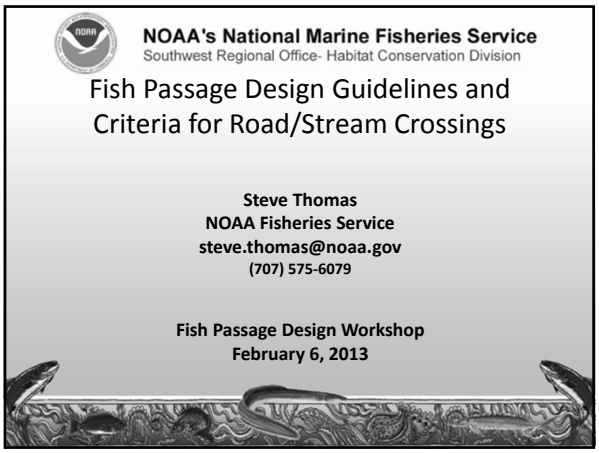


Presentation Purpose

Present NMFS and CDFW design guidelines and criteria for road/stream crossings in California

Presentation Outline

- Stream Connectivity
- Barriers in General
- Characteristics of Fish Friendly Crossings
- Design Strategies
- Criteria for Three Design Options
- Retrofits for Fish Passage
- CDFW Design Checklists

Questions

Why are there federal and state resource agency design guidance documents for fish passage at stream crossings ?

How should these guidance documents be used by engineers, consultants, agencies, and other practitioners?

Stream Crossing Design Guidance Documents

- Provide consistent standards between state and federal resource agencies, NMFS and CDFG
- Serve as a basis for communications between project proponents and resource agencies during design development process
- Allow project designers to understand agency requirements from outset of design process
- Foster opportunities for early involvement of resource agency engineers/biologists in design development and review process

Stream Connectivity

- Connecting the Road from one side of the stream to the other
- Connecting the Stream from one side of the road to the other
- Connecting the Stream Ecosystem from one side of the road to the other

High Level Ecosystem Management Goal:

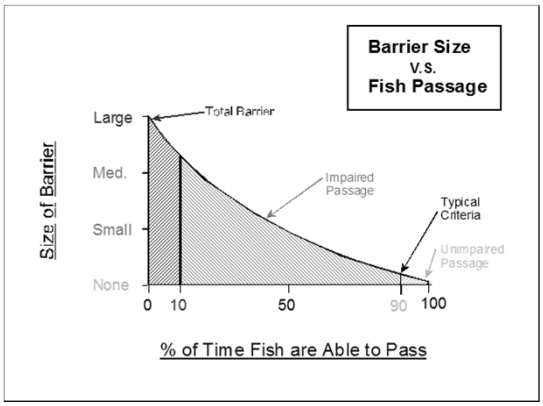
Reduce Habitat Fragmentation caused by road networks

Remember, lot's of critters need, or seek to have safe and timely passage at stream crossings.

Habitat Fragmentation can be a serious limiting factor to many fish and wildlife species

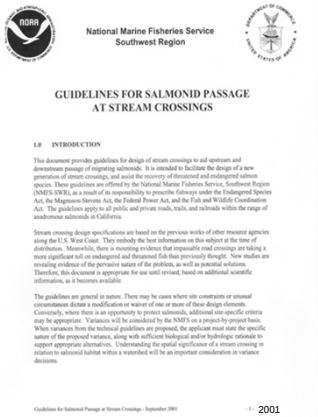
Classification of Barriers

- Temporal - Impassable to fish some of the time based on flow conditions
- Partial - Impassable to some fish all the time
- Total - Impassable to all fish all the time
- Function of species, life stage, hydrology, and hydraulics



Characteristics of Fish Friendly Crossings

- Crossing width is at least as wide as active channel
- Crossing bottom is buried below the stream bed
- Natural bed material has accumulated along the bottom of the crossing
- The water surface within the crossing blends smoothly with upstream and downstream water surfaces without excessive drops
- Obvious turbulent conditions are not present
- No obvious signs of excessive scour of the tailwater pool



