Traditional Hydraulic Designs for Fish Passage at Stream Crossings

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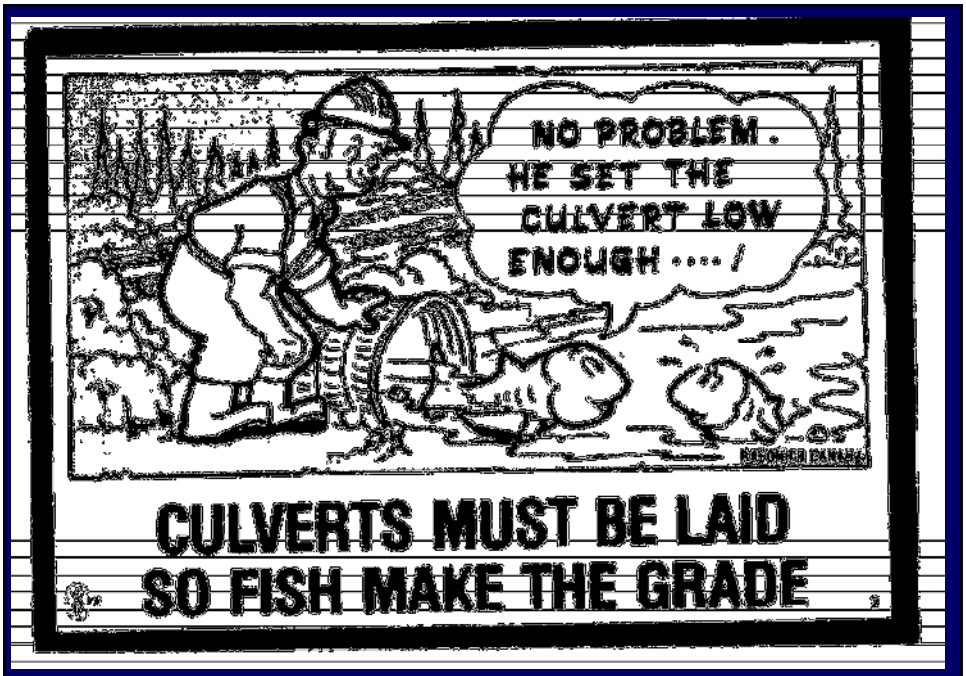

This isn't the first time we tried to get fish passage right...

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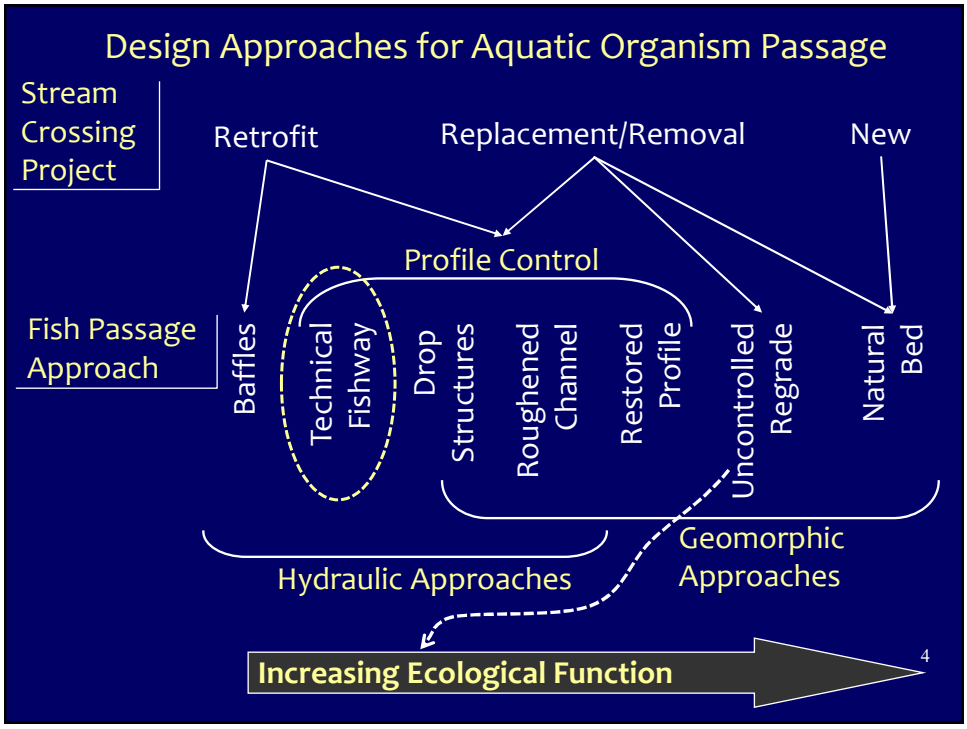
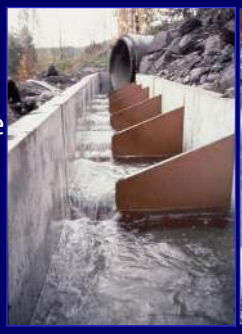
From: USFS 2008 Stream Simulation Design Manual

