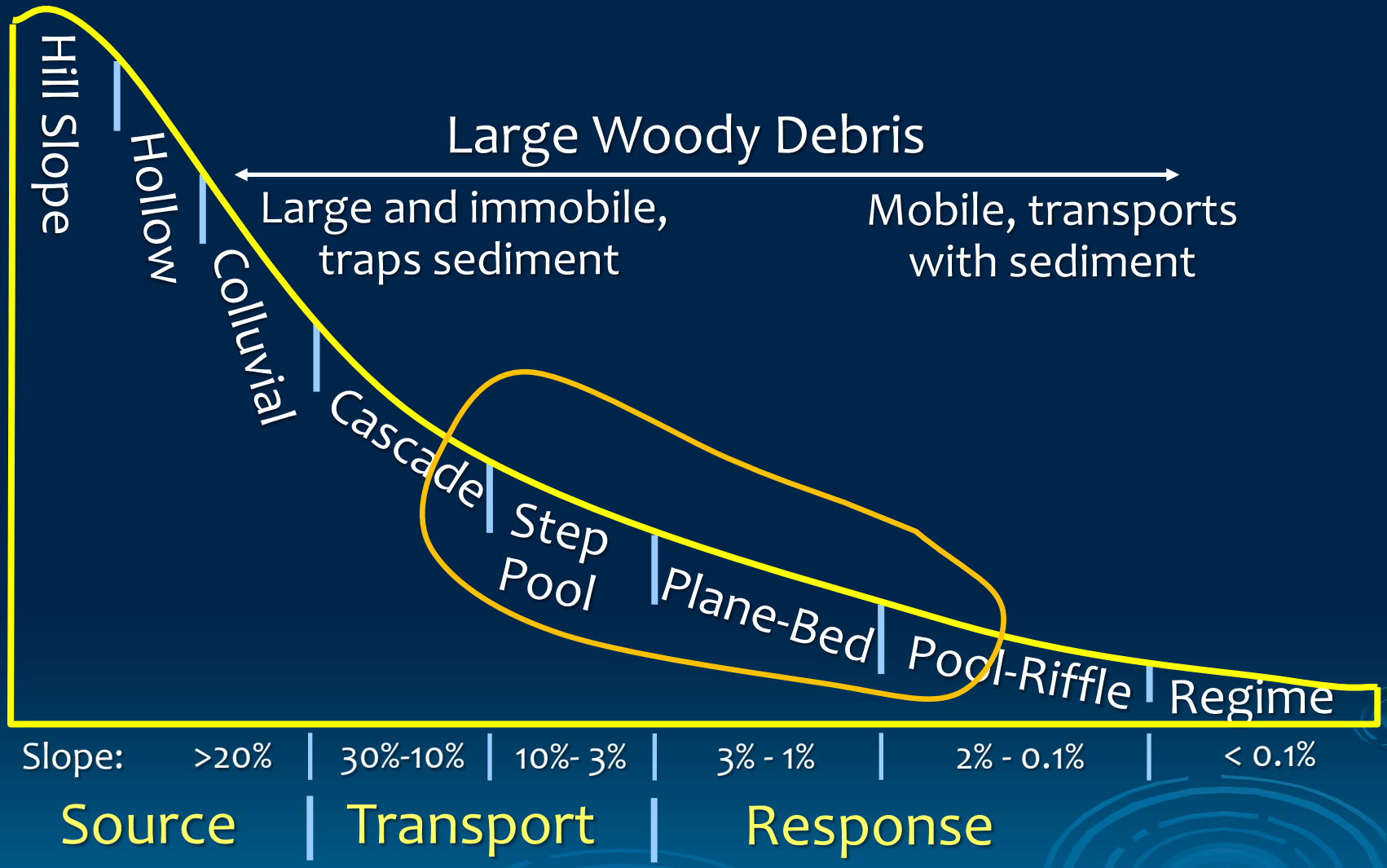


Design Approaches for Aquatic Organism Passage



Natural Steep-Stream Morphology

Generalized Stream Classification



(from Montgomery and Buffington, 1993)

Geomorphically-Based Roughened Channel Concept

Common Channel Types

Increasing Slope

- Roughened Riffles
- Plane Bed Channel (rock ramps)
- Rapids or Chutes & Pools
- Step-Pools
- Cascades & Pool

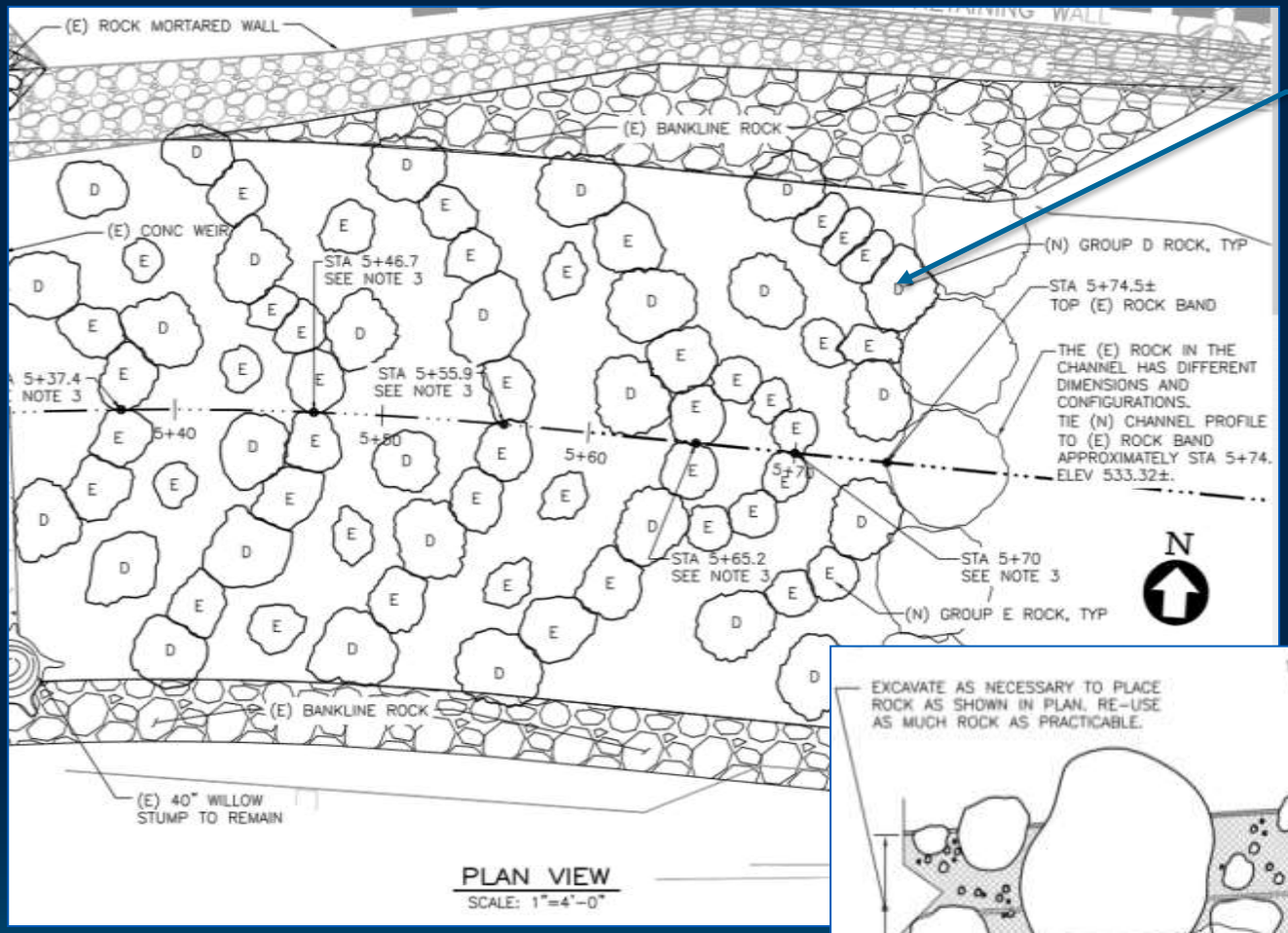
Caution:

- Only use channel types & slopes that the target species/lifestage are known to ascend
- Risk increases further the roughened channel characteristics deviates from the natural channel (i.e. slope, bed material, entrenchment)

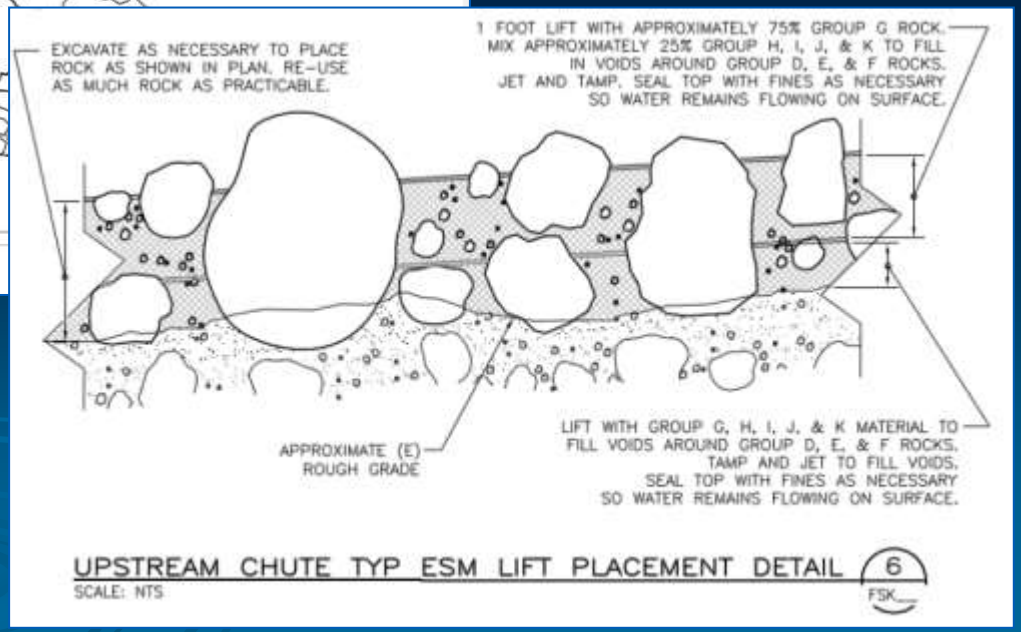
Geomorphically-Based Roughened Channels

- Channel constructed steeper than the adjacent channel (profile control)
- Based on morphology of steeper stream channel
- **Stable** *engineered streambed material (ESM)* forms channel bed & banks, with smaller material filling voids
- Quasi-hydraulic design for target species/lifestages [velocity, depth, drop, turbulence-EDF]

Roughened Channel Rock Placement Plan

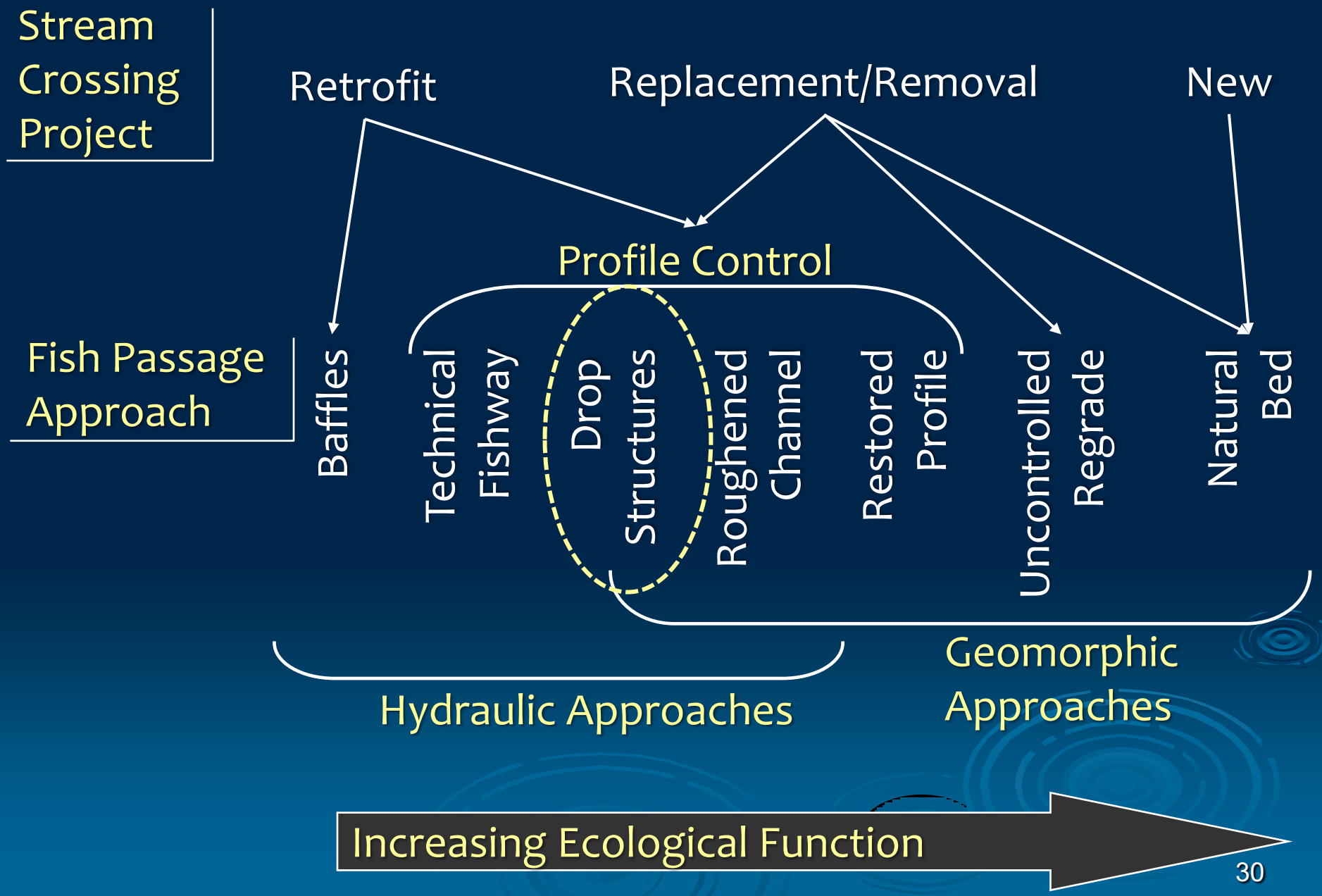


Placement Plan for Structure Rocks [D, E] within ESM



Material Placement in Lifts

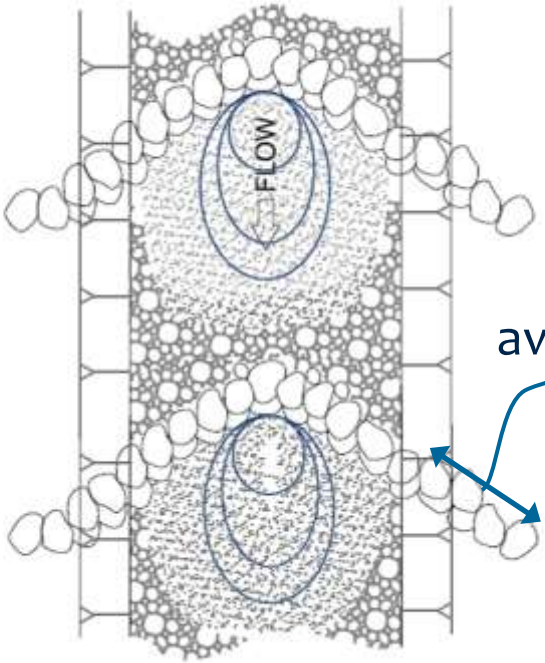
Design Approaches for Aquatic Organism Passage