National Marine Fisheries Service
Southwest Region

GUIDELINES FOR SALMONID PASSAGE AT STREAM CROSSINGS

1.0 INTRODUCTION

This document provides guidelines for design of stream crossings to aid upstream and downstream passage of migrating salmonids. It is intended to facilitate the design of a new generation of stream crossings, and assist the recovery of threatened and endangered salmon species. These guidelines are offered by the National Marine Fisheries Service, Southwest Region (NMFS SWR), as a result of its responsibility to prescribe fishways under the Endangered Species Act, the Magnuson-Stevens Act, the Federal Power Act, and the Fish and Wildlife Coordination Act. The guidelines apply to all public and private roads, trails, and railroads within the range of anadromous salmonids in California.

Stream crossing design specifications are based on the previous works of other resource agencies along the U.S. West Coast. They embody the best information on this subject at the time of distribution. Meanwhile, there is mounting evidence that impassable road crossings are taking a more significant toll on endangered and threatened fish than previously thought. New studies are revealing evidence of the pervasive nature of the problem, as well as potential solutions. Therefore, this document is appropriate for use until revised, based on additional scientific information, as it becomes available.

The guidelines are general in nature. There may be cases where site constraints or unusual circumstances dictate a modification or waiver of one or more of these design elements. Conversely, where there is an opportunity to protect salmonids, additional site-specific criteria may be appropriate. Variances will be considered by the NMFS on a project-by-project basis. When variances from the technical guidelines are proposed, the applicant must state the specific nature of the proposed variance, along with sufficient biological and/or hydrologic rationale to support appropriate alternatives. Understanding the spatial significance of a stream crossing in relation to salmonid habitat within a watershed will be an important consideration in variance decisions.

Guidelines for Salmonid Passage at Stream Crossings - September 2001 1 2001

NMFS-Engineering (Southwest Region) developed original design guidance in 1996-2000 era

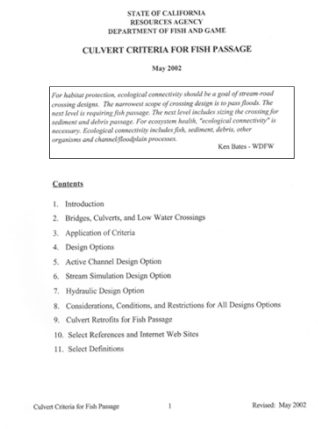
based on:
• observational and practical design experience,

• scientific literature reviews on fish swimming ability and culvert hydraulics,

• study and comparison with design criteria in northwest states,

•a survey and assessment report by scientists and engineers from Humboldt State University

http://swr.nmfs.noaa.gov/hcd/policieshtm



STATE OF CALIFORNIA
RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

CULVERT CRITERIA FOR FISH PASSAGE

May 2002

For habitat protection, ecological connectivity should be a goal of stream-road crossing designs. The narrowest scope of crossing design is to pass floods. The next level is requiring fish passage. The next level includes sizing the crossing for sediment and debris passage. For ecosystem health, "ecological connectivity" is necessary. Ecological connectivity includes fish, sediment, debris, other organisms and channel/floodplain processes.

Ken Bates - WDFW

Contents

1. Introduction
2. Bridges, Culverts, and Low Water Crossings
3. Application of Criteria
4. Design Options
5. Active Channel Design Option
6. Stream Simulation Design Option
7. Hydraulic Design Option
8. Considerations, Conditions, and Restrictions for All Designs Options
9. Culvert Retrofits for Fish Passage
10. Select References and Internet Web Sites
11. Select Definitions

Culvert Criteria for Fish Passage 1 Revised: May 2002

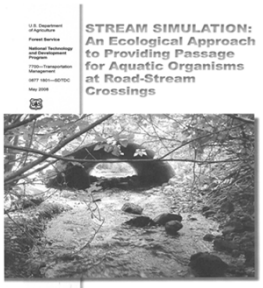
CDFG's May 2002 "Culvert Criteria for Fish Passage"

