**The Pre-Design Phase**
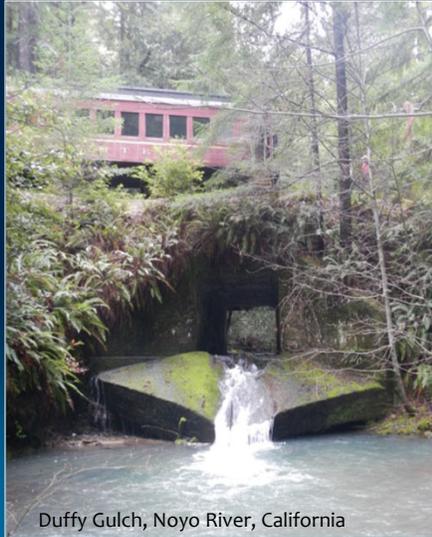**Geomorphic Based Stream Crossing Projects**

Duffy Gulch, Noyo River, California

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

Michael Love & Associates
*Hydrologic Solutions*

1



Replaced 1979 – At Grade

(a)

1998 – Culvert outlet scour creates large pool, resulting in 1-foot outlet drop

(b)

This isn't the first time we tried to get fish passage right…
*From: USFS 2008 Stream Simulation Design Manual*

2

Primary Sources for Pre-Design Guidance

**US Forest Service, 2008**
Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings

https://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/

**NOAA West Coast Fish Passage Guidelines**
Pre-Design Guidelines for CA Fish Passage Facilities

https://www.fisheries.noaa.gov/west-coast/habitat-conservation/west-coast-fish-passage-guidelines

**CDFW 2009 Part XII: Fish Passage Design and Imlpementation Manual**
http://www.dfg.ca.gov/fish/resources/habitatmanual.asp

**CDFW Fish Bulletins**
No. 183: The Use of Log and Boulder Weirs in Stream Habitat Restoration
No. 184: The Use of Large Wood in Stream Habitat Restoration
No. 185: The Use of Low-Tech Process-Based Stream Habitat Restoration
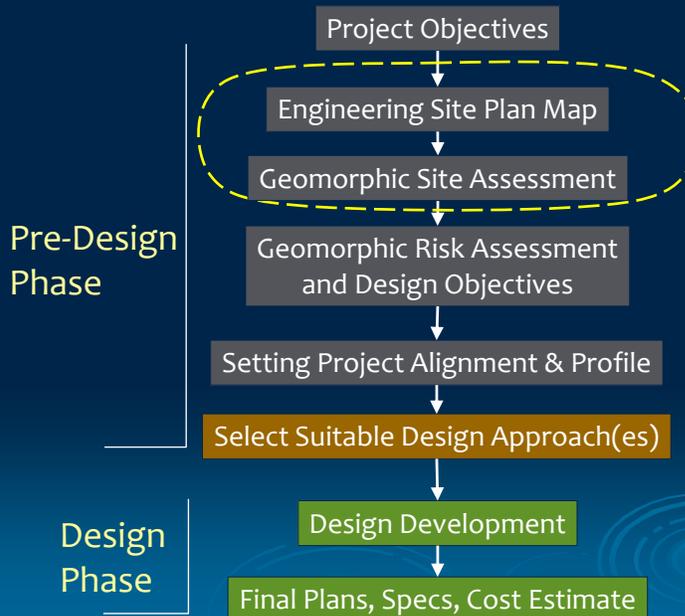
**Washington Department of Fish and Wildlife, 2013**
Water Crossing Design Guidelines

http://wdfw.wa.gov/publications/01501/

3

❿3



Passage Design Process

Project Objectives

Engineering Site Plan Map

Geomorphic Site Assessment

Pre-Design Phase

Geomorphic Risk Assessment and Design Objectives

Setting Project Alignment & Profile

Select Suitable Design Approach(es)

Design Phase

Design Development

Final Plans, Specs, Cost Estimate

4

❿4

## Surveying Channel and Floodplain Features

Arrows show rod locations for cross-section survey

Coarse-gravel flood plain is vegetated with willows and grasses

Edge of flood prone zone
Slope break
Top of bank
$D_{BF}$
Active Channel
Bottom of bank
Thalweg
Bottom of bank
Bankfull Elevation
Edge of flood plain
Edge of low terrace
Debris jam with 6-inch logs on low terrace
Scoured side channel on low terrace
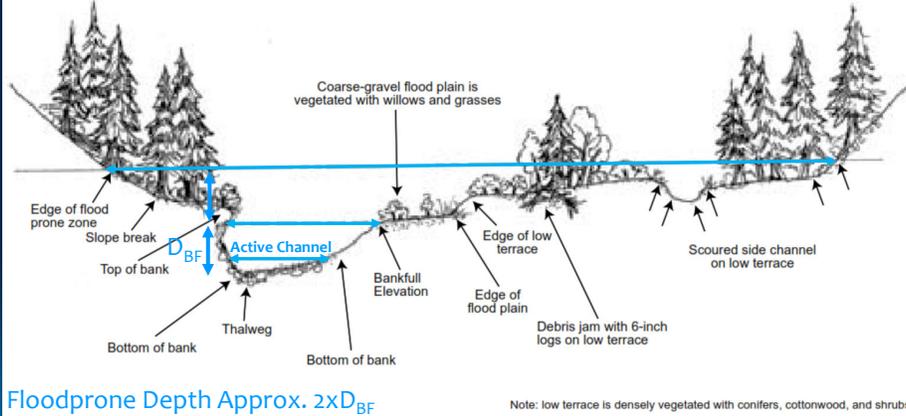
Floodprone Depth Approx. 2x$D_{BF}$

Note: low terrace is densely vegetated with conifers, cottonwood, and shrubs.
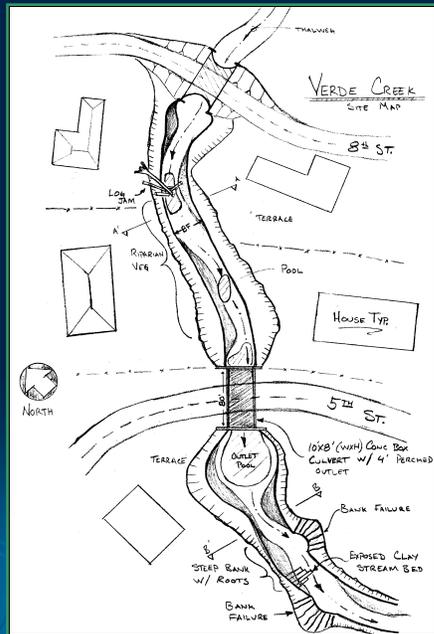
*From: USFS 2008 Stream Simulation Design Manual*

