APPENDIX A(1)

Definition of Barriers

Barriers to fish migration exist in many ways shapes, and forms. The range of salmon and steelhead has always been limited to some extent by natural features, such as sandbars, landslides, waterfalls, and boulder cascades. Man has further truncated their range with an astounding variety of instream features and effects, such as dams, culverts, water diversions, tidegates, and many others. The habitat fragmentation resulting from this expansion of impediments to fish passage has played a major role in the decline of salmon and steelhead populations worldwide.

The following explanations provide a more thorough examination of some of the barriers identified and assessed in this report.

However, barriers should not be examined in a vacuum. Appendix B(1) provides an overview of the broader range of habitat conditions necessary for the survival and perpetuation of anadromous fish stocks. Fish passage improvement proponents are urged to examine proposed barrier modification or removal projects in the context of all necessary habitat conditions.

NATURAL FEATURES

Upper Limits to Anadromy

Sustained slope can be a useful tool to estimate upper limits to anadromy. The California Department of Fish and Game has conducted a literature review of this subject and selected a sustained slope of >8% as measured off of a topographic map to define the upper limit of anadromy for the California Salmonid Stream Habitat Restoration Manual, Section IX. That guideline is offered with the caveat that field level knowledge is best to use, since slopes from topographical maps often fail to capture important geographic features, such as bedrock falls or chutes.

The Oregon Department of Forestry rules characterize gradient barriers as natural falls and chutes of >8’ for adult salmon and steelhead, and >4’ for resident trout. Any falls >2’ must have a jump pool that is 1.25 times deeper than the jump height. Channel steepness with pools is characterized as follows: >20% for 30’ or more more adult salmn and steelhead and 20% for >20’ for resident trout. Channel steepness without pools is >12% for >30’ for adults and >12% for >20’ for resident trout (Robison, et al. 1999 Oregon Road/Stream Crossing: Restoration Guide). DFG and Taylor, below, found this to be too steep for anadromy in California.

Washington State Department of Fish and Wildlife defines a natural point barrier as a falls or chute > 12’ in height, and defines a gradient barrier as a sustained slope of >20% over a distance of >160 meters, though this analysis fails to break out particular species (WDFW 1998 SSHEAR Program). DFG considers this too steep for California.

The Washington Department of Transportation initially considered a >7% slope for >160 meters as a gradient barrier, but then, following extensive field surveys, increased the gradient to >12% for >160 meters (WDOT, 1997).

In the experience of one consultant, field checks of slopes measured at >8% over a >200' distance from topo maps typically yield some natural point barrier within that stream reach. This professional always tries to use points identified in the field by recent stream surveys to accurately pinpoint the true limit of anadromy (Taylor, pers. Comm., 2002).

Powers and Osborn (1982) presented a detailed analysis of waterfalls and culverts as physical barriers to upstream migration by salmon and trout. Analysis techniques are based on combining barrier geometry and stream hydrology to define the existing hydraulic conditions within the barrier. These conditions then can be compared to known fish capabilities to determine fish passage success. A systematic classification system is developed which defines the geometric and hydraulic parameters for a given stream discharge. This classification system is organized in a format that can be used to catalog barriers in fisheries enhancement programs. The analysis compares hydraulic conditions and fish capabilities in detail, as the fish enters the barrier, attempts passage and exits the barrier. From this comparison the parameters which prohibit passage can be determined. Hydraulic conditions are a function of the barrier qeometry and stream hydrology, and the stream flow is constant at the time each step in analysis is performed. Therefore, the barrier geometry must be modified to alter the hydraulics to meet fish capabilities. Modifications can be accomplished by: installing instream "control" structures which deflect the flow or raise pool levels; blasting to alter or remove rock; and installing a fishway to bypass the barrier. Modifications should not be attempted until the analysis defines the excessive parameters which should be modified.

Log Jams

Log jams, often associated with inappropriate timber harvest practices, are an historically natural feature of some watersheds which may or may not serve as barriers to fish passage, and which may provide important habitat conditions for anadromous salmonids. Log jams can provide habitat complexity, provide cover, trap sediment, and stabilize eroding banks, recreating conditions under which anadromous salmonids adapted over thousands of years. They can also accelerate erosion, impair fish passage, and have other deleterious effects. Log jams are best evaluated for passability and overall ecological import on a case by case basis.

Many of the most severe log jam and debris barriers present in coastal watersheds were treated to improve fish passage by the DFG during the 1970s in conjunction with the California Conservation Corps. Although criticized today for the efficiency with which field crews removed woody debris from streams under this program, critics often fail to acknowledge that treated barriers were often anthropogenic in origin, resulting from inappropriate timber harvest practices, and posed severe impediments to fish passage. On page 7 of the report, a photo of Terwer Creek illustrates the scale of a contemporary log jam likely impeding fish passage. The American Fisheries Society publication “Stream Obstruction Removal Guidelines” (1983) provides a succinct, though somewhat outdated, examination of log jam treatment methodology. Overall, many fisheries biologists consider log jams to be of low priority for treatment at this time (Flosi, Harris, personal communication).

ANTHROPOGENIC FEATURES

Dams

Dams benefit society by providing water storage for flood control and navigation; debris containment; electrical power generation, recreation, fish and wildlife habitat, and improving water quality (Collier and others 2000). However, impacts of dams on migrating fish, natural geomorphic processes in streams such as sediment transport, and flows and temperatures of river systems have become evident. The environmental effects of dams and other structures have become apparent over time through observation, study and evaluation. With declines of many fish populations in California and listing of salmonids under the federal Endangered Species Act, all dams and other structures are being considered in restoration and recovery efforts.

While dams can benefit society, today science shows they also cause considerable harm to rivers. Dams change the chemical, physical, and biological processes of rivers and related fish and wildlife, and reduce or eliminate economically profitable recreational opportunities. Dams block free-flowing river systems, hindering the flow of nutrients and sediments and impeding fish and wildlife migration. Upstream of dams, stagnant reservoir pools and altered flow timing confound the reproductive cues and behaviors of many fish species. Dams also alter water temperatures and oxygen levels critical to species survival and to good water quality. Because dam owners often own large parcels of land above and below dams, significant portions of publicly owned rivers are effectively inaccessible to members of the public.

The process of blocking a moving river inherently changes the ecosystem, destroying the natural processes dependent on that system-and hindering recreational activities. The impacts can include:

- Inundating wildlife habitat
- Reducing river levels
- Blocking or slowing river flows
- Altering timing of flows
- Fluctuating reservoir levels
- Altering water temperatures
- Decreasing water oxygen levels
- Obstructing the movement of gravel, woody debris, and nutrients
- Blocking or inhibiting upstream and downstream fish passage
- Altering public river access
- Impacting negatively the aesthetics and character of a natural setting

Studies show that fish populations in rivers have declined drastically from historic levels due in large part to dams and water diversion projects. Dams have particularly harmed migratory fish such as salmon, steelhead, American shad, striped bass, sturgeon, alewife, herring, and American eel. Dams can significantly delay the time that it takes for juvenile migratory fish to be flushed to the ocean by turning fast-flowing rivers into slow-moving reservoirs. This delay is very harmful to the fish as their bodies undergo physiological changes that prepare them to survive in salt water. This evolutionary biological process cannot be delayed to accommodate delays in reservoirs. The stagnant reservoirs also expose young fish to predators and disease and often lethally high water temperatures. Further, many fish die when forced through the power turbines associated with hydropower dams.

Dams also take a heavy toll on adult fish returning from the ocean to spawn upstream. Many dams provide no mechanism to allow fish to pass above the dam, thus blocking off thousands of miles of spawning habitat nationwide. When fish passage does exist, many migratory fish have trouble finding the fish ladders on dams or die when exposed to high water temperatures in the ladders. Scientists believe that many of the adult fish that eventually reach their spawning grounds are often too exhausted from the journey over the dams and through the unnaturally warm reservoirs to spawn successfully. As a result, the number of adults returning to spawn is often far below the number needed to ensure the survival of many migratory species.

In the Pacific Northwest, chinook, sockeye, pink, chum, and coho salmon, along with steelhead and cutthroat trout have all experienced dramatic declines on dammed rivers. Salmon runs that numbered in the millions before the era of dam building have now dwindled to only hundreds, and in many instances have been completely wiped out. A startling 80 to 95 percent of Snake River salmon are killed by the series of eight federal dams and reservoirs that these migrating fish must pass on their trip to and from the ocean. This type of destruction is by no means a Northwest phenomenon. The US Fish and Wildlife Service estimates that 91 percent of migratory fish habitat in northern New England is blocked by dams. These dams have contributed to the reduction of Atlantic salmon populations to less than one percent of historic levels, with the native salmon fully extirpated from many of New England's rivers. And American shad, which was once a cultural icon for the Mid-Atlantic, has been decimated to the point that people no longer realize its historical significance.

Reversing these negative impacts and restoring damaged ecosystems, including rebuilding depleted fish and wildlife populations, has often been a significant reason in decisions to remove dams. For example, numerous dams in the case studies section of this report, such as Butte Creek in California, was taken out in order to reestablish a free-flowing stream and the fish and wildlife that depend on a natural river system, as were numerous other dams around the country.

Adult and juvenile fish migrating upstream and downstream are completely blocked by very large dams that have no fish ladders or other ways to get past. Migratory blockage at large dams is due primarily to the height limitations for fishways and the ability of fish to climb or swim extreme elevations, and loss of downstream migrants in large reservoirs and through turbines (Bell 1990). To fish accustomed to rivers, a lack of current in reservoirs causes them to wander upstream and downstream in search of an exit from the reservoir. Wandering can be fatal to fish because of the energy they expend and their susceptibility to predation (Bell 1990). Dams as small as a foot high can prevent passage if there is not enough streamflow, or if the downstream face or footing of the dam is too long or shallow for fish to overcome. Downstream-migrating juvenile salmonids face stress, injury, and death by passing over the tops of dams and landing on concrete or rocks below, becoming caught in recirculating hydraulics at the base of dams, or becoming prey to piscivorous fish that congregate at dams or ladders.

Over the past 75 years, dams in Southern California streams constructed for water withdrawal and diversion have caused considerable loss of steelhead freshwater habitat (McEwan and Jackson 1996). Habitat fragmentation and population decline increases the chances for inbreeding, loss of rare alleles, and genetic drift, all processes that impact species' ability to respond to environmental changes over the long-term and remain viable. Research to determine the level of genetic diversity of rainbow trout populations from Big Pico Creek south to Pauma Creek in Southern California was conducted to determine levels of genetic diversity (Nielsen and others1997). It was determined that rainbow trout that retained access to the ocean had significantly higher levels of genetic diversity than those who's migrations were blocked by dams.

Alteration of stream continuity by structures such as dams and riprap stabilization has contributed to the decline of Chinook salmon and steelhead trout populations. Kope and Botsford (1990) found that the overall decline of Sacramento River salmon was closely tied to the construction of the Red Bluff Diversion Dam. Comstock (1992) documented a diversion dam in the Santa Clara River drainage that blocked migration of adult steelhead trout and diverted the fish to percolation basins where they were killed. Riprap bank stabilization was identified as a leading cause of declining salmon populations in the Sacramento River (Buer and others1984). The most important source for spawning gravel in the Sacramento River is bank erosion. Riprap bank stabilization reduces the amount of gravel that is available for salmon spawning habitat in this system (Shields 1991).

Sustained unnatural flows below dams cause loss of breeding and rearing habitat for amphibians, such as the arroyo southwestern toad of southern California (Sweet 1991, USFWS 1994), and other aquatic fauna. Habitat loss affects larval, newly metamorphosed and adult life stages of aquatic fauna, causing high mortality (Sweet 1992).

Chinook salmon and rainbow trout were once important parts of aquatic ecosystems at low to middle elevation in western Sierra Nevada streams. Dams have excluded these species from much of their former habitat, which has significantly altered the stream communities of which they were once part. These species were not only abundant by themselves but also provided food and energy for other native fishes (Moyle and Randall 1998). Populations of bald eagles and other animals that depend on migrating salmon for food may decrease dramatically if the salmon are eliminated (Spencer and others 1991). Water quality and nutrient cycling can also be impacted by loss of key faunal components. Salmon release nutrients when they die after spawning, affecting algal biomass and primary production (Kline and others 1990) as well as secondary insect consumers (Schuldt and Hershey 1995). This nutrient release is considered essential for maintaining productivity of nursery areas for future salmon stocks (Mathison 1972). Consequently, when dams block salmonid migration routes, patterns of nutrient cycling in entire river ecosystems can be altered.

For further information about dam decommissioning, American Rivers has produced a report entitled Dam Removal Success Stories, available at
http://www.americanrivers.org/damremovaltoolkit/successstoriesreport.htm

Some postulate that landlocked populations of anadromous fish, specifically steelhead, located above impassable dams may contribute to the maintenance of remnant populations below the dams, suggesting one-way passage of steelhead during one phase of their life history. This hypothesis awaits further examination to determine its validity.

Summer Dams

The National Oceanic and Atmospheric Administration Fisheries Division recently released a report on "The Effects of Summer Dams on Salmon and Steelhead in California Coastal Watersheds and Recommendations for Mitigating Their Impacts." The full report can be viewed at http://swr.nmfs.noaa.gov/hcd/policies/summer dams.pdf Excerpts from that report appear below.

In rivers and streams across California, summer dams are often installed during the dry season to impound water for recreation, irrigation, groundwater recharge, and livestock watering. These dams affect salmon and steelhead by creating unnatural and adverse habitat conditions including: blocking and/or restricting fish movement, loss of habitat diversity and complexity, increases in water temperature, altered stream flows, increased turbidity and sedimentation, and habitat for salmonid predators.

Summer dams are quite common in California. Although their exact number and locations are not known, it is widely acknowledged that they are numerous and widespread throughout the State. Within the Russian River basin alone, it has been estimated that several hundred summer dams are installed annually (Chase et al. 2000). The widespread use of summer dams is a source of significant concern as is the fact that many of these dams are constructed illegally without going through any type of formal permitting or environmental review process. Although the total impact of summer dams to listed salmonids cannot be quantified based on the available data, the impact is likely severe within many designated critical habitat areas for salmon and steelhead trout.

A detailed understanding of the impacts of summer dams is necessary to the development of informed recommendations and a more consistent approach to the review of existing or proposed summer dam projects.

Summer dams in the state of California are regulated and permitted through the California Department of Fish and Game (CDFG) 1601 permit process. Unfortunately, many summer dams do not go through this process as they are constructed by individuals or organizations who are either not aware of the existing regulations or choose to ignore them. This problem has been compounded by the fact that enforcement of the regulations governing the construction of summer dams has, in many areas of California, been relatively difficult.

Although some of the more extensive facilities are operated by municipalities and public agencies, most summer dams are constructed and operated by private parties. Summer dams are used for range improvement, irrigation, recreation, groundwater recharge, and as municipal and private water sources. Summer dams are constructed using a number of techniques the two most common of which are know as flashboard and earth berm dams. Flashboard dams consist of removable wooden planks and a permanent foundation, wing-walls, and spillway apron. Earthen berm summer dams are constructed by pushing up berms of riverbed or bank material, or by placing gravels, rock, and/or other materials into the stream channel.

Summer dams adversely affect salmon and steelhead as well as habitat elements considered essential to their survival. Summer dams affect salmonid populations either directly through mortality, physical damage, and disruption of life history patterns and/or indirectly through adverse modification and loss of critical habitat. The changes to the physical structure of the stream channel, coupled with the impoundment of water, dam construction/removal methods, as well as materials commonly used for summer dams, create conditions that are detrimental to salmon and steelhead adults, smolts, juveniles, fry, and eggs.

Salmonids require cool clear running water to support their freshwater life history stages (Bjornn and Reiser 1991). Essentially, the free flowing stream environment preferred by salmonids is converted to a lake or pond environment to the extent which the impoundment affects surface flows and the stream channel upstream of the summer dam. This may be for a few tens of feet, several hundred yards, or thousands of yards depending upon the size of the summer dam and size of stream or river on which it is located.

In some cases, summer dams may be installed as early as April, but most are probably installed in June. In most cases summer dams are removed at the end of summer or in early fall, prior to increases in river flows which could result in localized flooding or damage to permanent dam infrastructure. Installation in April would affect steelhead and coho migration to spawning grounds, steelhead and coho spawning, steelhead and coho egg incubation, and steelhead and coho smolt runs in many river systems in California. Installation in June may also affect egg incubation and alevins of steelhead and perhaps coho salmon. The presence of summer dams during the late spring, and through the summer will affect juvenile (including young of the year) steelhead and coho. Depending upon how long summer dams remain in streams, their presence, and removal, could affect adult chinook migration.

The analysis of the effects of summer dams on salmonids and their critical habitat uses the following categories:

- stream flow;
- stream channel and riparian areas;
- water temperature;
- habitat diversity and complexity
- fish passage;
- predation;
- sedimentation and turbidity;
- dam construction and removal; and
- cumulative effects of summer dams.

Each type of effect is analyzed in relation to salmon and steelhead life history stages and constituent elements of critical habitat. Because migration timing varies by species and river system, as does the timing of summer dam installation and removal, some of the effects to migrating and spawning salmonids, and their eggs and alevins, will depend upon time specific information not currently available. Effects to juveniles of each species will occur if they are present in the river system of concern. Chinook juveniles spend less time in freshwater streams than coho or steelhead, and may avoid many of the effects of summer dams in some cases. However, this will depend upon the specific run times of each chinook ESU.

Stream Flow

When summer dams are installed they may de-water stream reaches downstream by preventing surface flow from passing downstream of the impoundment structure. The amount of stream area de-watered, and duration of flow suppression, will vary based upon a variety of factors, including the amount of flow in the river or stream, the structure of the dam itself, watershed climate and geologic conditions, and water use within the watershed. In addition, the removal of summer dams may result in quickly dewatering upstream areas. In some cases, migrating and spawning adult steelhead may still be present in rivers and streams when summer dams are installed. However, salmonid eggs, alevins, and juveniles, including young of the year (YOY), are more likely to be present at this time. The removal of summer dams will affect coho and steelhead juveniles, and could also affect migrating adult chinook.

Quick reductions in flow and dewatering of the stream channel could harm several life history stages of salmonids including migrating adults and smolts, eggs, fry, alevins, and juveniles (including YOY) by stranding them in small pools if flows become fragmented and on the dry river bed if they are unable to escape to areas still containing water. Salmonid eggs are more tolerant of dewatering than other life history stages. Chinook eggs were found to have a 98% survival rate when dewatered once for twelve consecutive days (this survival rate declined considerably after repeated dewatering). However, nearly all pre-emergent chinook juveniles (alevins) died after experiencing a single six hour dewatering (Becker et al. 1982, 1983).

Adult and juvenile salmon and steelhead separated from water by stranding will not survive longer than ten minutes (Washington Department of Fisheries 1992). Stranded fish in pools unconnected to surface flows can survive for longer periods of time, perhaps several weeks or months. However, fish in such a condition are often exposed to higher rates of predation, higher temperatures, and/or oxygen depletion (Cushman 1985, Washington Department of Fisheries 1992). Returning higher flows may provide respite from these conditions, but the fitness of these fish, and therefore their chance of survival, has likely been reduced by the higher physiological costs of surviving in poor habitat conditions.

Exact behavioral mechanisms in salmonid juveniles for responding to changes in flow rates are not well understood (Washington Department of Fisheries 1992). For example, juvenile steelhead are more vulnerable to stranding than adults, and fry are particularly vulnerable in cobble substrates. Fry have been found in laboratory experiments to retreat to spaces among cobbles when dewatering occurs, instead of moving to areas still maintaining water (Washington Department of Fisheries 1992). NOAA FISHERIES and CDFG have documented the stranding of juvenile steelhead during the removal of a summer dam on House Creek during 1999. These fish would have died had they not been rescued by CDFG (NOAA FISHERIES 2000).

Summer dam removal may also flush YOY salmon and steelhead downstream to unsuitable habitat areas if removal results in high stream flows directly downstream of the dam. If refugia are not available to escape high flows, YOY salmonids will be carried downstream and could wind up in unsuitable habitats.

Stream Channel and Riparian Areas
Summer dams create homogenous relatively featureless stream reaches devoid of suitable cover and habitat complexity for rearing salmon and steelhead juveniles. Mechanical means (bulldozers) are often used to re-contour stream beds and banks upstream of summer dams to create areas for recreational swimming. This is often done by flattening and widening the stream bed, and re-contouring stream banks to produce a gently sloping beach area. Summer dams that are created by placing flashboards in permanent structures such as concrete wing walls are also likely to impound sediment and large woody debris during flood flows, even when the flashboards are removed. Such impoundments restrict the supply of sediment and large woody debris (LWD) downstream, raises the channel bed behind the dam, and may result in maintenance needs that further disrupt the stream channel near these dams. The result is usually a lack of pool/riffle structure and habitat complexity in the area affected by water impoundment.

