GUIDELINES
FOR
SALMONID PASSAGE
AT
STREAM CROSSINGS

Final Draft

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National Marine Fisheries Service
Southwest Region

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 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.

Protocols for fish-barrier assessment and site prioritization are under development by the California Department of Fish and Game (CDFG). These will be available in updated versions of their *California Salmonid Stream Habitat Manual*. NMFS anticipates adopting of a set of state protocols that are consistent with these culvert guidelines. Also, when applying for the State of California ALake and Streambed Alteration Agreement," a local CDFG office will apply these guidelines in the Agreement. In addition, most streams in California support important populations of non-salmonid fishes, amphibians, reptiles, macroinvertebrates, insects, and other organisms important to the aquatic food web. Some of these may also be threatened or endangered species. Therefore, the project applicant should check with the local Fish and Game office, the U.S. Fish and Wildlife Service (USFWS), and/or tribal biologists to ensure other species are fully considered.

2.0 PREFERRED CROSSINGS

The following structure types should be considered in order of preference:

1. *Bridge* (with no encroachment into the channel 100-year flood plain)
2. *Streambed simulation strategies*: bottomless arch, embedded culvert design, or ford; embedded round metal culvert, concrete box culvert, or compound culvert designs
3. *Non-embedded culvert*: less than 0.5% slope
4. *Baffled culvert, or structure designed with a fishway*: slopes greater than 0.5%

AStreambed simulation@ refers to a situation where substrate and flow conditions within the crossing structure mimic the natural streambed above and below the structure.

In fish spawning areas, only full span bridges or streambed simulations are acceptable.

3.0 DESIGNING NEW CULVERTS

The guidelines below are adapted from stream crossing criteria published by the Oregon Department of Fish and Wildlife (ODFW, 1997) and Washington Department of Fish and Wildlife (WDFW, 1999). NMFS-Southwest Region is reviewing the guidelines in light of on-going field research.

3.1 Maximum Water Velocities at the High Flow Design Discharge

Culvert Length (ft)	*Average Velocity (ft/s), Adults*	*Average Velocity (ft/s), Juveniles*
0-60	6.0	1.0 *
60-100	5.0	1.0 *
100-200	4.0	streambed simulation
200-300	3.0	streambed simulation
Over 300	2.0	streambed simulation

* Average velocity refers to the calculated average of velocity within the barrel of the culvert.

* Juvenile velocity criteria for upstream passage are applied during the seasonal migration period of this life stage. Consult local CDFG or NMFS biologists.

3.2 Minimum Water Depth at Low Flow

For non-embedded culverts, minimum water depth during expected salmonid passage periods shall be twelve (12) inches for adult steelhead and salmon, and six (6) inches for juvenile salmon.

For embedded (streambed simulation) culvert designs, minimum depth must meet or exceed conditions found in the adjacent natural channel.

3.3 Hydrology

Salmonids migrate through waterways at select stream flows, not at all flows. Also, artificial structures can not practically provide ideal salmon passage at all flows. Thus, correct hydraulic design for a stream crossing specifies an **acceptable range of flows**, based on monthly periods when salmonids migrate. Migration periods may be unique for streams in different regions of California, so local NMFS and CDFG biologists should be consulted at the beginning of the design process.

Unimpeded passage of water, sediment, and debris over a wide range of flows is necessary to maintain channel processes, hydraulic and geologic stability in the culvert vicinity, and habitat values over a stream reach.

The **high fish passage design flow** should be based on the 2% exceedance discharge of daily occurring flow during the migration season**.** In the absence of hydrological data or methods necessary to compute the 2% exceedance discharge of daily occurring flow, the high fish passage discharge flow should be based on the discharge occupied by the cross-sectional area of the active stream channel.

The **low flow design depth** for adults should be based on the 2-year, 7-consecutive day discharge or the 95% exceedance flow for the migration period of the salmonid species of concern.

Hydraulic design for **juvenile upstream passage** is usually based on flows that are representative of the months in which juveniles typically migrate, not winter flood flow capacity. Check with NMFS or a local CDFG office to determine the salmon migration season in each watershed.

Infrequently maintained stream crossings or culverts located in rural areas should accommodate the 100-year flood flow with a **Headwater-to-Diameter Ratio** less than one (HWD<1) . This is to ensure a low risk of channel degradation, stream diversion, and failure over the life span of the crossing.

Structural design of stream crossings must be sufficient to pass the maximum storm with a recurrence interval of at least 100 years.