⓾5

## Making a Site Sketch of Stream Reach
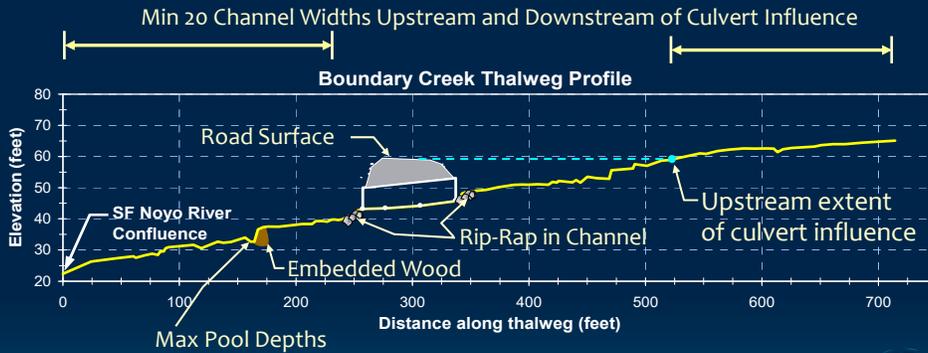


Site Sketch should identify:

• Channel Bends
• Exposed Roots
• Overhanging Banks
• Bank Irregularities
• Woody Debris
• Bank Erosion
• Sediment Storage
• Sediment Inputs

⓾6

## Longitudinal Thalweg Profile

Min 20 Channel Widths Upstream and Downstream of Culvert Influence

**Boundary Creek Thalweg Profile**

- Road Surface
- SF Noyo River Confluence
- Rip-Rap in Channel
- Embedded Wood
- Upstream extent of culvert influence
- Max Pool Depths

*Elevation (feet)* — 20, 30, 40, 50, 60, 70, 80

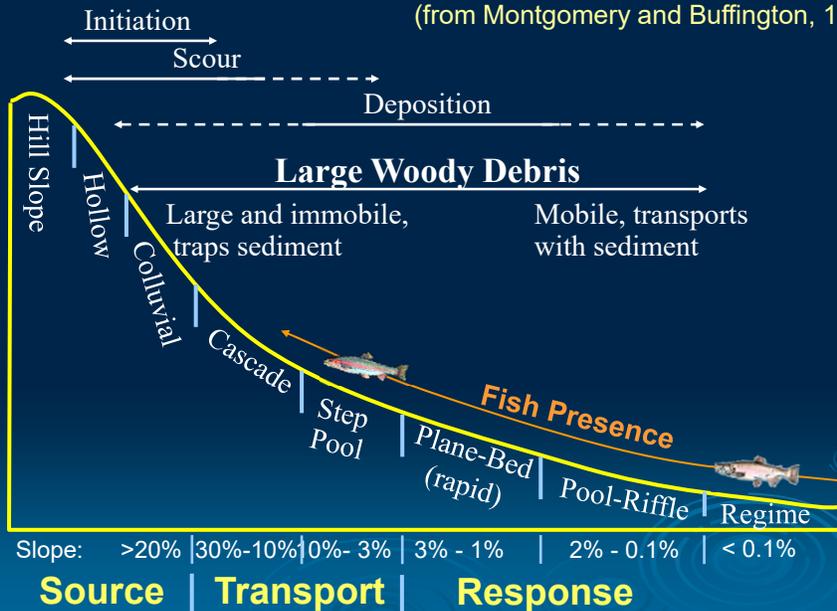*Distance along thalweg (feet)* — 0, 100, 200, 300, 400, 500, 600, 700

- Extend survey well past culvert influence Recommend Min Profile Length = 20 channel widths
- Survey captures pool depths, riffles

- Survey "forcing features" controlling grade Note long-term stability of each forcing feature
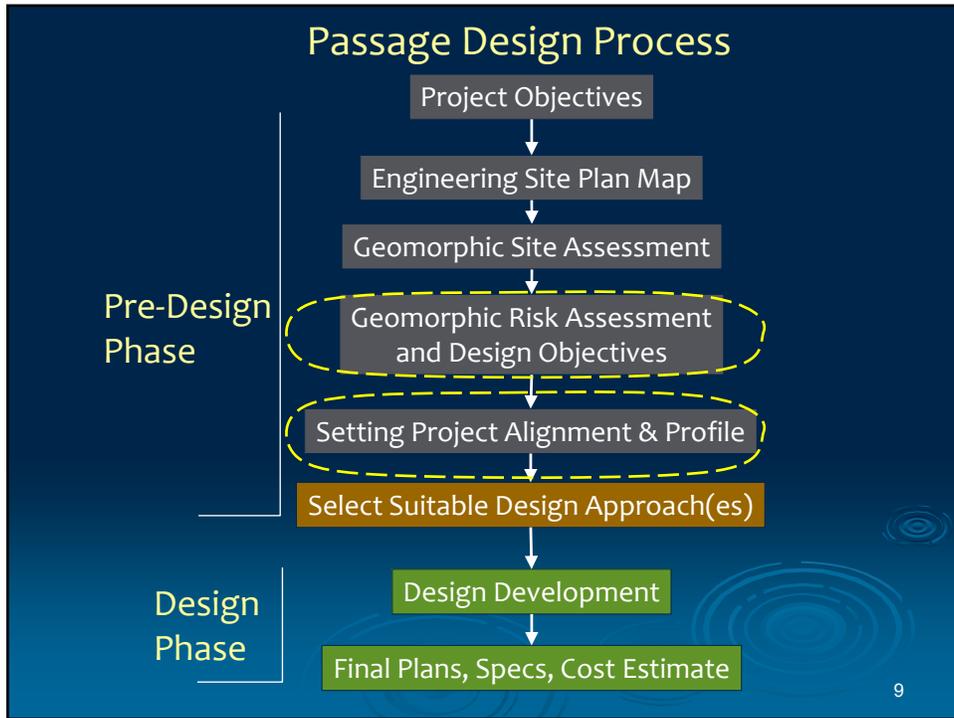- Survey base and top of features controlling grade Bedrock, large colluvium, embedded wood, debris jams…