In addition to the mechanical disruption of the stream channel, the impoundment of water is also likely to contribute to the degradation of stream habitat by flooding riparian areas (often now former riparian areas if the dam has been installed for many decades) with water during the period a dam is in place. Many riparian plant species, such as most stream side trees in California, cannot survive for long periods of time in flooded environments. Summer dams will eventually preclude such riparian vegetation from the original channel banks, resulting in the potential for increased bank instability during winter storms, widening channels, loss of channel pool/riffle structure, and lack of vegetative cover. The functional values of riparian corridors and the benefits they provide to aquatic systems in general, and stream fish populations in particular, are well documented (Hall and Lantz 1969; Karr and Schlosser 1978; Lowrance et al. 1985; Wesche et al. 1987; Gregory et al. 1991; Platts 1991; Welsch 1991; Castelle et al. 1994; Wang et al. 1997). Loss of riparian vegetation due to summer dams may increase fine sediment input to flowing water, reduce insect drop, and decrease amount of woody debris recruitment into the system.

Water Temperature

Impoundment of water at summer dams will often increase the amount of water surface exposed to direct solar radiation. This heated surface water is often returned to the stream downstream of the summer dam by flowing over a spillway or over the top of the dam. Increases in stream temperature are a significant concern for salmon and steelhead, as stream temperature affects their metabolism, behavior, and mortality (Bjornn and Reiser 1991). Many streams in California are already at or near high temperature thresholds identified in the literature for salmon and steelhead. A study of summer spreader dams in California found that those creating large unshaded ponds typically had water temperatures higher than the unaffected stream reaches in the Guadalupe River and in Los Gatos and Coyote Creeks (Habitat Restoration Group 1994). The study indicated that due to the already high water temperatures found in these creeks, additional warming from these dams, even if relatively small, would still be of concern for steelhead. Additionally, the first year of bottom releases from these dams did not appear to alleviate downstream warming. (Habitat Restoration Group 1995).

Habitat Diversity and Complexity

Salmonid habitat diversity is the frequency of occurrence, spatial arrangement, and mix of habitat types present within a given stream reach – pools, riffles, glides, pocket water, and cascades. Habitat complexity is the presence and mix of physical stream features – cobbles, boulders, small and large woody debris, undercut banks, and alcoves. Salmonid populations require relatively high levels of habitat diversity and complexity. This is especially true for rearing juvenile salmon and steelhead. Researchers working in small coastal California streams have noted that the abundance of juvenile coho salmon and steelhead trout is significantly higher in stream sections containing a diverse mix of habitat types and high levels of habitat complexity (unpublished data, NPS 1999).

A key component of habitat diversity is pool/riffle structure. Pool/riffle structure is particularly important to salmonids, as it creates conditions suitable for their survival. In streams, pools are inter-spaced between and among riffles and other areas of higher velocity water. The quantity and spacial arrangement of pools, riffles, and other instream habitat types will vary based on stream size, gradient, local geology, riparian inputs, and management impact. Coho salmon juveniles prefer pool habitat (Reeves et. al. 1989, Bisson et al. 1988, Hall and Knight 1981, Chapman and Bjornn 1969, Shapavolov and Taft 1954) while juvenile steelhead are frequently most abundant in the transition zone between pool and riffle habitat areas (unpublished data, NPS 1999).

Pool/riffle structure provides spawning areas for salmonids. Spawning salmon require clean gravels with interstitial water flow to supply salmon eggs and alevins with oxygen and remove wastes. The flows associated with riffles help force water through gravels near pool tail-outs, for example. Summer dams often degrade and remove stream pool/riffle structure in the area affected by water impoundment and the use of heavy equipment. If salmon spawn successfully, eggs and alevins may become swamped by ponded water if summer dams are then installed during incubation periods. Such habitat conditions will result in high rates of mortality for both salmonid eggs and alevins.

Pool/riffle structure provides year round rearing areas for coho and steelhead, and is used by chinook juveniles during their shorter freshwater rearing life stage. While summer dams might be thought by some to provide pool habitat for salmon and steelhead rearing, it should be emphasized that “the presence of abundant space does not necessarily mean there will be large numbers of fish. The space must be in the right context with other needs of the fish” (Bjornn and Reiser 1991). Lake and pond-like areas created by summer dams degrade the other habitat needs of fish and: 1) are unlikely to provide the abundant cover needed by salmonids; 2) restrict their movement in streams; 3) create conditions supportive of fish that prey on salmonids; and 4) do not provide the diversity of stream habitats needed by salmon and steelhead juveniles, especially steelhead.

Steelhead juveniles are found in many different types of stream habitats (Shapavolov and Taft 1954, Bisson et al. 1988) including riffles. In general, steelhead are thought to feed near pool riffle crests, in order to catch aquatic macro invertebrates as they are swept into pools, and/or utilize areas of swifter water for feeding. Summer dams remove tributary pool/riffle structure and replace it with large ponded areas of slack water. Thus, they are likely to reduce the quality of habitat for steelhead by reducing the amount of riffle and pool/riffle crest areas available. Chinook juvenile numbers in Idaho have been found to increase as the size of natural stream pools increased until a threshold size is reached, when more and more of the downstream pool areas went unused (likely due to limited food supply downstream of the pool inlet) (Bjornn and Reiser 1991). As noted in the species description, coho salmon prefer deep, dark, dense pools with cool temperatures and good food supplies.

There is evidence that steelhead will utilize thermally stratified natural pools in streams in California if such areas provide the only refuge from high temperatures (Nielsen et al. 1994; Mathews and Berg 1997). While some larger summer dams may create thermally stratified pools that could act as a temperature refuge, it must be remembered that they also increase temperature problems downstream, restrict the ability of steelhead to move upstream or downstream, and create conditions supportive of fish that prey on salmonids.

Fish Passage

Migration timing for spawning runs of salmonids will vary by species, river system, and fluctuations in climate conditions. In California, coho salmon generally migrate to spawning areas from September through February, steelhead generally migrate from November through June, and chinook salmon may be found migrating during a portion of the time between March through December, depending upon the run (Weitkamp et al.1995, Busby et al. 1996, Meyers et al.1998).

Most summer dams are created by pushing up stream bed materials. However, some are created by placing temporary structures among more permanent modifications to stream channels. Dams placed in streams during adult spawning runs will prevent adult salmonids from migrating unless fish passage is provided. Most summer dams do not provide passage. Adult steelhead prevented from migrating to spawning grounds upstream of the dams may not be able to complete their life cycle, thus further reducing the spatial distribution of the species. It is speculated that many summer dams are installed prior to June, making them likely to impact steelhead migration, spawning, and egg incubation. On the Russian River, dams have often been installed during mid-spring prior to Memorial Day.

In addition to timing concerns, summer dams that are created through the use of permanent seasonally removable installations using flashboards may impede salmonids from migrating even with flashboards removed due to constriction of the channel at the dam site and resulting stream flow velocity barriers, and/or physical impediments caused by the permanent dam foundation. In addition, the dam may have a concrete apron (drop structure) to provide protection from storm flows which prevents salmonids from jumping over and through the dam. Drop structures associated with summer spreader dams have been found to completely block salmon migration (Habitat Restoration Group 1995). Salmonids hindered from migrating by summer dams with drop structures and/or wing walls may be exposed to increased chances of predation and higher metabolic rates further reducing their survival chances and ability to spawn successfully. Salmonids prevented from migrating will directly decrease an ESU's viability.

Smolt timing for coho in California may occur from February through July. Chinook smolt timing in California is variable, and may occur at almost any time of year depending upon the specific run and climate conditions. Steelhead (smolts and surviving adults) generally emigrate to the ocean from February through June (Weitkamp et al.1995, Busby et al. 1996, Meyers et al.1998). If summer dams are installed during smolt runs, smolts will become trapped upstream of the dams and will not be able to complete their life cycle, thus reducing the number of salmon and steelhead likely to return from the ocean from that year class. Although it may be possible for bypass flows to be constructed at some summer dams, having smolts spend time in a pond environment while they search for a way downstream will result in higher energy cost and increased chances of predation. Adult fish are also likely to experience increased risk of predation and the extra cost in energy expended during the delay may reduce the ability of fish to successfully spawn (Mundie 1991, Banks 1969).

Regardless of the potential to block salmon and steelhead migration to and from the ocean via summer dam installation, the changes to the stream channel caused by summer dams may adversely affect migrating adults and smolts. Migrating adult and smolts are likely to find these areas devoid of cover to escape predators and devoid of habitat complexity to provide resting/holding areas for adults should flow conditions change during their migratory journey. In addition, the wide flat channel areas created by many summer dams are likely to hinder adult migration at low flows by spreading out flow and creating areas too shallow for salmon and steelhead to migrate. A study of the Santa

Clara Valley Water District spreader dams noted above concluded that streambed alteration at the dams had created wide shallow riffle areas that were contributing to salmonid passage obstructions (Habitat Restoration Group 1995).

For salmonids, the first movement during rearing involves dispersal from the redd to seek initial rearing areas. While older fish may establish "stations" or territories during summer rearing (Edmundson et al., 1968), recent research questions the assumption that little movement outside territories occurs, and questions the methodology of studies that support restricted movement of stream dwelling salmonids (Gowan et al. 1994). A literature review conducted by Kahler and Quinn, 1998, for the Washington Department of Transportation concludes that "...stream dwelling salmonids are often highly mobile. Upstream movement was observed in nearly all studies that were designed to detect it, and in all species, age classes, and seasons. There are variations in the movement patterns of fish populations both between and within river systems". In their well known study on Waddell Creek just north of the city of Santa Cruz, California, Shapovalov and Taft documented steelhead and coho juvenile movement during the summer months by using migrant traps and fin clip marking (Shapovalov and Taft 1954). Weir and radio tagging studies from other areas indicate that trout and salmonid juvenile movement during the summer months is not unique to California (Bjornn 1971, Cederholm and Scarlett 1981, Alexander and MacCrimmon 1974).

Juvenile salmonids can move during summer and autumn rearing to avoid natural and/or anthropogenic reductions in stream flow, to seek more appropriate habitats based on food availability and/or intraspecific interactions, seek refuge from high water temperatures, to avoid high turbidity, and to move into winter habitats that provide refuge from high water velocities (Kahler and Quinn 1998, Erman and Leidy 1975). Newly emerged fry may move as little as a few meters from the redd, or as far as several kilometers, including the use of other tributaries. Summer movement of rearing juveniles can range from a few meters to tens of kilometers (a few hundred meters appears to be the most common distance reported), with the least amount of movement usually occurring in late August (Kahler and Quinn 1998). Movement to winter habitats usually occurs in fall to early winter and is mostly upstream to seek refuge from high winter flows in lower order tributaries and off channel habitats. Salmonids in interior climates may move to seek cooler temperatures and larger substrate for better hiding cover. Reported distances moved range from a few meters to over 50 kilometers (Kahler and Quinn 1998). Summer dams will restrict the ability of juvenile salmonids to avoid flow reductions, high temperatures, predators, limiting food supplies, and intra/interspecific competition, thus reducing the survival chances of individual fish.

Coho salmon rearing

After emergence, coho salmon quickly move into rearing areas such as deep channel pools and off channel rearing areas such as wall-base channels and ponds. Most of this movement takes place in April and May, but in some areas June may have the most movement (Kahler and Quinn 1998). Hartman et. al., 1981, notes that the seaward movement of coho fry is frequently observed in the Pacific Northwest during spring and summer, with the most likely explanation being aggressive behavior from dominant (large sized) fry that displaces smaller fry downstream. The first major fall/winter storm usually triggers movement to winter rearing areas. Most of this movement takes place in October - November, with distances ranging from hundreds of meters to tens of kilometers (Kahler and Quinn 1998). In Shapovalov and Taft's nine year study of steelhead and coho at Waddell Creek, 95% of coho juveniles migrated downstream between April 8 and June 9[1]. Coho juveniles (YOY and age 1) were caught in the investigator's downstream migrant trap in numbers ranging from one to several hundred at the end of May and beginning of June. During mid to late June the numbers of migrants caught ranged from zero to eight. A very small number of YOY coho (1-2) migrated downstream from July to September in four of the years studied. Based on scale samples of adult coho in Waddell Creek, Shapovalov and Taft concluded that all of the age 1 coho migrating downstream were going to sea in the same season they migrated downstream (Shapovalov and Taft 1954).

Steelhead rearing
Steelhead juvenile movement appears to be more variable. Steelhead may move at any time during the summer (Kahler and Quinn 1998). In Shapovalov and Taft's nine year study of steelhead and coho at Waddell Creek, steelhead juveniles (YOY and age 1 fish) were caught in numbers ranging from a few hundred to a few thousand in the investigator's downstream migrant trap during June - September of every year. Steelhead juveniles were also caught in much lower numbers (6-93) in the investigator's upstream migrant trap during June through August in six of nine years. In five of nine years a few steelhead juveniles were caught in the upstream migrant trap in September. Most of these fish were age 1 juveniles or YOY. According to Shapovalov and Taft, most of the upstream migrants had previously migrated downstream (likely spending some time in the lagoon) and were likely to make a subsequent downstream migration during the same season (Shapovalov and Taft 1954). Investigation of juvenile rainbow trout[2] movement has also been done on an interior snow melt stream in Northern California. Upstream and downstream migrant traps placed on a tributary to Sagehen Creek showed that rainbow trout fry moved downstream during July through August 15 of 1973, and from July - September in 1974. The first year was a dry year in which tributary flows did not reach Sagehen Creek after August 15. During 1974, there was enough snow pack to keep the tributary flowing into Sagehen Creek all year (Erman and Leidy 1975).

Chinook salmon rearing
Studies have documented chinook moving both upstream and downstream during the summer (Kahler and Quinn 1998). In California, coastal chinook spend most of their time rearing in the ocean and will migrate to estuarine areas soon after emergence (within

---

[1]Shapovalov and Taft note that their downstream numbers represent only a sample of the total population of coho and steelhead moving downstream as high flows often over topped the downstream trap. Upstream trap numbers for steelhead likely represent nearly all of the steelhead moving upstream.

[2]NOAA FISHERIES considers rainbow trout to be the non-anadromous form of steelhead. Thus, behavior is expected to be very similar during juvenile rearing.

60-150 days), although some may spend up to a year rearing in freshwater rivers (Myers et al. 1998). Chinook in the Central Valley are divided in to several different groups based on run timing and habitat utilization, but they all exhibit an ocean type life history strategy. As with coastal runs, most emigrate to the ocean as sub-yearlings. While high summer temperatures (July - August) in the Central Valley do appear to limit downstream migration, some migration does take place during every month of the year. Chinook are usually mainstem spawners, and distances of downstream migration to estuaries may range from several to tens of kilometers (Meyers et al. 1998).

Predation

Summer dams create lake-like habitats that support the survival of salmon and steelhead predators such as bluegill, large and small mouth bass, green sunfish, cray fish, pike minnow, kingfisher, heron, egrets, bull frogs, turtle, and osprey. These wildlife are known to prefer lake and reservoir habitats and some are popular warm water game fish (McGinnis 1984). It is common knowledge that some or all of these non-endemic game fish have been purposefully stocked in the impoundments created by some summer dams to increase recreational fishing opportunities. While these predators may not survive in some rivers and streams after summer dams are removed, they are likely to do well in ponds and lakes created by summer dams, and feed on juvenile salmon and steelhead. In areas where they are unfortunately common in rivers and streams, summer dams provide excellent habitat for piscine predators and hunting grounds for their salmonid prey.

Sedimentation and Turbidity

Sediment and turbidity is likely to result from summer dam construction and/or removal. Construction methods using heavy equipment in flowing water to push up stream bed materials into a summer dam will undoubtedly create sedimentation and turbidity downstream. Removal of the dam in the same manner will have similar results. Many summer dams have more permanent structures to which flash boards are added in the spring or summer and removed prior to high winter flows. Quick removal of flashboards results in high water velocity (depending upon the amount and height of water impounded behind the flash boards) which will produce sedimentation, turbidity, and stream channel scour downstream.

High turbidity concentrations can effect fish in several ways, including increased mortality, reduced feeding efficiency, and decreased food availability (Berg and Northcote 1985; McLeay et al. 1987; Newcombe and MacDonald 1991; Gregory and Northcote 1993; Velagic 1995;). Substantial sedimentation rates could bury less mobile organisms (Ellis 1936; Cordone and Kelley 1961) that serve as a food source for many fish species, degrade instream habitat conditions (Cordone and Kelley 1961; Eaglin and Hubert 1993), cause reductions in fish abundance (Alexander and Hansen 1986; Berkman and Rabeni 1987) and reduce growth in salmonids (Crouse et al. 1981). The deposition of fine sediments resulting from summer dam construction and removal is likely to bury/suffocate salmon and steelhead eggs and alevins if they are present.

Instream channel construction activities associated with summer dams may coincide with the presence of a number of salmon and steelhead life history stages. In most cases, juvenile (including YOY) coho and steelhead will be present. Juveniles are much more vulnerable to turbidity and sedimentation than adults, as they lack the ability to quickly escape degraded areas and may not be able to swim far enough or long enough to reach clear water. The turbidity produced by instream channel construction activities is likely to be temporary (lasting for at most several hours at each point in a river or stream through which it passes). However, turbidity from removal of flashboards and earthen berm dams may be far in excess of water quality standards and avoidance and minimization standards as applied in section 7 consultations. In nearly all cases, NOAA FISHERIES requires avoidance and minimization measures for turbidity (and sedimentation) by prohibiting the use of berms in flowing water constructed from channel bed or bank materials. In addition, these section 7 projects are one time events and do not occur on a yearly basis.

Dam Construction and Removal

Dam construction and removal may coincide with the presence of a number of salmon and steelhead life history stages. In most cases, juvenile (including YOY) coho and steelhead will be present. If construction equipment is used to create summer dams when salmonid eggs and/or alevins may be present in stream beds, it is possible that eggs and/or alevins could be directly crushed by equipment or destroyed when the stream bed is manipulated. In many cases this may be an unlikely occurrence because the extensive localized channel modification caused by previous years of summer dam installation and removal will prevent suitable spawning habitat from occurring. However, in these cases no information is available to indicate how heavy equipment arrives at summer dam sites. If it is driven up or down the streambed for any distance, the above effects may occur.

Cumulative Effects of Summer Dams

The cumulative effects of summer dams are watershed wide in scope. To adequately address the cumulative impacts of summer dam projects it is necessary to assess the effects that a project is going to have, not only in the immediate action area, but throughout the watershed. The large number of summer dams present on river systems like the Russian River compounds the impact of all the effects of individual dams. One of the most significant cumulative impacts of numerous summer dams within a watershed is habitat fragmentation. Habitat fragmentation has been identified as an important factor in the decline of salmon and steelhead trout populations (NOAA FISHERIES 1996, NOAA FISHERIES 1996a, Myers et al. 1998). Although summer dams are not installed all year, in many instances they are in place for about six months (June-November) or longer. Hundreds of these dams in river systems for this length of time will fragment habitat on a large scale, affecting part of the adult and smolt migration as well as most rearing juveniles.

At this time, the state of California does not know the number of summer dams, their locations, or how many currently are permitted as required by State law.

Streamflow and Diversions
Streamflow, whether affected or not by diversion of instream flows, can as impair the free migration of aquatic resources through either dewatering stream channels, or creating temporal barriers that result from inhospitable water temperatures or water quality conditions.

NOAA FISHERIES has established Guidelines for Salmonid Passage at Stream Crossings, which is included below. However, 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. NMFS guidelines may be viewed in full at this site: http://swr.ucsd.edu/hcd/NMFSSCG.PDF

For more detailed information pertaining to fish passage analysis at unassessed sites, Part IX of the California Salmonid Stream Habitat Restoration Manual details the DFG-approved method for assessing passability at stream crossings.

Although adult anadromous salmonids typically migrate upstream during higher flows triggered by hydrologic events, it is presumed that migration is naturally delayed during extreme large flood events. Conversely, during low flow periods water depths within the channel can become impassable for adult and/or juvenile salmonids. Therefore, hydraulic analysis is one of the most important components of this assessment.

Because flow is not gaged on most small streams, it must be estimated using techniques that often require hydrologic information about the stream crossing's contributing watershed. Information needed includes:

- Drainage area
- Mean annual precipitation
- Average basin elevation

Most of this information can be obtained from USGS topographic maps, precipitation records, and water resources publications by various agencies. See Part IX in this appendix for further details and accepted assessment methods for assessing stream crossings for passability. Details about the report are available from the DFG's Fish Passage Program Coordinator, Julie Brown at jbrown@dfg.ca.gov.

Road Crossings
Roads and other infrastructure built across streams have been recognized (Robison and others 2000) as potential barriers to fish migration. Fords, pipelines, bridge footings, and energy dissipaters present problems to migrating fish depending on streamflow, horizontal distance, and depth of water over the structure. Culverts may become perched by downstream scouring or erosion making them too high for adult or juvenile fish to access under low streamflows, as well as a location of potential physical injury from landing on rip-rap or concrete placed below the outlet to control erosion. At high flows, the force of the water shooting through a culvert may create velocity barriers that can

overwhelm fish trying to migrate upstream. Culverts at road/stream crossings have come under intense scrutiny nation-wide as efforts to restore habitat conditions to recover declining populations of listed salmonids and other fishes have received significant State and federal funding. Recent surveys and investigations have documented the significance of road construction impacts to migratory paths of anadromous salmonids in the Pacific Northwest alone (GAO 2001; Hunsberger 1999; R. Taylor 2000, 2001; NOAA FISHERIES 2002 in prep.)