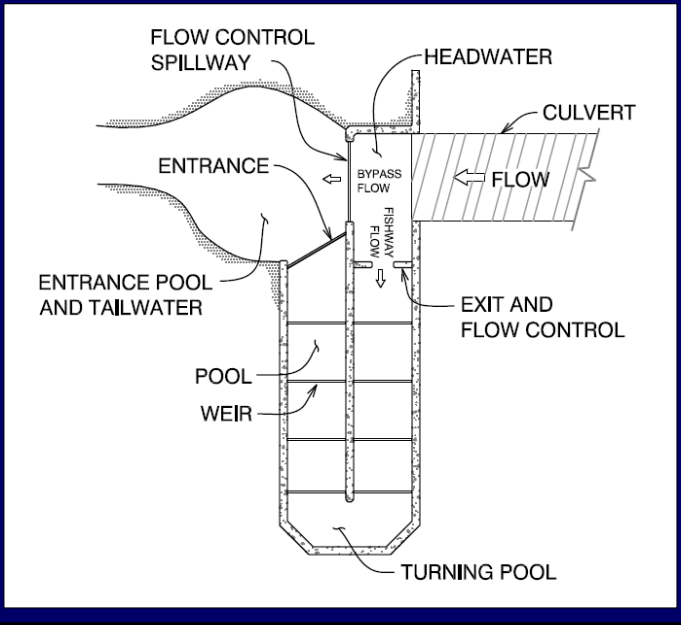


Technical Fishways

- Rigid permanent bed control (typically concrete or sheetpile)
- Passage typically optimized for target species
- Can be constructed steeper than most geomorphic based profile controls
- Minimum footprint
- Narrow flow range for passage
- High construction, operation, maintenance cost

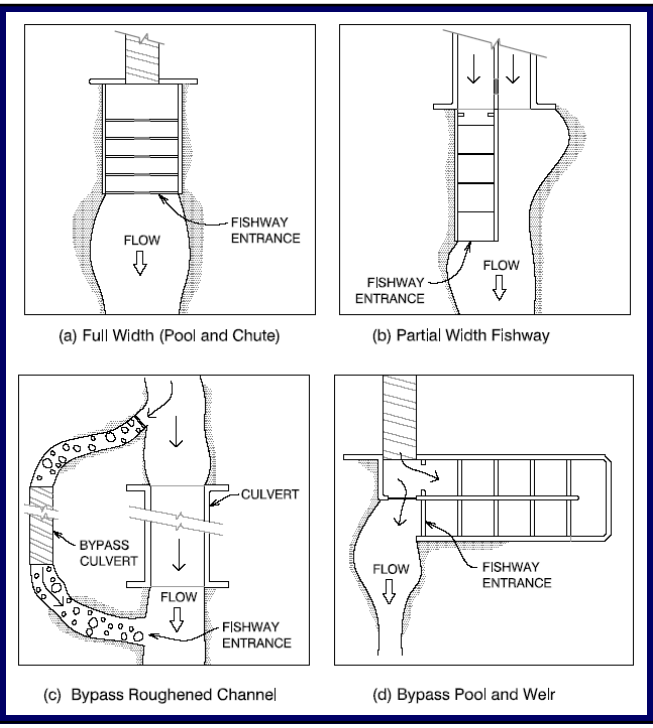


Fishway Nomenclature



6

Fishway Layouts



7

Roughened Chute Fishways
Denil and Alaskan Steeppass

- Uses roughness to control velocities
- Placed at steep slopes
- Passes adult salmonids and alewives (but not weaker swimming fish)
- Tend to clog quickly with debris
- Operates over narrow flow-range
- Convey small portion of total flow (poor fish attraction in some cases)