⓿7

## Generalized Stream Classification

(from Montgomery and Buffington, 1993)

Initiation

Scour

Deposition

**Large Woody Debris**

Large and immobile, traps sediment

Mobile, transports with sediment

Hill Slope

Hollow

Colluvial

Cascade

Step Pool

Plane-Bed (rapid)

Pool-Riffle

Regime

*Fish Presence*

| Slope: | >20% | 30%-10% | 10%- 3% | 3% - 1% | 2% - 0.1% | < 0.1% |

**Source | Transport | Response**

⓿8

## Passage Design Process

Project Objectives
↓
Engineering Site Plan Map
↓
Geomorphic Site Assessment
↓

**Pre-Design Phase**

Geomorphic Risk Assessment and Design Objectives
↓
Setting Project Alignment & Profile
↓
Select Suitable Design Approach(es)
↓

**Design Phase**

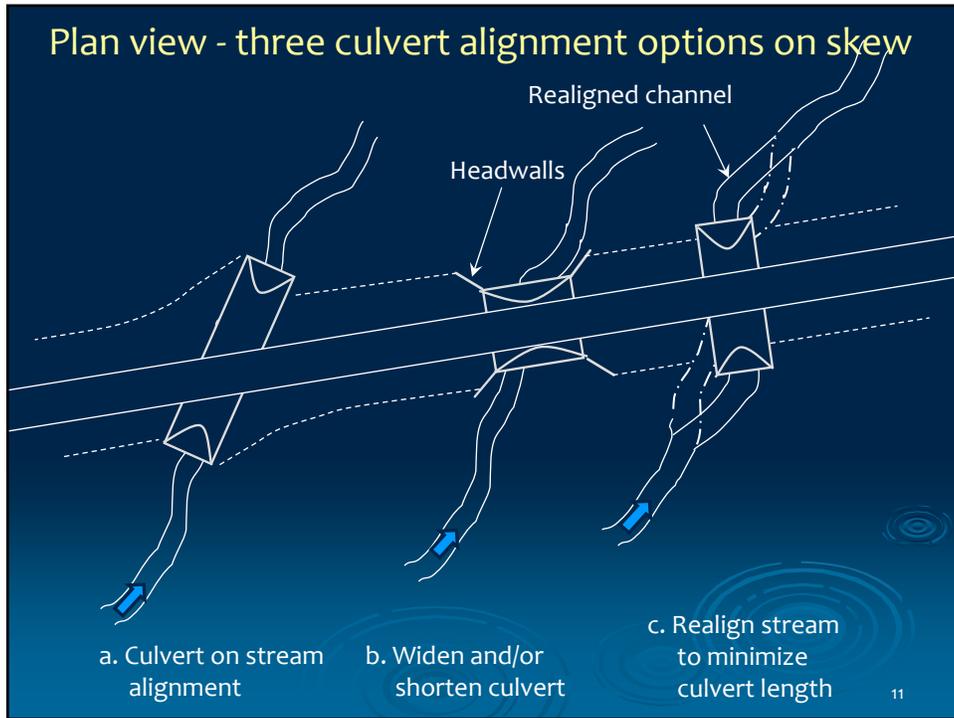Design Development
↓
Final Plans, Specs, Cost Estimate

9

⓾9

## Alignment

- Concurrent with profile design

- Important factor for debris blockage and failure
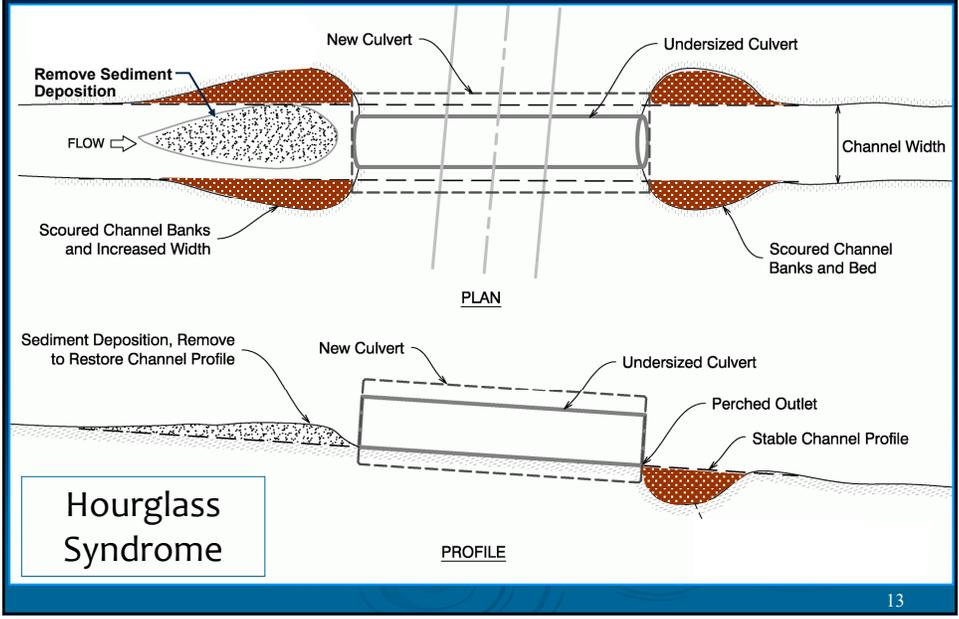
- Consider existing and future stream channel

⓾10

Plan view - three culvert alignment options on skew

Realigned channel

Headwalls

a. Culvert on stream alignment

b. Widen and/or shorten culvert

c. Realign stream to minimize culvert length

11

⑩11



Flow Expansion at Inlet Transitions Turns Debris and Leads to Plugging

12

⑩12

Restoring Channel Geometry at Transitions

Hourglass Syndrome

13

❿13



Example of Restored Channel Geometry at Outlet

Before - Outlet Scour Pool

After – Restored Streambanks at Outlet

14

❿14

# Channel Profile Analysis

**Upper Noyo River MP 28.8 Crossing Thalweg Profile**

Legend:
- Thalweg
- Water Surface
- Top of Bank
- Pebble Count
- Log Jams
- Boulder Steps
- Historic Culvert