Roads and other infrastructure built across streams are widely recognized as potential barriers to fish migration (e.g., DFG 1998, ODFW 1999, WDFW 1999, NOAA Fisheries 2001). Culverts, fords, pipelines, bridge footings, and energy dissipaters have the potential to present obstacles to migrating fish depending on stream flow, horizontal length of the structure, and depth of water over or through the structure. Movement through culverts and over other types of stream crossings is important not only for adult salmonids during spawning migrations, but also for juveniles and non-anadromous fishes moving within a stream system (Fausch and Young 1995, Warren and Pardew 1998, Kahler and Quinn 1998, Kahler et al. 2001, DFG 2002). Culverts at road/stream crossings have come under intense scrutiny nationwide and particularly in the Pacific Northwest as efforts to restore habitat conditions to recover declining populations of listed salmonids and other fishes have received significant state and federal funding (ODFW 1999, GAO 2001).

To successfully migrate past a structural stream crossing such as a culvert road crossing, a fish must be able to traverse the length of the structure and make it to the first resting area upstream (Kahler and Quinn 1998). Stream crossings have the potential to become migration barriers when they are designed without the goal of fish passage in mind or when the stream channel degrades due to changes in hydrology (WDFW 1999). Culverts may become barriers when any of the following five common conditions exist (WDFW 1999):

- excessive drop at the culvert outlet;
- high velocity in the culvert;
- inadequate depth in the culvert;
- excessive turbulence within the culvert;
- debris accumulation at the culvert inlet.

The total number of stream crossings in California that act as fish passage barriers is unknown, but is thought to be in the thousands (DFG 2002). Identifying where culverts are located and evaluating them for fish passage are important steps in restoring streams for anadromous fishes. In California, the Department of Fish and Game has adopted an involved protocol, outlined in the table below, for evaluating culverts to determine if they act as temporal, partial, or total fish passage barriers and then prioritizing culverts for corrective action (DFG 2002).

Definitions of barrier types and their potential impacts. (DFG 2002 adapted from Robison et al. 2000).

Barrier Category	Definition	Potential Impacts
Temporal	Impassable to all fish at certain flow conditions (based on run timing and flow conditions).	Delay in movement beyond the barrier for some period of time.
Partial	Impassable to some fish species, during part or all life stages at all flows.	Exclusion of certain species during their life stages from portions of a watershed.
Total	Impassable to all fish at all flows.	Exclusion of all species from portions of a watershed.

A common situation is for culverts to become perched above the streambed due to scouring and erosion downstream from the culvert outlet, making them too high for fish to access under low stream flows. Culverts that are properly designed to provide fish passage should have little or no drop between the water surface elevations inside and outside of the culvert (NOAA Fisheries 2001). Guidelines and design criteria for providing fish passage at culverts have been developed for Pacific salmonids by state agencies (WDFW 1999, ODFW 1999, DFG 2002) and the National Marine Fisheries Service (NOAA Fisheries 2001). Design criteria vary, depending on the performance abilities of different target species and life stages. For example, a culvert with a one-foot drop from the outlet to the stream below might not present a barrier to a migrating adult steelhead, but could be a total barrier to juveniles trying to move upstream past the stream crossing (See Table below). Similarly, design criteria have been developed for numerous other factors, such as water depth and velocity, which influence the ability of a fish to pass through a culvert. A general guideline in planning new stream crossings is to use bridges that span the width of the stream when possible so that effects to the natural dynamics of the stream environment are minimized or avoided altogether (NOAA Fisheries 2001). However, if it is determined that stream crossings already in place are acting as fish passage barriers, there are ways in which they can be retrofitted to provide passage (DFG 2002).

Maximum Drop at Culvert Outlet (from DFG 2002).

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.

Construction of new culverts requires CEQA review in the context of a 1600 Streambed alteration permit, while alterations or maintenance/replacement of existing structures are categorically exempt. Nevertheless, alterations or maintenance/replacement of existing structures does require a streambed alteration permit, and culvert passage requirements are available for review in both the DFG habitat restoration manual, and in the current 1600 manual. DFG staff has the discretion to be less stringent at sites without salmonids.

NOAA FISHERIES and DFG have developed criteria for water velocities, water depths and high and low passage flows for adult and juvenile salmonids. The draft DFG guidelines appear in Part IX of the California Salmonid Stream Habitat Restoration Manual, and are included in draft form in the appendix of this report. Details about the report are available from the DFG's Fish Passage Program Coordinator, Julie Brown at jbrown@dfg.ca.gov. Both sets of guidelines address fish passage at road crossings and culverts.

Gravel Mining Operations

Instream gravel pits and associated large ponds can impair the free passage of salmonids either through the alteration of the channel, or the associated effects on water quality. Pits and ponds, by altering the channel, can provide habitat for warm water, or slack water, predatory fish that prey on juvenile salmonids. These predators include non-native striped bass, largemouth and smallmouth bass, catfish, or natives such as the northern pikeminnow. Juvenile salmonids migrating downstream can become disoriented in the slow waters of a pond and become more vulnerable to predation. Many of these ponds lack adequate cover for juvenile salmonids trying to avoid predators. At the edges of these ponds, however, cover provides non-native bass a place to hide and ambush juvenile fish that may seek out the same areas for cover. Alterations to the stream temperatures resulting from mining operations can prove deleterious, or even deadly to juvenile salmonids that are acclimated to the colder water of their spawning areas. Warm-water stress also increases susceptibility to predators.

Flood Control/Grade Control Structures

Flood control structures such as concrete-lined channels or riprapped stream channels or drop structures can also impede upstream migration if there are no places for fish to rest as they work against a flow of high velocity water. Channelized or de-watered stream reaches create adverse habitat conditions, such as warm water that exceeds tolerance limits, or lack of cover that limits shading, food production, predator avoidance capacity and ultimately survival and growth of migrating juveniles.

Instream Flows

Millions of dollars flow to restoration efforts each year, but in many watersheds diminished instream flows present as serious and as chronic a barrier to fish passage as the largest dam. The State consumes 25% of the nation's available fresh water supply each year, with 80% going to agriculture. Much of this water is sold at far below the dollar price it requires to deliver it. This resource allocation problem will only increase with time as the state's population continues to grow.

Allocation of water is the jurisdiction of the State Water Resources Control Board, Division of Water Rights, which reviews applications for water rights. The traditional rules of western water law, and the Board's implementation of those rules, have contributed greatly to a system that has lead, in many cases, to altered and depleted stream flows unfavorable to aquatic resources. The Board provides an excellent summary of the water rights process in California at their website at http://www.waterrights.ca.gov/application/forms/infobook.htm while CERES hosts an informative website on water law and policy in California at http://ceres.ca.gov/theme/env_law/water_law/

Two data sources provide an excellent starting point for examining the presence of diversions in coastal watersheds.

The first is the State Water Resources Control Board, Division of Water Rights, Fully Appropriated Stream list http://www.waterrights.ca.gov/html/faslist.htm. Fully appropriated status suggests that further diversions from fully appropriated streams would exacerbate instream habitat conditions, and possibly contribute to the creation of temporal barriers to fish passage in various life stages.

The next source of data is also available from the Division of Water Rights. It is a full GIS presentation of existing points of diversion, with brief descriptions. The link to the data, which requires signing up with a password, is http://165.235.31.51/login.html

By definition, an applicant for water rights or a permit from the Board seeks permission to divert water from instream. Little environmental analysis is required of the applicant, and the Board does little to review or address the cumulative effects of withdrawals on instream flows and aquatic ecosystems.

This condition has been exacerbated of late in coastal watersheds by manifold claims of diverters that their wells, located adjacent to stream channels, are capturing groundwater, which is currently unregulated by any state agency.

It is believed that stream flows in coastal watersheds, and biological habitat supported by the stream flow—including that of salmonid fish—are being reduced by groundwater well extractions (extractions) from wells located adjacent to the streams. This type of situation—extractions reducing stream flow and impacting habitat—is a problem throughout the State of California, particularly in central coast watersheds where stream flows during the dry season are very low and competitive demands by agriculture, development and municipalities are by default ranked higher than biota. Reduction of stream flow through extractions is a type of diversion of waters of the State for which oversight and regulation is vested to the SWRCB.

The DFG has been attempting for years to resolve the issue of diversion of stream flows due to extractions. In December 1999 the Department filed a complaint with the SWRCB concerning a groundwater well field in the lower Pilarcitos Creek watershed that is believed to be diverting stream flow from the Creek for horticultural purposes. The SWRCB dismissed the complaint stating that the wells are impacting flow, but the State does not have jurisdiction over extraction diversions, or other diversions by groundwater wells, located in alluvium3. Few, if any, coastal watersheds in California—including many that contain public trust resources—do not contain significant quantities of alluvium through which groundwater is transmitted, and diverted through extraction.

In January 2002 an effort was made to convince the SWRCB to assume a more assertive role concerning the diversion of stream flow though extraction. Emeritus Professor Joseph Sax of the Boalt Hall Law School of the University of California at Berkeley, an acknowledged expert in water law, produced a report submitted to the SWRCB that contained the recommendations that: (1) the SWRCB adopt clear criteria to implement existing statutory purpose by taking jurisdiction over groundwater uses that directly and appreciably diminish stream flows; (2) the SWRCB proactively use existing jurisdiction to implement constitutional prohibitions on waste, unreasonable use and methods of use, to protect public trust resources, and safeguard established rights in stream flows; and, (3) the SWRCB implement comprehensive groundwater basin management where serious basin-wide problems exist, to achieve genuine integration of surface and groundwater administration in California. Of note, the complaint filed by the DFG in 1999 is referenced in the Sax Report. This report is available at the State Water Resources Control Board archives, or
http://www.waterrights.ca.gov/hearings/SaxReport/SubStreamRpt(2002-01-20).pdf

The DFG supported the Sax's Report and emphasized the recommendations of members of a Technical Advisory Committee (TAC) called to assist Professor Sax in producing the report. The TAC recommended monitoring stream flow and groundwater extractions to determine if extractions in the lower Pilarcitos Creek are impacting important public trust resources dependent on stream flow such as salmonid habitat.

The DFG has determined that it is appropriate to initiate a monitoring program as recommended by the TAC and inferred in the Sax Report. However given current funding constraints and anticipated severe budget cuts, the DFG is unable to fund the purchase of the equipment necessary to monitor stream flow and groundwater elevations in the Pilarcitos Creek watershed. Since diverters are not required to conduct such monitoring, no monitoring takes place, and the DFG is unable to provide baseline information in support of a State-wide requirement that groundwater well diverters with wells located near stream channels obtain a streambed alteration permit from the Department under section 1600 of the California Fish and Game Code.

Given the importance of instream flow, and appropriate depth to allow free passage of anadromous fish through all their life history stages, resolution of this issue is one of the most important components facing the improvement of fish passage in coastal watersheds.

However, the status quo of water rights with relation to the protection and enhancement of coldwater fishery resources is sufficiently unresolved that the Conservancy has chosen to focus this report on infrastructure associated with water diversions, rather than the

3 Clay, silt, sand, gravel, or similar detrital material deposited by running water

remaining instream flows potentially serving as barriers to fish passage. The authors of this report urgently recommend that a more thorough examination of instream flows, or the lack thereof, and how they impair fish passage in coastal watersheds.

Temperature

Temperature, like instream flows, often creates a temporal barrier to the migration of anadromous fish in all their life history stages. As temperatures exceed certain limits, fish tend to congregate and await more favorable conditions in which to migrate. Such delays in migration resulting from high water temperatures can even result in fatalities of the type and magnitude which took place on the Klamath River in September, 2002, in which approximately 32,000 adult salmonids perished due, in part to migration delays caused by water quality conditions.

Due to the complexity and temporal nature of the effects of water quality on fish migration, this report will not address this topic, but recommends that future barrier removal project proponents and partners consider the effects of existing temperature limits as barriers to fish passage, particularly in the context of Basin Plan requirements for water bodies under the Porter-Cologne Act and the Clean Water Act.

Tidegates

Little focus has been placed on the role tidegates and other obstructions located in estuaries have played in impeding the recovery of salmon and steelhead populations. These features include all manner of obstructions to off-channel rearing/foraging habitat that has no spawning habitat upstream. It is quite likely that the simplification, isolation, and reclamation of our tidal estuaries has been a key contributing factor to the decline of salmon and steelhead populations. These low lying fresh/brackish water ponds and backwatered sidechannels that were historically connected to the stream channel are often overlooked in the course of watershed assessments and restoration strategies, due in part to the fact that most contain no upstream spawning habitat, and have historically been written off as insignificant. However, they were likely extremely productive foraging habitat for many age classes of salmonids, and access to these areas should be considered in the course of any strategy for the modification or removal of barriers to fish passage.

Water Quality

Water quality is the ability of a water body to support all appropriate beneficial uses. Recent studies in Washington by the National Marine Fisheries Service have demonstrated declining spawning success and even mortality of coho salmon drawn to urban polluted streams. For purposes of this report, water quality will be discussed only in terms of fish habitat.

Water quality can vary seasonally, corresponding to precipitation, discharges, and diversions (Schreck and Moyle 1990). It can also vary year to year depending on drought or wet conditions (Corbitt 1998).

Some factors affecting water quality:

Alkalinity
Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes (keeps the pH fairly constant) and makes water less vulnerable to acid rain. The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity (McGhee 1938, Schreck and Moyle 1990, Corbitt 1998).

Ammonia
Ammonia is toxic to fish and aquatic organisms, even in very low concentrations. When levels reach 0.06 mg/L, fish can suffer gill damage. When levels reach 0.2 mg/L, sensitive fish like trout and salmon begin to die. As levels near 2.0 mg/L, even ammonia-tolerant fish like carp begin to die. Ammonia levels greater than approximately 0.1 mg/L usually indicate polluted waters (McGhee 1938, Schreck and Moyle 1990, Corbitt 1998).

The danger ammonia poses for fish depends on the water's temperature and pH, along with the dissolved oxygen and carbon dioxide levels. Remember, the higher the pH and the warmer the temperature, the more toxic the ammonia. Also, ammonia is much more toxic to fish and aquatic life when water contains very little dissolved oxygen and carbon dioxide (McGhee 1938, Schreck and Moyle 1990, Corbitt 1998).

Carbon Dioxide
Carbon dioxide quickly combines in water to form carbonic acid, a weak acid. The presence of carbonic acid in waterways may be good or bad depending on the water's pH and alkalinity. If the water is alkaline (high pH), the carbonic acid will act to neutralize it. But if the water is already quite acid (low pH), the carbonic acid will only make things worse by making it even more acid (McGhee 1938, Schreck and Moyle 1990, Corbitt 1998).

Chlorine
Chlorine is also used as a disinfectant in wastewater treatment plants and swimming pools. It is widely used as a bleaching agent in textile factories and paper mills, and it's an important ingredient in many laundry bleaches (Schreck and Moyle 1990).

Free chlorine (chlorine gas dissolved in water) is toxic to fish and aquatic organisms, even in very small amounts. However, its dangers are relatively short-lived compared to the dangers of most other highly poisonous substances. That is because chlorine reacts quickly with other substances in water (and forms combined chlorine) or dissipates as a gas into the atmosphere (Corbitt 1998).

Nitrate
Nitrate is a major ingredient of farm fertilizer and is necessary for crop production. When it rains, varying nitrate amounts wash from farmland into nearby waterways. Nitrates also get into waterways from lawn fertilizer run-off, leaking septic tanks and cesspools, manure from farm livestock, animal wastes (including fish and birds), and discharges

from car exhausts. Nitrates stimulate the growth of plankton and water weeds that provide food for fish. This may increase the fish population. However, if algae grow too wildly, oxygen levels will be reduced and fish will die (McGhee 1938, Schreck and Moyle 1990, Corbitt 1998).

Dissolved Oxygen

Dissolved oxygen (DO, pronounced dee-oh) is oxygen that is dissolved in water. It gets there by diffusion from the surrounding air; aeration of water that has tumbled over falls and rapids; and as a waste product of photosynthesis (Schreck and Moyle 1990, Corbitt 1998).

If water is too warm, there may not be enough oxygen in it. When there are too many bacteria or aquatic animals in the area, they may overpopulate, using DO in great amounts (Schreck and Moyle 1990, Corbitt 1998).

pH

The balance of positive hydrogen ions (H^+) and negative hydroxide ions (OH^-) in water determines how acidic or basic the water is. When analysts measure pH, they are determining the relative concentration (expressed in exponential, or "power" form) of hydrogen ions; the term "pH" comes from the power of Hydrogen. The pH scale ranges from 0 (high concentration of positive hydrogen ions, strongly acidic) to 14 (high concentration of negative hydroxide ions, strongly basic). Most fish can tolerate pH values of about 5.0 to 9.0 (Schreck and Moyle 1990, Corbitt 1998).

When it rains, varying amounts of phosphates wash from farm soils into nearby waterways. Phosphates stimulate the growth of plankton and water plants that provide food for fish. If too much phosphate is present, algae and water weeds grow wildly, choke the waterway, and use up large amounts of oxygen. Many fish and aquatic organisms may die (Schreck and Moyle 1990, Corbitt 1998).

Turbidity

Turbidity interferes with sunlight penetration. Water plants need light for photosynthesis. If suspended particles block out light, photosynthesis—and the production of oxygen for fish and aquatic life—will be reduced. If light levels get too low, photosynthesis may stop altogether and algae will die. It’s important to realize conditions that reduce photosynthesis in plants results in lower oxygen concentrations and large carbon dioxide concentrations. Large amounts of suspended matter may clog the gills of fish and shellfish and kill them directly (Schreck and Moyle 1990, Corbitt 1998). Recent postulations also suggest that increased turbidity levels may result in decreased growth rates for juvenile salmonids.

Coliform Bacteria

Coliform bacteria are bacteria that grow in the digestive tracts of humans and other warm-blooded animals, and indicate the presence of sewage and other sources of fecal pollution. They are measured by counting the number of bacteria colonies that grow from a 100 milliliter water sample. Sources of coliform bacteria include wastewater discharges, septic tanks, domestic animals, and wildlife. Fecal coliform counts greater than about 200/ml are thought to be unsafe for swimming (Schreck and Moyle 1990, Corbitt 1998).

Heavy Metals

Heavy metals are toxic to fish if the accumulated levels get too high. The problem is that heavy metals not only accumulate in waterbodies but they also accumulate in the tissues of fish. In the organs of the fish they cause a variety of physiological problems, which ultimately lead to disease and death (May 1999, Brumbaugh et al. 2000).

The solubility of trace metals in surface waters is predominately controlled by the water pH, the type and concentration of ligands on which the metal can adsorb, and the oxidation state of the mineral components and the redox environment of the system (May 1999, Brumbaugh et al. 2000).

The behavior of metals in natural waters is a function of the substrate sediment composition, the suspended sediment composition, and the water chemistry. Sediment composed of fine sand and silt will generally have higher levels of adsorbed metal than will quartz, feldspar, and detrital carbonate-rich sediment. Metals also have a high affinity for humic acids, organo-clays, and oxides coated with organic-clays, and oxides coated with organic matter (May 1999, Brumbaugh et al. 2000).

Sources of Heavy Metals

Nonpoint sources:

Natural: Chemical and physical weathering of igneous and metamorphic rocks and soils often release heavy metals into the sediment and into the air. Other contributions include the decomposition of plant and animal detritus, precipitation or atmospheric deposition of airborne particles from volcanic activity, wind erosion, forest fire smoke, plant exudates, and oceanic spray (May 1999, Brumbaugh et al. 2000).

Anthropogenic:

Surface runoff from mining operations usually has a low pH and contains high levels of metals such as iron, manganese, zinc, copper, nickel and cobalt. The combustion of fossil fuels pollutes the atmosphere with metal particulates that eventually settle to the land surface. Urban stormwater runoff often contains metals from roadways and atmospheric fallout (May 1999, Brumbaugh et al. 2000).

Point sources:

Domestic wastewater effluent contains metals from metabolic wastes, corrosion of water pipes, and consumer products. Industrial effluents and waste sludges may substantially contribute to metal loading (May 1999, Brumbaugh et al. 2000).

APPENDIX A(2)

California Fish Passage Assessment Database

METHODOLOGY AND DOCUMENTATION

August 1, 2004

CONTENT

Database Development
Passage Locations (GIS)
Data Quality and Limitations
Database Overview (Data Content)
Data Entry and Viewing Forms
Table Relationships
Table Descriptions

Database Development

The Passage Assessment Database (PAD) was developed to provide a common framework for the collection, management and analysis of potential barriers to fish passage in California streams. It is intended to capture a set of basic information about each potential barrier to aid in inventorying and assessing fish passage issues on a statewide scale. The set of data fields included in the PAD were chosen to meet the needs of the Coastal Conservancy's barrier assessment program, and were reviewed by the member agencies of the Fish Passage Forum. The PAD was designed to be flexible, so that as the database grows, other modules may be added to increase data detail and complexity.

There are two main components of the PAD, the Passage table and the Datasets table. The Passage table contains or links to all of the core information about individual fish passage sites (potential barriers). For a complete list of passage information collected in the PAD, refer to the table descriptions below. The Datasets table contains one record for each source of data that is included in the PAD. There are thus many records in the Passage table corresponding to a single record in the Datasets table. The Datasets table contains information about the entire dataset, including the person and agency responsible. Also included in the Datasets table is a list of any other passage information that was provided in the original dataset but is not entered into the PAD because it is currently outside of the scope of this database. As a result, it will be possible to locate further information about records in the PAD if greater detail is desired.