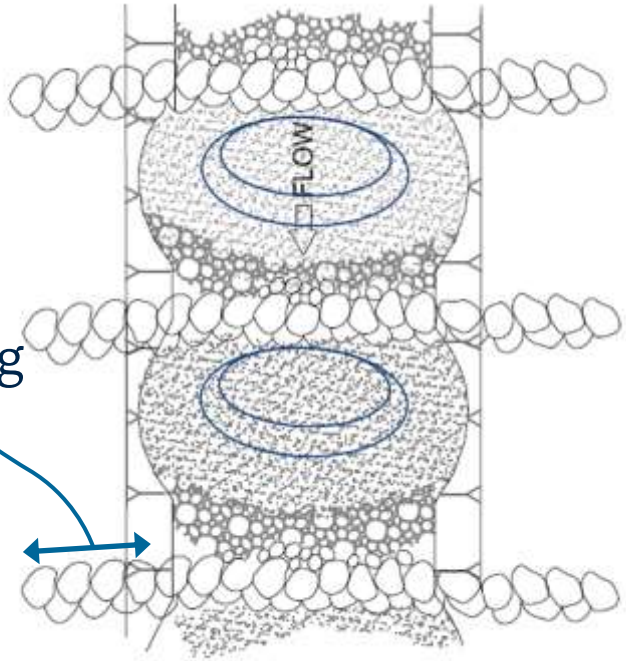
Shape of Rock Weirs Controls Scour Pool Shape

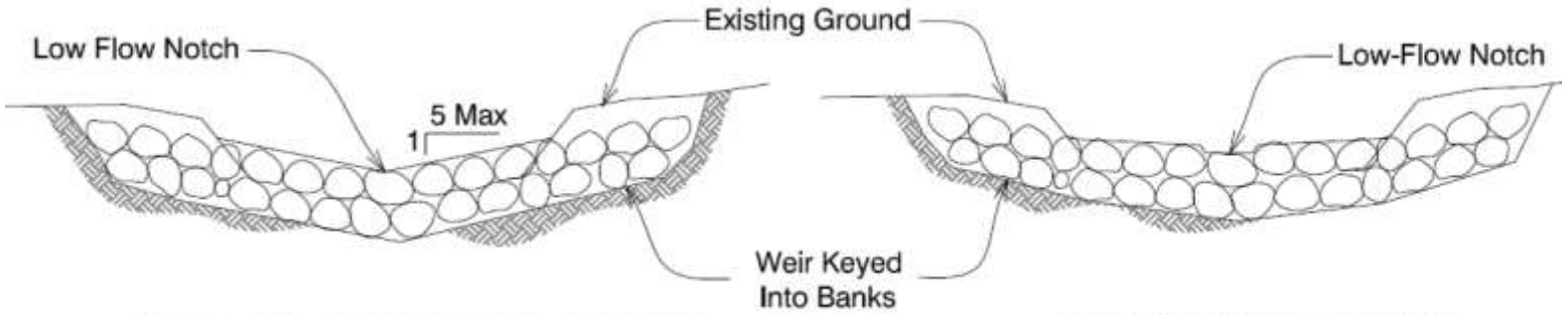
Arch Concentrates Scour
(Longer/Narrower Pools)

Straight Weirs Spread Scour
(Shorter Pools/Wider)



