

Hydraulic Design Overview



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Premise of the Hydraulic Design Approach

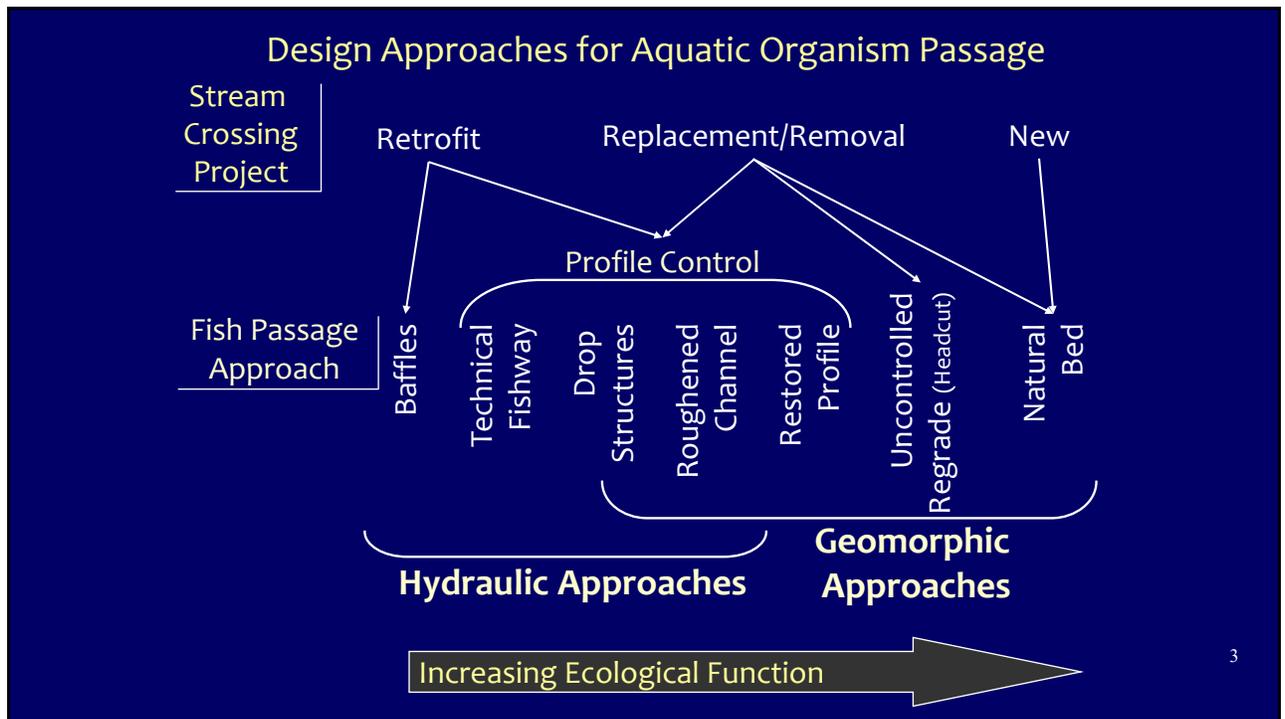
Hydraulic Design matches the hydraulic performance of a project with the swimming abilities of a target species and age class of fish.

Less likely to provide other ecosystem benefits, or passage for non-target species.