In an assessment of fish passage issues on a statewide basis, some of the most important data collected about potential barriers are those related to their status and type. The status of a structure or site refers to the degree to which it is impassable. The PAD has eight categories of passage status:

- *Total*: A complete barrier to fish passage for all anadromous species at all life stages at all times of year.
- *Partial*: Only a barrier to certain species or life stages.
- *Temporal*: Only a barrier at certain times of year.
- *Temporal and partial:* Only a barrier to certain species or life stages and only at certain times of year.
- *Temporal and total*: Total barrier only at certain times of year.
- *Not a barrier*: Structure/site has been determined not to be a barrier to any species or life stages, and is passable year-round.
- *Structure may not still be in existence*: Data were obtained from an old dataset, and are likely to have been removed or washed away.
- *Unknown*: Dataset had no information about barrier status.

There are 14 types of structures or sites in the PAD:

- *Dam*: A barrier built across a stream or river to obstruct the flow of water. Includes debris, earth, rock, flashboard, drop structure, arch, weir, gravity, wing gabion, etc.
- *Road crossing*: A structure crossing a creek or stream that allows water underneath or over the road. Includes culvert, bridge, low-flow, etc.

- *Utility crossing*: Some type of utility line, water, gas, etc. that crosses a creek or stream and impedes passage of fish.
- *Diversion*: A place where the flow of water has been diverted from one course to another or directed in order to control the drainage from a section of ground. Includes screened and unscreened.
- *Flood control channel*: Any partially or completely excavated channel intended to convey above-normal discharges.
- *Grade control*: Stabilizing weirs constructed in the streambed to prevent lowering of the channel bottom. This includes bedrock chutes.
- *Flow measurement weir*: A notch or depression in a levee, dam, embankment or other barrier across or bordering a stream, through which the flow of water is measured or regulated.
- *Gravel/borrow pits*: Excavated area where materials have been removed for use as fill elsewhere.
- *Fish passage facility*: Provide fish passage past obstructions that would otherwise prevent or hinder their upstream progress. Fishways include Step-and-pool, Denil ladders, and Alaskan steep-pass types.
- *Non-structural:* Anything naturally occurring that restrains or obstructs passage. Includes waterfall, grade, temperature, subterranean flows, landslide, velocity, etc.
- *Tidegate*: A structure at a stream ocean mouth that limits the tidal flow within the estuary.
- *Fish trap*: A trap set up to catch fish usually for scounting and monitoring purpose; should always be only a temporal barrier.
- *Other*: Any structure type not included in the above list (type is noted in the name or site comments).
- *Unknown*: Dataset does not specify the structure/site type.

The PAD incorporates the barrier ranking criteria recommended in Section IX of the California Salmonid Stream Habitat Restoration Manual published by the Department of Fish and Game. Terminology used for the passage status is also consistent with Section IX. The database also captures numerical watershed priority rank and priority category (e.g., high, medium, low) within a given dataset source if that information was provided.

The PAD is intended to be compatible with a variety of other data sources related to anadromous fish issues. All potential barriers are saved with geographic location information. With a small number of exceptions (see Data Quality and Limitations discussion below), all locations are stored in a shapefile. This file can be used to represent the potential barriers on maps or to provide latitude/longitude coordinates. The shapefile is created by digitizing the potential barriers along the streams in which they are located. Because each potential barrier is referenced to standardized hydrography, it is very easy to combine the PAD data with other fisheries data tied to the same hydrography. For a more detailed description of the digitizing process and the hydrography used, see Passage Locations (GIS) below.

All source datasets compiled for entry into the PAD are also available in their original format. To obtain these data, please contact:

Michael Bowen
State Coastal Conservancy
1330 Broadway, 11th Floor
Oakland, CA 94612-2530
(510) 286-0720
mbowen@scc.ca.gov

Periodically updated PAD data and project documentation is available for viewing, query and download on the website www.CalFish.org.

This document contains: a description of the Geographic Information System (GIS) that accompanies the PAD, a discussion of data quality and limitations, images of the main data entry and viewing forms, and descriptions of all tables in the PAD and their relationships.

Passage Locations (GIS)

The basis for digitizing most structures and sites in the PAD is 1:100,000 (100K) hydrography. Each stream in the hydrography is routed and identified with a unique identification number. Structure/site locations are stored as "addresses" along the hydrography, referenced with the stream's unique ID and their distance from its mouth. This process standardizes the many different data formats that are brought together in the PAD.

There are some locations that cannot be tied to the hydrography. For example, there are many tributaries that are too small to be represented in 1:100,000 scale hydrography. In these and other related cases, the potential barriers are stored simply as shapefiles with no reference to the hydrography. This means that all structures/sites can be included on maps and in analyses.

Locations are digitized in 100K streams using a pair of customized ArcView extensions. One extension allows single points to be entered one by one using hard copy maps or text descriptions of the site as reference. The other extension snaps entire datasets of points to the 100K hydrography from existing shapefiles. Points are snapped to the nearest stream within a set distance.

Datasets with location information in latitude/longitude coordinates collected using Global Positioning Systems (GPS) were processed by converting the GPS coordinates to decimal degrees and then snapping these points to the 100K hydrography.

All geographic data that are received for use in the PAD are saved in their original format as well as in their final standardized format. If there are any problems with the PAD data, it will always be possible to return to the original dataset for a solution.

Data Quality and Limitations

The PAD was compiled using information about fish passage from a large number of sources. These datasets were originally created for a number of different purposes, from general stream habitat surveys to rigorous assessments of fish passage barriers. As a result, the datasets vary widely in the type, amount and quality of data they contain. Following are brief descriptions of the data quality issues encountered during data acquisition and entry into the PAD.

- Although there are many records in the PAD, there are many potential barriers that are not yet included. This may be because the structures have not yet been inventoried; or they may have been inventoried but have not yet been made available to this project. As a result, it is impossible to draw final conclusions about the state of fish passage in California. The data in the PAD are a reflection of the datasets that have been found to date by PAD staff, not the actual state of fish passage in streams. For example, the PAD includes very comprehensive data about diversions in come coastal watersheds but not in others. This does not mean that there aren't many diversions in the other watersheds, but rather that the PAD does not yet include diversion data for these watersheds.

- Many datasets have no assessment of whether the inventoried structures are barriers to fish passage, and if so, whether the structures are partial, temporal or total barriers. There are 15,984 structures in the database which have an unknown status or may not be in existence anymore (9,057 in coastal watersheds), compared to 3,575 structures (3,323 coastal only) that are known to be barriers (either partial, temporal, temporal & partial, temporal & total or total). An additional 741 structures (636 coastal only) in the database are known not to be barriers.

- Many datasets are also missing other information that should be included in the database. For example, many datasets do not have any structure or land ownership information.

- In some cases, the datasets do not have very precise location information. For example, some stream surveys only mention that there is a barrier or structure within a defined reach of stream, making it impossible to pinpoint the barrier location. Structures described in this way are maintained in the GIS as linear shapefiles, and are available in that form on the attached CD. For the purposes of creating the maps in this report, all linear locations were converted to a single point at the beginning of the linear stream reach.

- Structure locations are referenced to 1:100,000 hydrography. Some datasets describe locations using the distance of the structure from the stream mouth – these were digitized using this measure on the hydrography. However, because the 1:100,000 hydrography does not follow the exact course of the stream, measured distances along a stream do not reflect reality. Errors were minimized by referencing structures to other landmarks whenever possible.

- Datasets with location information in latitude/longitude coordinates were snapped to the hydrography in order to standardize all location data in the PAD. This necessarily means that the points are shifted from the coordinates given in the original dataset, and the standardized locations do not reflect the actual map location of the point. Original coordinates are kept with the original data set.

- Because many datasets overlapped in their geographic range, information about the same potential barrier could sometimes be found in several different datasets. In most cases, the duplicates were identified during data entry or in subsequent data quality evaluation. However, the database may still contain a slight overestimate of the numbers of potential barriers surveyed.

- There are some passage records in the database that do not have spatial information associated. This is either due to nonsense locations in the original datasets or because the original dataset did not include any spatial information. The passage sites without location information are not displayed on maps.

Database Overview (Data Content)

PASSAGE

Passage ID

Passage Name
Dataset ID
Structure Owner (Agency/Organization)
Landowner
Ownership Type
(Federal, State, County, Private, etc.)
Passage Type
Passage Status
(Total, Partial, Temporal, Temporal & Partial, Temporal & Total, Not a Barrier, Structure may not be in existence, Unknown)
Is Treatment Needed?
Treatment Status
(Planned, Ongoing, Complete, Unknown)
Date Structure Installed
Date Structure Removed
Are Photos of the Site Available?
Protocol/tools/standards used to assess site
Stream Name
Tributary To
LLID
Start Measure along Stream (ft)
End Measure along Stream (ft)
Latitude (decimal degrees)
Longitude (decimal degrees)
Datum of Longitude/Latitude
Quad Map Information
County
Watershed (4^{th} field Hydrologic Unit)
Reference
Treatment Recommendation
Site Comments
Barrier Ranking Criteria and Score
Watershed Numeric Priority
Watershed Priority Category

DATASET

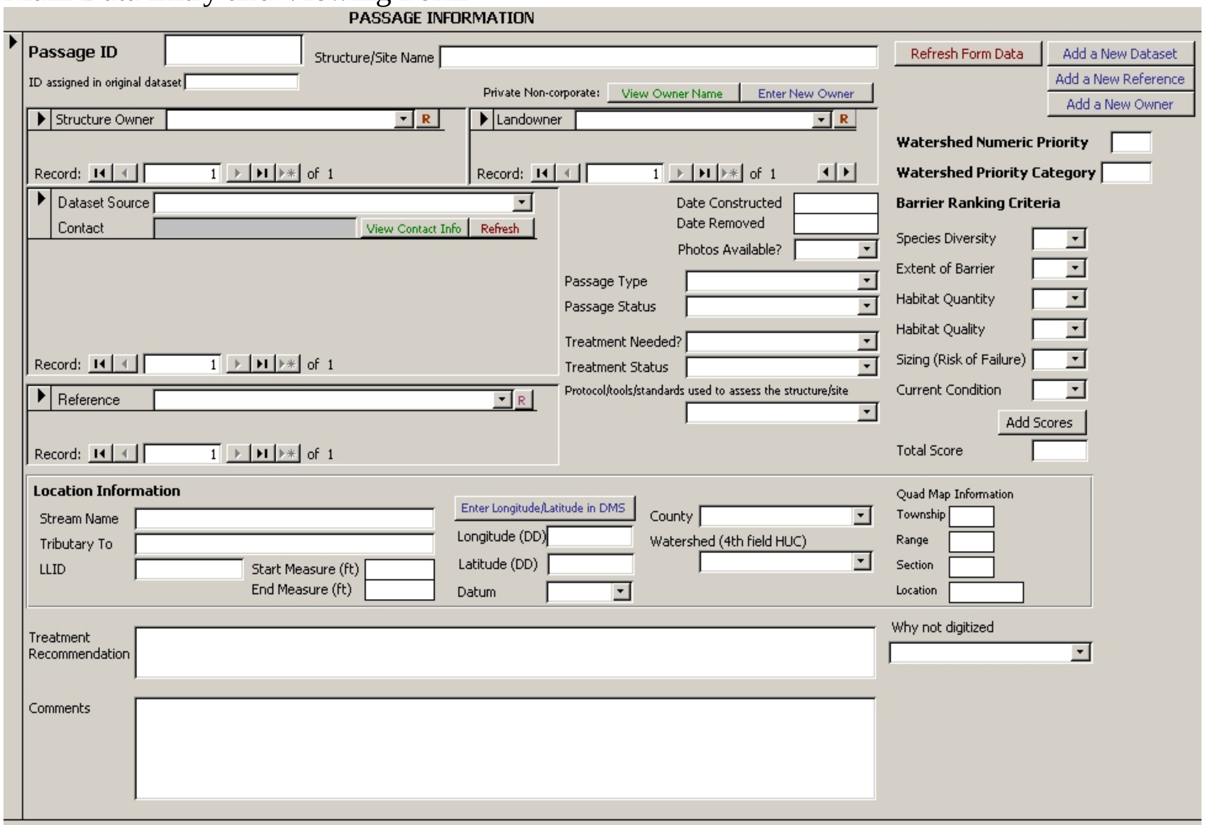
Dataset ID

Data Contact Person
Source
Agency/Organization
Other Data Available
(Not captured in the current passage assessment database)
Dataset Comments

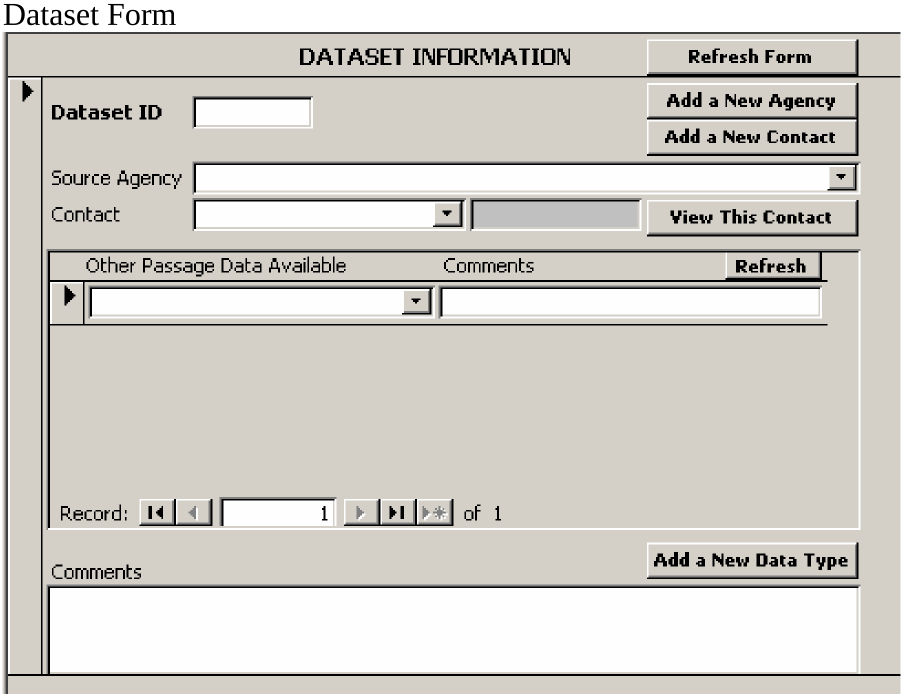
These are not the actual table or field names.
For an entity relationship diagram, see page 11
For the field names, see pages 12 - 16.

Data Entry and Viewing Forms

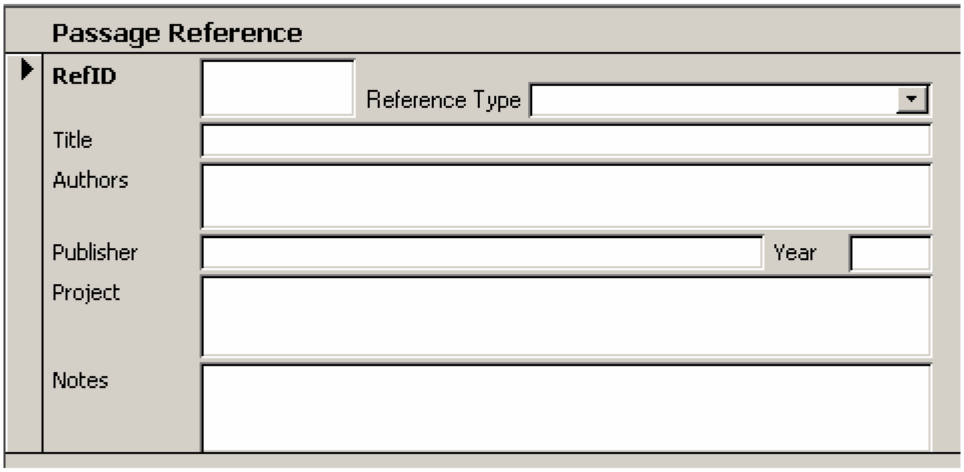
Main Data Entry and Viewing Form



Dataset Form



Reference Documents Form



Contact Information Form

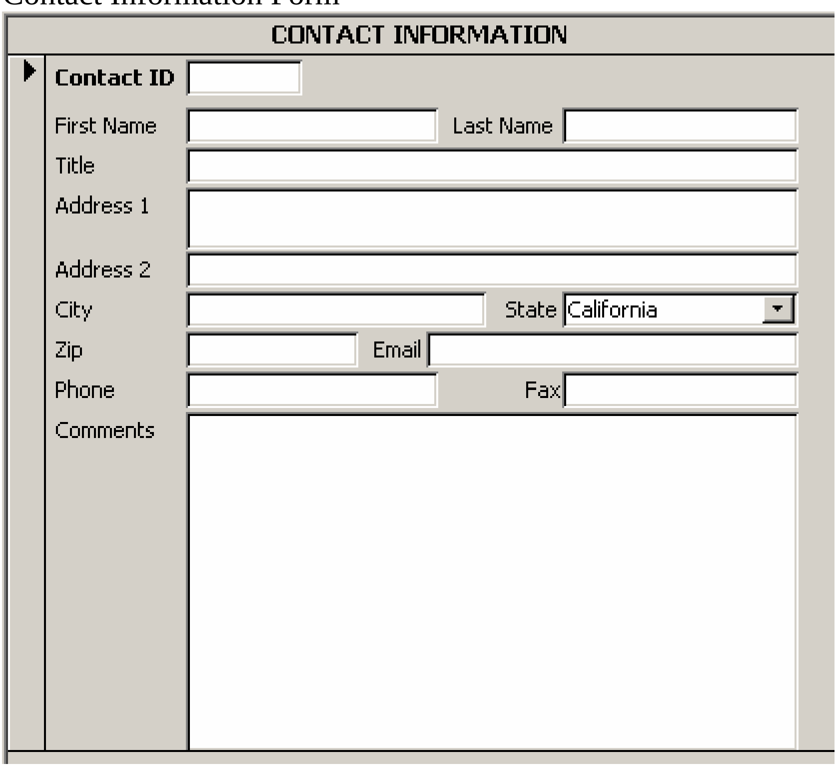


Table Relationships

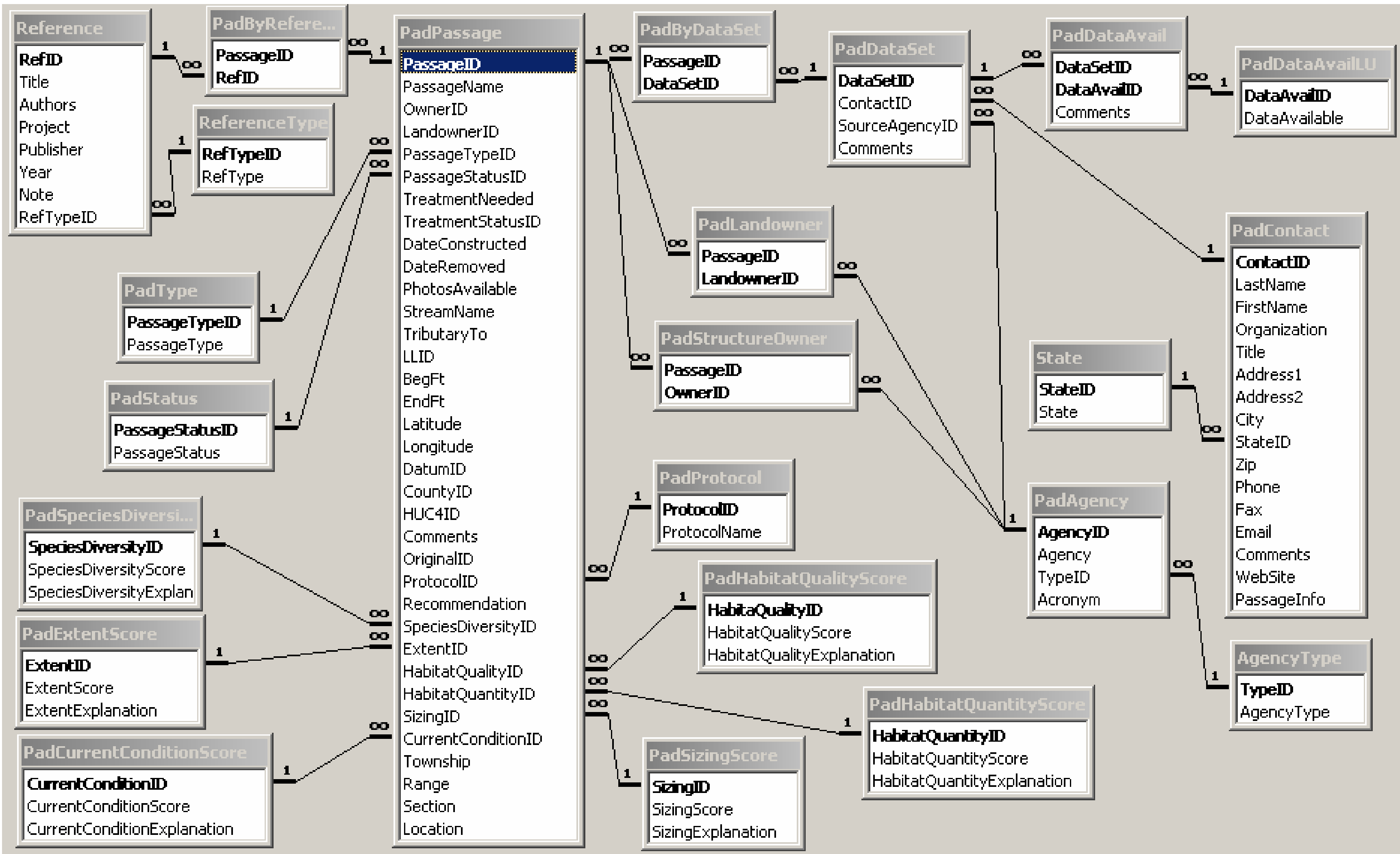


Table Descriptions

Main Passage Data Table (PadPassage)