Key into banks to avoid flanking

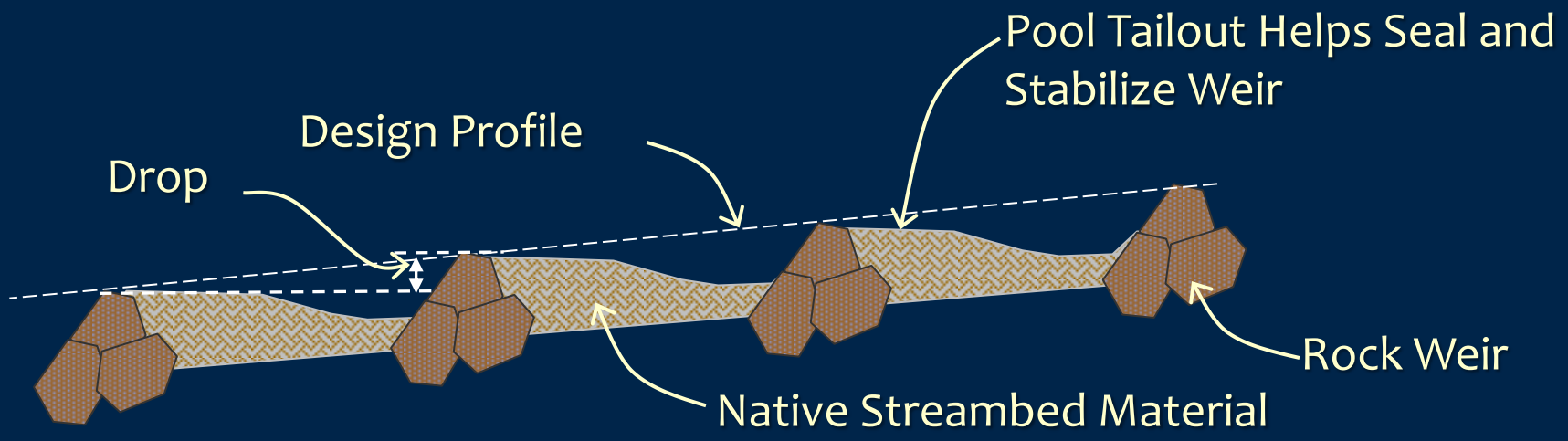


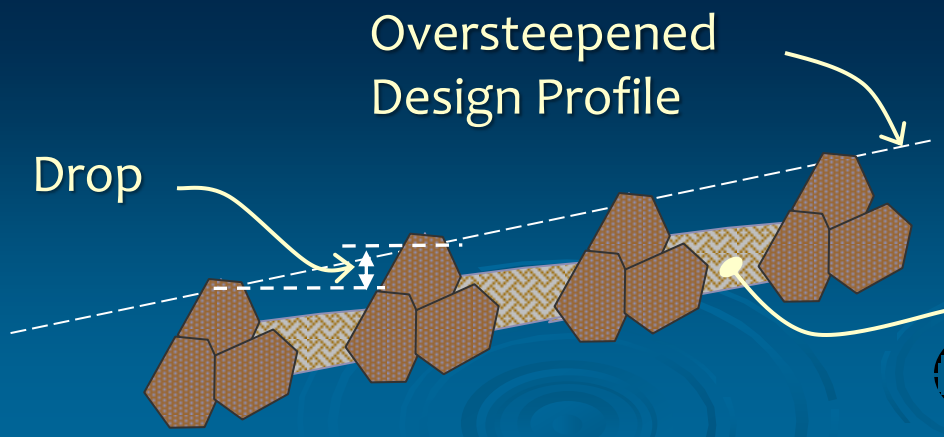


ARCH AND CHEVRON ROCK WEIR

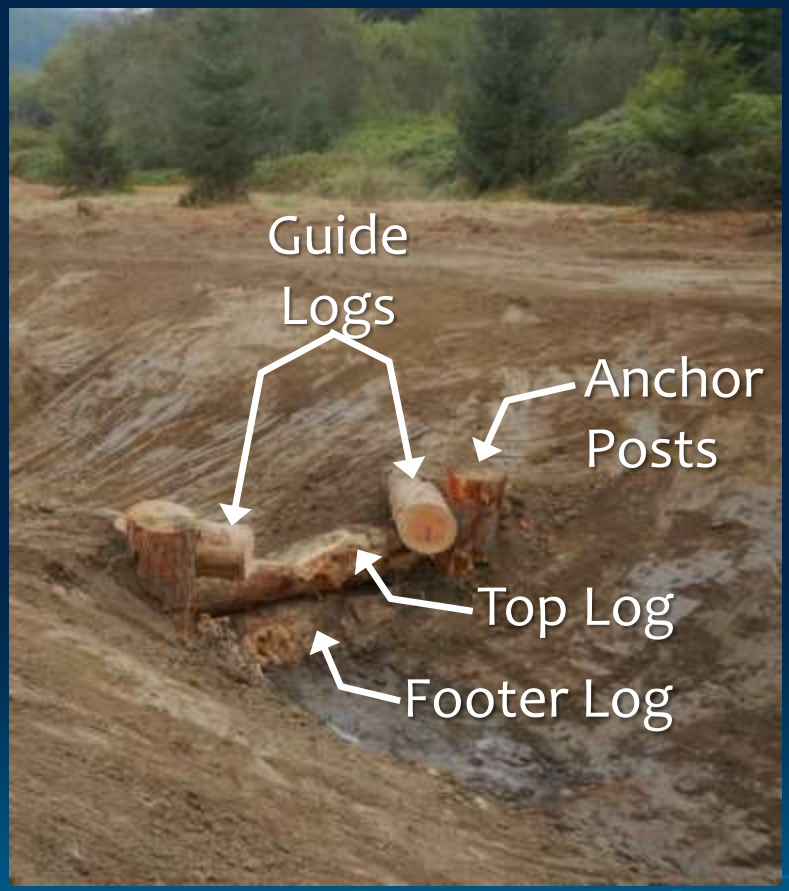
STRAIGHT ROCK WEIR

Spacing of Rock or Log Weirs



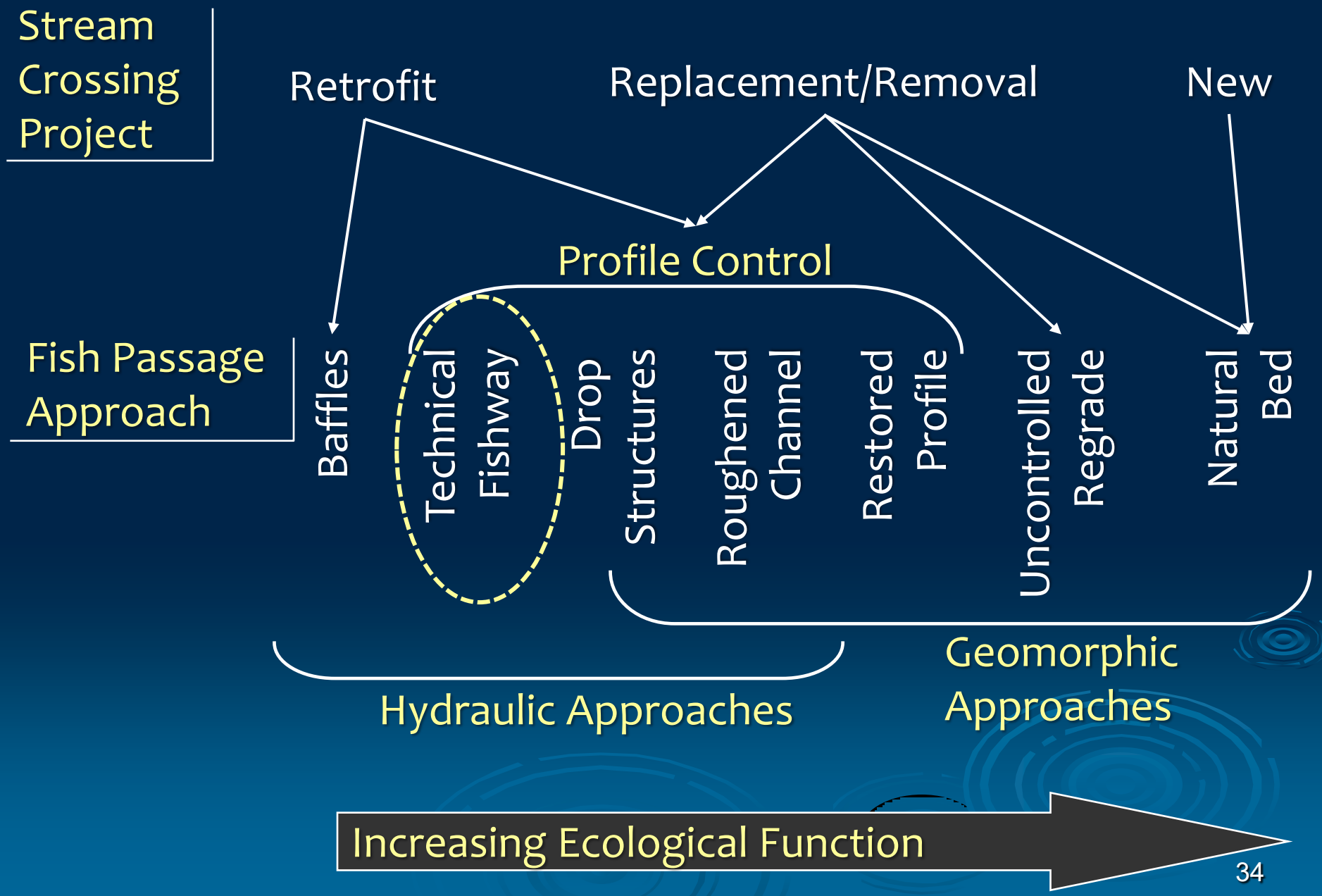


Log Weir Design

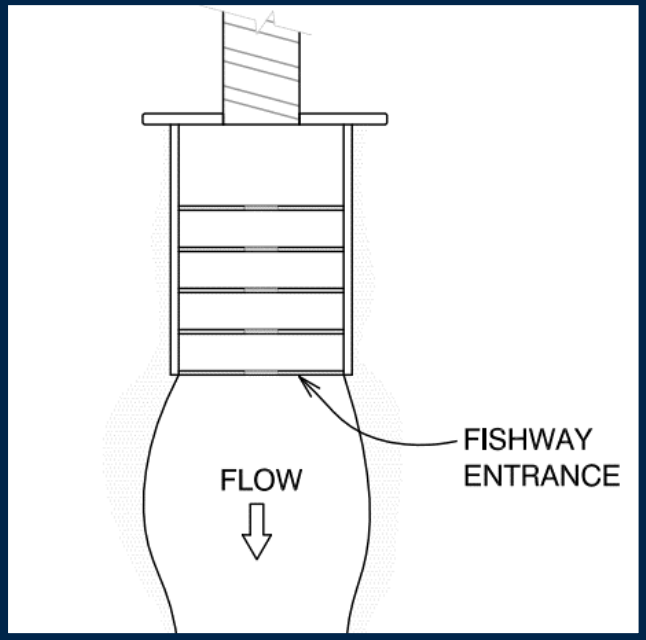


- Top Log and Guide Logs Thru-Bolted to Anchor Posts
- Top Log Anchored to Footer Log

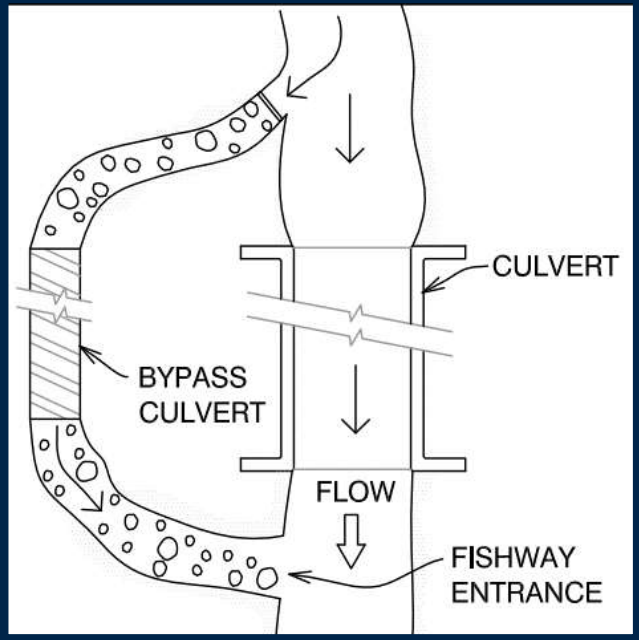
Design Approaches for Aquatic Organism Passage