3.4 Other Hydraulic Considerations

Besides the upper and lower flow limit, other hydraulic effects need to be considered, particularly when installing a culvert:

Water surface elevations in the stream reach must exhibit **gradual flow transitions**, both upstream and downstream. Abrupt changes in water surface and velocities must be avoided, with no hydraulic jumps, turbulence, or drawdown at the entrance. A **continuous low flow channel** must be maintained throughout the entire stream reach.

In addition, especially in retrofits, **hydraulic controls** may be necessary to:

- provide resting pools
- concentrate low flows
- prevent erosion of stream bed or banks
- allow passage of bedload materials

Culverts and other structures should be **aligned with the stream**, with **no abrupt changes in flow direction** upstream or downstream of the crossing. This can often be accommodated by changes in road alignment or slight elongation of the culvert. Where elongation would be excessive, this must be weighed against better crossing alignment and/or modified transition sections upstream and downstream of the crossing. In crossings that are unusually long compared to streambed width, natural sinuosity of the stream will be lost and sediment transport problems may occur even if the slopes remain constant. Such problems should be anticipated and mitigated in the project design.

Bottomless arches and **embedded culverts** shall be placed at or near the same gradient as the natural streambed and shall be wider than the active stream channel. The **active channel** is considered to be the wetted channel up to the ordinary high water marks. Embedded culverts must be one foot deeper than the streambed grade, or embedded by at least 20% of its height; whichever is greater. Hydraulic capacity must be compensated for expected deposition in the culvert bottom.

4.0 RETROFITTING OR REPLACING CULVERTS

For future planning and budgeting at the state and local government levels, **redesign and replacement** of substandard stream crossings will contribute substantially to the recovery of salmon stocks throughout the state. Unfortunately, current practices do little to address the problem: road crossing corrections are usually made by some modest level of incremental, low cost “improvement” rather than re-design and replacement. These usually involve bank or structure stabilization work, but frequently fail to address fish passage. Furthermore, bank stabilization using hard point techniques frequently denigrates the habitat quality and natural features of a stream. Nevertheless, many existing stream crossings can be made better for fish

passage by cost-effective means. The extent of the needed fish passage improvement work depends on the severity of fisheries impacts, the remaining life of the structure, and the status of salmonid stocks in a particular stream or watershed.

For work at any stream crossing, **site constraints** need to be taken into consideration when selecting options. Some typical site constraints are ease of structure maintenance, construction windows, site access, equipment, and material needs and availability. The decision to replace or improve a crossing should fully consider actions that will result in the greatest net benefit for fish passage. If a particular stream crossing causes substantial fish passage problems which hinder the conservation and recovery of salmon in a watershed, complete redesign and replacement is warranted. *Consolidation and/or decommissioning of roads can sometimes be the most cost-effective option*. Consultations with NMFS or CDFG biologists can help in selecting priorities and alternatives.

4.1 Culvert Retrofit Guidelines

The goal for retrofitting culverts is to achieve the same results as a new culvert design. If this is not achievable, the following guidelines should be used:

1) Non-embedded culverts must be backwatered using hydraulic controls, with the downstream end **fully submerged** for adult passage. If a jump into the culvert is planned, the project designers must document why the culvert can not be designed without a jump.
2) A **change in water surface elevation** (a jump) of up to one foot is acceptable for adult passage conditions, provided water depth and velocity in the culvert meet all other hydraulic guidelines.
3) A **jump pool** must be provided that is *at least* 1.5 times the jump height, or a minimum of two feet deep, whichever is deeper,.
4) Culverts that are too long or too high gradient require **resting pools**, or other forms of velocity refuge, for fish of all life stages.
5) When the existing grade of a culvert results in excessive velocities, add **roughness elements** to the culvert. Roughness elements may improve fish passage conditions, but they are not intended as a remedy for culverts that are grossly beyond the velocity limits specified in Section 3.1.
6) If the crossing contains multiple culverts, retrofitting with baffles in one of the culverts may be sufficient as long as **low flow channel continuity** is maintained and the culvert is reachable by fish at low stream flow.
7) **Baffles** and **Low Flow Channels** may be important elements in retrofitting culverts (in lieu of replacement), but they will often decrease culvert capacity and increase debris clogging and deposition. Thus, if a culvert is retrofitted with baffles, large roughness elements, or a low flow channel, road owners or operators need to compensate for loss of hydraulic capacity by increasing inspections and timely maintenance.

8) Where a **fish ladder** is required, NMFS or CDFG fish passage specialists should be consulted.