CDFW/NMFS do not allow these types of fishways for permanent installations and are actively removing them

8

Technical Fishways for Stream Crossings

Partial Width Pool-and-Chute Fishway

Bypass Pool-and-Weir Fishway

Full Width "Vortex" Pool-and-Chute Fishway

Bypass "Serpentine" Pool-and-Weir

Fishway Types: Pool & Weir

Sloping Weir Crest (V-weir) Creates Good Passage Conditions along Edge

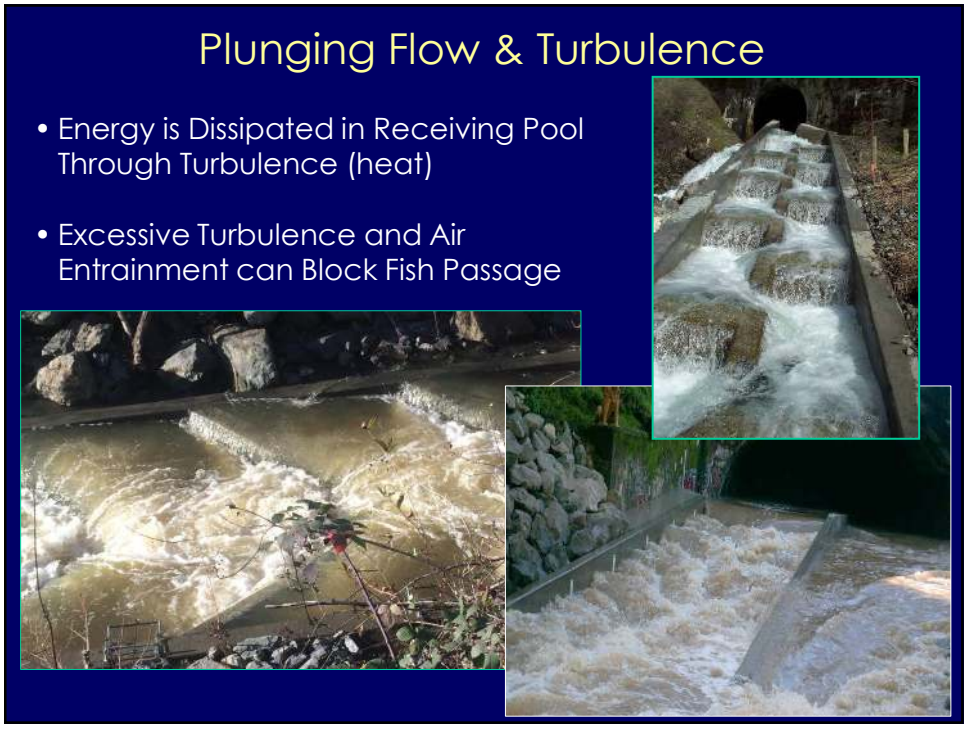
$$Q_{v-weir} = \frac{8}{15} C_d \sqrt{2g} \tan\left(\frac{\theta}{2}\right) H_{v-weir}^{2.5}$$

Where:

$$C_d = 0.6072 - 0.000874\theta + 6.1\times10^{-6}\theta^2$$

10


Fishways using “zero” stream length
Little Park Cr
Photos: Kozmo Bates


Plunging Flow & Turbulence
• Energy is Dissipated in Receiving Pool Through Turbulence (heat)
• Excessive Turbulence and Air Entrainment can Block Fish Passage

Example of Energy Dissipation Factor (EDF) in Pool and Weir Fishway

$$EDF = \frac{\gamma Q h}{V}$$

Calculate EDF in a fishway pool:

Q = 7.5 cfs
H = 1.0 ft
Pool; L=6', w=5', d=4'

$$EDF = \frac{62.4\ lb/ft^3 \times 7.5\ ft^3/s \times 1.0\ ft}{6\ ft \times 5\ ft \times 4\ ft}$$