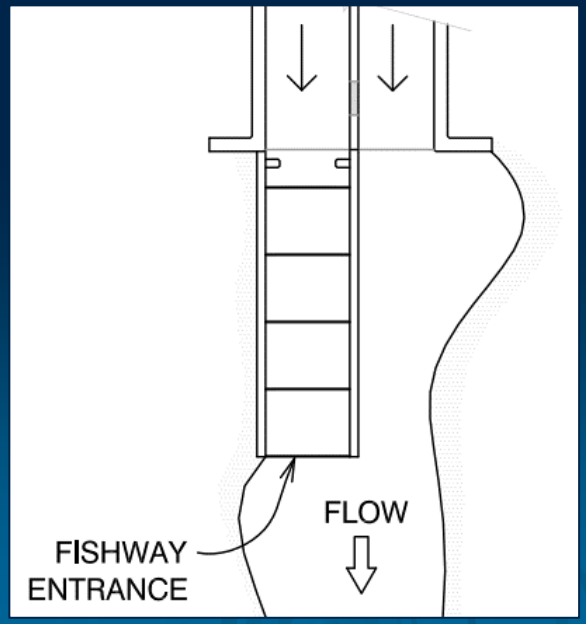
Technical Fishway Configurations



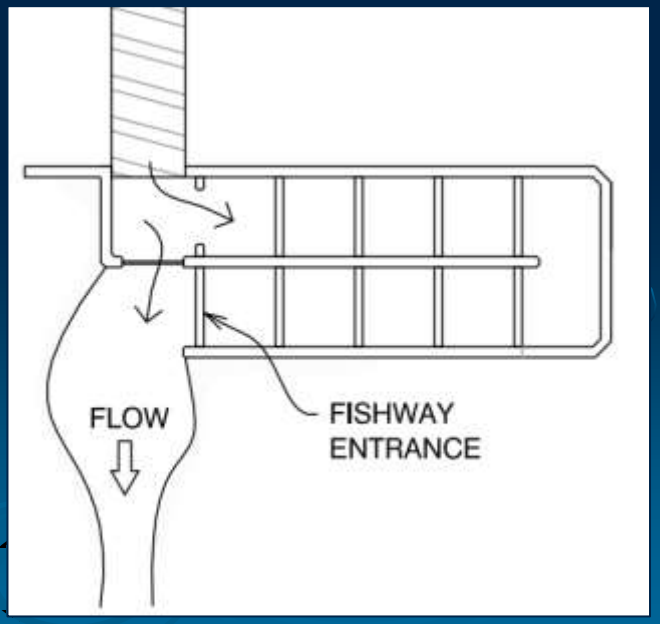
Full Width



Bypass Fishway



Partial Width Fishway



Bypass Fishway

Technical Fishways for Stream Crossings

Full Width "Vortex" Pool-and-Chute Fishway

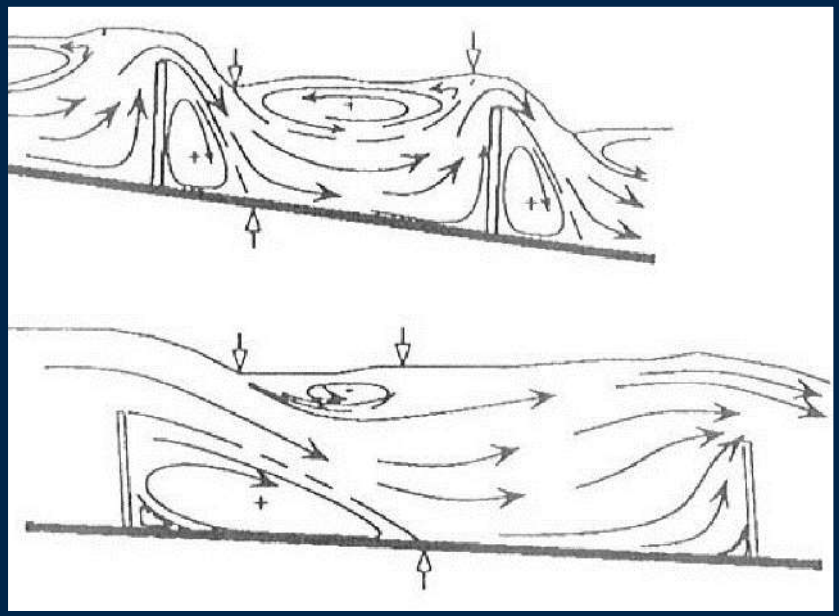
Bypass Pool-and-Weir Fishway

Partial Width Pool-and-Chute Fishway

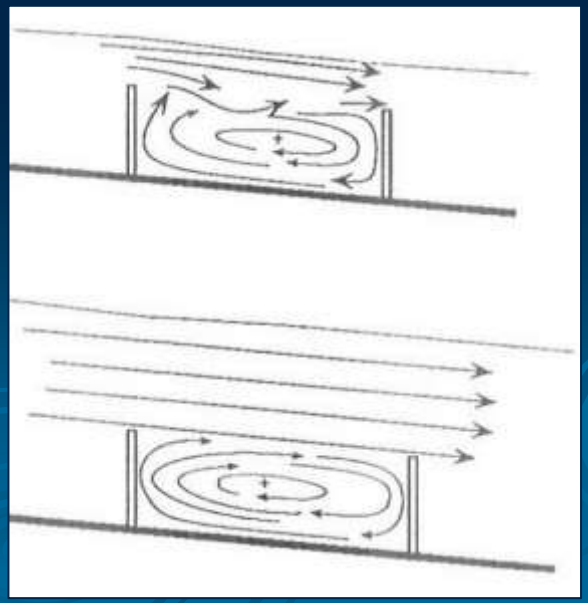
Bypass "Serpentine" Pool-and-Weir Fishway

Flow Regimes of Technical Fishways

Plunging (weir flow)



Streaming
(hydraulic roughness)