• compatible with "Guidelines for Salmonid Passage at Stream Crossings" (NMFS 2001)

• addresses both anadromous non-anadromous species

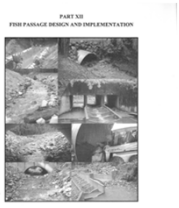
• supplemented by Part XII of CDFG's Stream Restoration Manual in 2008, with more detailed design and applied engineering guidance

Additional Resources



2008

www.fs.fed.us/eng/pubs/pdf/StreamSimulation/index.shtml



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

2008

CALIFORNIA SALMONID STREAM HABITAT RESTORATION MANUAL

PART XII
FISH PASSAGE DESIGN AND IMPLEMENTATION
2008

Prepared for:
California Department of Fish and Game
and
Pacific Fish, Wildlife, and Wetlands Restoration Association

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Antonio Llanos, P.E.

Anadromous Salmonid Passage Facility Design, July 2011

- NOAA/NMFS-NWR http://www.nwr.noaa.gov/Publications/Reference-Documents/Passage-Refs.cfm
- A compendium of NMFS-NWR's fish passage criteria documents
- NMFS-SWR may defer to NMFS-NWR guidelines where criteria are not available in our own publications

Application of Criteria

- Intended for new and replacement culverts
- Applies conceptually to bridges and low-water crossings
- Can be guidelines for stream restoration projects
- Not all crossings are required to have fish passage
- Some crossings may require passage for only specific species or age classes of fish

Design Options

- Active Channel Design
- Stream Simulation Design
- Hydraulic Design

Design Options

Allowable Design Options

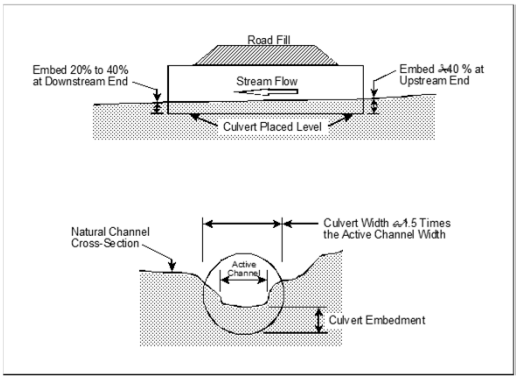
Fish Passage Requirement	Active Channel Design Option or Stream Simulation Design Option	Hydraulic Design Option For Upstream Fish Passage	Hydraulic Capacity & Structural Integrity
Adult Anadromous Salmonids	X	X	
Adult Non-Anadromous Salmonids	X	X	
Juvenile Salmonids	X	X	
Native Non-Salmonids	X	Conditional based on species swimming data	
Non-Native Species	X		
Fish Passage Not Required	X		X

Table 2

Active Channel Design Option

- Simplified conservative design
- Determination of fish passage flows, velocities, and depths not required
- Suitable for the following conditions:
  - New and replacement culvert installations
  - Simple installations with channel slopes 3%
  - Short culvert lengths (less than 100 feet)
  - Passage required for all fish

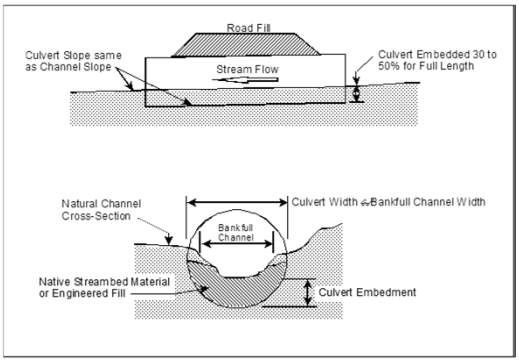
Active Channel Design Option



Stream Simulation Design Option

- Design process intended to mimic the natural stream process within a culvert
- Determination of fish passage flows, velocities, and depths not required
- Requires greater level of engineering expertise than Active Channel Option
- Suitable for the following conditions:
  - New and replacement culvert installations
  - Complex installations with channel slopes up to 6%
  - Longer culvert lengths (greater than 100 feet)
  - Ecological connectivity required