Labels:
- Localized Aggradation
- Existing 9 ft CMP
- Historical Culvert
- Local Slope 0.92 %
- Stable Boulder/ Bedrock Channel
- Log Jam becoming Flanked
- Semi-Stable Log Jam
- Stable Boulder Steps

Y-axis: Elevation (ft), Arbitrary Datum — 120 to 180
X-axis: Station (ft) — 0+00 to 18+00

15

⑩15

# Estimating Channel Bed Structure Stability

Table 5.3—A qualitative method for determining channel-bed structure stability. (USFS Stream Simulation Manual)

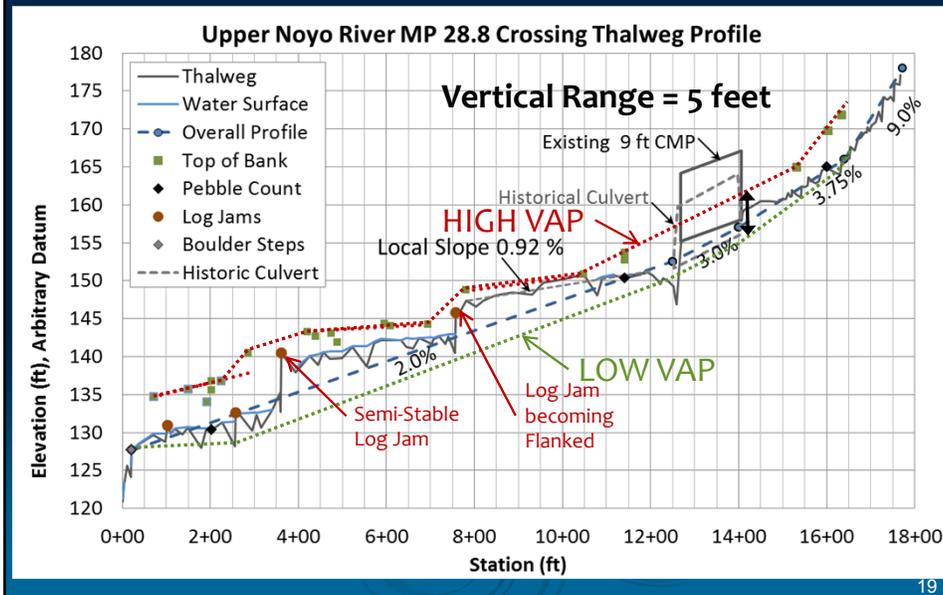| Structure composition | Stability Rating | Structure Characteristics |
|---|---|---|
| Bedrock | High | Bedrock ledges or falls span entire stream width |
| Boulder-cobble steps | High | Boulder-cobble steps span entire width of stream. Rocks are tightly keyed in place, and keyed-in material extends below base of scour pool below step. |
| Cobble-boulder or cobble-gravel pool tail crests or riffle crests | High | Cobble-boulder or cobble-gravel pool tail crests or riffle crests span the entire width of stream. Particles are tightly packed, embedded into the channel bed, and coarser than the remainder of the channel bed. |
| Log | High | Wood is sound and well anchored, spanning entire stream width. |
| Composite log and rock | High | Wood is sound and well anchored, may or may not span entire stream width. Rock pieces are well keyed in place and bridge gaps so that composite structure controls width from bank to bank. |
| Boulder-cobble steps, cobble-gravel steps | Moderate | Steps do not span entire width of stream or are loosely keyed in place. Keyed-in rocks may not extend below base of scour pool below step. Alternatively, step key pieces are not in contact with each other. |
| Cobble-boulder or cobble-gravel pool tail crests or riffle crests | Moderate | Pool tail crests span entire width of stream, but the largest particles are similar in size to those elsewhere observed along the channel bed. Alternatively, particles are moderately packed and/or moderately embedded into the channel bed. |
| Log | Moderate | Wood is rotten and punky. It may span entire stream width, but anchoring is susceptible to bank scour and movement during high flood events. |
| Cobble-gravel steps or pool tail crests | Low | Steps do not span entire width of stream, and/or are composed of loosely packed materials. Pool tail crests are constructed of material no coarser than rest of stream bed. |
| Log | Low | Wood is very rotten and punky, may or may not span entire stream width, and anchoring is poor and susceptible to bank scour and movement during bankful flood events. Indications of movement are visible where pieces are anchored into the bank. |
| Composite log and rock, beaver dams | Low | Wood is very rotten and punky, or structure is made of loosely packed pieces that are poorly anchored. Structure does not span entire stream width. Rock is small in size and subject to movement at bankfull flood events. Beaver dams are poorly constructed or old and inactive. Large key logs are not present. |