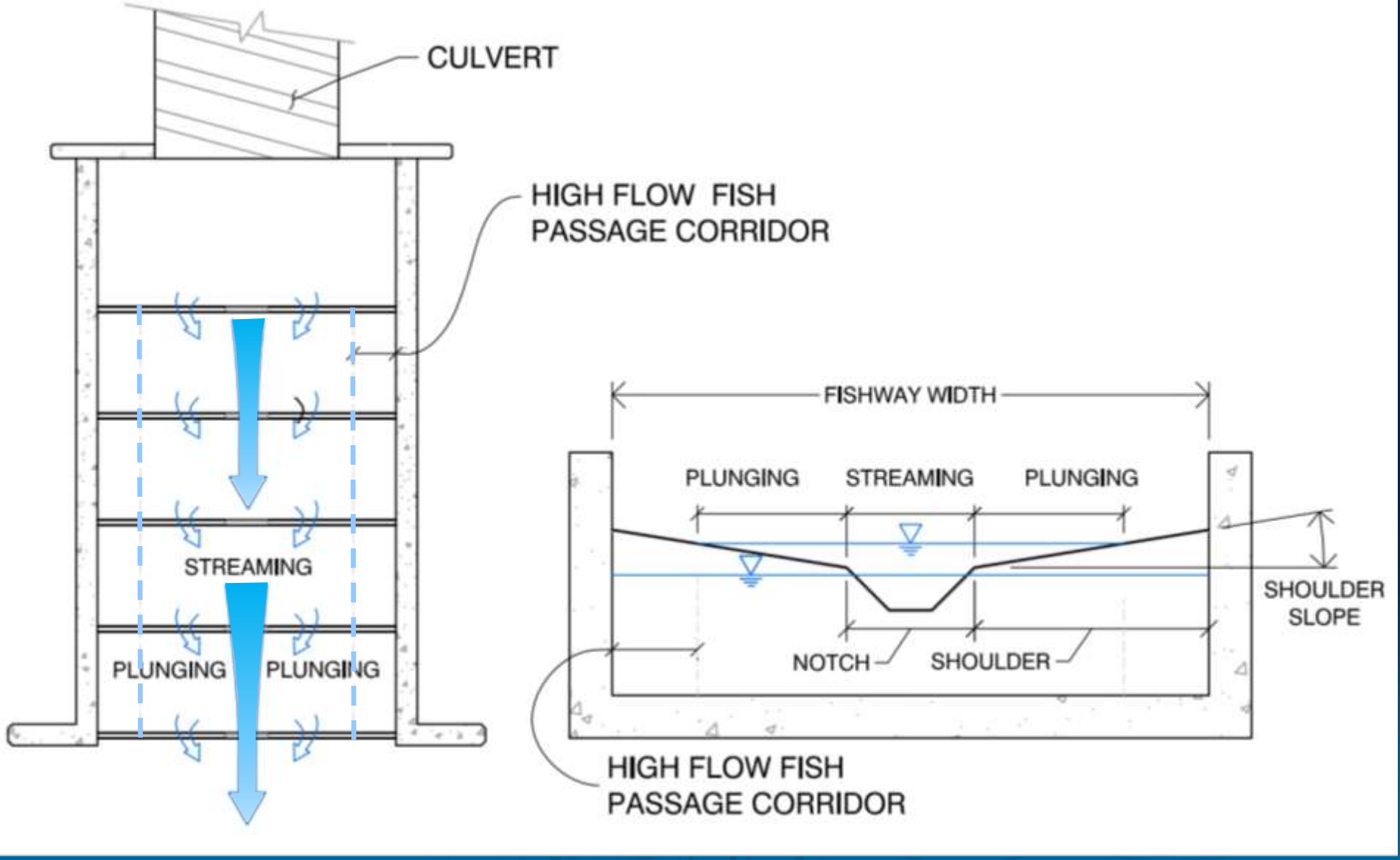
from Ead, 2004

Fishways & Turbulence

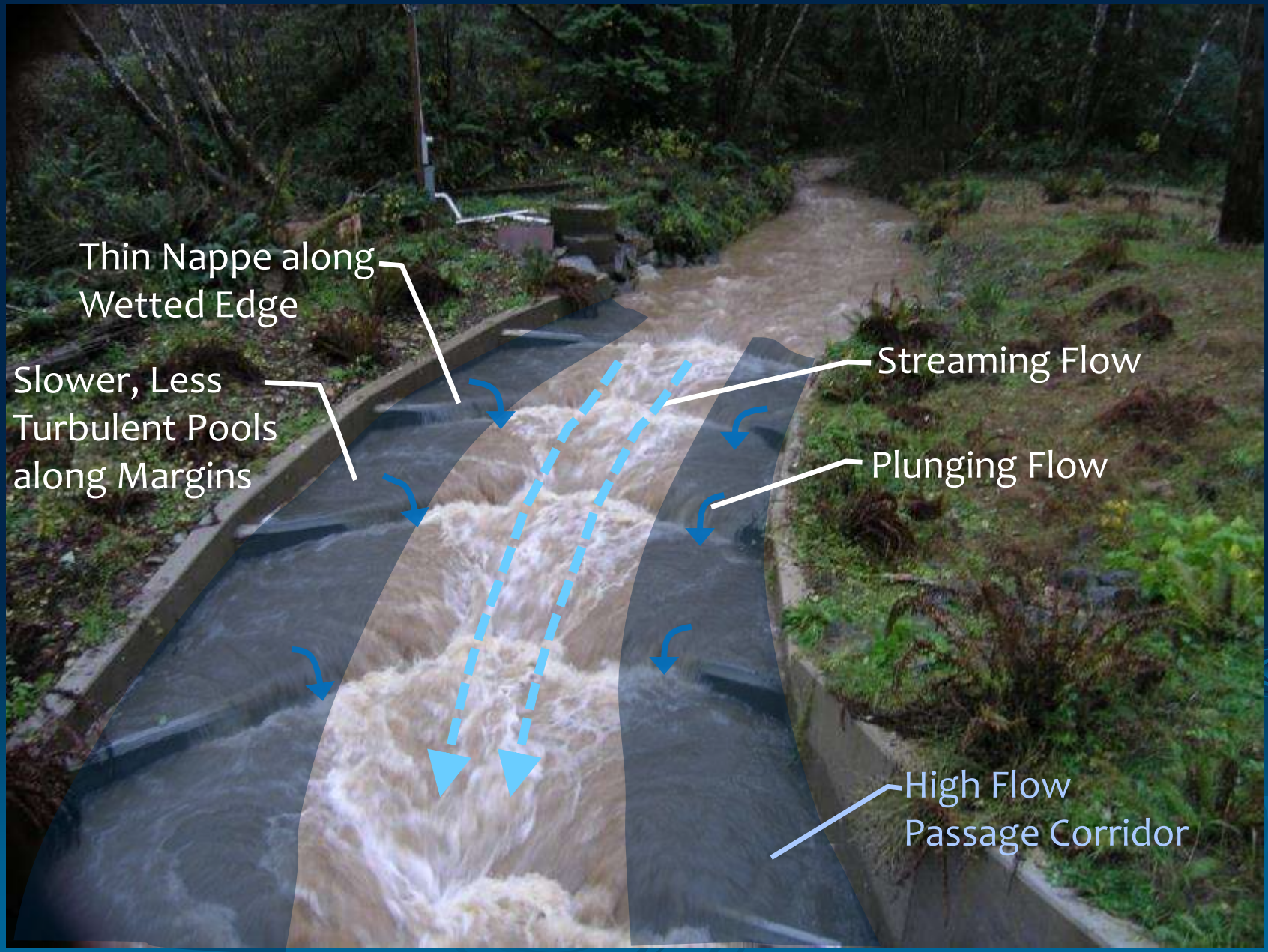
- Energy is Dissipated in Receiving Pool through Turbulence (heat)
- Excessive Turbulence can Block Fish
- The Energy Dissipation Factor (EDF) provides Rate Energy Dissipates per Volume of Water