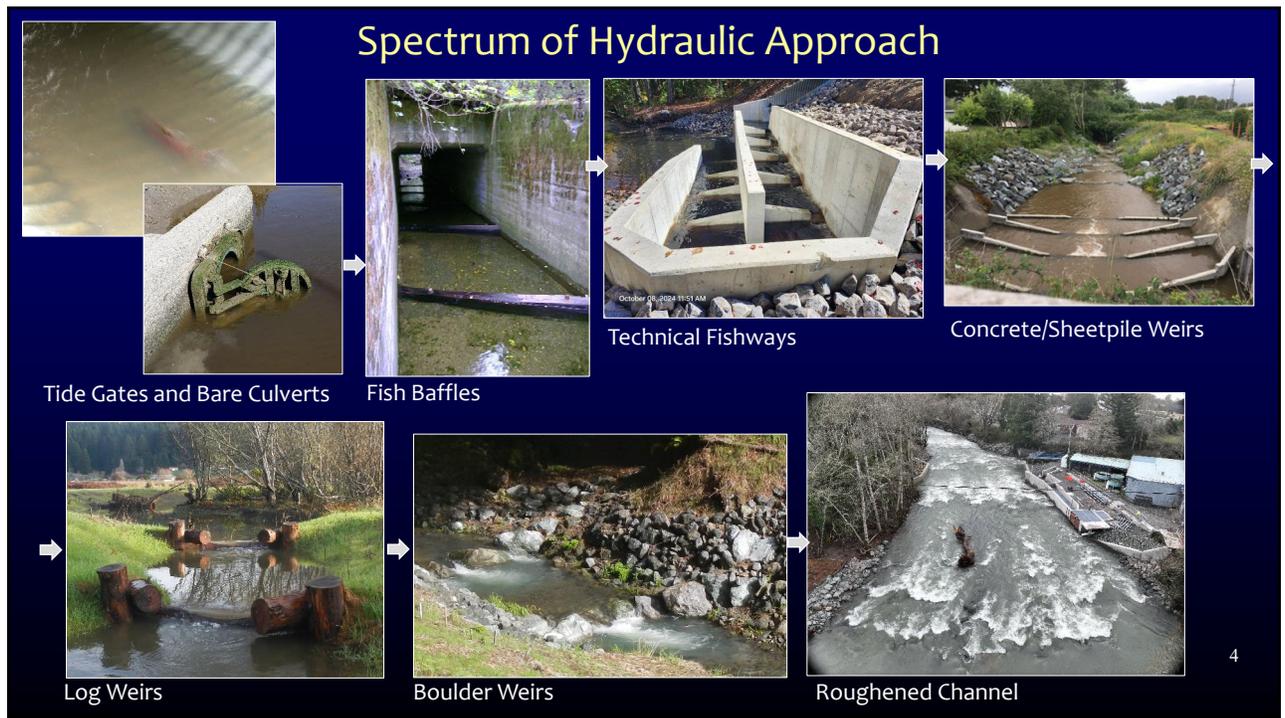
Requires significant data analysis, including hydrologic analysis and hydraulic modeling.

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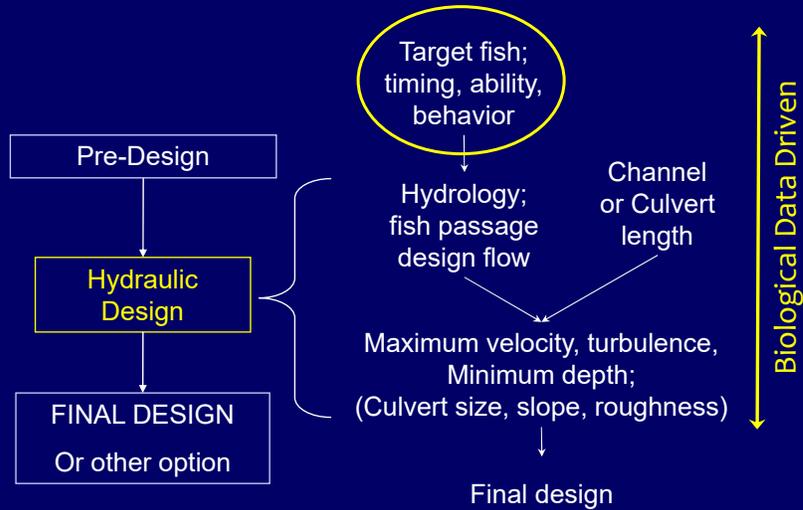


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Hydraulic Design Approach



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Target Species & Life Stages

List of Fish Species found in one small urban stream in Arcata, CA (from Darren Ward, CPH, 2024)

Fish Passage Hydraulic Criteria and Design Flows

- Primarily developed for Salmonids, and Pacific Lamprey to lesser extent
- Consult literature and biologist for non-salmonid target species