= 3.9 ft-lb/sec/ft^3
< 4.0 ft-lb/sec/ft^3

Adult Resident Trout
Max EDF = 3 ft-lb/sec/ft3

13

Hybrid Fishway Type: Pool & Chute Fishway

Plunging at Low Flow

Streaming & Plunging at High Passage Flow

Photos: Kozmo Bates

Hybrid Fishway Type: Pool & Chute Fishway


Low Passage Design Flow

Big Sulphur Creek Retrofit


High Passage Design Flow

Pool and Chute Fishways:

- Can be built at slopes up to 10%
- At this slope, avoid overall drop greater than approximately 7 feet
- Lower slopes, may increase overall drop

Vortex Pool & Chute Fishway


Plunging at Low Passage Flow

Fishway Slope = 7%
8" Drops
Overall Fall = 7 feet

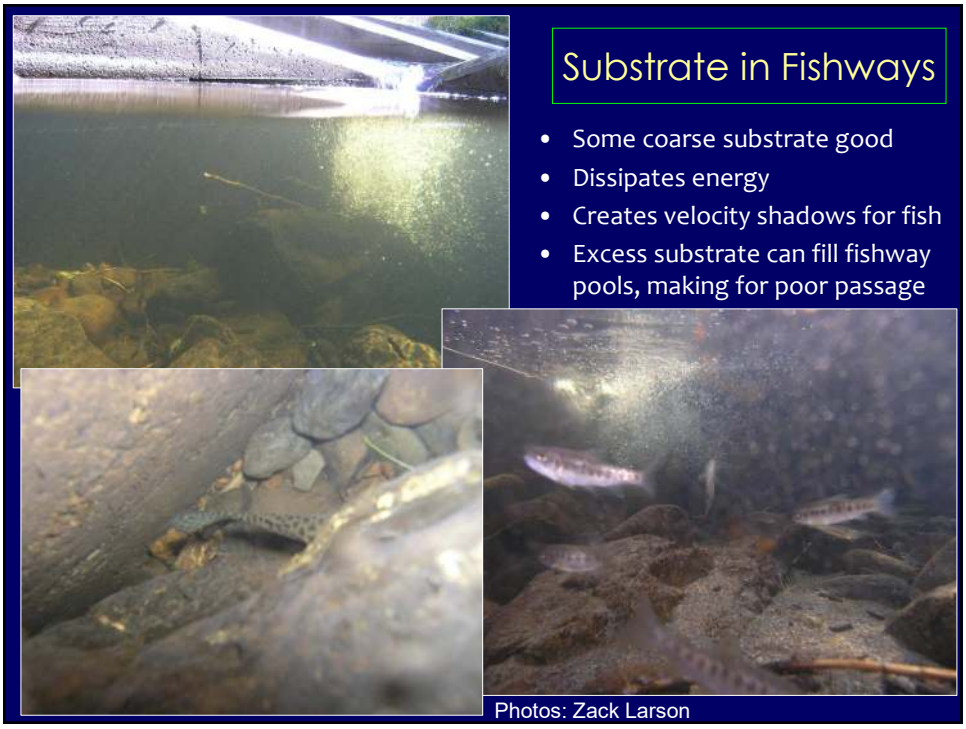
Maintains Plunging along Shoulders & Dry Shoulder for "Passage Corridor"


Streaming down Center at High Passage Flow

Pool & Chute Fishway Limitations

- Applicable to low head dams and some culvert retrofits
  - At fishway slope of 10%, observed undesirable hydraulics with total drop across fishway greater than 6 to 7 feet.
  - At slopes of 7% to 8% and drops up to 12 feet, undesirable hydraulics not observed
- Must be relatively straight due to streaming flow (no switchbacks)
- Fishway velocities at downstream end are High, and can cause downstream channel scour.