Field Name	Data Type	Description
PassageID	Number	Unique ID for a single fish passage site (may or may not be a barrier).
PassageName	Text	Name of the site (if available).
OwnerID	Number	Unique ID for the name of the owner of the structure. Refer to the PadAgency table.
LandownerID	Number	Unique ID for the owner of the land adjacent to the structure/site. Refer to the PadAgency table.
PassageTypeID	Number	Unique ID for the type of fish passage site. Refer to the PadType table.
PassageStatusID	Number	Unique ID for the status of the site (complete, partial, not a barrier, unknown). Refer to the PadStatus table.
TreatmentNeeded	Number	Is treatment needed to restore fish passage at the site? (0=No, 1=Yes, 99=Unknown)
TreatmentStatusID	Number	Unique ID for the status of site treatment (planned, ongoing, completed, unknown). Refer to the PadTreatmentStatus table.
DateConstructed	Date/Time	Date the structure was constructed.
DateRemoved	Date/Time	Date the structure was removed.
PhotosAvailable	Number	Are photos of the site available? (0=No, 1=Yes, 99=Unknown)
StreamName	Text	Name of the stream in which the structure/site is located.
TributaryTo	Text	Downstream name.
LLID	Text	Unique ID of the stream in which the structure/site is located. California standard Long/Lat ID. Based on hydrography 2003 version.
BegFt	Number	The distance in feet from the mouth of the stream to the downstream end of the site. Based on hydrography 2003 version.
EndFt	Number	The distance in feet from the mouth of the stream to the upstream end of the site.
Latitude	Text	Latitude of the site location in decimal degrees.
Longitude	Text	Longitude of the site location in decimal degrees.
DatumID	Text	The datum of the latitude/longitude of the site.
CountyID	Number	Unique ID for the county in which the site is located. Refer to the County table.
HUC4ID	Number	Unique ID for the 4th-field hydrologic unit (watershed) in which the site is located. Refer to the HUC4 table.
Site Comments	Memo	Additional information about the site.
OriginalID	Text	ID assigned to the barrier in the original structure/site dataset (for example, the number assigned to the site by the agency that originally collected the data).
ProtocolID	Number	Unique ID for the protocol/tools/standards used to assess the potential barrier. Refer to the BarProtocol table.
Recommendation	Memo	Specific recommendations for improving passage at the barrier, including removal or remediation.
SpeciesDiversityID	Number	Score based on Federally or State listed salmonid species. Refer to the PadSpeciesDiversityScore table.
ExtentID	Number	Score based on values from the "percent passable" results from FishXing. Refer to the PadExtentScore table.
HabitatQualityID	Number	Score based on the length in feet to a sustained 8% gradient or field-identified limit of anadromy above the barrier. Refer to the PadHabitatQualityScore table.
HabitatQuantityID	Number	Score based on available habitat information. Refer to the PadHabitatQuantityScore table.
SizingID	Number	Score related to flow capacity. Refer to the PadSizingScore table.
CurrentConditionID	Number	Refer to the PadCurrentConditionScore table.
Township	Text	Township of the quad map.
Range	Text	Range of the quad map.
Section	Text	Section of the quad map.
ReasonID	Number	Reason why the record is not digitized.
PriorityRanking	Number	Priority ranking within a watershed and the providing source.

General Dataset Information Table (PadDataSet)

Field Name	Data Type	Description
DataSetID	Number	Unique ID for the dataset to which this structure/site belongs (the agency source of the data).
ContactID	Number	Code for agency's contact or project manager.
SourceAgencyID	Number	Unique ID for the agency contributing the structure/site data. Refer to the PadAgency table.
Comments	Memo	Additional information about the data source.

Passage and Dataset Linking Table (PadByDataSet)

Key	Field Name	Data Type	Description
PK	PassageID	Number	Unique ID for a single fish passage site. Refer to Barrier table.
PK	DataSetID	Number	Unique ID for the dataset to which this site belongs (the agency source of the data). Refer to BarDataSet table.

Other Data Available in Dataset Table (PadDataAvail)

Key	Field Name	Data Type	Description
PK	DataSetID	Number	Unique ID for the dataset to which this structure/site belongs (the agency source of the data). Refer to PadDataSet table.
PK	DataAvailID	Number	Unique ID for other type of structure/site data available from this source. Refer to PadDataAvailLU table.
	Comments	Memo	Other information about the type of data available.

Other Data Available Lookup Table (PadDataAvailLU)

Key	Field Name	Data Type	Description
PK	DataAvailID	Number	Unique ID for other type of passage data available from this source.
	DataAvailable	Text	Description of other type of passage data available.

Agency/Organization Table (used for both data source and ownership fields) (PadAgency)

Key	Field Name	Data Type	Description
PK	AgencyID	Number	Unique agency ID (assigned to agencies and other organizations).
	Agency	Text	Agency or organization data source or structure/site owner.
	TypeID	Number	Code for type of agency or organization.
	Acronym	Text	Agency or organization acronym (if any).

Agency/Organization Type Lookup Table (AgencyType)

Key	Field Name	Data Type	Description
PK	TypeID	Number	Code for type of agency. Primary key for this table.
	AgencyType	Text	Text description of the type of agency.

Contact Person Information Table (PadContact)

	Field Name	Data Type	Description
🔑	ContactID	Number	Code for agency's contact or project manager.
	LastName	Text	Famile name of the contact person or project manager.
	FirstName	Text	Given name of the contact person or project manager.
	Organization	Text	Name of agency or organization with which the contact is associated.
	Title	Text	Job title of contact person.
	Address1	Text	Mailing address line 1 of the contact or project manager.
	Address2	Text	Mailing address line 2 of the contact or project manager.
	City	Text	City where mail is received.
	StateID	Number	StateID for the State. Cross reference to State table.
	Zip	Text	Zip code.
	Phone	Text	Phone number(s) of the contact or project manager; (area code) prefix-number.
	Fax	Text	Fax number(s) of the contact or project manager; (area code) prefix-number.
	Email	Text	E-mail address(es) of the contact or project manager.
	Comments	Memo	Additional information or comments.
	WebSite	Text	Relevant web site address.
	PassageInfo	Text	Whether the contact has any fish passage information.

Passage Type Lookup Table (PadType)

	Field Name	Data Type	Description
🔑	PassageTypeID	Number	Unique ID for the type of structure/site.
	PassageType	Text	Description of the structure/site type.

Passage Status Lookup Table (PadStatus)

	Field Name	Data Type	Description
🔑	PassageStatusID	Number	Unique ID for the status of the structure/site.
	PassageStatus	Text	Description of the status of the structure/site. (Total, Partial, Temporal, Temporal & Partial, Temporal & Total, Not a Barrier, May not still be in existence, Unknown)

Passage Treatment Status Lookup Table (PadTreatmentStatus)

	Field Name	Data Type	Description
🔑	TreatmentStatusID	Number	Unique ID for the status of barrier treatment.
	TreatmentStatus	Text	Description of the barrier treatment status. (Planned, Ongoing, Completed, Unknown)

County Lookup Table (County)

	Field Name	Data Type	Description
🔑	CountyID	Number	Unique county ID.
	County	Text	California county name.

Hydrologic Unit Lookup Table (HUC4)

Field Name	Data Type	Description
HUC4ID	Number	4th field hydrologic unit code.
HUC4Name	Text	Name of the 4th field hydrologic unit.

Passage Reference Table (Reference)

Field Name	Data Type	Description
RefID	Number	Unique ID for a structure/site reference. Can be any documentation relating to the site (published or not).
Title	Text	Title of the document.
Authors	Text	Document authors.
Project	Text	Description of any project(s) of which the reference was a part.
Publisher	Memo	Document publisher (if any).
Year	Number	Year the document was produced or published.
Note	Memo	Additional information about the reference.
RefTypeID	Number	Unique ID for the type of reference. Refer to the ReferenceType table.

Passage and Reference Linking Table (PadByReference)

Field Name	Data Type	Description
PassageID	Number	Unique ID for a single fish passage site. Refer to Passage table.
RefID	Number	Unique ID for a structure/site reference. Can be any documentation relating to the site (published or not). Refer to Reference table.

Reference Type Lookup Table (ReferenceType)

Field Name	Data Type	Description
RefTypeID	Number	Unique ID for type of reference.
RefType	Text	Description of the reference type.

Barrier Ranking Criteria

Species Diversity Lookup Table (PadSpeciesDiversityScore)

Field Name	Data Type	Description
SpeciesDiversityID	AutoNumbe	Unique ID for the species diversity score.
SpeciesDiversityScore	Number	Score values representing species diversity, based on Chapter IX of the California Salmonid Stream Habitat Restoration Manual.
SpeciesDiversityExplanation	Text	Explanation of the score values according to the ranking criteria from the Chapter IX of the California Salmonid Stream Habitat Restoration Manual.

Extent of Barrier Lookup Table (PadExtentScore)

Field Name	Data Type	Description
ExtentID	AutoNumber	Unique ID for the extent of barrier score.
ExtentScore	Number	Score values representing extent of barrier, based on Chapter IX of the California Salmonid Stream Habitat Restoration Manual.
ExtentExplanation	Text	Explanation of the score values according to the ranking criteria from the Chapter IX of the California Salmonid Stream Habitat Restoration Manual.

Habitat Quantity Lookup Table (PadHabitatQuantityScore)

Field Name	Data Type	Description
HabitatQuantityID	AutoNumber	Unique ID for the habitat quantity score.
HabitatQuantityScore	Number	Score values representing habitat quantity, based on Chapter IX of the California Salmonid Stream Habitat Restoration Manual.
HabitatQuantityExplanation	Text	Explanation of the score values according to the ranking criteria from the Chapter IX of the California Salmonid Stream Habitat Restoration Manual.

Habitat Quality Lookup Table (PadHabitatQualityScore)

Field Name	Data Type	Description
HabitaQualityID	AutoNumber	Unique ID for the habitat quality score.
HabitatQualityScore	Number	Score values representing habitat quality, based on Chapter IX of the California Salmonid Stream Habitat Restoration Manual.
HabitatQualityExplanation	Text	Explanation of the score values according to the ranking criteria from the Chapter IX of the California Salmonid Stream Habitat Restoration Manual.

Sizing (Risk of Failure) Lookup Table (PadSizingScore)

Field Name	Data Type	Description
SizingID	AutoNumber	Unique ID for the sizing score.
SizingScore	Number	Score values representing sizing, based on Chapter IX of the California Salmonid Stream Habitat Restoration Manual.
SizingExplanation	Text	Explanation of the score values according to the ranking criteria from the Chapter IX of the California Salmonid Stream Habitat Restoration Manual.

Current Conditions Lookup Table (PadCurrentConditionsScore)

Field Name	Data Type	Description
CurrentConditionID	AutoNumber	Unique ID for the current condition score.
CurrentConditionScore	Number	Score values representing condition of a barrier, based on Chapter IX of the California Salmonid Stream Habitat Restoration Manual.
CurrentConditionExplanation	Text	Explanation of the score values according to the ranking criteria from the Chapter IX of the California Salmonid Stream Habitat Restoration Manual.

APPENDIX A(3)

CALIFORNIA HABITAT RESTORATION PROJECT DATABASE

Data Documentation Summary (Updated September 2004)

INTRODUCTION

The California Habitat Restoration Project Database (CHRPD) is a cooperative project involving the California Department of Fish and Game (CDFG), NOAA Fisheries, and the Pacific States Marine Fisheries Commission. Initiated in 1999, the CHRPD captures and manages data about anadromous habitat restoration projects with an emphasis on detailed project cost data. The database includes a georeferenced location for each project, allowing the data to be easily viewed in a geographic format.

The database includes habitat improvement, watershed assessment and planning, monitoring, land and water right acquisition, watershed organization support, education, and hatchery projects (including trapping, spawning, rearing and releasing salmonids).

DATA CATEGORIES

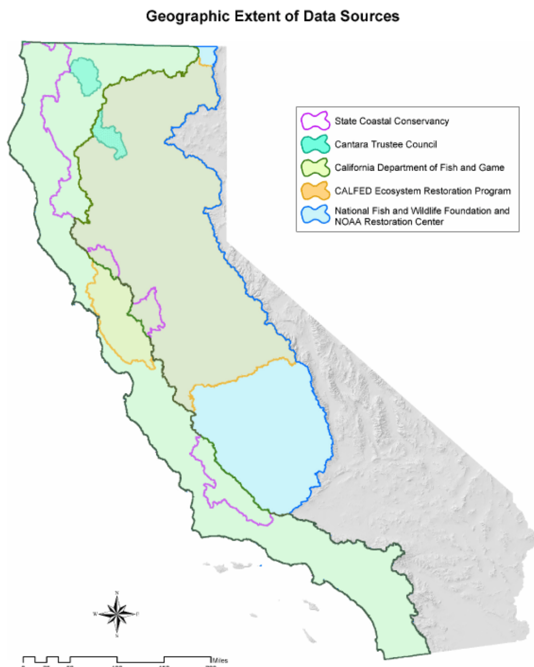
- Data source(s)
- Beginning and ending dates of project
- References (any published or unpublished documents relating to the project)
- Purpose
- Final analysis and final report
- Participants (including type of participation, monetary contribution and contact)
- Funding sources (and amounts requested and approved)
- Site-specific data:
  - o Site location
  - o Land cover and land use
  - o Restoration goals
  - o Treatment details
  - o Post-project monitoring
  - o Land ownership
  - o Treatment recommendations (assessment projects)
  - o Metrics of project size/scale
- Species affected
- Contract-tracking, including invoices, amendments and deliverables
- Relationships between projects

DATABASE STRUCTURE

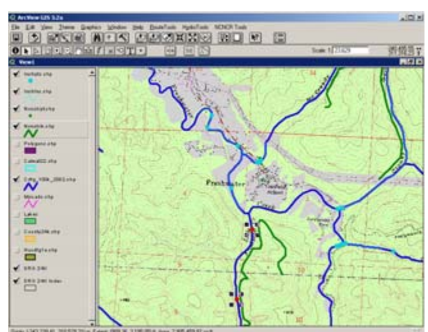
The CHRPD is based on the StreamNet Data Exchange Format (Version 2004.1, http://www.streamnet.org). New tables have been added to accommodate specific needs for data collection in California, including contract tracking information and watershed planning data.

DATA SOURCES

- California Department of Fish and Game, Fisheries Restoration Grant Program (1981 to the present)
- National Fish and Wildlife Foundation (1997 to the present)
- State Coastal Conservancy (1997 to the present)
- NOAA Restoration Center (1996 to the present)
- California Conservation Corps (in progress)
- Cantara Trustee Council (1997 to the present)
- Wildlife Conservation Board (in progress)
- U.S. Fish and Wildlife Service (in progress)



GEOGRAPHIC INFORMATION



Each project is assigned a spatial location. The majority of these consist of locations (points and lines) along stream reaches, which tie the projects to 1:100,000 hydrography. Polygons and non-stream points and lines are also digitized.

ON THE WEB

Data and documentation is available online at www.CalFish.org.

CONTACTS

Pacific States Marine Fisheries Commission:

Robin Carlson	Stan Allen
(916) 324-8298	(503) 595-3114
rcarlson@dfg.ca.gov	stan_allen@psmfc.org

APPENDIX A(4)

California Fish Passage Assessment Database

DATA SOURCES COMPILED TO DATE

August 1, 2004

DATA SOURCE	COUNTY	Number of Passage Sites
Alameda County Flood Control and Water Conservation District	Alameda	88
California Coastal Conservancy	Statewide	13
California Conservation Corps	San Luis Obispo	63
California Department of Fish and Game	Statewide	10,983
California Department of Parks and Recreation	Sonoma	4
California Department of Transportation, District 05	San Luis Obispo and Monterey	51
California Department of Transportation, Division of Environmental Analysis	Statewide	193
California Department of Water Resources	Statewide	1,354
California State Water Quality Control Board	Santa Cruz	226
California Trout Incorporated	Ventura	1
Central Coast Salmon Enhancement	San Luis Obispo	19
Circuit Rider Productions	San Mateo, Santa Clara and Santa Cruz	47
City of Mill Valley	Marin	31
Coastal San Luis Resource Conservation District	San Luis Obispo	15
East Bay Municipal Utility District	Alameda and Contra Costa	32
Ecotrust	Napa	271
Eel River Watershed Improvement Group	Del Norte and Humboldt	8
Entrix, Incorporated	Los Angeles,Ventura	68
Environmental Science Associates	Santa Cruz	39
Friends of Napa River	Napa County	271
Friends of the Eel River	Lake and Mendocino	2
Green Foothills Foundation	San Mateo	96
Greystone Environmental Consultants	Los Angeles	10
Humboldt State University	Humboldt	202
Kamman Hydrology and Engineering, Inc.	San Mateo	19
Karuk Tribe of California	Humboldt and Siskiyou	11
Land Conservancy of San Luis Obispo County	San Luis Obispo	62
Matt W. Stoecker and Conception Coast Project	Santa Barbara and Ventura	514
Mattole Restoration Council	Humboldt and Mendocino	10
Mendocino Redwoods Company	Mendocino	3,947
Napa County Resource Conservation District	Napa	2

National Marine Fisheries Service	Statewide	282
Natural Heritage Institute	Contra Costa	2
Occidental Arts and Ecology Center	Sonoma	5
Orange County, California	Orange	3
Point Reyes National Seashore	Marin	3
Prunuske Chatham, Inc. (Ecological Restoration)	Sonoma	1
Redwood National Park	Humboldt	7
Resource Conservation District of the Santa Monica Mountains	Los Angeles	5
Ross Taylor and Associates	Del Norte, Humboldt, Mendocino, Siskiyou, Sonoma, Trinity and Marin	946
Salmon Protection and Watershed Network	Marin	60
San Francisco Bay Regional Water Quality Control Board	Napa	323
San Francisquito Creek Watershed Council Steelhead Taskforce	San Mateo and Santa Clara	73
San Francisquito Watershed Council	San Mateo and Santa Clara	45
San Pedro Creek Watershed Coalition	San Mateo	9
Santa Cruz County Resource Conservation District	Santa Cruz	51
Santa Ynez River Consensus Committee	Santa Barbara	12
Save-the-Redwoods League	Del Norte	2
Sonoma County Water Agency	Sonoma	14
Southern California Steelhead Coalition	Los Angeles, San Diego, Santa Barbara and Ventura	35
Stewards of Slavianka	Sonoma	80
Stoecker Ecological Consulting / Community Environmental Council	Santa Barbara and Ventura	133
The Water Institute - California State University	Monterey	10
Timber Products Company	Trinity	6
Trout Unlimited	Mendocino and San Diego	2
U.S. Army Corps of Engineers	Statewide	1,558
U.S. Bureau of Land Management	Humboldt and Mendocino	2
U.S. Department of Interior	Orange	47
U.S. Fish and Wildlife Service	San Diego County	6
U.S. Forest Service	Statewide	467
United Anglers	Marin	4
Ventura County Flood Control District	Ventura	29
Ventura County Planning Division	Ventura	52
Yurok Tribe	Del Norte and Humboldt	135

California Fish Passage Assessment Database

DATA SOURCE REFERENCES

Alameda County Flood Control and Water Conservation District. Da Costa, E. Fish Habitat and Fish Population Assessment for the San Lorenzo Creek Watershed, Alameda County, California. 2002.

Balance Hydrologics, Inc. Arana Gulch Watershed Enhancement Plan Phase 1: Steelhead and Sediment Assessments, Santa Cruz, California. 2002.

California Coastal Conservancy. Fishman, N. Email Communication. 2003.

California Coastal Conservancy. Kroll, Ch. Email Communication. 2003.

California Coastal Conservancy. Wayman, D. Email Communication. 2003.

California Conservation Corps. Close, B. J. Electronic Files. 2003.

California Trout Incorporated. Craig, F. Email Communication. 2003.

Caltrans. Cesena, Ch. CHMPPUB Database. 2003.

Caltrans, Division of Environmental Analysis. Abafo, S. DFG Culvert list (doc). District 2 Fish Passage projects (doc). Thorne091302 Culverts on Siskiyou 96 (doc). D5 Fish Passage HQ Project List (xls). District 5 Sites (xls). Marin County Culvert Data CALTRANS Sites R. Taylor 08Nov02n (xls). 2003.

California State Water Quality Control Board. Hope, D. Personal Communication. 2003.

CDFG. Babcock, C. Email Communication. 2003.

CDFG. Bairrington, P. Personal Communication. 2003.

CDFG. Cleugh, E. Personal Communication. 2003.