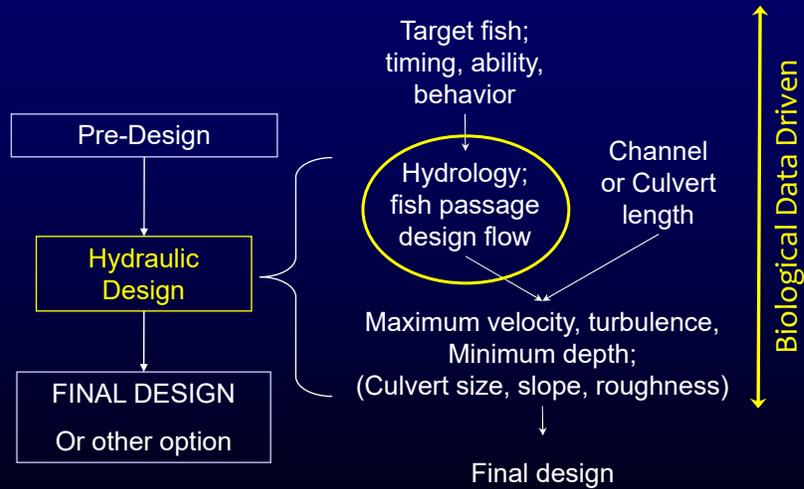
Common Name	Scientific name
Coho salmon	Oncorhynchus kistuch
Coastal cutthroat trout	Oncorhynchus clarkii clarkii
Threespine stickleback	Gasterosteus aculeatus
Western brook lamprey	Lampetra richardsoni
Night Smelt	Spirinchus starksi
Pacific staghorn sculpin	Leptocottus armatus
Prickly Sculpin	Cottus asper
Coastrange sculpin	Cottus aleuticus
Starry Flounder	Platichthys stellatus
Tidewater goby	Eucycloglobius newberryi
Yellowfin goby	Acanthogobius flavimanus
Longjaw mudsucker	Gillichthys mirabilis
Flounder sp	Pleuronectidae



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Hydraulic Design Approach



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Fish Passage Flow Considerations

Migration Timing

➤ Purpose of upstream movement

- ❖ spawning
- ❖ thermal refugia
- ❖ foraging
- ❖ pop. density

➤ Sensitivity to delay

- ❖ wet year
- ❖ dry years

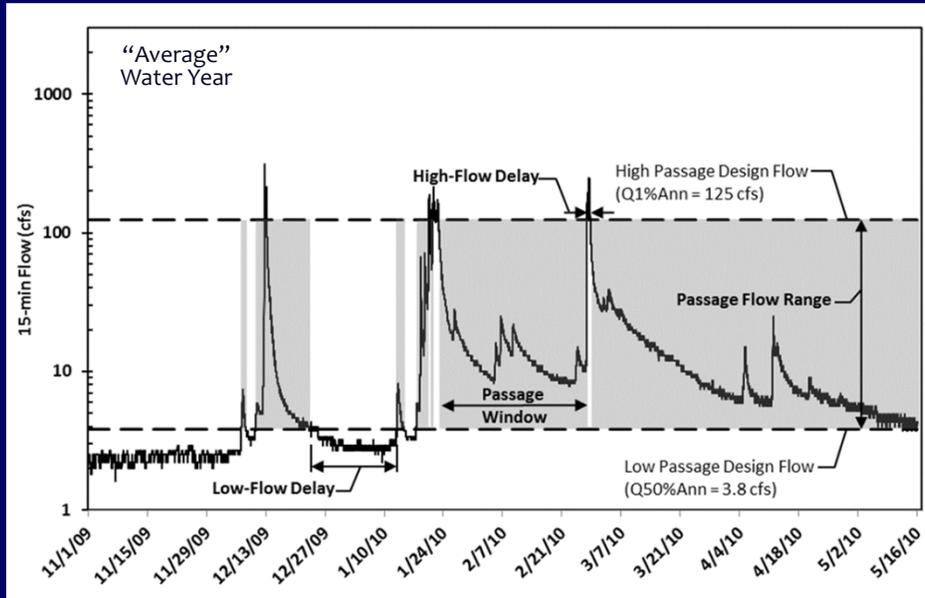
➤ Hydrologic Characteristics

- ❖ peaky
- ❖ long duration (spring runoff)
- ❖ spring feed
- ❖ infrequent events



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Considering Delay when Selecting Fish Passage Design Flows