17



Substrate in Fishways

- Some coarse substrate good
- Dissipates energy
- Creates velocity shadows for fish
- Excess substrate can fill fishway pools, making for poor passage

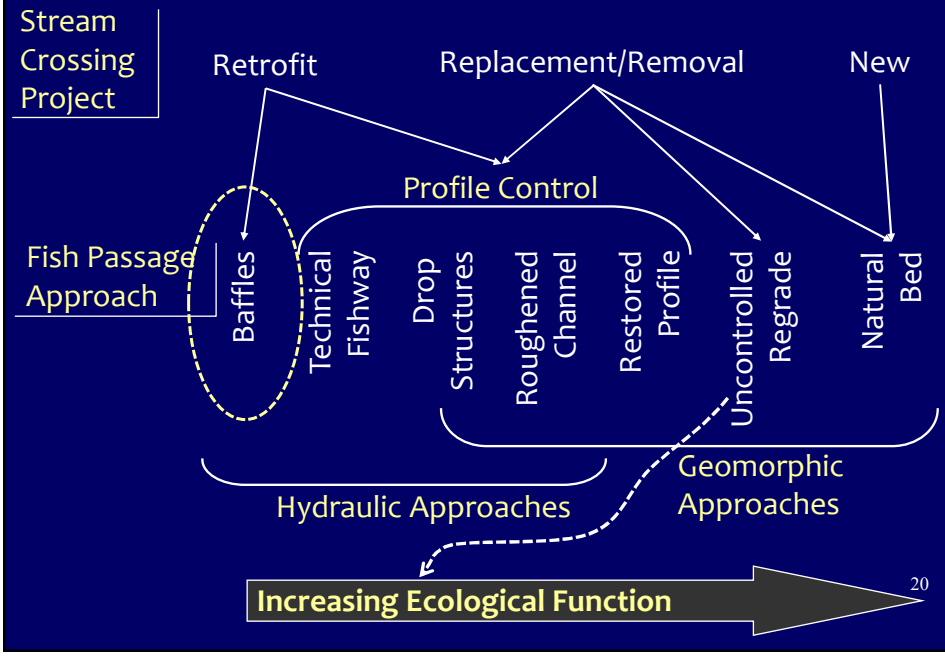
Photos: Zack Larson

Inspection and Maintenance of Technical Fishways

- Develop and Inspection and Maintenance Plan
- Plan inspections after every large flow event and annually to ensure timely clearing of debris/sediment
- Maintenance may include repairs to damaged concrete and steel
- A biological monitoring may be needed at project start-up to ensure project objectives are satisfied

19

Design Approaches for Aquatic Organism Passage



20

Hydraulic Retrofits of Culverts for Fish Passage using Baffles

Concrete Angled Baffle Retrofit

Slip-lined CMP with Corner Baffles

Baffles for Fish Passage

Culvert Retrofit Improves Fish Passage

- Increases Hydraulic Roughness
- Decreases Velocity
- Increases Depth

Invert Paving with steel Corner Baffles Added

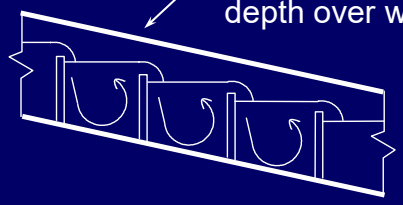
22

Baffles for Fish Passage

Two Hydraulic Regimes

- **Plunging Weir Flow (Low Flow)**
  - sharp crested weirs
  - turbulence dissipated in pool below baffle
  - excess turbulence generally not an issue
- **Streaming Flow (High Flow)**
  - hydraulic roughness
  - uniform turbulence

Plunging (weir flow)



Streaming
(hydraulic roughness)

Increased relative
depth over baffle

Turbulence in Streaming Flow

Moderate Flow – Transition from weir to roughness

- Energy is Dissipated in Receiving Water Column Through Turbulence (heat)
- Excessive Turbulence Creates can Block Fish Passage

Hydraulic Roughness & Turbulence

Corner Baffles

EDF in Baffled Culverts 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)

Thresholds (rule-of-thumb for Baffles):
Adult Salmon: EDF > 5 ft-lb/s/ft^3

26

Baffles from Yesteryear

Ramp Baffles

Lack of Depth at Low Flows
Functional over Narrow Flow Range

Off-Set Baffles

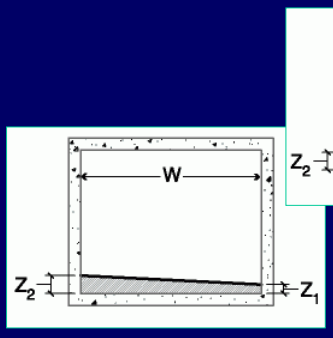
Tend to Catch Debris!!!
Slot Velocities too Fast for Small Fish

