Upstream Fish Passage – Design Selection Process

Prepared by the Fish Screen Oversight Committee

Contents

Comment [AB1]: A general glossary of terms seems appropriate. Different agencies and individuals have different definitions to some of the criteria and designs contained in this document.

Introduction

In an effort to enhance inter- and intra-agency collaboration when selecting fishway designs for upstream fish passage, the Fish Screen Oversight Committee (FSOC) developed the Upstream Fish Passage – Design Selection Process. The FSOC envisions fish managers, engineers, and others using the protocol during the initial evaluation and planning phases that culminate in the selection of a fish passage structure. The goal of this effort *was not* to develop a protocol that replaces existing policies, guidelines, etc., but instead to provide a "tool" that can be used by groups to develop a consensus position relative to an appropriate fish passage design. Although NOAA *will not* require that this process be implemented, the FSOC and NOAA encourage collaborators to consider using the protocol when selecting an appropriate fishway.

Upstream Fish Passage – Design Selection Process

In any fishway design process, numerous factors contribute to the selection of a specific design. For a design to be successful, objectives must be clearly defined and achievable. The FSOC recognizes that no fishway system is capable of allowing passage of all species and life stages on a continuous basis. Although the process detailed below may not be needed for all design decisions, the protocol will assist with the decision-making process when multiple species or life stages are present at a particular site. Because the need may exist to "weight" one scoring criteria category higher than another, those using the process are encouraged to develop their own consensus-based weighting system prior to initiating the effort.

Physical and behavioral attributes for fish species and fishway design selection are based on interpretations of various study results and fishway facility experience, as well as the professional opinions of the FSOC members. When selecting scoring criteria, subbasin plans or recovery plans should be consulted, as well as considering future projections relative to climate change, water use, etc. To ensure that a collaborative process ensues during the selection of an appropriate fishway design for upstream fish passage, the FSOC recommends implementing the following process:

1. Contact each fisheries agency (federal, state, and tribal), as well as other entities that have an interest in the river basin. Additional entities, with appropriate expertise, can be brought in through an invitation from a state, federal or tribal party.
2. Each agency will provide a list of specific species and life stages that should be provided with upstream passage at the proposed fishway site. For each species and life-stage, the need for upstream passage should be explained in terms of:
    a. ESA status.
    b. Impeded or blocked access to upstream spawning or rearing habitat (or other).
    c. Approximate percentage of upstream basin where spawning or rearing habitat is impeded or blocked.
    d. Whether upstream passage at the proposed site is a limiting factor for species sustainability.

    e. Other factors, such as culturally significant, commercially important, important for sport fisheries, ecologically important etc.
3. Identify upstream passage timing (i.e. passage season) for each life-stage and species.
4. Complete "Scoring Criteria" spreadsheet (Appendix A) to determine priority species and/or life-stage.
5. Select initial conceptual fishway design for priority species/life-stage using Appendices B and C. For ESA-listed anadromous salmon and steelhead, use NMFS criteria as a starting design basis. Include other design criteria, as available, as a starting basis for other species.
6. Do any components of the initial conceptual fishway design hamper passage of a lower priority species?
    a. If yes, evaluate if another fishway alternative is more suitable for lower priority species, without compromising priority species. If available, select this alternative conceptual fishway design. If no alternative is available, go to step 7.
    b. If no, use selected option for conceptual fishway design.
7. Can the initial conceptual fishway design components be modified or augmented to facilitate passage of lower priority species?
    a. If yes, modify or augment fishway components as appropriate.
    b. If no, go to step 8.
8. Can the fishway operation be modified on a passage seasonal basis to facilitate passage of lower priority species?
    a. If yes, modify operation as appropriate.
    b. If no, use selected fishway alternative for conceptual design development and minimize impacts on other species.