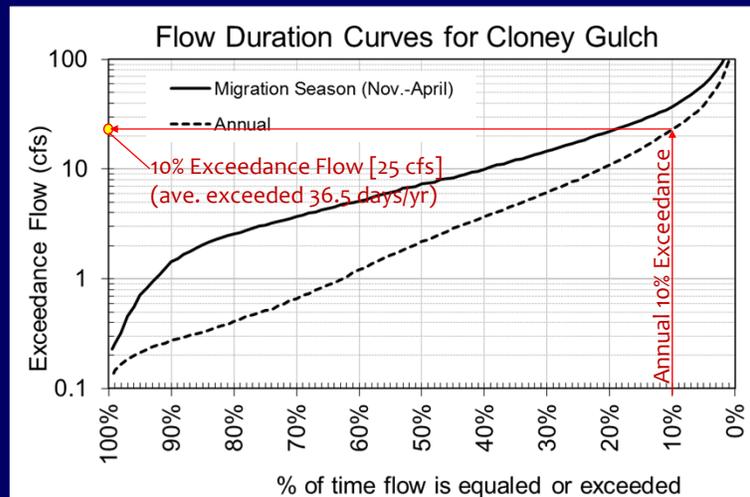


From: Lang and Love (2014)

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Fish Passage Design Flows

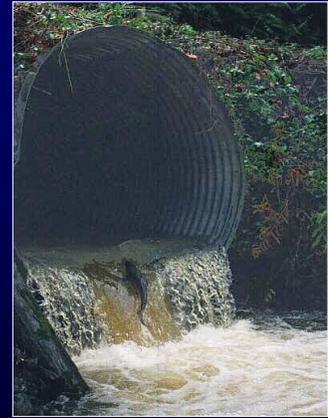
- Typically based on Flow Duration Curves constructed using daily average discharge
- CA Juvenile & Resident Salmonid criteria based on entire year
- CA (NMFS) Adult Anadromous Salmonid high flow criteria based on Migration Period



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Observations of Adult Salmon Leaps at Sullivan Gulch

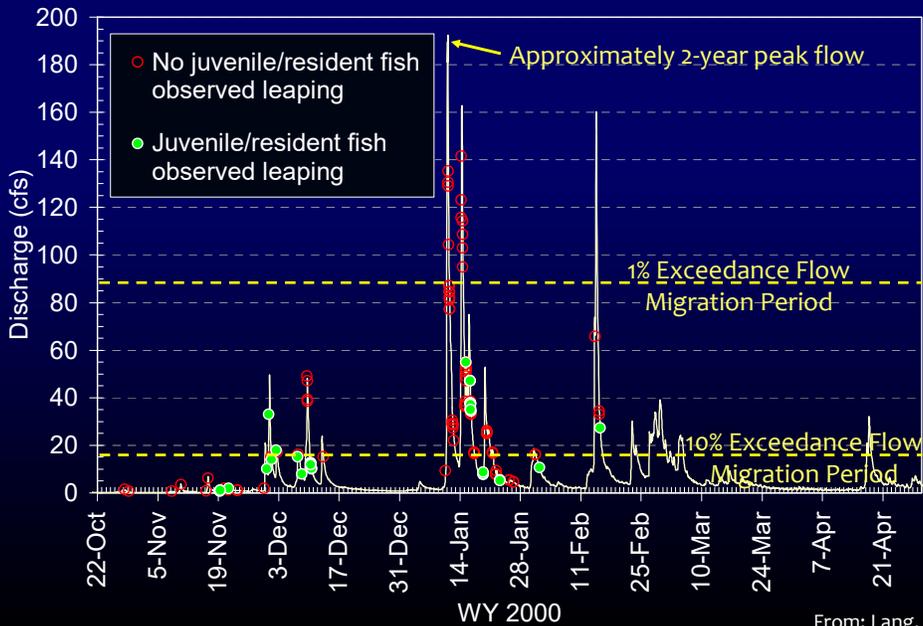


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From: Lang, Love Trush, (2002)

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Observations of Juvenile (<5") Leaps at Sullivan Gulch



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From: Lang, Love Trush, (2002)

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Fish Passage Flows for Hydraulic Designs

California Fish Passage Flow Requirements (CDFW, 2001; NMFS, 2002 and 2019)