⑩16

⑩17
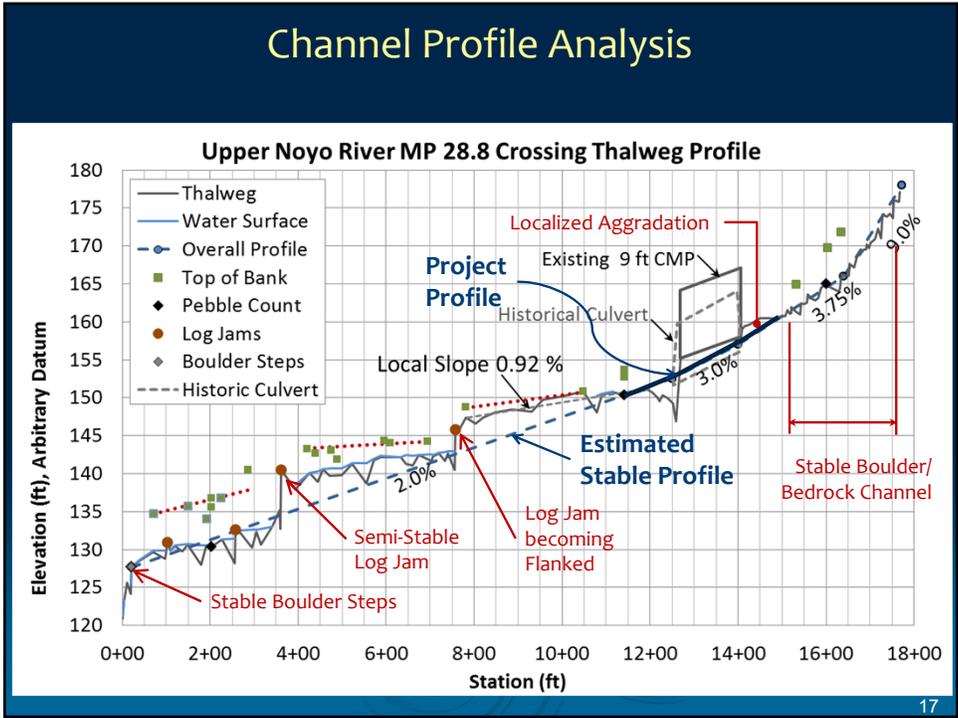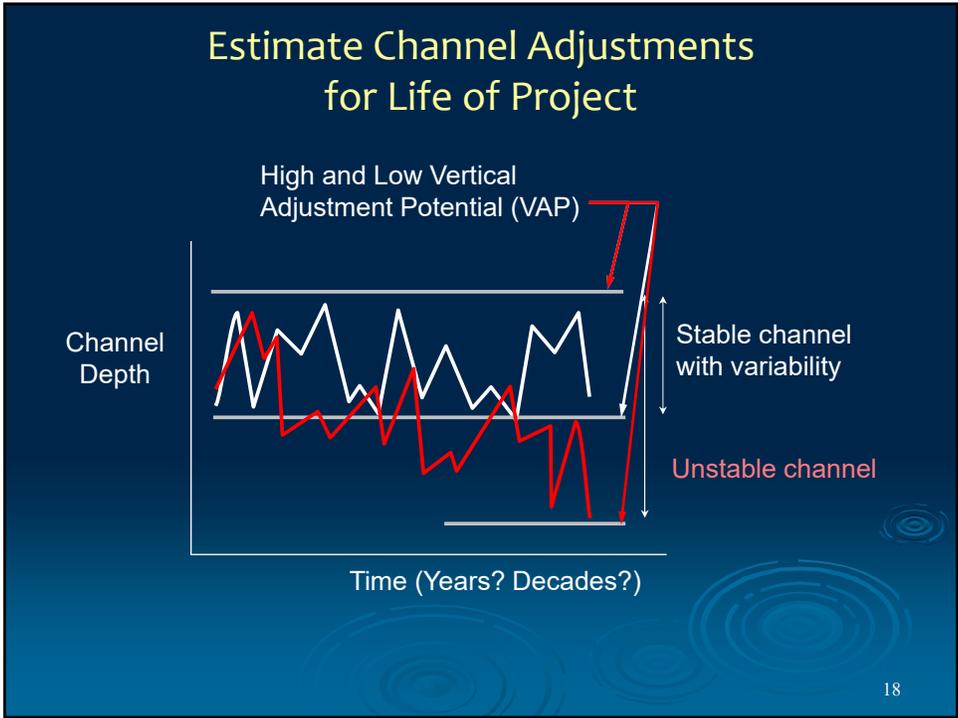


⑩18

Vertical Adjustment Potential (VAP) Profiles
Estimates the range of possible channel profiles for life of project

Upper Noyo River MP 28.8 Crossing Thalweg Profile

**Vertical Range = 5 feet**

Legend:
— Thalweg
— Water Surface
—•— Overall Profile
▪ Top of Bank
♦ Pebble Count
● Log Jams
♦ Boulder Steps
--- Historic Culvert

Existing 9 ft CMP
Historical Culvert
HIGH VAP
Local Slope 0.92 %
9.0%
3.75%
3.0%
2.0%
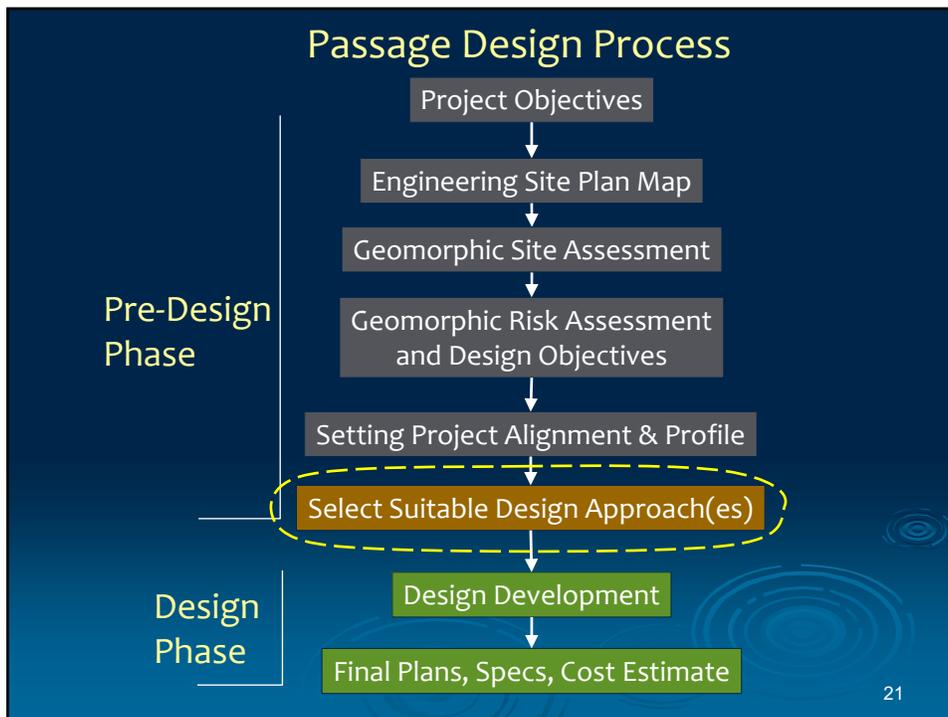LOW VAP
Log Jam becoming Flanked
Semi-Stable Log Jam