APPENDIX A

Upstream Passage Assessment Criteria (per subbasin or recovery plan)

	0	1	2	3	4
Life history present at passage site			Upstream migratory – resident or anadromous juvenile	Spawning migration and other life history present	
ESA status	Not warranted	Proposed listing	Species of concern	Threatened	Endangered
Abundance	Stable populations	Not known	Species abundance enhanced by providing upstream passage	Species abundance limited by upstream impediment	Species nearly extinct
Habitat type upstream, including future projections		Rearing	Thermal refuge	Spawning	All
Habitat connectivity need – juveniles	Good quality and quantity (more than 2/3 of basin total) of rearing habitat available	Good quality and quantity (between 1/3 and 2/3 of basin total) of rearing habitat available downstream	Poor quality or limited rearing habitat downstream (less than 1/3 of basin total)	Lack of access to upstream habitat is limiting factor for species	
Habitat connectivity need – adults	All spawning habitat downstream	Good quality and quantity (more than 2/3 of basin total) of spawning habitat available downstream	Poor quality or limited (between 1/3 and 2/3 of basin total) spawning habitat available downstream	Very poor quality or limited (less than 1/3 of basin total) spawning habitat available upstream	Spawning habitat only available upstream
Culturally important species	No	Yes			
Commercially important species	No	Yes			
Recreationally important species	No	Yes			
Ecologically important species	No	Yes			

APPENDIX A - Continued

Example: Review of Feed Canal (Umatilla River, OR) using the Upstream Passage Assessment Criteria

	Species Present				
	Fall Chinook	**Spring Chinook**	**Steelhead**	**Bull Trout**	**Suckers**
Life history present at passage site	3	3	3	3	2
ESA status	0	0	3	3	0
Abundance	3	3	3	1	3
Habitat type upstream	3	2	3	2	1
Habitat connectivity need – juveniles	0	0	2	1	0
Habitat connectivity need – adults	1	3	2	3	0
Culturally important species	0	1	1	0	0
Commercially important species	1	1	0	0	0
Recreationally important species	1	1	1	0	0
Ecologically important species	1	1	1	1	1
Total	13	15	19	13	6

APPENDIX B

Fishway Description and Fish Use

For each of the fishways, many variations exist. The following information represents general characterizations regarding performance and fish use, and should not be considered universal. Because each site is different, no single design may work well in all locations.

Fish Use (see species applicability sheet)	Fishway Type	Description	Positives	~~Negatives~~Concerns
Works ~~well~~ for: - adult Chinook, coho, sockeye, chum, steelhead, bull trout, mountain whitefish, cutthroat trout spp., and redband/rainbow trout **May work for (depending on configuration):** - sucker spp. and lamprey spp. - juvenile Chinook, coho, steelhead, bull trout, cutthroat trout spp., and rainbow/redband trout	**Vertical Slot**	Swim through fishway that provides resting pools and slots that fish need to use for a quick "burst" to swim through. The invert of each slot is set at a given height difference from that of the slot directly upstream.	- Self-adjusting/self-regulating - Provides resting areas (pools) - Swim-through fishway that does not require a fish to leap - Passage can occur at any depth in the water column - Provides moderate to excellent attraction flow	- Slots can catch debris - Slot velocities and pool re-circulation can be difficult for weaker swimming fish - Large footprint and expensive - Uses significant amounts of water, small stream application is difficult - Design must adhere to traditional or acceptable model dimensions and orientations

Comment [AB2]: Sometimes they don't work well. That goes for all fishway types. Other factors may be at work, such as site conditions, and hydrology.

Comment [AB3]: Relative to other fishway design options in this document.

Comment [AB4]: If you're going to deviate from fishway geometries outlined in the literature or modified thru extensive documented monitoring, you're going to need to produce a physical model.