Species/Lifestage	Low Passage Design Flow		High Passage Design Flow	
	Annual Exceedance Flow	Alternative Minimum Flow	Exceedance Flow	Based on 2-year Flow*
Adult Anadromous Salmonids	50%	3 cfs	1% Migration Period	50% of Q2-yr
Adult Non-Anadromous Salmonids [#]	90%	2 cfs	5% Annual	10% of Q2-yr
Juvenile Salmonids	95%	1 cfs	10% Annual	5% of Q2-yr
Non-Native Salmonids [#]	90%	1 cfs	5% Annual	N/A
Desirable Non-Native Species [#]	90%	1 cfs	10% Annual	N/A

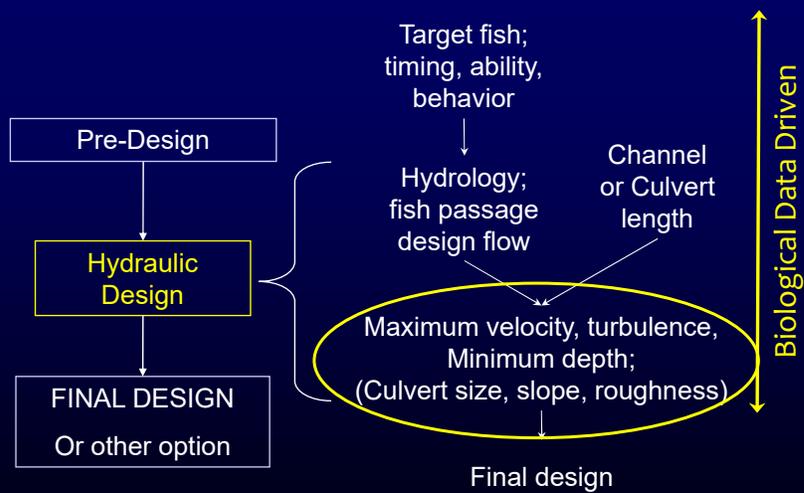
* Refer to NMFS (2019) Fish Passage Addendum #1 for to determine when to use.

[#] Non anadromous design flows from CDFW, 2001.

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Hydraulic Design Approach



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Hydraulic Approach: Minimum Depth

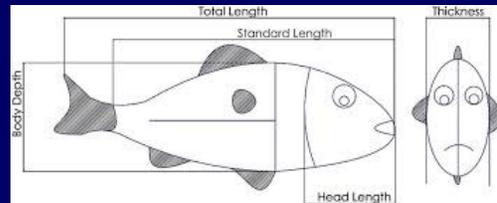
NOAA Fisheries West Coast Region and CDFW allowable velocities

Species/Lifestage	Minimum Flow Depth (ft)
Adult Anadromous Salmonids	1.0
Adult Non-Anadromous Salmonids	0.67
Juvenile Salmonids	0.5
Native Non-Salmonids Non-Native Species	Species specific swimming performance data is required for the use of the hydraulic design option for non-salmonids. Hydraulic design is not allowed for these species without this data.

Excerpt from the Morphometric Data Table:

Common name	Family	Genus	Species	BD/TL	TL/SL	TL/FL
broad whitefish	Salmonidae	Coregonus	nasus	0.232	1.165	1.099
humpback chut	Cyprinidae	Gila	cypha	0.224	1.252	1.134
humpback whitefish	Salmonidae	Coregonus	pidschian	0.196	1.142	1.078
inconnu	Salmonidae	Stenodus	leucichthys	0.174	1.146	1.080
lake sturgeon	Acipenseridae	Acipenser	fulvescens	0.118	1.186	1.096

Where: BD = Body Depth, TL = Total Length, SL = Standard Length, FL = Fork Length
from FishXing User Manual, 2006



from Machavaram, Sahu, and Paradkar, 2019

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What do we know about them?

Swim Speed Variable

- Fish Size
- Water Temperatures
- Swimming Mode and Length:
 - Aerobic (sustained swimming)
 - Anaerobic (burst swimming)
 - Mixed Mode (prolonged swimming)
- Method of Testing:
 - Lab settings, method of capture...
- Stressors:
 - Chemical, lack of depth, distance traveled, time spent in fresh water...