Stream Simulation Design Option



Stream Simulation and Active Channel Design Considerations

- Requires stream channel information and analysis to ensure design objectives and performance goals are met over the long term
- Information/Analyses needed:
  - Topography of the stream channel extending both upstream and downstream
  - Determination of bankfull or active channel width
  - Flood flows
  - Sediment and substrate characteristics

Hydraulic Design Option

- Design process that matches the hydraulic performance of a culvert with the swimming ability of target fish species and age class
- Determination of fish passage flows, water velocity and flow depth is required
- Knowledge of the swimming ability and behavior of the target fish is required
- Requires engineering expertise, hydrologic data analysis, and hydraulic calculations

Hydraulic Design Option

- Suitable for the following conditions:
  - New, replacement, and retrofit culvert installations
  - Low to moderate channel slopes (less than 3%)
  - Active Channel or Stream Simulation design options are not physically feasible
  - Swimming ability and behavior of the target species of fish is known
  - Ecological connectivity is *not* required
  - Use for evaluation of proposed improvements to existing culverts or other crossings

Hydraulic Design Option
Culvert Setting and Dimensions

- Minimum Culvert width is 3 feet
- Culvert slope not to exceed the slope of the channel if culvert is embedded
- Culvert slope not to exceed 0.5% if culvert is not embedded
- Where possible, the culvert should be embedded a minimum of 20%, or at least 1 foot.

Hydraulic Design Option

Maximum Water Velocity For Adult Salmonids

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

Table 6

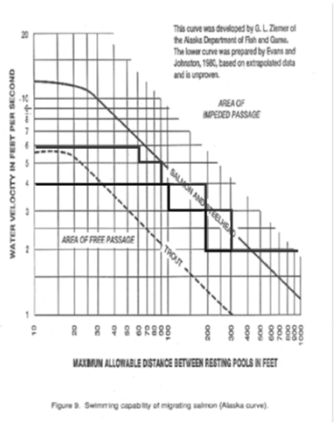


Figure 9. Swimming capability of migrating salmon (Alaska curve).

Hydraulic Design Option

Maximum Water Velocity and Minimum Flow Depth

Maximum Average Water Velocity and Minimum Depth of Flow

Species/Lifestage	Maximum Average Water Velocity (fps)	Minimum Flow Depth (ft)
Adult Anadromous Salmonids	See Table 6	1.0
Adult Non-Anadromous Salmonids	See Table 6	0.67
Juvenile Salmonids	1	0.5
Native Non-Salmonids	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.	
Non-Native Species		

Table 5

Fish Passage Window

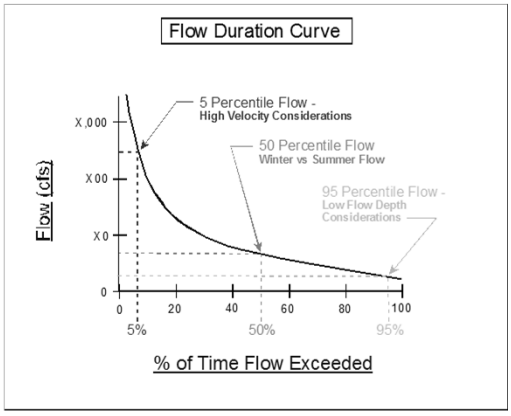
High and low fish passage flows

- Low passage flow: minimum water depth must be maintained down to the LPF
- Hi passage flow: average culvert water velocity must remain below the maximum allowed value up to the HPF

Hydraulic Design Option: Hydrology

Flow Duration – Flow Exceedance

- A flow duration curve describes the natural flow characteristics of a stream by showing the percentage of time that a flow is equal to or greater than a given value during a specified period (annual, month, migratory period.)
- Flow exceedance values are important for describing the flow conditions under which fish must be able to pass



Hydraulic Design Option: Hydrology

Recurrence Interval (or Flood Frequency)

- Statistically derived values- generally used to specify hydraulic capacity and structure design flows.
- Referred to as Q2, Q10, Q100, etc.