Fish Use (see species applicability sheet)	Fishway Type	Description	Positives	~~Negatives~~Concerns
Works ~~well~~ for: - adult and juvenile Chinook, coho, sockeye, chum, steelhead, cutthroat trout spp., and redband/rainbow trout - adult bull trout **May work for (depending on configuration):** - mountain whitefish - sub-adult bull trout ~~**Does not work for:**~~ - sucker spp., chum, and lamprey spp.	**Pool and Weir**[1]	Fishway that utilizes plunging flow over weirs, separated by energy dissipation pools. Each weir is set at a given height differential from the weir directly up or down stream. Fish pass by swimming thru the jet ~~leaping~~or leaping over ~~each~~ the weir.	~~- Provide passage at a wide range of flows~~ ~~- Use the least amount of water (great for low flow passage)~~ - Provides resting areas - Most debris passes over the top of weirs - Simple in design, less engineering than other fishways	- Requires manual adjustment of each weir if water surface elevations up and/or downstream change - Gravel and sediment can settle in pools - Fish are required to leap in order to pass, which could lead to increased chance of injury - Provides passage over reduced range of flows - Provides poor to moderate attraction flow - Design and location of fishway entrance is critical.
Works ~~well~~ for: - adult and juvenile Chinook, coho, sockeye, steelhead, cutthroat trout spp., bull trout, redband/rainbow trout, and mountain whitefish May work for (depending on configuration): ~~**Does Not Work For:**~~ - chum and sucker spp. ~~(when in plunging flow regime)~~ -lamprey spp.	**Pool and Chute**[1]	Hybrid fishway with both plunging flow and streaming flow~~. at certain flows (mid to higher flows). Primarily acts as a pool and weir at low flows.~~ Works well for applications with limited project space and the structure spans the entire channel. Fish pass by swimming thru the jet or leaping over the weir.	- Potentially smaller fishway footprint over other designs ~~(does not need to dissipate energy during high flows)~~ ~~- Potentially two methods of fish passage (leap over, or swim through) at certain flows~~. - Works at wide range of flows - Self-adjusting - Provides moderate to excellent attraction flow ~~Strong attraction flow (when channel spanning)~~	~~- High turbulence during high flows~~ ~~- Limited resting areas for fish~~ ~~- Attraction can be an issue if not channel spanning~~ - High degree of engineering needed to decipher plunging/streaming flow regime and correlate to fish passage - Passage provided at top of the water column only ~~- Ladder must be straight (no turns)~~ - Best for low head applications (<5-6 ft.)

Comment [AB6]: This statement can be a bit confusing. Many fish species, including chum, suckers, and lampreys will swim through the weir jet during a plunging flow regime.

Comment [AB5]: Pool and weir fishways can be modified to pass these species. For these species, passage may be more correlated to EDF than fishway type.

Comment [AB9]: Resting areas are designed to produce and EDF of 2ft-lbs/ft^3/s. These are not high turbulence areas.

Comment [AB8]: Typically designed to produce streaming flow in the low flow notch and plunging flow along the notch margins at the 95% exceedence flow. This means streaming flow and plunging flow is occurring over the entire expected range of fish passage flows.

Comment [AB7]: Pool and chute fishways inherently provide a bit better passage for these species than pool and weir fishways due to the existence of streaming flow throughout the passage window. Pool and chute fishways can be further modified to better pass these species. For these species, passage may be more correlated to EDF than fishway type.

Fish Use (see species applicability sheet)	Fishway Type	Description	Positives	~~Negatives~~Concerns
Works ~~well~~ for: - adult Chinook, coho, sockeye, steelhead, cutthroat trout spp., bull trout, redband/rainbow trout, and mountain whitefish **May work for (dependent on configuration and velocities):** - chum, sucker spp. - juvenile Chinook, coho, steelhead, bull trout, redband/rainbow trout, and cutthroat trout spp. **Does not work well for:** - lamprey spp.	**Baffled Chute (denil and steeppass)**	Baffled flumes that are designed to control depth and velocities by baffle dimensions and configuration. Baffles create turbulence that break up velocities for fish to swim through.	- Small and economical - Swim-through fishway which can provide "sweet spot" for passage - Steeppasses are portable and can be used at traps and in temporary capacities - Can be placed in steep configurations, gaining a lot of height in a short horizontal distance	- Very susceptible to debris - Cannot be used in locations where chute is downstream passage route - Due to high velocities, requires resting pools in larger installations - May use large quantities of water (depending on design) - Steeppass typically limited to temporary uses