5.0 GENERAL RECOMMENDATIONS

Trash racks should not be used near the culvert inlet because **debris** will accumulate. This leads to severely restricted fish passage, and potential injuries to fish.

Livestock fences should be avoided in streambeds, including above or below stream crossings. Where fencing cannot be avoided, it should be removed during adult salmon upstream migration periods. Otherwise, a minimum of 9 inches clear spacing should be provided between pickets, up to the high flow water surface. Timely clearing of debris is also important, even if flow is getting around the fencing. Cattle fences that raise with increasing flow are highly recommended.

Where sub-surface flow may occur, **cut-off walls** shall be included in the stream crossing and in the downstream weir designs.

Culverts over 100 feet in length may require **lighting within the culvert barrel** provided by either a vertical riser (for natural light) or artificial daytime lighting at 75 foot intervals or less.

NMFS and CDFG set in-stream work windows in each watershed. Work in the active stream channel should be avoided during the times of year salmonids are present. Temporary crossings, placed in salmonid streams for water diversion during construction activities, should meet all of the guidelines in this document. However, if it can be shown that the location of a temporary crossing in the stream network is not a fish passage concern at the time of the project, then the construction activity only needs to minimize erosion, sediment delivery, and impact to surrounding riparian vegetation.

Construction disturbance to the area should be minimized and the activity should not adversely impact fish migration or spawning.

If a stream is temporarily diverted by pumps, in order to facilitate construction, an acceptable **fish screen** must be used to prevent entrainment or impingement of small fish. Contact NMFS or CDFG hydraulic engineering staff for appropriate fish screen specifications.

If salmon are likely to be present, **fish clearing or salvage operations** should be conducted by qualified personnel prior to construction. If these fish are listed as threatened or endangered under the federal or state Endangered Species Act, consult directly with NMFS and CDFG biologists to gain authorization for these activities. Care should be taken to ensure fish are not chased up under banks or logs that will be removed or dislocated by construction. **Return any**

stranded fish to a suitable location in a nearby live stream by a method that does not require handling of the fish.

Culverts shall only be installed in a de-watered site, with a **sediment control** and **flow routing plan** acceptable to NMFS or CDFG. The **work area shall be fully restored** upon completion of construction with a mix of **native, locally adapted, riparian vegetation**. Use of species that grow extensive root networks quickly should be emphasized. Sterile, non-native hybrids may be used for erosion control in the short term if planted in conjunction with native species.

Unacceptable wastewater associated with project activities shall be disposed of off-site in a location that will not drain directly into any stream channel.

6.0 POST-CONSTRUCTION EVALUATION

Post-construction evaluation is important to assure the intended results are accomplished, and that mistakes are not repeated elsewhere. There are three parts to this evaluation:

1) Verify the culvert is installed in accordance with proper design and construction procedures.
2) Measure hydraulic conditions to assure that the stream meets these guidelines.
3) Perform biological assessment to confirm the hydraulic conditions are resulting in successful passage.

NMFS and/or CDFG technical staff may assist in developing an **evaluation plan** to fit site-specific conditions and species. The goal is to generate feedback about which techniques are working well, and which require modification in the future. These evaluations are not intended to cause extensive retrofits of any given project unless the as-built installation does not reasonably conform to the design guidelines, or an obvious fish passage problem continues to exist. Over time, the NMFS anticipates that the second and third elements of these evaluations will be abbreviated as clear trends in the data emerge.

7.0 MAINTENANCE AND LONG TERM ASSESSMENT

Any physical structure will continue to serve its intended use only if it is properly maintained. During the storm season, timely inspection and removal of debris is necessary for culverts to continue to move water, fish, sediment, and debris. In addition, all culverts should be inspected at least once annually to assure proper functioning. **Summary reports** should be completed annually for each crossing evaluated. An annual report should be compiled for all stream crossings and submitted to the resource agencies. A less frequent reporting schedule may be agreed upon for

proven stream crossings. Any stream crossing failures or deficiencies discovered should be reported to CDFG in the annual cycle and corrected promptly.

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http://www.nwr.noaa.gov/1salmon/salmesa/4ddocs/orfishps.htm

FishXing software and learning systems for the analysis of fish migration through culverts
http://www.stream.fs.fed.us/fishxing/

USDA Forest Service Water-Road Interaction Technology Series Documents
http://www.stream.fs.fed.us/water-road/index.html

British Columbia Forest Practices Code Stream Crossing Guidebook for Fish Streams
http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/stream/str-toc.htm

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