10 19

Vertical Adjustment Potential (VAP)
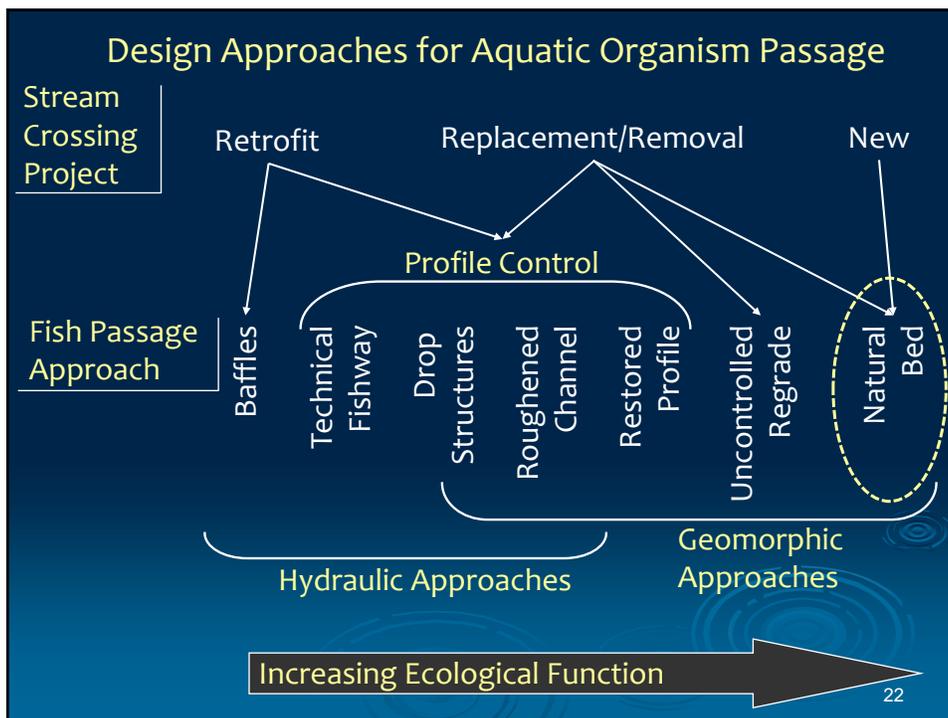
Develop VAP with long profile and field investigations:

✓ 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)

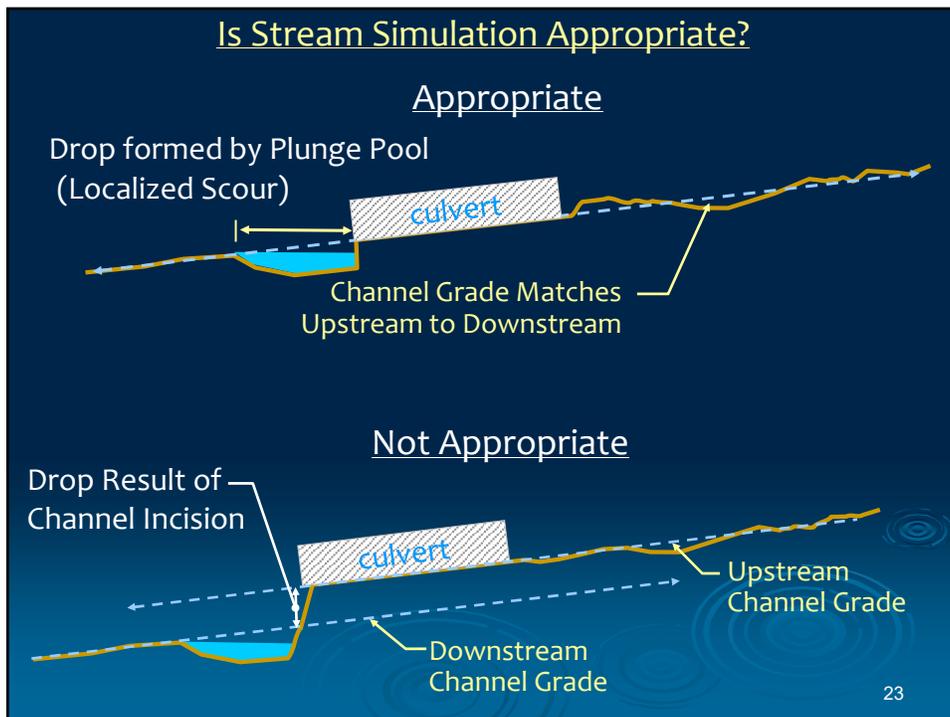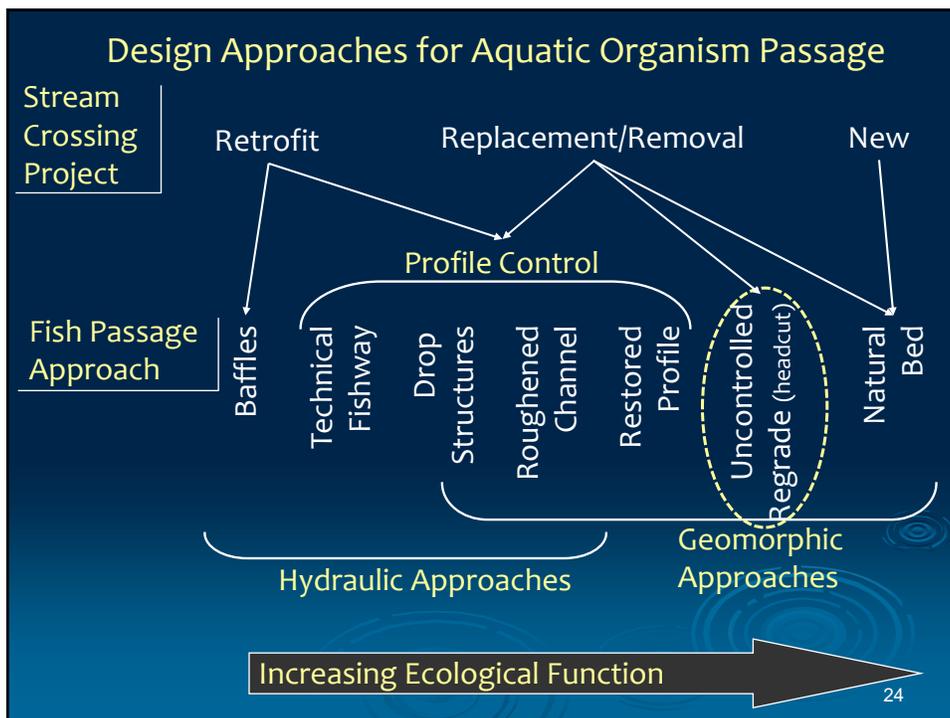✓ Historical information (existing invert elev. and slope)

10 20

**Passage Design Process**

Project Objectives

Engineering Site Plan Map

Geomorphic Site Assessment

Geomorphic Risk Assessment and Design Objectives

Pre-Design Phase

Setting Project Alignment & Profile

Select Suitable Design Approach(es)

Design Phase

Design Development

Final Plans, Specs, Cost Estimate

21

10 21



**Design Approaches for Aquatic Organism Passage**

Stream Crossing Project

Retrofit

Replacement/Removal

New

Profile Control

Fish Passage Approach

Baffles

Technical Fishway

Drop Structures

Roughened Channel

Restored Profile

Uncontrolled Regrade

Natural Bed

Hydraulic Approaches

Geomorphic Approaches

Increasing Ecological Function

22

10 22

Is Stream Simulation Appropriate?