Pool and Chute Fishways

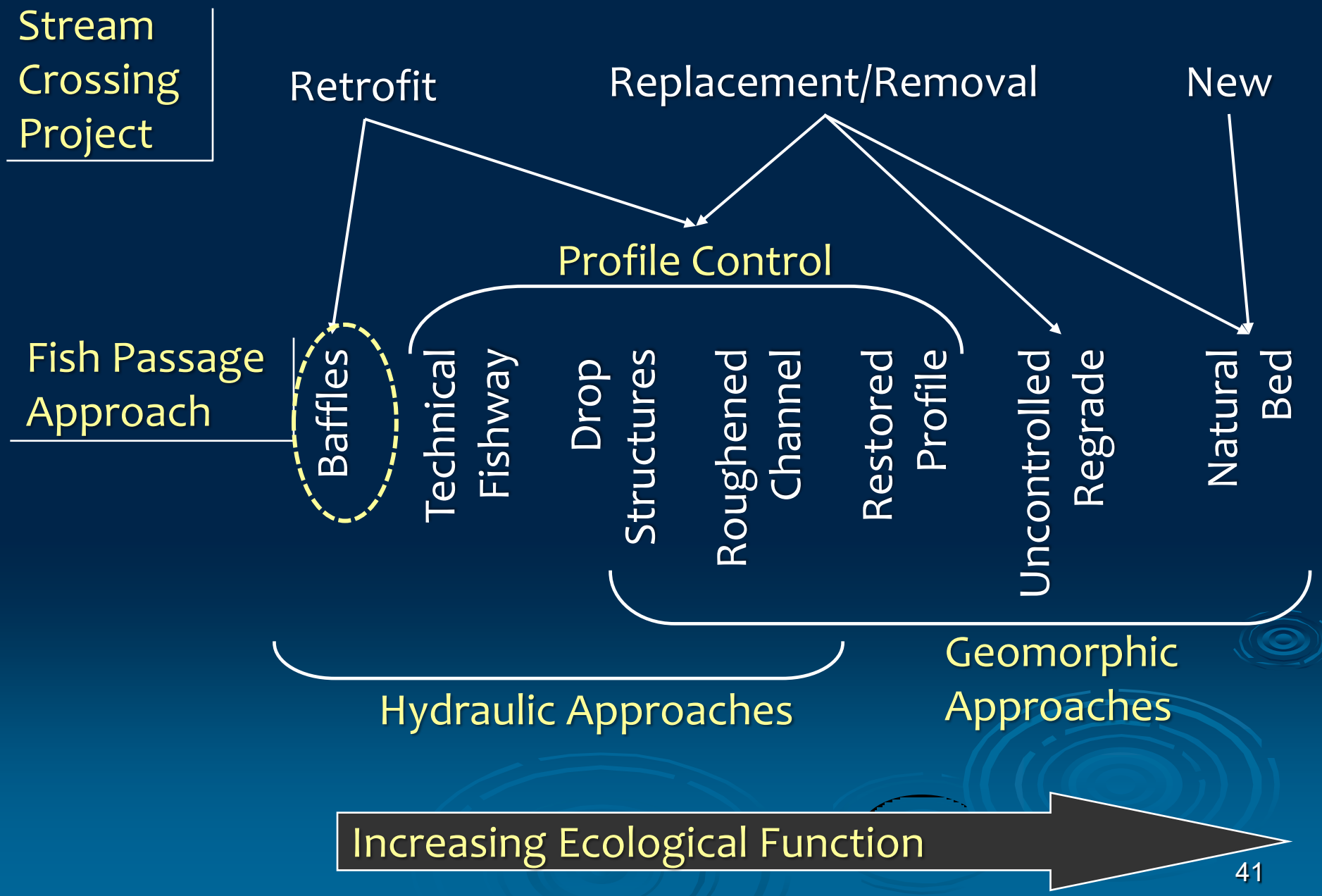
Simultaneous Plunging and Streaming



Pool and Chute Fishway Hydraulics



Design Approaches for Aquatic Organism Passage

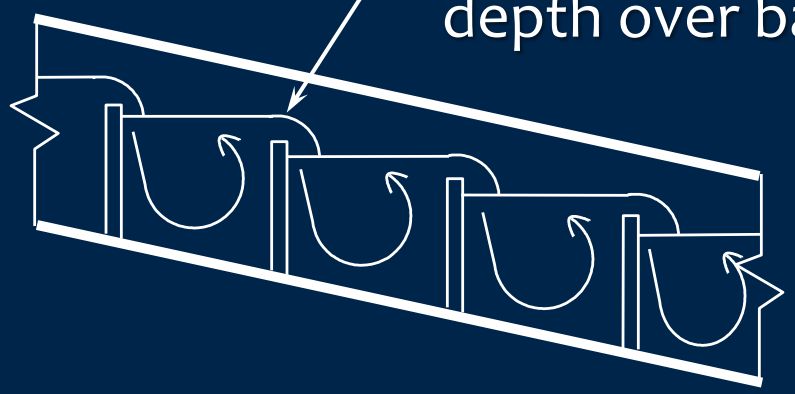


Culvert Baffle Retrofits for Fish Passage

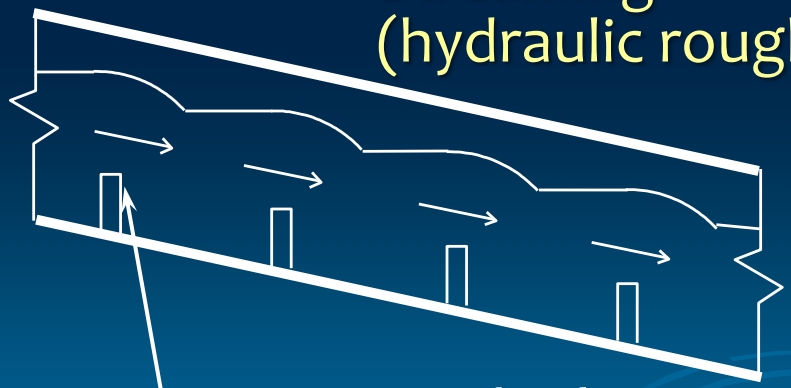
Baffles Improves Fish Passage

- Increases Hydraulic Roughness
- Decreases Velocity
- Increases Depth
- **Limited to Culvert Slopes Less than 3%** (excessive turbulence at higher slopes)

Plunging (weir flow)



Streaming
(hydraulic roughness)



Turbulence Limits Passage

Energy Dissipation Factor (EDF)

EDF in Channels with Streaming Flows:

$$EDF = \frac{\gamma QS}{A}$$

S = Channel/Culvert Slope (ft/ft)

Q = Flow (cfs)

A = Wetted Area (sf)

γ = Unit Weight of Water (62.4 lb/cf)

Corner Baffles

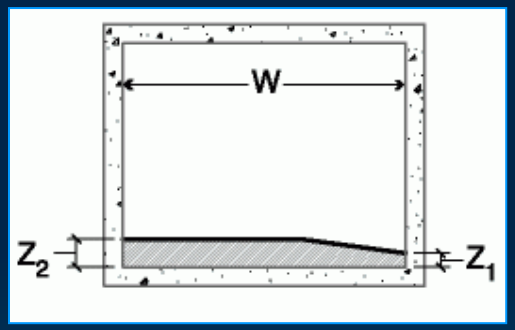
Thresholds (rule-of-thumb):
Adult Anadromous Salmonids:

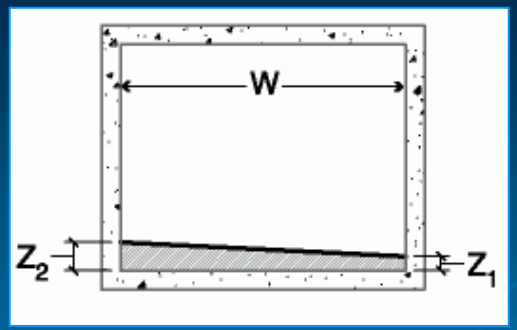
- Baffles: EDF $\leq$ 5 ft-lb/s/ft^3
- Roughened Channels: EDF $\leq$ 7 ft-lb/s/ft^3

Roughened Channel

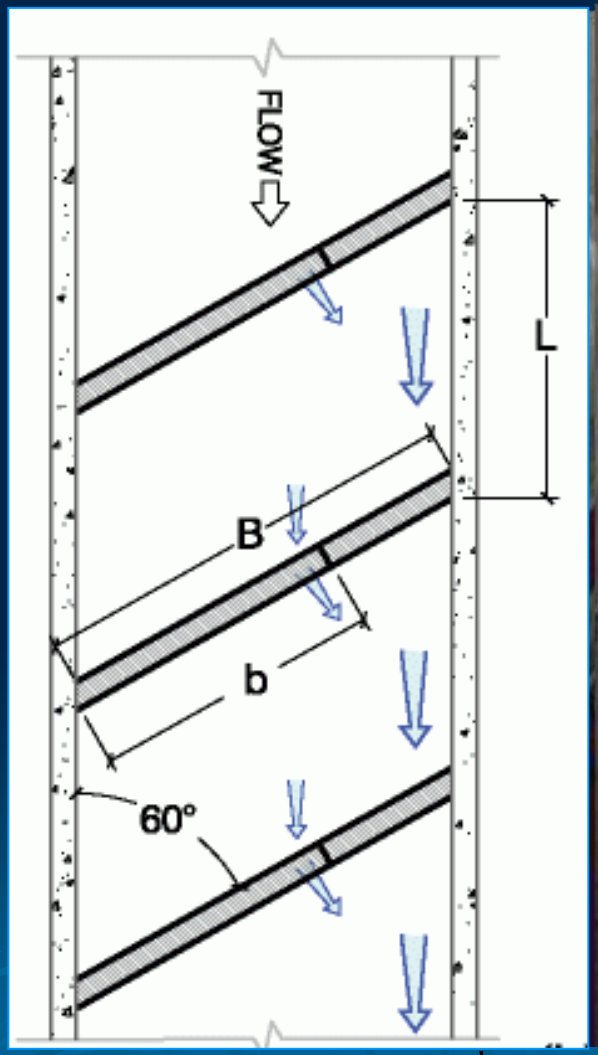
Angled Baffles for Retrofitting Flat-Bottom Culverts