CDFG. Cleugh, E. and C. McKnight. Steelhead Migration Barrier Survey of San Francisco Bay Area Creeks (Contra Costa, Alameda, Santa Clara and San Mateo Counties) (pdf). 2002.

CDFG. Coey, B. CCR Ladders and Trouble Spots (doc). Barrier List Nelson (doc). CDFG CAB San Lorenzo River Barriers (txt). 2002.

CDFG. Cox, B. Email Communication. 2003.

CDFG. Downie, S. Personal Communication. 2003.

CDFG. Flossi, G. Personal Communication. 2003.

CDFG. Garrison, P. Electronic Files. 2003.

CDFG. Garrison, P. 2000-2001 Trinity River Tributaries Winter-Run Steelhead Spawning Survey Report. 2002.

CDFG. Gilroy, M. Quad Mapbook with Marked Barrier Information. 1960 to present.

CDFG. Gingras, M. CDFG CAB San Lorenzo River Barriers (txt). 2002.

CDFG. Grass, A., D. Highland. CCR Ladders and Trouble Spots. 2002.

CDFG. Harris, S. Personal Communication. 2003.

CDFG. Highland, D. Personal Communication. 2003.

CDFG. Holmes, A. Temporary Barriers Project 1601 Permits Issued by the Central Valley Bay-Delta Office. 2001.

CDFG. Hovey, T. Personal Communication. 2003.

CDFG. Jones, W. Personal Communication. 2003.

CDFG. Jong, B. North Coast California Coho Salmon Investigation Files. 1910 to present.

CDFG. Larson, M. Personal Communication. 2003.

CDFG. McAllister, B. Personal Communication. 2003.

CDFG. Miller, J. Fish Passage Improvements Projects. Caltrans District 2 Fish PAC. 2003.

CDFG. 1960 – 1990 Stream Survey Protocols for Del Norte and Humboldt Counties.

CDFG. Nelson, J. DFG Barrier List (doc). 2002.

CDFG. Nelson, J. Monterey Barriers (doc). 2002.

CDFG. Nelson, J. SLO Barrierlist (doc). 2004.

CDFG. O'Brien, J. Personal Communication. 2003.

CDFG. Oshima, I. Geographic Names Information System, Waterfalls (shp). 2003.

CDFG. Preston, L. Personal Communication. 2003.

CDFG. Raquel, P. Diversions Oct02 (shp). 2002. DiversionsUpdates (shp). 2003.

CDFG. Russian River Basin Fisheries Restoration Plan. Draft. 2002.

CDFG. Snyder, B. Fish Passage Inventory. Fish Habitat Completion Form. 1960 to 1970.

CDFG. Titus, R. G., D. C. Erman, W.M. Snider. History and Status of Steelhead in California Coastal Drainages South of San Francisco Bay. In preparation. 2003.

CDFG. Vejar, A. Email Communication. 2003.

CDFG. Whitman, M. Personal Communication. 2003.

CDPR. O'Neil, B. Barriers (doc). 2003.

CDWR. Bulletin 250. 2003.

CDWR. Lee, Ch. DWR Bay Area (xls). 2002.

CDWR. Division of Safety of Dams. Lee, Ch. DSOD New (xls). 2003.

CDWR. Division of Safety of Dams. Wong, Ch. Spatial Files. 2003.

Central Coast Salmon Enhancement. O'Henley, C. Electronic Files. 2002.

Circuit Rider Productions, Inc. Email Communication. 2003.

Coastal San Luis Obispo Resource Conservation District. McEwen, M. Excerpt from Draft Steelhead Restoration Planning Project for the Morro Bay Watershed by John Dvorsky. 2002.

Coastal Watershed Council. Conrad, M. T. and J. Dvorsky. Aptos Creek Watershed Assessment and Enhancement Plan. 2003.

Coastal Watershed Council. Conrad, M. T. and S. Chartrand. Gazos Creek Watershed Assessment and Enhancement Plan. 2003.

East Bay Municipal Utility District. Myers, J. Email Communication. 2003.

Ecotrust. Spatial Files. 2002.

Eel River Watershed Improvement Group. Vaughn, H. Email Communication. 2002.

Entrix Incorporated. Franklin, R.F., S. S. Dobush. Malibu Creek Steelhead Habitat Assessment. 1989.

Entrix Incorporated. Loomis, K. Email Communications. 2003.

Entrix Incorporated. Ventura River Watershed Technical Investigation Summary Report and Recommendation. 2003.

Entrix Incorporated and Woodward Clyde Consultants. Ventura River Steelhead Restoration and Recovery Plan Steelhead Restoration and Recovery Plan. 1997.

Environmental Science Associates. Coast Dairies Long-Term Resource Protection and Use Plan Existing Conditions Report. 2000.

Friends of the Eel River. The Eel River Reporter. 2003.

Friends of Napa River. Malan, Ch. Snorkel Survey (Spring 2001) Information for the Napa River Watershed. 2001.

Green Foothills Foundation. San Mateo County Compendium of CDFG Stream Survey Protocols and Related Documentation (pdf). 2003.

Greystone Environmental Consultants. Biological Assessment for the Southern California Steelhead for the National Park Service General Management Plan /

Environmental Impact Statement for the Santa Monica Mountains National Recreational Area. 2002.

Kamman Hydrology and Engineering, Inc. Cordilleras Creek - April 8, 2002. Preliminary Fish Passage Assessment. 2002.

Karuk Tribal Fisheries. Draft 2002 Coho Distribution Summary. 2003.

Land Conservancy of San Luis Obispo County, Stark, B. Electronic Files. 2002.

Love, M. Stonybrook Creek Fish Passage Assessment. 2001.

Mattole Restoration Council. Larson, Ch. Spreadsheet Fish Passage Barriers Mattole. (xls). 2002.

Mendocino Redwood Company. Surfleet, Ch. Spatial Files. 2002.

Mendocino Redwood Company. Wagschal, A. Mendocino Redwood Company CD (shp). 2002.

Napa County Resource Conservation District. BioEngineering Associates. Assessment of Streambank and Channel Conditions with Prescriptions to Restore for 10,000 ft of Dry Creek, Napa County. 2003.

Napa County Resource Conservation District. Hadhazy, L. Email Communication. 2003

NMFS. Capelli, M. Email Communication. 2003.

NMFS. Jones, W., NMFS California Anadromous Fish Distribution. California Coastal Salmon and Steelhead Current Stream Habitat Distribution Table (pdf). NMFS Draft 1/00. 2000.

MNFS. Glowacki, S. Personal Communication. 2004.

NMFS. Southwest Regional Office NMFS. Central Valley Chinook Salmon Current Stream Habitat Distribution Table. 2000.

NMFS. Spina, A. Email Communication. 2003.

Occidental Arts and Ecology Center. Dolman, B. Email Communication. 2003.

Orange County, California. Aliso Creek Watershed Study Management Team. Water Quality Monitoring Program. 2001.

Payne, T. R. Assessment of Steelhead Habitat in Upper Matilija Creek Basin. 2003.

Philip Williams and Associates, Ltd., Prunuske Chatham, Inc., Callander Associates. Pilarcitos Creek Restoration Plan. 1996.

Prunuske Chatham. Austensen, E. Fish Barrier Summary to DWR & CCC (doc). 2003.

Redwood National and State Parks. Anderson, D. Fish Barriers 10-02 (doc). 2002.

Resource Conservation District of the Santa Monica Mountains. Dagit, R., K. Reagan, C. A. Swift. Topanga Creek Watershed Southern Steelhead Trout Preliminary Watershed Assessment and Restoration Plan Report. 2003.

Ross Taylor and Associates. Taylor, R. N. Final Report: Humboldt County Culvert Inventory and Fish Passage Evaluation. 2000.

Ross Taylor and Associates. Taylor, R. N. Final Report: Coastal Mendocino County Culvert Inventory and Fish Passage Evaluation. 2001.

Ross Taylor and Associates. Taylor, R. N. Final Report: Del Norte County Culvert Inventory and Fish Passage Evaluation. 2001.

Ross Taylor and Associates. Taylor, R. N., M. Love, T. D. Grey, A. L. Knoche. Final Report: Trinity County Culvert Inventory and Fish Passage Evaluation. 2002.

Ross Taylor and Associates. Taylor, R. N. Siskiyou County Culvert Locations and Characteristics (xls). 2002.

Ross Taylor and Associates. Taylor, R. N. and Assoc. Marin County Stream Crossing Inventory and Fish Passage Evaluation, Final Report. 2003.

Ross Taylor and Associates. Taylor, R. N., T. D. Grey, A. L. Knoche, M. Love. Russian River Stream Crossing Inventory and Fish Passage Evaluation Final Report. 2003.

Salmon Protection and Watershed Network. Walder, R., M. Corsini, T. Steiner. Inventory of Select Migration Barriers in the San Geronimo sub-Watershed (Spring 2002). 2002.

San Diego Trout. Greenwood, A. Email Communication. 2003.

San Francisquito Creek Watershed Council. Stoecker, M. Salmonid Migration Barriers/Impediments in the San Francisquito Creek Watershed, San Francisco Bay, California. 2002.

San Francisquito Creek Watershed Council. Stoecker, M. San Francisquito Watershed Council Salmonid Migration Barrier Spreadsheet, 9/13/03 (xls). 2003.

San Francisquito Watershed Council. Showalter, P. Long-Term Monitoring and Assessment Plan for the San Francisquito Creek Watershed. 2002.

San Francisquito Watershed Council. Smith, J. J., D. R. Harden. Adult Steelhead Passage in the Bear Creek Watershed. 2001.

San Pedro Creek Watershed Coalition. San Pedro Creek Watershed Assessment and Enhancement Plan. 2002.

Santa Cruz County Resource Conservation District. Soquel Creek Watershed Assessment and Enhancement Plan. 2003.

Santa Ynez River Consensus Committee. Lower Santa Ynez River Fish Management Plan. 2000.

Save-the-Redwoods League. Hartley, R. K. Mill Creek Interim Management Recommendations. 2002.

Siskiyou County Farm Bureau. Shasta Valley Water Diversion. 2002.

Sonoma County Water Agency. Evaluation of Fish Habitat and Barriers to Fish Migration: Russian River Mainstem and Lower Dry Creek by Winzler and Kelly Consulting Engineers. 1978.

Sonoma Ecology Center. Pier, W. Email Communication. 2003.

Southern California Steelhead Coalition. Edmondson, J. Platform Paper – Southern California Fish Barriers. 2002.

Southern California Steelhead Coalition. Finney, K., J. Edmondson. Swimming Upstream: Restoring the Rivers and Streams of Coastal Southern California for Southern Steelhead and Other Fishes. 2002.

Southern California Steelhead Coalition. Pritchett, D. Personal Communication. 2003.

Stewards of Slavianka. Luna, M. Willow Creek Channel Study (doc). Fife Creek In-Stream Structures (xls). 2003.

Stoecker and Conception Coast Project 2002. Stoecker, M.W. Steelhead Assessment and Recovery Opportunities in Southern Santa Barbara County, California. 2002.

Stoecker Ecological Consulting. Stoecker, M. Sisquoc River Dataset (Access Database). 2003.

Swanson Hydrology and Geomorphology. Dvorsky, J., D. Alley, J. Smith. San Lorenzo River Salmonid Enhancement Plan. 2002.

The Watershed Institute, Cailfornia State University. Smith, D., B. Curry, D. Jackson, A. Thistle, Ch. Marin. Steelhead Habitat Assessment and Restoration in Upper Williams Canyon Creek: Mitteldorf Redwood Preserve, Monterey County, California. 2003.

Tri-County F.I.S.H. Team. Lang, R. Personal Communication. 2003.

Trout Unlimited. Katz, D. Email Communication. 2003.

Trout Unlimited. Sutherland, G. Personal Communication. 2003.

United Anglers. Batty, T. Fish Barriers in West Marin County (fax). 2003.

U.S. ACE, Los Angeles District. San Juan and Aliso Creek Watershed Management Study Orange County, California. 1997.

U.S. ACE, Los Angeles District. Aliso Creek Watershed Study Orange County, California. Draft Watershed Management Report Feasibility Phase. 2001.

U.S. ACE. Rippey, K. Personal Communication. 2003.

U.S. ACE. Ragon, R. National Inventory of Dams (shp). 2002.

U.S. BLM. Fuller, D. Email Communication. 2002.

U.S. DI, Fish and Wildlife Service. Lang, J. S., B. F. Oppenheim, R. N. Knight. Southern Steelhead *Oncorhynchus mykiss* Habitat Suitability Survey of the Santa Margarita River, San Mateo, and San Onofre Creeks on Marine Corps Base Camp Pendleton, California. 1998.

U.S. DI, Fish and Wildlife Service. Wilkinson, Ch. And Ch. Collier. San Juan Creek Watershed Management Feasibility Study Orange County, California. 2000.

U.S. FS. Klamath National Forest. Fish Passage Assessment in Klamath National Forest. 2003.

U.S. FS. Olson, B. 2001 Regional Fish Passage Study. (GIS, Access Database). 2001.

Wetlands Recovery Project. Thiel, B. Personal Communication. 2003.

Yurok Tribal Fisheries Program. Hillemeier, D. Lower Klamath Barrier Assessment (xls). 2002.

Yurok Tribal Fisheries Program. Gale, D. B. Inventory and Assessment of Anadromous Fish Passage Barriers in the Lower Klamath River Sub-basin, California. 2003.

Acronyms

Caltrans	California Department of Transportation
CDFG	California Department of Fish and Game
CDPR	California Department of Parks and Recreation
CDWR	California Department of Water Resources
NMFS	National Marine Fisheries Service.
U.S. ACE	United States Army Corps of Engineers
U.S. BLM	United States Bureau of Land Management
U.S. DI	United States Department of the Interior
U.S. FS	United States Forest Service

doc	Microsoft Word Document
pdf	Adobe Acrobat Document
shp	ArcView Spatial File
xls	Microsoft Excel Document

APPENDIX B(1)

Biology & Life History

The following summary entitled "Winter Steelhead and Chinook and Coho Salmon Life Cycles and Habitat Requirements" helps view barriers in the context of overall species requirements throughout their life history. All proponents of barrier modification or removal projects are urged to review this section, and give careful consideration to all habitat requirements prior to prioritizing and selecting projects for implementation.

WINTER STEELHEAD AND CHINOOK AND COHO SALMON LIFE CYCLES AND HABITAT REQUIREMENTS

Jerry J. Smith
Dept. Biological Sciences
San Jose State University

I. **Upstream Migration of Adults**

A. **Timing:** Fall Chinook – September through November
Coho – late November through mid-February
Steelhead – late December through April

B. **Requirements:** Sufficient streamflow to provide passage over shallow riffles, log jams, falls, etc.

C. **Potential Problems**

1. Shallow, broad, "critical riffles"
2. Other natural barriers – falls, logjams, sandbars
3. Man-made barriers – culverts, dams, streamflow alterations
4. Seasonal streamflows
5. Altered amount and timing of streamflows, due to reservoirs and diversions
6. Fishing pressure by sportsmen and poachers
7. Failure or delay in sandbar breaching in dry years (including due to diversions or coastal modifications)

D. **Potential Solutions**

1. Minimum streamflow requirements (bypasses, reservoir releases)
2. Barrier modification or removal (most logs should be left in the stream)
3. Fishing regulations and their enforcement
4. Sandbar management plans which allow artificial breaching under rare severe drought conditions (for access by coho salmon)

II. Spawning (Reproduction)

A. **Timing:** Fall Chinook – September through December
Coho – late December through February
Steelhead – late December through April
Early spawning means potentially early emergence, longer growing season and larger first-year size (coho). Later spawning reduces risk of nest ("redd") destruction by storms.

B. **Requirements:** Sufficient cool streamflow over good, clean pea- to apple-sized gravels, good streambed hydraulic configuration (usually at head of riffles) of sufficient depth, and with escape cover (usually a deep pool with cover) nearby.

C. **Potential Problems**

1. Siltation of gravels due to logging, development and/or road building, resulting in smothered eggs or easily washed away nests.
2. Low winter streamflows, resulting in poor aeration of eggs (or rarely, stranding of nests.
3. High winter streamflows, resulting in washing away of earlier nests (this is especially likely for chinook and coho, which spawn near the beginning of the winter storm season). Large funnel-shaped watersheds generate higher floodpeaks than smaller, narrower watersheds (which may serve as flood year spawning refuges).
4. Reservoirs may alter winter flows, increasing or decreasing flood risks.
5. Weak year classes or gaps from 3-year cycle of female coho; the ghost of bad years past.

D. **Potential Solutions**

1. Land use plans to reduce erosion from logging, road building and/or development, and their enforcement.
2. Hatchery incubation? (with concern for genetic problems of hatcheries)
3. Hatchery manipulation for 2-year-old (precocial) female coho
4. Addition of gravels or structures which can trap gravels (expensive, requires continuous effort)

III. Rearing

A. **Timing:** Fall Chinook – November through January through April to May
(3-6 months in fresh water)

Coho – April through April to May of the following year (1 year in fresh water)
Steelhead – April through April to June of the following year (spring, summer, winter or spring – 1 year in fresh water) or two spring-through-spring periods (2 years in fresh water)

B. **Requirements:** Escape or hiding cover (undercut banks, logs, pools, surface turbulence, unburied cobbles), suitable water quality (temperature, oxygen, clarity), and minimal rations for Maintenance. Steelhead: fast-water feeding areas and/or high food abundance for Growth. Coho: productive pools and glides with cover and good food availability. Enough light for algal and insect production and for sight feeding.

1. Small, low flow tributary streams (Little Sur, Scott, Corralitos, Redwood creeks) tend to provide less food and produce small fish after one year, resulting in poorer survival of salmon going to the ocean and usually requiring steelhead to spend two years in the stream. Growth occurs primarily in the spring, when fast water is available (and possibly when light is more available). Steeper streams lack abundant, good pools for coho. Small streams mostly provide maintenance habitat. Water quality (temperature, oxygen, turbidity (muddiness)) is usually not a problem.
2. Larger, warmer streams (Carmel and San Lorenzo rivers, Uvas Creek, Russian River?) cannot provide enough food in summer to maintain coho or steelhead in pools. Only fast-water riffles, and pools immediately downstream of them, can support steelhead. However, these riffles often provide steelhead with enough food for summer growth; many fish grow large enough to go to the ocean after one year in the stream. Augmented streamflows from reservoirs (for conveyance or groundwater percolation) can produce good steelhead habitat by providing fast-water feeding areas, despite higher water temperatures (and increased steelhead food demands); unless water temperature is too high, warmer water primarily produces a food problem, rather than a direct physiological threat.
3. Small, productive seasonal ponds (such as Sprig Lake at Mt. Madonna County Park) can sometimes provide excellent rearing conditions for steelhead, if they are not too warm and if food is abundant. However, the value can be lost if the ponds are drawn down too low in the fall or emptied into dry or warm streambeds downstream before the winter rains.
4. Lagoons (Carmel River, Waddell, Soquel, and Pescadero creeks) form at the mouth of most streams in summer due to sandbar development, creating freshwater or brackish lakes. If water quality (high temperature, low oxygen) is not a problem and

conditions for food production are good (adjacent marshes, algae and aquatic plant production), lagoons can rear large numbers of fast-growing steelhead. Lagoons are usually too warm for coho salmon rearing in summer.

C. **Potential Problems**

1. Loss of escape cover and pool depth due to sedimentation and channel alteration, due to development, roads or timber harvest (reducing the number of fish and possibly their growth, by reducing food)
2. Loss of large woody debris (LWD) due to timber harvest and clearing for flood control. Shift from durable streamside conifers as wood source to small, brittle, short-lived alders.
3. Reduction of streamflow due to spring and summer water diversion (reducing fish abundance and/or growth).
4. Turbid water, which reduces feeding efficiency, due to watershed clearing and development or to turbid reservoir releases.
5. Large reductions in streamside vegetation, resulting in high water temperatures and fish food demands.
6. Drawdown or early draining of seasonal ponds.
7. Draining of summer lagoons for recreation, urbanization or agriculture. Lack of sufficient freshwater inflow resulting in brackish, layered, warm conditions.

D. **Potential Solutions**

1. Regulation of development to reduce erosion and streamside modifications.
2. Strict timber harvest regulations that reduce sedimentation and maintain sufficient canopy (temperature) and LWD recruitment, especially of large conifers.
3. Restrictions on LWD removal for flood control or "barrier" removal. Wood is good!
4. Minimizing onstream spring and summer water diversions.
5. Redesign of outlet works and altered regulations on draining of seasonal ponds.
6. Maintaining and enhancing summer lagoons.

IV. **Overwintering**

A. **Timing**: December through April

B. **Requirements:** Deep pools and backwater habitats with good escape cover, especially undercut banks, logs and rootwads, to protect fish from high streamflows. (Similar to the pools and escape cover which provide summer maintenance habitats.) Logjams may be extremely valuable refuges during floods. Clear water between major storms to allow for feeding and growth.

C. **Potential Problems**

1. Filling of pools with sediment accompanying development, road building and/or timber harvest.
2. Removal of logs from streams as a flood control measure or modification of the riparian forest.
3. Development, road building, logging and other watershed modifications, including reservoirs, which prolong turbid runoff associated with storms.

D. **Potential Solutions**

1. Regulation of development and streamside vegetation removal to prevent erosion and sedimentation.
2. Careful and limited log removal for flood control.
3. Maintenance and creation of complex woody pools, including logjams and backwaters.