Appropriate

Drop formed by Plunge Pool (Localized Scour)

culvert

Channel Grade Matches Upstream to Downstream

Not Appropriate

Drop Result of Channel Incision

culvert

Upstream Channel Grade

Downstream Channel Grade

23

⑩23



Design Approaches for Aquatic Organism Passage

Stream Crossing Project

Retrofit          Replacement/Removal          New

Profile Control

Fish Passage Approach

Baffles | Technical Fishway | Drop Structures | Roughened Channel | Restored Profile | Uncontrolled Regrade (headcut) | Natural Bed

Hydraulic Approaches          Geomorphic Approaches

Increasing Ecological Function

24

⑩24
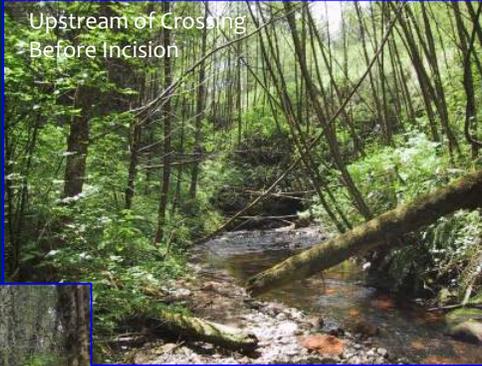
Uncontrol Regrade

Wynoochee trib – 2002

Channel regraded to bedrock

Upstream of Crossing Before Incision

Upstream of Crossing After Incision

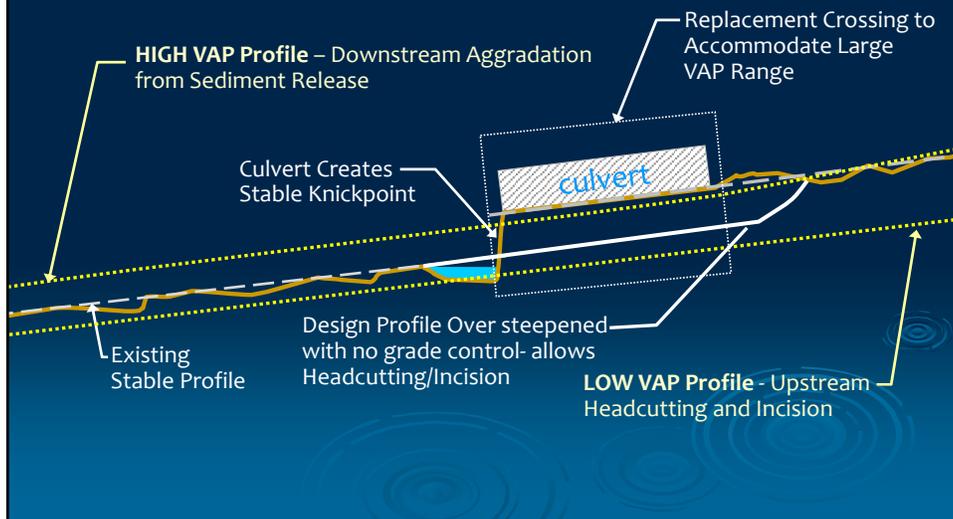Example from Kozmo Bates

25

⑩25



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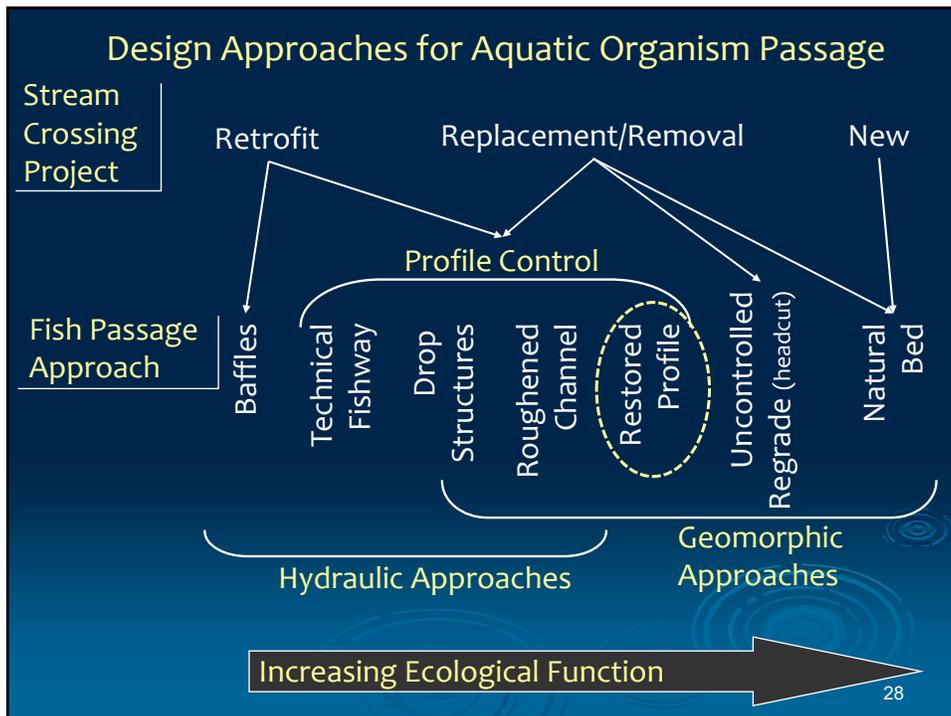### (no grade control – "Uncontrolled Regrade")