Hydraulic Design Option

Low Design Flow for Fish Passage

Used to determine minimum water depth within a culvert

Low Design Flow for Fish Passage		
Species/Lifestage	Percent Annual Exceedance Flow	Alternate Minimum Flow (cfs)
Adult Anadromous Salmonids	50%	3
Adult Non-Anadromous Salmonids	90%	2
Juvenile Salmonids	95%	1
Native Non-Salmonids	90%	1
Non-Native Species	90%	1

Table 4

Hydraulic Design Option

High Design Flow for Fish Passage

Used to determine maximum water velocity within a culvert

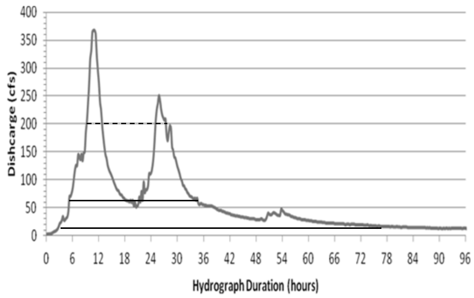
High Design Flow for Fish Passage		
Species/Life Stage	Percent Annual Exceedance Flow	Percentage of 2-yr Recurrence Interval Flow
Adult Anadromous Salmonids	1%	50%
Adult Non-Anadromous Salmonids	5%	30%
Juvenile Salmonids	10%	10%
Native Non-Salmonids	5%	30%
Non-Native Species	10%	10%

Table 3

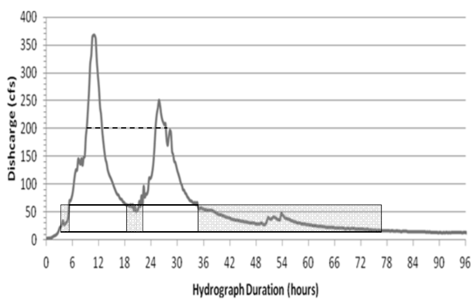
Calculating high fish passage design flows

- NMFS and DFG criteria originally set a value of 50% of the Q2 flood frequency as an acceptable "high fish passage design flow" for salmonids throughout CA.,
- NMFS is currently reviewing this standard for the south CA coast because of the "flashy nature" of streams and the limited time available for steelhead to swim up to spawning grounds
- A unique [higher] "high fish passage design flow" criteria may be warranted for Southern California steelhead passage. NMFS hopes to sponsor additional research to provide a scientific basis for any changes, if warranted

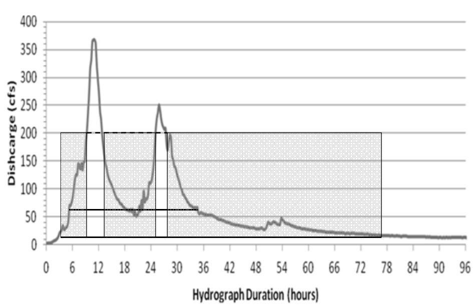
Stream Hydrograph with High Fish Passage Flows



Stream Hydrograph with High Fish Passage Flows



Stream Hydrograph with High Fish Passage Flows



More on high flow fish passage design criteria:

Case Study: San Jose Creek in Goleta CA., 2008-09 both high flow methods were calculated:

Full Q2 Flow event	50% Q2 method	1% Exceedance Flow (mean daily discharge)	1% Exceedance (15 minute interval data)	Proposed high flow design criteria**
600 cfs	300 cfs	57 cfs	78 cfs	50 cfs

** This initial high flow design criteria was proposed by designers because it was presented as the estimated flow where sediment begins to mobilize in San Jose Creek...