V. **Migration of Juvenile Fish (Smolts) to the Ocean**

A. **Timing:** Late March through early June

B. **Requirements:** Sufficient flow to allow safe passage (and protection from predators) during the migration season. Flows prolonged enough to allow fish to feed and grow quickly in spring in either the stream or the estuary before migrating to the ocean. Clear late winter and spring streamflows, to allow for rapid growth prior to and during the migration. Larger fish adjust more easily to ocean water and are better at avoiding predators; they are much more likely to return as adults.

C. **Potential Problems**

1. Reduced streamflow, due to diversions, forcing fish to migrate out as small fish early in the spring or remain in the stream to feed and risk being trapped ("Go or grow conflict").
2. Prolonged turbid streamflows in spring, due to development or due to turbid releases from reservoirs. Turbid water stops or reduces feeding and growth.
3. Channel modifications for flood control or other purposes (San Lorenzo River), resulting in difficult downstream passage.
4. Loss of good estuaries that allow gradual adjustment for the saltwater transition.
5. Early sandbar closure, due to reduced streamflows or modification of coastline conditions.

D. **Potential Solutions**

1. Streamflow protections which allow spring migration.
2. Restrictions on developments that produce turbid spring flows.
3. Restrictions on channel modifications or their redesign to allow passage.
4. Reduction in watershed erosion to reduce sedimentation of the estuary.
5. Restoration and maintenance of estuaries.
6. Management plan to allow artificial breaching of sandbars under unusual drought conditions to allow outmigration of coho smolts.

VI. Ocean Residence

A. **Timing:** Chinook – Two or more summers for males, three or four years for females (die after spawning)
Coho – One or two years for males, two years for wild females (die after spawning)
Steelhead – One to four years (may spawn many times)

B. **Requirements:** Food is usually abundant in the ocean and once the young salmon or steelhead survive the transition to salt water they usually have very high survival rates and grow very quickly (8 to 12 inches during their first year in the ocean). Fish range the ocean for hundreds or thousands of miles and find their way back to their home stream by magnetic navigation (long range) and stream odor (short range).

C. **Potential Problems**

1. Heavy coastal and open ocean sport and commercial fishing.
2. Large increases in marine mammals.
3. Long-term shifts back and forth in productive ocean zone between north (Alaska) and south, which reduce ocean survival and growth.
4. El Niño years, when upwelling is reduced, reducing ocean productivity and fish growth and survival.

D. **Potential Solutions**

1. Regulation of ocean fishing, including cutbacks in harvest during periods of poor ocean survival and growth.
2. Emergency control of marine mammals at stream mouths when predation threatens weak salmonid stocks?

VII. Other Salmonids or Changes in Steelhead and Coho Biology North of Central California

A. **Coho Salmon**

1. Progressively earlier adult migration and spawning further north.
2. Often two years of freshwater residence due to slower growth in cool, shaded northern habitats and higher survival or 2 year old smolts.

B. **Steelhead**

1. Earlier adult migration and spawning for winter steelhead further north.
2. Often three years' fresh water growth further north.
3. "Summer steelhead" enter streams in late spring, spend summer in deep pools of cooler streams and spawn in fall/ early winter (Eel River).

C. **Chinook Salmon**

1. Stream type fish spend one year in fresh water and then migrate to use near-shore ocean
2. Ocean type fish migrate to ocean in spring and summer of first year and use offshore ocean habitats
3. Juvenile chinook tend to feed in faster water (like steelhead) rather than use pools (like coho).
4. Migration/spawning times differ for various chinook stocks – i.e., Spring run, Fall run, Late-fall run, Winter run (Sacramento River only).

D. **Sockeye Salmon**

1. Associated with Washington, Canadian and Alaskan watersheds that have accessible lakes for rearing by plankton-feeding juvenile sockeye (1 – 3 years).
2. Land-locked sockeye (**Kokanee**) have been stocked in many reservoirs
   and lakes (Tahoe) to provide a plankton-feeding sport fish.

E. **Chum** (Dog) and **Pink** (Humpback) **Salmon**

1. Spawn in the lower reaches of large rivers.
2. Migrate to the ocean within weeks of emerging from the nest.

F. **Coastal Cutthroat Trout**

1. Usually a headwater/ small stream spawner.
2. Two to three years in fresh water, with requirements similar to those of steelhead.
3. Juveniles migrate to the estuary for "ocean phase" of rearing.

An overview of the life history pattern of anadromous salmonids follows.

Chinook Salmon (Oncorhynchus tshawytscha)

Species Characteristics

As fully grown adults, Chinook salmon are the largest of Pacific salmon, typically growing to lengths of 75 to 80 cm and capable of reaching up to 140 cm. Spawning adults are olive brown to dark maroon in color with many small black spots on the back, dorsal fin, and tail fin. Both females and males have distinct black gums on the lower jaw. Spawning males can be distinguished from females by their darker coloration, hooked jaws, and slightly humped backs. Chinook salmon parr have 6-12 parr marks and individuals have an adipose fin that is clear in its center and at its base, but is pigmented on the upper edge (Moyle 2002).

Distribution

Chinook salmon have a trans-Pacific distribution, spawning in coastal North American streams from Alaska to California and in Asian streams in Russia and Japan. They are distributed in marine environments throughout the north Pacific. In California, Chinook salmon spawn in the larger coastal streams from the Oregon border south to San Francisco Bay, as well as in streams of the Central Valley and the San Francisco Bay-Delta drainages (Moyle 2002). Historically, Chinook occurred in coastal California streams as far south as the Ventura River (NOAA Fisheries 1998).

Taxonomy and Systematics

Among members of the genus *Oncorhynchus*, Chinook salmon are most closely related to coho salmon and occasionally hybridize with coho in streams where the species spawn together (Moyle 2002). Distinct populations of the species are recognized as “runs” or “stocks” that show adaptations to local and regional environmental conditions and represent important units for management of the species (Moyle 2002). In California, distinct runs that are widely recognized among fisheries managers and others include (1) Smith River fall run, (2) Klamath-Trinity fall run, (3) Klamath-Trinity spring run, (4) Klamath late fall run, (5) Redwood Creek fall run, (6) Little River fall run, (7) Mad River fall run, (8) Humboldt Bay tributaries fall fun, (9) Eel River fall run, (10) Bear River fall run, (11) Mattole River fall run, (12) Garcia River fall run, (13) Russian River fall run, (14) Central Valley fall run, (15) Central Valley late fall run, (16) Sacramento River winter run, and (17) Central Valley spring run (Moyle 2002).

Using the concept of Evolutionary Significant Units, NOAA Fisheries (1999) currently recognizes six ESUs of Chinook salmon in California, based on genetic and life history similarities among populations. They are the (1) Southern Oregon and Northern California Coastal ESU, including Chinook salmon in coastal streams from Cape Blanco in southern Oregon to, and including, the lower Klamath River in California; (2) California Coastal ESU, in streams from the Klamath River south to San Francisco Bay;

(3) Upper Klamath and Trinity Rivers ESU, including all Chinook salmon in the Trinity River and in the Klamath River upstream from the mouth of the Trinity River; (4) Central Valley fall-run ESU, including fall-run and late-fall-run Chinook salmon in the Sacramento and San Joaquin rivers and their tributaries; (5) Central Valley spring-run ESU; and (6) Sacramento River winter-run ESU, presently found only in the mainstem Sacramento River downstream from Keswick Dam.

Life History

Like other Pacific salmon, Chinook salmon are anadromous, meaning that they begin life in fresh water habitats, migrate to marine environments to feed and mature, and return to the streams of their origin to spawn. Chinook and other Pacific salmon, unlike steelhead trout, are typically semelparous, meaning that they die soon after spawning. Within the species, Chinook salmon exhibit a variety of life history patterns. In general, two main types of life history patterns are recognized: *ocean-type* and *stream-type*. Ocean-type Chinook are those that, as adults, spawn soon after entering fresh water and, as juveniles, spend a relatively short time rearing in fresh water (typically 3-12 months) before migrating to the ocean as smolts (Moyle 2002). Stream-type Chinook are those that migrate into fresh water before they have fully matured and, as juveniles, spend a relatively long period of time in fresh water before going to sea (usually greater than 1 year) (Moyle 2002). Both ocean-type and stream-type Chinook salmon occur in California.

Life history patterns of Chinook salmon can further be described by run-timing, which is the time of year that individuals migrate from the ocean into fresh water. Fall-run Chinook enter fresh water during late summer and in the fall. They are considered an ocean-type Chinook, spawning in the lowland reaches of larger rivers and their tributaries (Moyle 2002). Juveniles rear in fresh water for less than a year before moving out to sea. All of the Chinook salmon that spawn in California as part of the Southern Oregon and Northern California Coastal and the California Coastal ESUs are fall-run fish. Currently, Chinook spawning in tributaries to San Francisco Bay are all fall-run fish as well. There is a fall run of Chinook in the Upper Klamath/Trinity river system and the fall run is the largest salmon run in the Central Valley and its tributaries. Distinct late fall runs of Chinook have been identified, mainly in the Sacramento River, but also in the Upper Klamath and Trinity rivers (Moyle 2002). Winter-run Chinook salmon spawn only in the Sacramento River and exhibit intermediate characteristics between ocean-type and stream-type life history patterns, because they migrate into fresh water as immature fish, but juveniles remain in streams for less than a year (Moyle 2002). Formerly, winter-run Chinook spawned and reared in the Pit and McCloud rivers, but they are now blocked from reaching their historic spawning habitat by Shasta Dam. Spring-run Chinook are stream-type fish, entering streams in spring and early summer and holding for several months before spawning in early fall. They historically migrated far into the upper reaches of large tributaries to the Sacramento, San Joaquin, Klamath, and Eel rivers, but much of their historic habitat is no longer accessible because of dams and they currently persist only in a few streams of the Sacramento and Klamath drainages (Moyle 2002).

Coastal cutthroat trout (*Oncorhynchus clarki clarki*)

Species Characteristics

Coastal cutthroat trout have numerous black body spots and yellow to red pigment marks that appear as slashes beneath each side of the lower jaw (Moyle 2002). In general, the body coloration of coastal cutthroats is similar to that of rainbow trout (*O. mykiss*), which even exhibit the throat markings in some cases. Coastal cutthroats tend to have heavier spotting than rainbow trout. However, the most definitive characteristic to differentiate between coastal cutthroats and rainbow trout is that coastal cutthroat trout have basibranchial teeth, which can be felt on the floor of the throat (Moyle 2002).

Distribution

Coastal cutthroat trout occur in coastal drainages from the Eel River in California north to Seward, Alaska. In California coastal cutthroat occur primarily in streams and lagoons that are within the coastal rain forest along the north coast (Moyle 2002).

Taxonomy and Systematics

Coastal cutthroat trout are one of three subspecies of cutthroat trout that are native to California. The interior forms of cutthroat trout that occur naturally in California are Lahontan cutthroat trout (*O. clarki henshawi*) and Paiute cutthroat trout (*O. clarki seleneris*). A fourth subspecies, the Colorado cutthroat trout (*O. clarki pleuriticus*), was introduced to California in 1931 (Moyle 2002).

Coastal cutthroat trout diverged from the interior subspecies of cutthroat trout about a million years ago and are distinctive from them in many ways (Moyle 2002). Among coastal cutthroat trout, six distinct population groupings have been recognized throughout Washington, Oregon, and California based on common characteristics. The groupings have been identified by NOAA Fisheries as different ESUs, with the Southern Oregon/California Coastal ESU encompassing all of the California populations of coastal cutthroat trout (Johnson et al. 1999).

Life History

Coastal cutthroat trout, like other Pacific salmonids, exhibit a variety of life history patterns. While coastal cutthroat trout are capable of anadromy, they have a much closer affinity to fresh water than most anadromous fishes (Moyle 2002). In general, coastal cutthroat trout go to the ocean only during the summer and then overwinter in their natal streams. Some individuals do not go past estuaries or lagoons during their seaward migrations and other cutthroat trout remain in fresh water their entire lives (Moyle 2002). Some populations are potadromous, meaning that they exhibit distinct migration patterns within a river system, but do not go to sea. In some cases, such as in the Smith River, resident, potadromous, and anadromous populations all coexist (Moyle 2002).

Growth in fresh water is slower than in marine environments. Coastal cutthroat trout are capable of reaching a maximum size of about 50 cm FL, but resident cutthroat only reach about half the size of a sea-run cutthroat at any given age. Maximum life span life span is usually 7 years (Moyle 2002).

Anadromous cutthroat trout reach sexual maturity at 2-4 years of age and may return to fresh water up to five times to overwinter and spawn. In northern California, upstream migrations of coastal cutthroat occur from August-October. Females dig redds in gravel ranging from 0.2 to 10.2 cm in diameter and may spawn multiple times sequentially. Embryos incubate 6-7 weeks before hatching and alevins remain in the gravel for an additional 1-2 weeks before emerging as fry (Moyle 2002).

Coho Salmon (Oncorhynchus kisutch)

Species Characteristics

Adult coho salmon typically attain fork lengths of 55-70 cm and weigh 3-6 kg. Spawning adults are generally dark and drab, however, the males may be intensely dark red on the sides of their bodies. Females are paler than males, usually lacking the red streak. Spawning males usually have a strongly hooked jaw and slightly humped back, the jaw of the female is not as distinctly hooked. Both sexes have small black spots on the back, dorsal fin, and upper lobe of the caudal fin. The gums of the lower jaw are gray, except the upper area at the base of the teeth, which is usually white (Groot and Margolis 1991, Moyle 2002, Weitkamp et al. 2002).

Adult coho in the ocean are steel-blue to slightly greenish on the back, silvery on the sides, and white on the belly. There are numerous small black spots on the back, upper sides, and base of the dorsal fin and upper lobe of the caudal fin. The adults have black mouths with white gums at the base of the teeth in the lower jaw (Groot and Margolis 1991, Moyle 2002, Weitkamp et al. 2002).

Juvenile coho salmon in freshwater are blue-green on the back, with silvery sides. The parr have 8-12 parr marks centered along the lateral line. The adipose fin is uniformly pigmented, or finely speckled giving it a grey or dusky color. The other fins lack spots and are usually orange tinted. The anal fin is pigmented between the rays, often producing a black and orange pattern (Groot and Margolis 1991, Moyle 2002, Weitkamp et al. 2002).

Distribution

Coho salmon occur in the north Pacific from central California to Point Hope Alaska. In Asia they ranged historically from North Korea and northern Japan to the Anadyr River in Russia. Coho generally spawn in smaller streams than Chinook Salmon (NOAA 1996, Moyle 2002, Weitkamp et al. 2002).

Taxonomy and Systematics

Among members of the genus *Oncorhynchus*, Coho Salmon are most closely related to Chinook Salmon and occasionally hybridize with Chinook Salmon in streams where the species spawn together (Moyle 2002).

Using the concept of Evolutionary Significant Units, NOAA Fisheries (1999) currently recognizes two ESUs of Coho salmon in California, based on genetic and life history similarities among populations. They are the (1) Central California Coast ESU, including all coho salmon from Punta Gorda in northern California south to and including the San Lorenzo River in central California, as well as populations in tributaries in San Fransisco Bay, excluding the Sacramento-San Joaquin river system, and (2) Southern Oregon/ Northern California Coasts ESU, including all coho salmon in coastal streams between Cape Blanco, Oregon, and Punta Gorda, California.

Life History

Adult coho salmon in general enter fresh water to spawn from September through January. In the short coastal streams of California, migration usually begins mid-November through mid-January (Baker and Reynolds 1986). Coho salmon move upstream usually after heavy fall or winter rains have opened the sand bars that form at the mouths of many California coastal streams, but the fish can enter the larger rivers earlier. On the Klamath River, coho salmon begin entering in early- to mid-September and reach a peak in late September to early October. On the Eel River, coho salmon return four to six weeks later than on the Klamath River (Weitkamp et al. 2002). Arrival in the upper reaches of these streams generally peaks in November and December. Neave (1943), Brett and MacKinnon (1954) and Ellis (1962) indicate that coho salmon tend to move upstream primarily during daylight hours (Weitkamp et al. 2002). They also state that diurnal timing varied by stream and/or flow, but the majority moved between sunrise and sunset.

Generally, coho salmon spawn in smaller streams than do chinook salmon. In California, spawning mainly occurs from November to January although it can extend into February or March if drought conditions are present. In the Klamath and Eel rivers, spawning occurs November to December (USFWS 1979). The fry emerge from the gravel between March and July, with peak emergence occurring from March to May, depending on when the eggs were fertilized and the water temperature during development

Rearing areas generally used by juvenile coho salmon are low gradient coastal streams, wetlands, lakes, sloughs, side channels, estuaries, low gradient tributaries to large rivers, beaver ponds and large slackwaters. The more productive juvenile habitats are found in smaller streams with low-gradient alluvial channels containing abundant pools formed by large woody debris (LWD). Adequate winter rearing habitat is important to successful completion of coho salmon life history (Moyle 2002, Weitkamp et al 2002).

After one year in fresh water, the smolts begin migrating downstream to the ocean in late-March or early April. In some years emigration can begin prior to March (CDFG unpubl. data) and can persist into July in some years (Weitkamp et al. 2002). Weitkamp et al. (1995) indicates that peak downstream migration in California generally occurs from April to late May/early June. Factors that affect the onset of emigration include the size of the fish, flow conditions, water temperature, dissolved oxygen (DO) levels, day length, the availability of food.

The amount of time coho salmon spend in estuarine environments is variable. Upon ocean entry the immature salmon remain in inshore waters, collecting in schools as they move north along the continental shelf (Moyle 2002, Weitkamp et al. 2002). Most remain in the ocean for two years, however, some return to spawn after the first year, and these are referred to as grilse or jacks.

Steelhead (Oncorhynchus mykiss)

Species Characteristics

Steelhead, the anadromous form of rainbow trout, can attain fork lengths of up to 115 cm and weights of up to 19.5 kg. The coloration of adults is highly variable. They are usually metallic blue to brown on the back, silvery on the sides, with numerous spots on the tail, adipose fin, dorsal fin, and back, and a pink to red lateral line. Resident stream forms are generally darker than lake or sea-run forms (McGinnis 1984, Groot and Margolis 1991, and Moyle 2002).

Distribution

Rainbow trout were originally native to coastal streams from the Kuskokwim River in Alaska down to streams in Baja California. Rainbow trout found in fresh water in Asia are native mainly to the north Pacific coast south of the Kamchaka Peninsula (Moyle 2002). In salt water, steelhead are found throughout the Pacific Ocean. Rainbow trout have been introduced worldwide. (NOAA 1998).

Taxonomy and Systematics

Among the members of the Genus *Oncorhynchus*, steelhead were once considered to be closely related to cutthroat trout because of similarities in appearance and life histories (Moyle 2002). They are, however, more closely related to the other Pacific salmon species. Distinct populations of the species are recognized as “runs” or “stocks” that show adaptations to local and regional environmental conditions and represent important units for management of the species (Moyle 2002). In California, distinct runs that are widely recognized among fisheries managers and others include (1) Klamath winter steelhead, (2) Klamath summer steelhead, (3) North Coast winter steelhead, (4) North Coast summer steelhead, (5) Central Valley steelhead, (6) Central Coast steelhead, (7) South/ Central Coast steelhead, (8) Southern steelhead.

Using the concept of Evolutionary Significant Units, NOAA Fisheries (1997, 2000) currently recognizes five ESUs of steelhead in California, based on genetic and life history similarities among populations. They are (1) Southern California ESU, including all steelhead in streams from the Santa Maria river to Malibu Creek, (2) South-Central California Coast ESU, including all steelhead in streams from the Pajaro River to, but not including the Santa Maria River, (3) Central California Coast ESU, including all steelhead in streams from the Russian River to Aptos Creek, and the drainages of the San Francisco and San Pablo Bays eastward to the Napa River, excluding the Sacramento-San Joaquin river Basin, (4) California Central Valley, including all steelhead in the Sacramento and San Joaquin Rivers and their tributaries, (5) Northern California ESU, including all steelhead in California coastal rivers basins from Redwood Creek to the Gualala river.

Life History

Steelhead can be found entering some Pacific coast streams virtually 12 months of the year; generally steelhead are classified as either winter run or summer run. Winter steelhead typically spawn in tributaries of mainstem rivers, when winter rains provide cold water for migration and spawning. Summer steelhead typically enter fresh water as immature fish and over summer in deeper pools, maturing and then spawning in winter or spring (NOAA 1998, Moyle 2002) Timing of the run varies with latitude, stream size, weather, genetics, hatchery to wild fish ratios etc. Winter fish usually enter most coastal streams following the first heavy freshets in late November with the peak occuring in late December and January. Spawning usually takes place in December or January in most California rivers, December through April in Oregon rivers; and in February through May in more northerly rivers, or in rivers with colder winter/spring flows (Moyle 2002).

The gravel they spawn in typically ranges from 1 to 130 millimeters (0.04 to 5.1 inches) in diameter. Steelhead females prepare a redd much the same way as any other salmon, by fanning the gravel with their tales. The redds are typically around 70 square feet (6.5 square meters) in size and a female may deposit anywhere from 200 to 12,000 eggs depending upon her size and maturity, with 3,500 being the average. Unlike salmon, steelhead are iteroparous, meaning that adults may spawn more than once (NOAA 1998, Moyle 2002).