Comment [AB10]: The denil in the trap at Priest Rapids Dam on the mid Columbia passes lamprey. A denil may not be optimal, but they will pass some lamprey. Low sloped denils that don't produce helicoidal flow probably have better passage conditions for lamprey than at higher slopes where helicoidal flow exists.

Fish Use (see species applicability sheet)	Fishway Type	Description	Positives	~~Negatives~~Concerns
Works ~~well~~ for: - adult and juvenile Chinook, coho, sockeye, steelhead, cutthroat trout spp., bull trout, redband/rainbow trout, and mountain whitefish **May work for (dependent on configuration):** - lamprey spp. **~~Does not work for:~~** - chum, sucker spp.	**Rock Weirs, ~~Log Weirs~~**	Nature-like fishway that utilizes boulders ~~or logs~~ to create weirs and pools, much like a pool/weir or pool/chute fishway to provide passage. ~~Typically fish are required to leap over weirs to pass, but generally~~ Generally both streaming and plunging flow regimes exist ~~at certain flows~~. Spacing between rocks provides slot and sometimes orifice passage.	- Natural appearance - Dependent on design/flow, can provide swim through and/or leap over passage. - Provides stream grade control ~~- Can be partial width or channel spanning, though channel spanning is preferred due to attraction and stability considerations~~	- Must be designed, engineered, and constructed carefully and correctly - Longevity can be a concern, especially if bed and banks are not armored and structural rocks are not ~~sized/designed~~placed correctly - ~~Generally~~ May requires maintenance (debris removal and rock replacement) ~~- Combination of sizing rock to withstand flood flows and provide passage sometimes does not pencil out~~ - Low-flow fish passage is a concern (sub-surface flow) - May not work downstream of reservoirs where fines settle out, or in any location devoid of fines. - Poor attraction flow. Design and location of fishway entrance is critical. Limited to slopes typically < 5%.

Comment [AB12]: BW fishways fail much more frequently due to insufficient armoring of the bed and banks. It's not the big rocks that move because they are too small. The big rocks move because the streambed moves out from underneath them, or the streambanks move away from them.

Comment [AB11]: I would not recommend the use of log weirs as a fishway design.

Comment [AB13]: Spacing becomes too close and weirs blow out.

Fish Use (see species applicability sheet)	Fishway Type	Description	Positives	~~Negatives~~Concerns
Works ~~well~~ for: - all species and life-stages in need of passage (depending on design/configuration, gradient, velocities, depths)	**Roughened Channel**	Nature-like fishway that utilizes natural aspects of a stream, such as riffles and pools, to provide passage. Typically, roughened channels are over-steepened and over- roughened as compared to the natural gradient and rock size.	- Natural appearance - Utilizes natural stream hydrology to provide passage - Allows for natural function and passage of sediment - Can be partial width or channel spanning or go around impediment, though channel spanning is far preferred due to attraction considerations	- Difficult to construct, need a high level of design/engineering to be successful - If not designed/constructed correctly, fish passage and longevity are at risk - Requires a lot of rock and streambed materials. Sometimes at a high cost. - Only applicable in low head installations (5ft - 6ft or less) - May not work downstream of reservoirs where fines settle, or in any location devoid of fines. ~~-~~Poor attraction flow. Design and location of fishway entrance is critical.
Works well for: - adult and juvenile Chinook, coho, sockeye, chum, steelhead, cutthroat trout spp., bull trout, redband/rainbow trout, and mountain whitefish **May work for (but likely problematic due to orifice velocities):** - sucker spp. and lamprey spp.	**Ice Harbor and Half Ice Harbor**	Fishway that utilizes pool and weir, as well as submerged orifice. Full ice harbor has partition between two weirs/orifices. Half ice harbor is full ice harbor cut in half (partition on one side, one weir with orifice on the other). Passage through this fishway is through either leaping over the weir, swimming thru the jet, or swimming through the orifice.	- Offers two routes of passage for fish that may prefer to either leap over the weir or burst through the orifice. - Best used at sites with good water supply and consistent reservoir and forebay levels. - Provides moderate to excellent attraction flow	- Large footprint - Requires ~~a lot~~ significant amount of water and stable flows - Submerged orifices ~~are~~ may be prone to plugging. ~~and are hard to clean~~