27

Angled Baffles for Flat-Bottom Culverts

Angled Baffles

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



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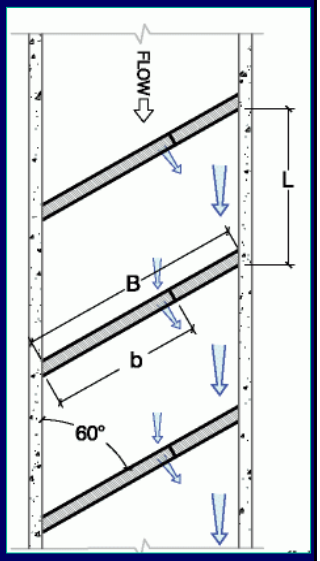


Plan

Angled Baffles for Flat-Bottom Culverts

Wooden Angle Baffle
(looking downstream)

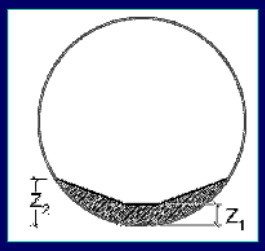
Double Angle Baffles for Wide Culvert ("Vortex Baffle")
(looking upstream)

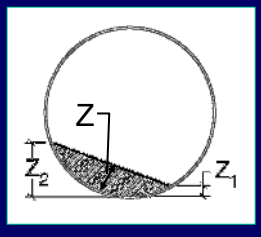
29

Corner & Weir Baffles

Weir Baffles

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





Corner Baffles

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

Outlet Transition

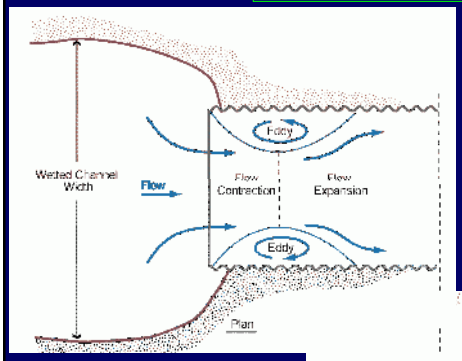
Low Flow

High Fish Passage Flow
(excessive hydraulic drop)

- Evaluate the Outlet Transition with FishXing
- Avoid Excessive Hydraulic Drop at Outlet
- Match Normal Depth to Tailwater

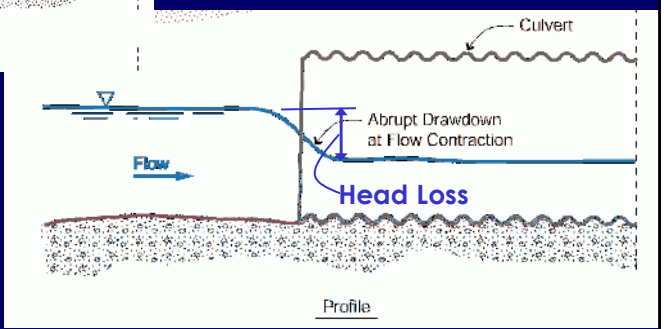
31

Inlet Transition



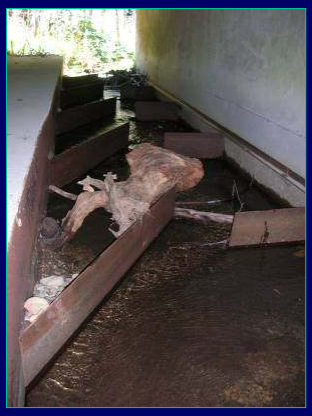
Max Inlet Head Loss for Fish Passage (Rule of Thumb)

- 0.5 feet for Adult Salmonids
- 0.2 feet for Juvenile Salmonids



Baffling Thoughts

- ONLY for Retrofits
- Requires Maintenance/Debris Cleaning
- Frequently Reduces Capacity
- Turbulence blocks fish
- Match normal depth to tailwater



For More on Design of Baffles:
Refer to the California Department of Fish and Wildlife Fish Passage Design Manual (Love & Bates, 2009)

33