This is not an acceptable design criteria and will not be accepted by NMFS in ESA consultations

Hydraulic Design Option

Maximum Drop at Culvert Outlet

Maximum Drop at Culvert Outlet	
Species/Lifestage	Maximum Drop (ft)
Adult Anadromous Salmonids	1
Adult Non-Anadromous Salmonids	1
Juvenile Salmonids	0.5
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	

Table 7

Hydraulic Design Option
Miscellaneous Hydraulic Considerations

- Hydraulic controls in stream channel
- Baffles in culvert – a "least preferred design method" for modern culvert passage
- Avoid adverse conditions
  - Supercritical Flow
  - Hydraulic Jumps
  - Highly Turbulent Conditions
  - Abrupt changes in water surface elevation at inlet and outlet

CDFW Checklists

- Fish Screens
- Fish Ladders
- Boulder Weirs
- Rock Chutes
- Roughened Channels
- At-Grade Diversions
- Bank Protection
- Road Crossings
  - Stream Simulation
  - No-slope Culvert
  - Hydraulic Design Culvert
    - New
    - Retrofit
  - Culvert Baffles (retrofits)
  - Bridge/Bottomless Culvert

FEMA- and Federal Highways-funded culvert replacement projects must meet all current fish passage criteria where fish passage is required.

All Design Options: "Big Picture, Stream Specific" Considerations, Conditions and Restrictions

- Anadromous salmonid spawning areas
- High design flow for structural integrity
- Oversizing for debris
- Interior illumination
- Multiple culverts
- Bottomless culverts
- Exceptions from criteria; variance procedures

"Problem Culvert" Retrofits for Fish Passage

- Problem culverts are usually undersized and often don't have excess hydraulic capacity
- Some problems may be correctable, but culvert will probably still be a partial barrier
- Use baffles and weirs inside culverts with caution
- If possible, use hydraulic control structures (rock weirs, etc.) to improve hydraulic conditions through the crossing
- Meeting the Hydraulic Design criteria should be the goal for problem culvert retrofits
- Variances are typically required from NMFS in ESA consultations; approval is not guaranteed; a formal variance procedure is required

NOAA Fisheries Service- Southwest Region
Request for Design Criteria Variance

1. Date:

2. Name and Contact Information of Petitioner:

3. Relationship of the petitioner to the project:

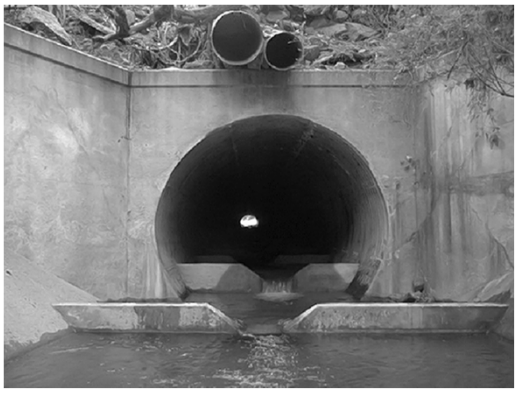
4. Brief description of the project and its location

5. Citation of aspect of NOAA Fisheries (SWR) criteria/guidance for which a variance is sought

6. Concise statement of reasoning/rationale as to why a variance is required or necessary
(hydraulic, biology, construction considerations, unusual circumstances that prohibit using a criteria, etc.)

7. Other pertinent information as necessary
e.g.- time constraints, program/policy implications, etc.

Note: all variances are considered on a case-by-case basis, based on presentation of adequate justification. Justification must be explained in terms of biological, engineering, or technical opportunities or constraints.
Variances are from established federal fish passage guidelines and design criteria in California contained in *Salmonid Passage at Stream Crossings* (NMFS 2001) and *Fish Screening Criteria for Anadromous Salmonids* (NMFS 1997)



In Conclusion

- Ideally, a culvert should not change the conditions that existed prior to it's installation
- The cross-sectional area of the stream should not be restricted by the culvert
- The channel slope should not be changed
- The channel roughness should remain the same
- Design it wide enough for stream fluvial processes to continue
- Set it deep enough to allow for the normal, or expected, variations in streambed elevation