Fish Use (see species applicability sheet)	Fishway Type	Description	Positives	~~Negatives~~Concerns
Works ~~well~~ for: - all species and life-stages in need of passage (depending on design/configuration, gradient, velocities, and depths)	**Stream Simulation**	Fishway that matches existing natural conditions in the stream. Often used in side channels to provide passage around diversions or in barrier removals. Stream simulation fishways match gradient, bed materials, depths, and velocities of the existing stream in the project vicinity.	- Provides fish passage at the same level that the stream naturally provides (i.e., fish do not know it is in a fishway)	- Difficult to impossible to do in situations where water surface elevations must be raised above natural conditions. For example, water surface must be raised to push water down an irrigation canal. - Large footprint - Expensive - High level of design time to survey reference reaches, and must be constructed carefully to include naturally features such as fines, low-flow channel. Poor attraction flow. Design and location of fishway entrance is critical.
[1] Ladder may be designed with submerged orifice. An orifice requires additional water but allows fish to burst through lower in the water column. Submerged orifices are prone to plugging and are difficult to clean. They may not work well for fish with limited swimming capabilities, depending on head drop between pools.				
Road Stream Crossings- Culverts and Bridges				
Works well for: - all species and life-stages in need of passage (depending on design/configuration, gradient, velocities, and depths)	**Stream Simulation Bridge/ culvert**	A bridge or culvert that spans the entire channel of the stream. Depending on agency criteria, the length of clear span will vary, but at minimum the crossing must clear span the entire channel. Also, features contained within the crossing must match the existing natural conditions in the stream. These features include gradient, jump heights, water depths, velocities, and bed materials.	- Provides fish passage at the same level that the stream provides naturally (i.e., the fish does not know it is in a fishway). - Preferred method of providing fish passage at road-stream crossings. - Minimal review time for permitting agencies	~~- Extensive in stream surveys needed to calculate active channel width, gradient, and bed material composition upstream and downstream of the crossing~~ - Poor attraction flow. Design and location of fishway entrance is critical.

Comment [AB14]: All the design data specific to SSD can be collected by 2-3 people in about an hour.

Fish Use (see species applicability sheet)	Fishway Type	Description	Positives	~~Negatives~~Concerns
Works ~~well~~ for: - ~~all~~ strongest swimming species and life-stages ~~in need of passage~~ Does not work well for: - weak swimming species and life stages. (~~depending on design/configuration, gradient, velocities, depths)~~	**Hydraulic Bridge/ Culvert**	A bridge or culvert which does not qualify as "stream simulation," but the resulting hydraulic conditions provided by the crossing meets the needs of the native migratory fish in need of passage. In order to meet hydraulic passage requirements, analyses must clearly show that the velocities, depths, and jump heights provide between the 95% and 5% exceedence flows (fish passage flows) meet the needs of the ~~native migratory~~target fish in need of passage.	- Can be less expensive than stream simulation (smaller structures) ~~- Can provide good fish passage in certain situations (particularly in lentic conditions or spring fed systems with very stable flows).~~	- Loss of natural function. Smaller crossings do not allow for internal bed and banks to form, and to dissipate energies of flood flows. - Limited range of application. - Very sensitive to changes in pipe slope. Small changes in pipe slope can quickly produce unacceptable passage conditions. - Moderately restrictive to passage of adult salmonid species. -Highly restrictive to passage of juvenile salmonids and native stream species.