Treadmill



Flame



Respirometer

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Hydraulic Approach: Allowable Velocities

NMFS West Coast Region and CDFW allowable velocities

Culvert Length vs Maximum Average Water Velocity for Adult Salmonids		
Culvert Length (ft)	Adult Non-Anadromous Salmonids (fps)	Adult Anadromous Salmonids (fps)
<60	4	6
60-100	4	5
100-200	3	4
200-300	2	3
>300	2	2
Juvenile salmonids*		1

* 2 fps allowable for short distances

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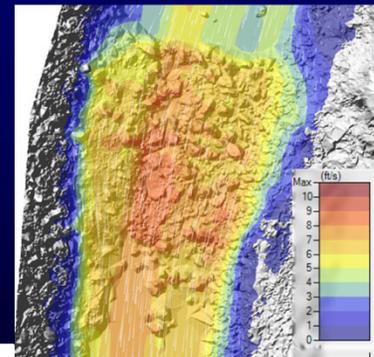
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Hydraulic Approach Roughness and Slope Controls Velocity

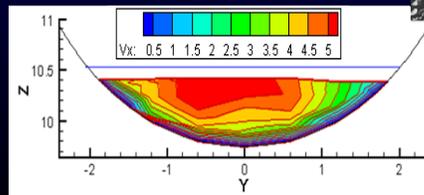
- Culvert walls
- Bed material
- Baffles
 - Limitations of turbulence, debris, maintenance
- Roughened channel
 - Bed stability
 - Variety of migration pathways
 - Turbulence limitation though higher than baffles



Powers, 1996



Rowdy Creek Roughened Channel 2D RAS Results



Battelle & DOE, 2003

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Turbulence

- Measured by Energy Dissipation Factor (EDF)
- Limits fish passage



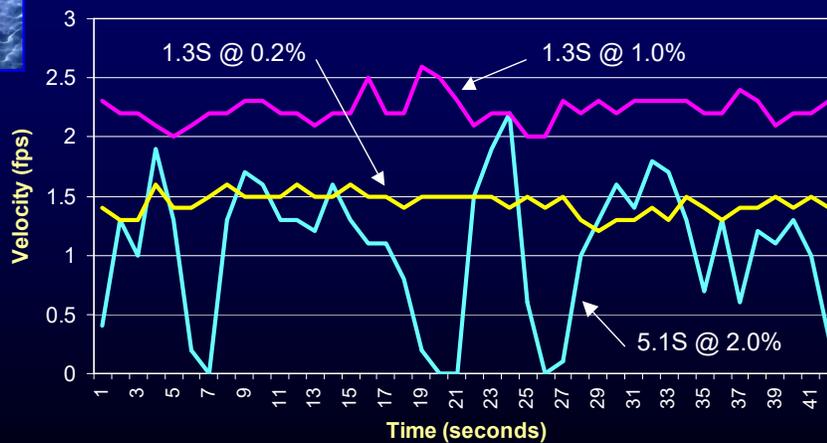
For Technical Fishways:	Max EDF
Adult Anadromous Salmonids	4 ft-lb/s/ft ³ (765 W/m ³)
Adult Resident Salmonids	3 ft-lb/s/ft ³ (575 W/m ³)

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Turbulence in $V_{occupied}$



(3S) 1/2" Spiral Corrugations, 36" CMP
 (1S) 1"x3" Spiral Corrugations, 36" CMP

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From Powers (1997)

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Example of Turbulence, EDF



Low Flow



Fish passage design flow
(for Pacific salmon)
EDF = 4 ft-lb/sec/ft³



Two times fish
passage design flow
EDF = 8 ft-lb/sec/ft³

From Kozmo Bates

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Hydraulic Approach: Maximum Drop

NMFS West Coast Region and CDFW Maximum Water Surface Drops

Species/Lifestage	Maximum Drop (ft)
Adult Anadromous Salmonids	1
Adult Non-Anadromous Salmonids	1
Juvenile Salmonids*	0.5 1.0 (NMFS, 2019)
Native Non-Salmonids	Where fish passage is required for native non-salmonids no hydraulic drop shall be allowed at the culvert outlet unless data is presented which will establish the leaping ability and leaping behavior of the target species of fish.
Non-Native Species	

* CDFW guidelines allow 1 ft drop for boulder weirs, 0.5 ft drops at other weirs. Consult with CDFW if considering using 1.0 ft rather than 0.5 ft in design

** Drop height criteria does not apply to stream simulation designs. Instead, drops should not exceed those found in the reference/natural channel reach.



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