Replacement Crossing to Accommodate Large VAP Range

HIGH VAP Profile – Downstream Aggradation from Sediment Release

Culvert Creates Stable Knickpoint

culvert

Design Profile Over steepened with no grade control- allows Headcutting/Incision

Existing Stable Profile

LOW VAP Profile - Upstream Headcutting and Incision

⑩26

Uncontrolled Regrade – Sediment Slug
Downstream channel overwhelmed by sediment slug from headcut
From Pat Powers
27

10 27



Design Approaches for Aquatic Organism Passage

Stream Crossing Project

Retrofit        Replacement/Removal        New

Profile Control

Fish Passage Approach

Baffles    Technical Fishway    Drop Structures    Roughened Channel    Restored Profile    Uncontrolled Regrade (headcut)    Natural Bed

Hydraulic Approaches        Geomorphic Approaches

Increasing Ecological Function
28

10 28

Restored Profile Option

replacement or existing

Design Profile: **Restored Channel Profile**

Downstream Channel Incised. Culvert Knickpoint

29

❿29



Restoring Incised Channels and Connectivity
Placing Wood - Profile Restoration

Neefus Gulch
Photo: Ross Taylor

Baker Creek
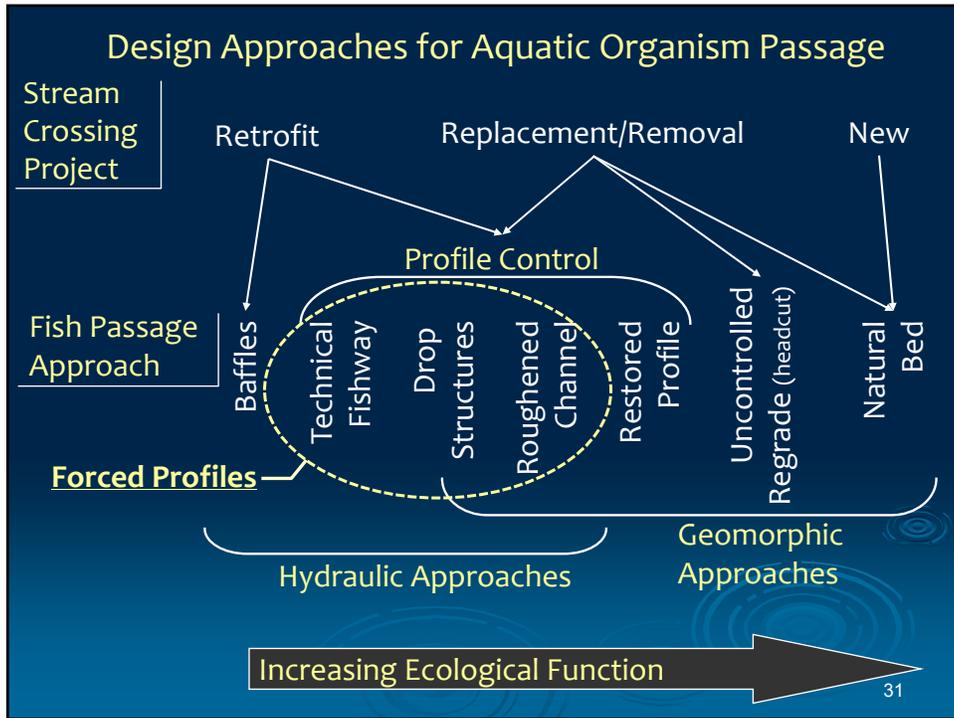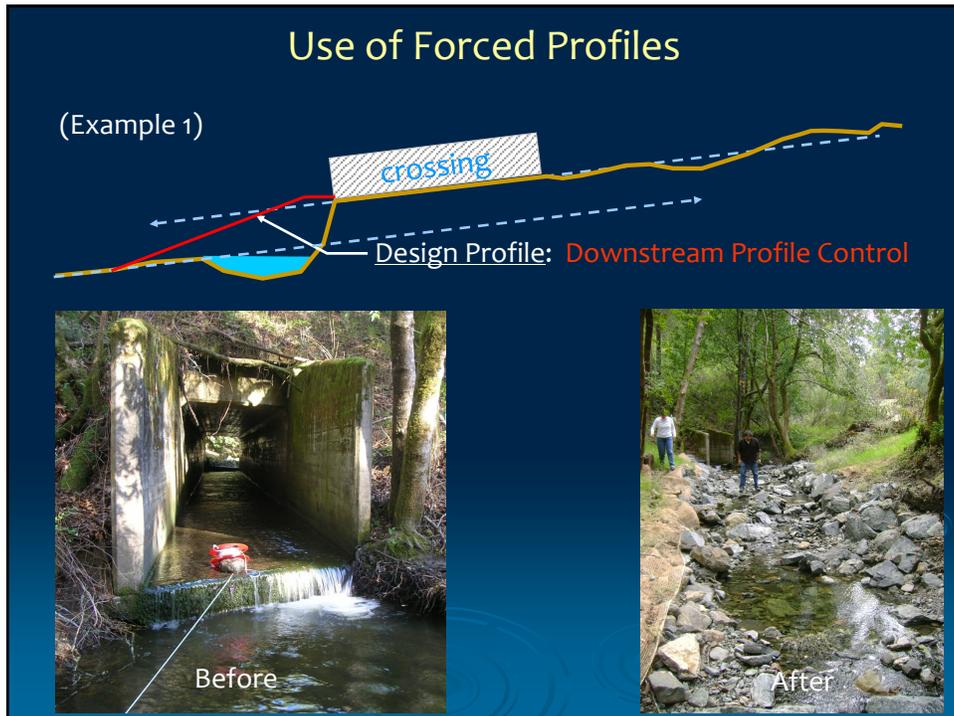photo: Sam Flanagan, BLM

30

❿30

Design Approaches for Aquatic Organism Passage

⑩31



Use of Forced Profiles

⑩32

Use of Forced Profiles

(Example 2)

Design Profile: Profile Control

Outlet

Jameson Creek Roughened Channel

Inlet

❿33



Use of Forced Profiles

(Example 3)

Design Profile: Combined Profile Control & Stream Simulation

34

❿34

10 35



10 36