Comment [AB15]: High restrictive, specie specific, design method.

APPENDIX C

Upstream Fish Passage Facility - Species Suitability

Species/Lifestage	Passage Facilities	Physical Ability	Behavioral Factors	Criteria Summary

Species/Lifestage	Passage Facilities	Physical Ability	Behavioral Factors	Criteria Summary
Adult: Chinook, coho, steelhead, sockeye, and cutthroat trout (sea run)	Vertical slot, pool and weir, pool and chute, ice harbor, half ice harbor, baffled chute, stream simulation, rock weirs, roughened channels, stream simulation road-stream crossing, appropriately designed hydraulic road-stream crossing	- Burst speed >16 fps - Swim long distances in approximately 2 fps flow	- Good leapers and swimmers, will readily jump if presented with a barrier, but prefer submerged swim through passage corridor. - When presented with a choice of high or low velocity, these fish will select high velocity first even if impassable. - Require strong attraction flows. - Reluctant to enter confined passage from open water. - Sockeye tend to pass in large groups.	- 12" jump heights - 2-4 fps in transport – channels - 8 fps at transition points (slots, orifices, weir crests), - - 4 ft/lbs energy in resting pools
Adult: chum	Pool and chute, ~~Vertical~~ vertical slot, roughened channel, stream simulation, ice harbor, half ice harbor, baffled chute, stream simulation road-stream crossing, appropriately designed hydraulic road-stream crossing	- Burst speed >10 fps - Swim long distances in approximately 2 fps flow	~~- Fish do not leap, but can pass through 8 fps velocity submerged for short distances.~~ ~~- Even the smallest features that require a fish to leap to pass can be barriers to adult chum.~~	- ~~0" jump heights~~ – fishway must be swim through. - 8 fps at transition points (slots, orifices). ~~- Fish cannot pass through fishways which require leaping to pass.~~ - 4ft/lbs energy in resting pools
Adult: pink salmon	Vertical slot, pool and weir, pool and chute, ice harbor, half ice harbor, baffled chute, stream simulation, rock weirs, roughened channels, stream simulation road-stream crossing, appropriately designed hydraulic road-stream crossing	- Burst speed >10 fps - Swim long distances in approximately 2 fps flow	- Fair leapers and swimmers, will readily jump if presented with a barrier. - Require strong attraction flows. - Reluctant to enter confined passage from open water.	- 9" jump heights - 2-4 fps in transport channels, - 8 fps at transition points (slots, orifices, weir crests), - - 4 ft/lbs energy in resting pools

Comment [AB16]: Even though ODFW has adopted NFMS criteria for transport channels, ODFW does not apply transport channel criteria consistent with its intended original use. The definition of this criteria and an example of its intended application needs to be provided somewhere in this document.

A general glossary of terms in the front of the document would seem appropriate as well.

Comment [AB18]: This statement can be a bit confusing, not just for chum, but for other species as well. Chum can pass through a hydraulic drop (plunging flow) without having to leap, in the same way shad pass over weirs in Columbia River fishways, they swim thru the jet. A 1ft drop in and of itself does not pose a barrier to chum. Many fish species swim through the weir jet during a plunging flow regime.

Comment [AB17]: WDFW has several pool and chute fishways that provide excellent adult chum passage. ODFW is currently designing pool and chute fishways for chum passage.