- Skew shunts flow and debris to low side
- Fish passage corridor on high side



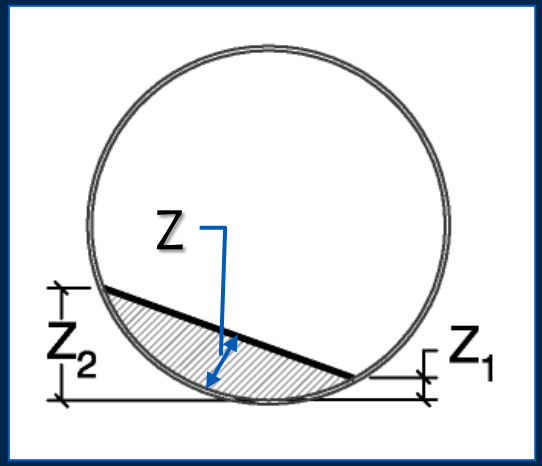


Section



Plan

Corner & Weir Baffles



Corner Baffles

- For circular culverts
- Smaller culverts
- Convey flow & debris along low side
- Passage along high side

Weir Baffles

- For circular or pipe-arch culverts
- For larger culverts (W>8’)
- Convey flow & debris in center
- Passage along sides

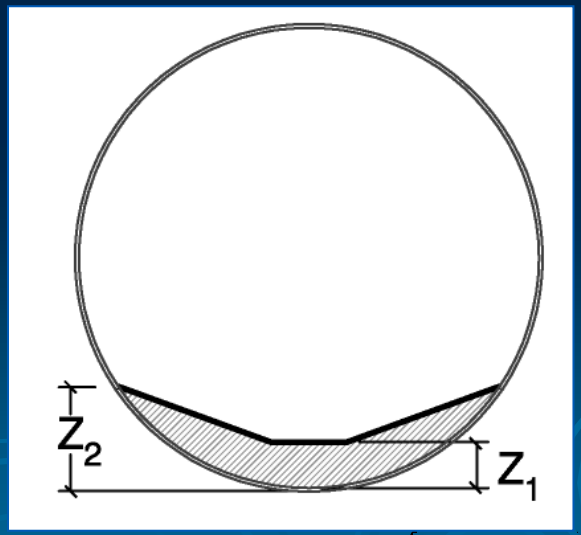
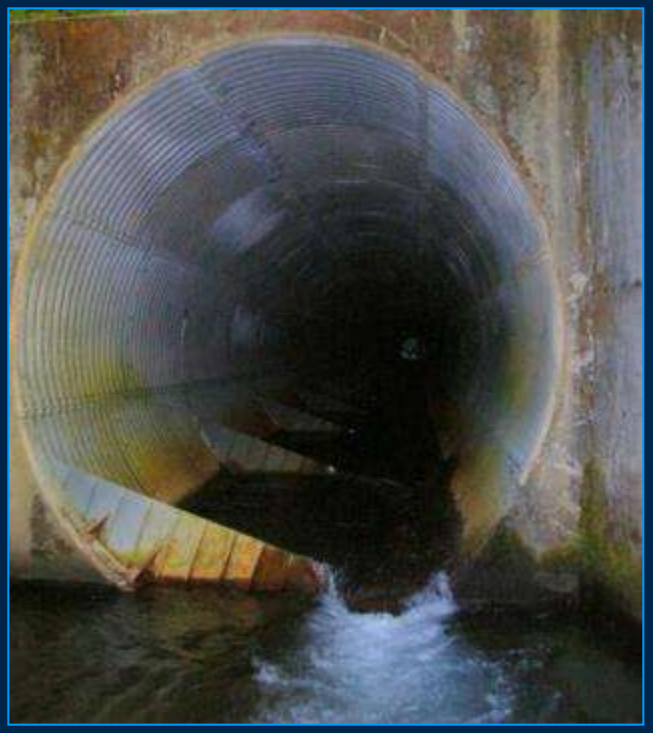


Photo: Kozmo Bates

Baffled Outlet Transition



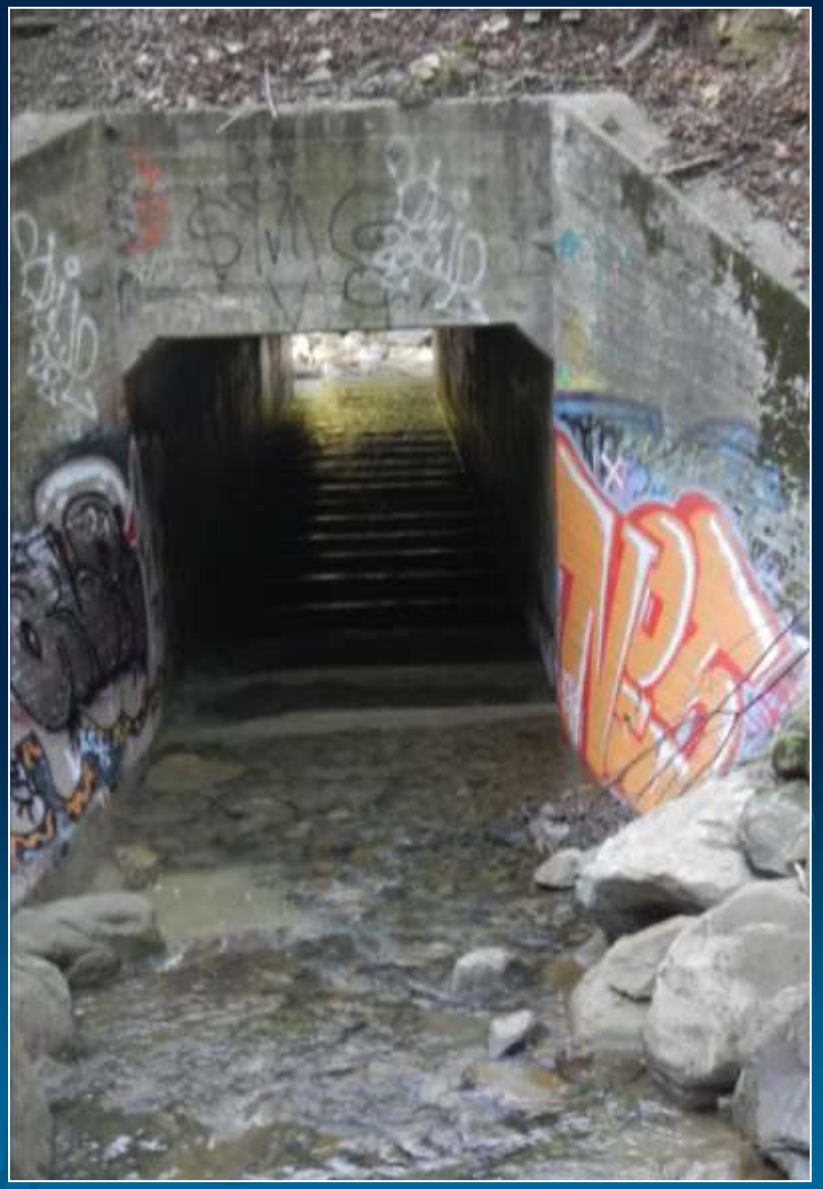
Low Flow

High Fish Passage Flow
(excessive hydraulic drop)

- ✓ Evaluate the Outlet Transition
- ✓ Avoid Excessive Hydraulic Drop at Outlet
- ✓ Tailwater should Meet or Exceed Depth in Baffled Culvert

Baffling Thoughts

- ✓ **ONLY for Retrofits**
- ✓ Requires regular inspection and debris clearing
- ✓ Passage effectiveness for smaller/weaker swimming fish is unknown
- ✓ Frequently reduces capacity
- ✓ Turbulence limits passage
- ✓ Give due attention to hydraulic transition at culvert outlet



Design Approaches for Aquatic Organism Passage