Species/Lifestage	Passage Facilities	Physical Ability	Behavioral Factors	Criteria Summary
Adult: redband/rainbow trout and cutthroat trout (resident/fluvial)	Vertical slot, pool and weir, pool and chute, ice harbor, half ice harbor, baffled chute, stream simulation, rock weirs, roughened channels, stream simulation road-stream crossing, appropriately designed hydraulic road-stream crossing	- Prolonged swim speed 1.6 fps - 4 fps - Burst swim speed 3.3 fps - 9.8 fps (depending on body size)	- Fish are good leapers and will readily do so. - Leaping ability is not as strong as adult salmon and steelhead. - For smaller fish, fishways with small jumps may work better than swim-through style due to weaker swimming ability.	- 6-12" jump heights, - 2 fps in transport channels, - 4 ft/lbs of energy in resting pools.
Adult: bull trout and mountain whitefish	Vertical slot, pool and weir, pool and chute, ice harbor, half ice harbor, baffled chute, stream simulation, rock weirs, roughened channels, stream simulation road-stream crossing, appropriately designed hydraulic road-stream crossing	- Prolonged swim speed 1.3 fps - 2.8 fps - Burst swim speed 2.6 fps for whitefish, no ranking for bull trout burst speeds	- Fish will leap, but these species tend to orient to the bottom of the water column and do not like to come to the surface. - Swim through fishway with low velocities (small pool-pool differentials) or stream simulation and roughened channels work best. - Bull trout tend to migrate at night.	- 6-12" jump heights - 2 fps in transport channels, - 4 ft/lbs of energy in resting pools.
Adult: sucker spp.	Vertical slot, roughened channel, stream simulation, ice harbor, half ice harbor, baffled chute, stream simulation road-stream crossing, appropriately designed hydraulic road-stream crossing	-Prolonged swim speed 1.5 fps -2.5 fps - Burst swim speed 6fps	- Fish are relatively weak swimmers, though have a decent burst when need be. - Sucker species do not and cannot leap. - Fishways must be swim through, stream simulation or roughened channel	- 0" jump heights - Fishway must be swim through. Fish cannot pass through fishways which require leaping to pass - 2 fps in transport channels - Maximum 4 fps in fishways (including discrete transitions) - 4ft/lbs energy in resting pools

Comment [AB19]: These statements can be a bit confusing. Many fish species swim through the weir jet during a plunging flow regime, including sucker. It may not be the optimal fishway design for sucker for other reasons. Fishways designed with a hydraulic drop can be modified to pass sucker. Passage of sucker may be more closely associated with EDF than fishway type.

Comment [AB20]: This is completely speculative. No data supports this claim.

Species/Lifestage	Passage Facilities	Physical Ability	Behavioral Factors	Criteria Summary
Adult: lamprey species	Roughened channel, stream simulation, lamprey specific fishway (lamp ramp), fishways using weirs with rounded edges	- Prolonged swim speed .5 fps -1.3 fps - Burst swim speed 2.8 fps	- Fish are weak swimmers and cannot/do not leap. Back eddies, 90 degree corners, and moderate to high velocities can block fish passage. - Require a wetted smooth surface or very slow velocities in order to pass. - Most lamprey pass at night.	~~- 0" jump heights,~~ - max velocities of < 2 fps. - - Specialized criteria include ramp heights, angles, velocity of water over surfaces, no corners and smooth passage sufaces.
Juvenile: Chinook, coho, steelhead, redband/rainbow trout, and cutthroat trout	Vertical Slot, Pool and Weir, Pool and Chute, Ice harbor, Half Ice Harbor, baffled chute, stream simulation, rock weirs, roughened channels, stream simulation road-stream crossing, appropriately designed hydraulic road-stream crossing	-Prolonged swim speed .5 fps -2.1 fps - Burst swim speed (no or limited data for juvenile burst speeds)	- Fish are good leapers and will readily do so. - Leaping ability is not as strong as adult salmon/steelhead. - For smaller fish, fishways with small jumps may work better than swim-through style due to weaker swimming ability.	- 6" to 9" jump heights (depending on agency criteria) - 2 fps in transport channels - 2-4 ft/lbs of energy in pools
Juvenile/sub-adult: bull trout	Vertical Slot, Pool and Weir, Pool and Chute, Ice harbor, Half Ice Harbor, baffled chute, stream simulation, rock weirs, roughened channels, stream simulation road-stream crossing, appropriately designed hydraulic road-stream crossing	-Prolonged swim speed 1.5 fps -1.7 fps - Burst swim speeds (no, or limited, data for juvenile burst speeds)	- Leaping ability/willingness is fairly unknown. - Fairly weak swimmers. Best passage is through roughened channel or stream simulation. Other fishways should be low velocity/low head, or small jump heights	- 6" jump heights - 2 fps in transport channels - 2-4 ft/lbs energy in pools

Comment [AB22]: Rounded wetted weirs can provide passage, even with drops in excess of 2-3 ft.

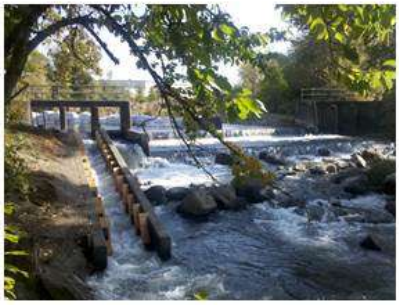
http://www.flickr.com/photos/usfwspacific/7755850962/in/set-72157631009824798

Comment [AB21]: http://www.flickr.com/photos/usfwspacific/7755850962/in/set-72157631009824798

Appendix D

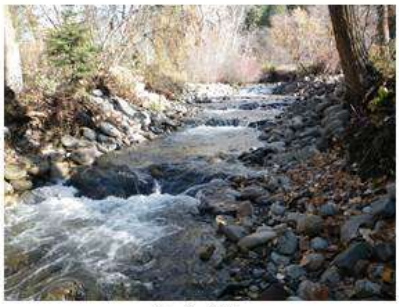
Examples of common fishways

Vertical Slot



Denil or Steeppass

Pool and Weir (full-channel)



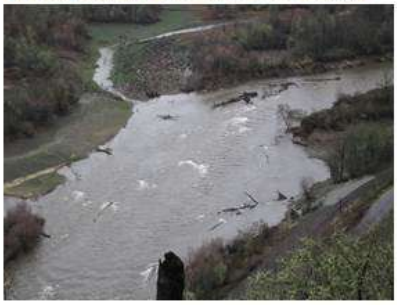
Rock Weir

Roughened Channel

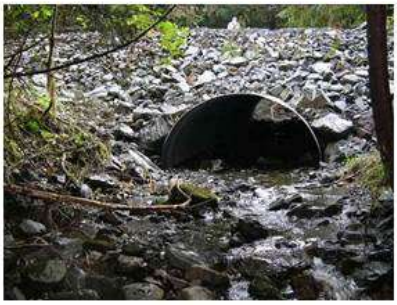
Ice Harbor

Appendix D

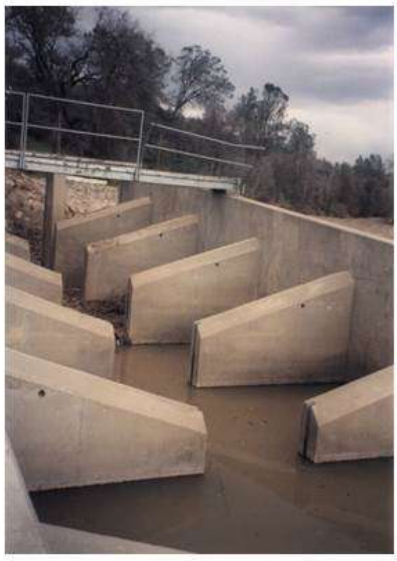
Examples of common fishways



Stream Simulation (in-stream)



Stream Simulation Culvert



Pool and Chute

Hydraulic Design Culvert

References