Eggs usually hatch in 3 to 4 weeks and fry emerge from the gravel 2 to 3 weeks later. Water temperature plays a major role in emergence time. Steelhead typically spend at least a year in fresh water, but may stay up to 3 years if water temperatures and available food are optimal. They will then typically spend 1 to 2 years in the ocean before returning to fresh water to spawn. Another curious life history pattern is the half-pounder, which is an immature steelhead that returns to fresh water after only 2 to 4 months in the ocean (NOAA 1998, Moyle 2002).

Consideration of Other Aquatic Organisms

Although the focus of this report is on barriers to anadromous fish passage, barriers effect a host of aquatic organisms, and impact entire ecosystems through the disruption of riverine connectivity. A report entitled Potential Impact of Road-Stream Crossings (Culverts) on the Upstream Passage of Aquatic Macroinvertebrates submitted to the United States Forest Service, San Dimas Technology and Development Center by the Xerces Society, provides a thorough examination of this topic and underscores the importance of barrier modification or removal to recover natural stream geomorphology for the purpose of improving instream habitat for all aquatic organisms.

APPENDIX B(2)

FEDERAL AND STATE ENDANGERED SPECIES ACT STATUS FOR CALIFORNIA ANADROMOUS FISH AS OF August 6, 2004.

SPECIES: ESU or DPS (ESA) or Population segment (CESA)	**STATUS**	**EFFECTIVE DATE OF LISTING or ACTION**	**CRITICAL HABITAT DESIGNATED?**	**ESA SECTION 9 TAKE PROHIBITIONS APPLY?**
COHO SALMON				
ESA - Southern Oregon/Northern Calif. Coasts	threatened	June 5, 1997	Yes	Yes (per Interim 4d Rule published 7/18/97)
ESA - Central California Coast	threatened	Dec. 2, 1996	Yes	Yes (4d Rule pub. 3/11/02) [1]
CESA - South of Punta Gorda, California	**endangered**	[2, 3]	na	na
CESA B from Punta Gorda, California to the Northern Border of California	**threatened**	[2]	na	na
CHINOOK SALMON				
ESA - Sacramento River Winter-Run	endangered	Emergency listed as threatened Aug 1989; final listed as threatened Nov 1990; reclassified as endangered Feb 3, 1994	Yes	Yes (2/3/94)
ESA - Central Valley Spring-Run	threatened	Nov. 15, 1999	No [4]	Yes (4d Rule pub. 3/11/02)
ESA - Central Valley Fall and Late Fall-Run	candidate	Sep. 16, 1999	no	no
ESA - Southern Oregon and Northern California Coastal	not warranted	Sep. 16, 1999	no	no
ESA - California Coastal	threatened	Nov. 15, 1999	No [4]	Yes (4d Rule pub. 3/11/02)
ESA - Upper Klamath - Trinity Rivers	not warranted	March 9, 1998	no	no
CESA - Winter Run	endangered	Sep. 22, 1989	na	na
CESA - Sacramento River Drainage Spring-Run	threatened	February 5, 1999	na	na
STEELHEAD				
ESA - Southern California	endangered	October 17, 1997	No [4]	Yes (10/17/97)
ESA - South-Central California Coast	threatened	October 17, 1997	No [4]	Yes (4d Rule pub. 7/10/00)
ESA - Central California Coast	threatened	October 17, 1997	No [4]	Yes (4d Rule pub. 7/10/00)
ESA - Central Valley, California	threatened	May 18, 1998	No [4]	Yes (4d Rule pub. 7/10/00)
ESA - Northern California	threatened	August 7, 2000	No	Yes (4d Rule pub 3/11/02)
ESA - Klamath Mountains Province	not warranted	March 28, 2001	no	no
COASTAL CUTTHROAT TROUT				
ESA - Southern Oregon/California Coasts	not warranted	April 5, 1999	no	no
GREEN STURGEON [5]				
ESA - Northern	candidate	January 29, 2003	no	no
ESA - Southern	candidate	January 29, 2003	no	no

[1] Supercedes 4d Rule promulgated 10/31/96

[2] Fish and Game Commission approved the regulation on Aug 5, 2004, which will become effective upon approval by the Office of Administrative Law.

[3] Includes Coho South of San Francisco Bay listed as endangered on 12/31/95

[4] Critical habitat designation rescinded 4/30/02

[5] NMFS published a 12- Month Finding on 1/29/03 that listing was not warranted for both green sturgeon distinct population segments

This update reflects the Fish and Game Commission action on 8/5/04 to adopt the regulation to add Coho Salmon North of San Francisco to the list of threatened and endangered species.

APPENDIX C(1)

Fish Passage Forum

In an effort to coordinate and facilitate efforts to improve fish passage in California's watersheds, The California Resources Agency convened in 1999 a group of state, local and federal agencies, fisheries conservation groups, researchers, restoration contractors, and others involved in fish passage improvement efforts. This group, the Fish Passage Forum, has served as a means to obtain regular updates on parallel efforts, and to explore more effective ways to restore and recover anadromous salmonid populations by improving fish passage throughout the State.

Forum participants have worked together to develop short-term solutions for several known high priority fish passage projects. They have also developed a strategic plan to facilitate and coordinate fish passage inventory and assessment, data sharing and database development needs, fish passage design, fish passage project implementation, training, and public education and outreach.

Fish Passage Forum: Year One Fish Passage Progress and Accomplishments (Fall 2000 to Fall 2001)

Workplan Objectives	Progress / Status
Develop inventory, evaluation and prioritization protocols for identifying and remedying potential fish passage barriers.	Ross Taylor developed passage inventory and evaluation protocols for DFG Restoration Manual. CalTrans began demonstrating protocols in collaboration with DFG. DWR will examine new protocls for use in CalFed area. USFS started training personnel in inventory protocols NOAA FISHERIES completed draft technical guidance for culvert design specifications.
Implement stream crossing inventories and conduct them across ownerships.	CalTrans secured funding for demonstration inventory of all its crossings in northern California district. USFS released Request for Proposal to conduct inventories in six National Forests. DWR submitted proposal to DFG to conduct inventories of dams or other barriers beside culverts and road crossings. 5 County Salmon Conservation group have finished inventory of county roads in Humboldt, Del Norte, and Mendocino; Siskiyou, Trinity and the Russian River in progress. FishNet 4C counties of Marin and Santa Cruz have applied for inventory funds.
Develop databases, GIS, and state clearinghouse function for fish passage information and barrier inventories.	Dep. of Water Resources Fish Passage Forum Improvement Program developed barriers database for CalFed area with Chico State. CalTrans working with UC ICE to develop database functions. DFG coordinating interagency effort to identify data protocol development needs and opportunities.

Train policy, implementation and permitting personnel to use existing and new protocols and practices.	Five Northern County holding second workshop on road related practices and policies for salmon protection in fall 2002. Enrollment includes multiple agencies. For Sake of Salmon funded by NOAA FISHERIES to hold training workshops on passage inventory protocols in fall 2002. Joint DFG / CalTrans training for engineers.
Develop long-term library	Humboldt State University assumes lead with established bibliography and library.
Develop streamlined permitting processes for fish passage enhancement projects.	DFG began working with NOAA FISHERIES, Corps, CalTrans to explore streamlining opportunities through DFG=s 1600 program and increased training requirements. DFG hired more staff for 1600 program, and more staff for Fisheries Grant Program. DFG working with FEMA to allow fish friendly upgrades using disaster funds. NOAA FISHERIES and DFG agree on design specifications.
Improve assistance for project design	NOAA FISHERIES is hiring more engineering staff to support project design and review. Five Northern Counties are hiring engineering help.
Provide for long-term project funding and implementation.	
Develop and implement monitoring programs for evaluating compliance and effectiveness of fish passage programs and projects.	DFG is developing restoration project effectiveness monitoring protocols.

Workplan Objectives	Progress / Status
Increase public awareness and information about importance of fish passage issues	Trinity county culvert ribbon cutting at West Weaver Creek. Small dam removal ceremony on Alameda Creek.

Draft 1/10/03
Memorandum of Understanding
A Coordinated Approach to Restoring Fish Passage for Anadromous Salmonids in Coastal Watersheds through Creation of Fish Passage Forum

Entered into between:

California Resources Agency
California Department of Fish and Game
California Department of Transportation
California Department of Water Resources
California State Coastal Conservancy
U. S. National Marine Fisheries Service
U.S. Forest Service
California Trout
Southern California Steelhead Coalition
Five County Salmon Conservation Group
FishNet 4C

Hereafter referred to as the Fish Passage Forum

I. Problem Statement

Man-made barriers to salmonid migration include road/stream crossings, irrigation diversions and dams. Road/stream crossings are extremely numerous and often cross multiple road ownerships within a watershed. Blocks and delays in migration affect adult and juvenile fish, preventing the useful use of available habitat, as well as inflicting injury or death of fish attempting to migrate upstream. A comprehensive California fish passage program is vital towards identifying, prioritizing, and treating migration barriers so that unimpeded migration of California's salmonid populations is achieved. Through coordinating resources and authorities and creating the Fish Passage Forum, a comprehensive program will be achieved.

II . Background:

In November, 1999, the California Resources Agency convened a group of interested state, local and federal agencies, fisheries conservation groups, researchers, restoration contractors, and others to discuss ways to restore and recover anadromous salmonid populations by improving fish passage at man-made barriers. This effort was part of the Resources Agency's effort to implement an eight point California Coastal Salmon and Watersheds Program which included an objective to coordinate fish passage activities.

Man-made barriers to fish passage include road/stream intersections, pipeline or other infrastructure crossings, erosion control/flood control structures (rip-rap, concrete channels, etc), and dams which block or delay migration. These barriers impact both adult and juvenile fish by preventing full use of available habitat or altering habitat, hydraulic conditions.

The Fish Passage Work Group discussed the need for improved efforts to identify barriers, evaluate and prioritize restoration opportunities, and implement projects in a timely fashion. It identified administrative, financial and technical impediments to addressing these issues, including information gaps, lack of watershed-level assessment and planning, and poorly coordinated project review and permitting processes. Group participants worked together to develop short-term solutions for these types of problems for several known high priority fish passage projects. They also established subgroups for coordinating activities related to: fish passage inventory and assessment protocols, data format and access protocols, information and literature collection, training, and public education and outreach.

As a result of these activities and discussions, it became very clear that there is a critical need for improving coordination of existing agency programs and private sector activities across jurisdictions to improve the timeliness and cost-effectiveness of fish passage restoration efforts.

III. Purpose

This MOU is intended to contribute to the protection and recovery of listed anadromous salmonid species in California by promoting the collaboration among public and private sectors on fish passage restoration programs and activities.

IV. Goals

This MOU supports voluntary, cooperative efforts for pursuing the following goals:

1. Protect, restore and maintain watershed, stream, and estuary conditions for passage by anadromous fisheries.

2. Identify passage barriers, opportunities to remedy them and priorities for implementing restoration projects.

3. Improve the State’s ability to implement fish passage restoration projects by coordinating agency and private sector efforts.

4. Secure adequate funding for fish passage restoration.

Expedite implementation of on-the-ground projects by coordinating and, where possible, streamlining agency permitting processes while ensuring that restoration programs comply with the State and/or Federal Endangered Species Act requirements for protecting listed species and any other applicable state or federal laws.”

5. Educate and increase public awareness of fish passage issues to develop support for solving problems and preventing new ones.

6. Ensure that any new structures created are properly designed to ensure fish passage.

V. Objectives

In order to achieve the goals listed above, this MOU will help to facilitate the collaboration and coordination among state, federal and local agencies, researchers, restoration contractors, landowners and other interested stakeholders through the Fish Passage Forum. The following objectives will be used by the Fish Forum to achieve the goals of the MOU. These objectives may be modified by participants of the forum through the annual work planning process, if needed.

1. Develop inventory, assessment, and prioritization protocols

- Develop consistent inventory and evaluation protocols for assessing passage at road/stream intersections and other barriers.
- Develop and communicate consistent protocols for prioritizing fish passage restoration at barriers
- Coordinate processes to prioritize fish passage restoration opportunities as possible, among agencies
- Communicate fish restoration activities to other agencies, landowners, watershed groups and others within each basin

2. Train field staff to use assessment and design protocols

- Implement workshops to train local agency field crews or other interested groups to properly conduct fish passage evaluations at road/stream intersections or other kinds of barriers.
- Train local, state and federal agency staffs in engineering criteria for fish passage design.

3.Coordinate assessment and prioritization across boundaries

- Conduct comprehensive inventories of barriers across road ownerships, including stream crossings, dams and other structures.
- Prioritize fish passage restoration opportunities and projects based on potential habitat improvement and fish population response, cost, and feasibility.

4. Develop common databases of necessary information

- Develop a system for compiling and maintaining a GIS database of fish passage barriers data that is compatible with and can link to other GIS-based information about salmonid occurrence, salmonid populations, and restoration project databases such as University of California's Natural Resource Project Inventory (or NRPI).

- Develop a database of cost information for repair and replacement activities.

5. Develop coordinated permitting processes for fish passage improvement projects

- Develop and promote use of joint permit application forms and processes
- Increase availability of regional permits
- Promote interagency consultations, 4(d) rules, and other mechanisms for programs, manuals, etc. that can be used to expedite review and implementation of individual projects
- Facilitate joint agency design and review of projects to expedite permitting
- Secure adequate staffing for permit review programs

6. Develop strategies and coordinate funding mechanisms to remedy barriers.

- Design, develop and provide necessary environmental documentation for fish passage projects by working with state, federal and local agencies, private sector and other parties.
- Secure additional engineering design support to fishery agencies
- Through establishing regional interagency teams, as appropriate, identify, fund and implement priority projects as soon as possible.

7. Develop guidelines for replacement of existing structures and construction of new ones that do not create fish passage problems.

- Write and issue guidelines that can be used by all parties and are based on sound science and can realistically be implemented.

8. Monitor and evaluate fish passage restoration effectiveness to ensure accountability.

- Establish mechanisms to monitor and ensure that projects are appropriately designed and implemented
- Establish mechanisms or programs to evaluate changes in habitat use that result from fish passage improvement projects
- Establish ways to estimate or quantify population increases that result from fish passage projects and to predict increases from proposed projects.

VI. Management

The Fish Passage Forum will use the following management procedures to implement the above objectives:

1. ***Develop annual work plans*** containing assignments and timelines for the objectives and fish passage improvement needs identified by the Forum:

2. ***Use existing sub-groups, or establish new ones as needed,*** to report back to full Forum on their progress, and to identify additional needs and opportunities.

3. ***Establish a Management Team, as needed***, to ensure communication among signatories and other Work Group participants on fish passage issues, to increase involvement of stakeholders from coastal watersheds with anadromous fisheries, and to monitor progress of full Work Group against objectives.

4. ***Develop a process for measuring effectiveness*** of coordinated efforts to contribute to listed fish recovery.

5. ***Develop a mechanism for reporting annual progress*** and effectiveness to agencies, Legislature, Congressional representatives and the public. These should educate the public, promote fish passage restoration, and publicize successful projects.

VII. Lead Agency Responsibilities

The Department of Fish and Game, as trustee for fisheries resources, will serve as the principle convener and coordinator for the Fish Passage Forum.

For the purposes of this MOU, lead agencies are defined as those participating state or federal agencies which have direct responsibilities for the protection or management of anadromous fisheries or fish habitat, or who have established fish passage restoration program elements. The lead agency signatories will participate in the Fish Passage Work Group to implement the actions described above and will undertake projects consistent with the above objectives. They will participate in the Work Group to prepare and implement annual work plans. As part of the ongoing cooperative effort to coordinate fish passage restoration that began before the development of this MOU, the signatory agencies and entities will undertake the following activities that are consistent with MOU goals and objectives and are within their statutory mandates and authorities, budgets, and staffing constraints.

Any federal funding or personnel needed to carry out any federal agency responsibilities under this MOU shall be subject to the availability of appropriated funds, pursuant to the Anti-Deficiency Act (31 U.S.C. Section 1341).

<u>Resources Agency</u>

1. The Resources Agency will develop policies and programs for improving the health and productivity of California's watersheds and the recovery of salmonid species which will support fish passage restoration goals. This includes coordinating activities among its departments, with other state, federal and local agencies, and with watershed and other non-profit

groups, landowners and the public to encourage cooperative restoration efforts.
2. The Resources Agency will participate in the management team, as needed.
3. The Resources Agency will, in its management of the North Coast Watershed Assessment Program, work with the MOU signatories and other agencies, landowners, and researchers to identify and map fish passage barriers across road ownerships within a watershed in order to identify any limiting factors for salmonids and to prioritize salmonid habitat restoration investments. The Resources Agency will make this data available to the public through websites and CDs.
4. The Resources Agency, as head of the California Biodiversity Council, will work with the Watershed Working Group to implement Best Funding Recommendations to coordinate and streamline grant and assistance programs, and improve accountability and tracking for fish passage and other types of watershed restoration projects.
5. The Resources Agency will continue to explore options for addressing concerns that may discourage landowners or local agencies from undertaking fish passage or other restoration activities.
6. The Agency will seek adequate funding and staffing to implement a comprehensive, effective program.
7. Ensure that new structures permitted by Agency departments comply with all state and federal laws.

California Department of Fish and Game

1. As the State Trustee Agency for the fisheries resource, the Department of Fish and Game (DFG) will assume leadership of the Fish Passage Workgroup from the Resources Agency when DFG staff (Fish Passage Workgroup Leader) becomes available. DFG will then continue to convene the Fish Passage Workgroup to coordinate fish passage assessment, planning, implementation, and monitoring activities.
2. As part of its key role in the North Coast Watershed Assessment Program (NCWAP), DFG will continue to assess the health of the North Coast watersheds, including identifying and mapping fish passage barriers across ownerships within a watershed in order to identify limiting factors for salmonids and to prioritize salmonid habitat restoration investments.
3. DFG will continue their Basin Planning and Restoration Program in coastal basins.
4. DFG will continue to review and permit, and ultimately enforce, activities under its legislative authority and codes (e.g. Streambed Alteration Agreements, CEQA, CESA, and THP's) to ensure that new impediments to fish passage are not created and fish passage improvement activities are performed in a manner

consistent with the protection and restoration of the natural resources of California.

5. In its permitting role, DFG will develop, with other signatory agencies, ways to facilitate an improved process for expediting the permitting of fish passage improvement projects
6. DFG will continue the funding of qualified fish passage activities through Coastal Salmon Restoration Initiative, Proposition 13, SB 271 and other funding sources administered or provided by DFG.

   DFG will continue to revise, publish and distribute the California Salmonid Stream Habitat Restoration Manual. This disseminates a common pool of restoration techniques, including fish passage, both within DFG and to other agencies, landowners, watershed groups and the public. DFG will consolidate internal information concerning fish passage. As part of this effort, DFG will pursue, with other MOU signatories, joint development and management of data depicting resource and facility information needed to assess, prioritize, and monitor fish passage restoration.
7. In cooperation with DWR and the other signatories, DFG will continue to provide technical guidance to identify sites needing fish passage remediation and to review and support fish passage projects.
8. DFG dive team will provide snorkel and SCUBA dive inspections for activities related to the improvement of fish passage on as needed and as available basis. (All dive requests shall be coordinated through the DFG Dive Safety Officer.)
9. As part of their various public information and education programs (e.g. Watershed Academy and the Streambed Alteration Process Training), DFG will continue to disseminate information regarding fish passage to the public. In addition, DFG will seek public input regarding fish passage improvement activities and interpret current activities for the public.
10. DFG will periodically assess its multiple efforts in fish passage for effectiveness with the goal of improving future activities

National Marine Fisheries Service (NMFS)

1. The NMFS will provide technical assistance on hydraulic engineering issues. This assistance will be limited to site evaluation, project proposal reviews.
2. The NMFS will provide guidelines for the design and installation at stream crossings.
3. NMFS will participate in the Fish Passage Work Group.
4. NMFS will provide available information to the Geographic Information System Subgroup for fish presence and fish barriers.
5. NMFS will coordinate with other permitting agencies to develop an improved process for expediting fish passage restoration projects.
6. NMFS will assist in prioritizing and selecting projects for funding.
7. NMFS will participate in the Management Group.

California Department of Transportation

1. Caltrans will meet and coordinate fish passage activities with other MOU signatories and agencies.

2. Caltrans will design stream crossings on new roadways to provide adequate fish passage in compliance with State and Federal regulations and fish passage guidelines from the National Marine Fisheries Service and the Department of Fish and Game.

3. **Caltrans will conduct assessments of existing State Highway culverts to determine if fish passage is blocked or impeded. Caltrans will perform assessments and analyses employing the inventory and evaluation protocols for assessing passage at road/stream intersections and other barriers contained in Chapter 9 of the Department of Fish and Game's "California Salmonid Stream Habitat Restoration Manual" and using passage criteria specified within the Department of Fish and Game's "Culvert Criteria for Fish Passage" and the National Marine Fisheries Service's "Guidelines for Salmonid Passage at Stream Crossings**".

4. Caltrans will develop a prioritized list of culvert sites for its use during the project development process in the planning stages of transportation improvement, protection, and maintenance projects.

5. Caltrans will develop a statewide Global Positioning System (GPS) database and a Geographic Information System (GIS) application that will spatially locate culvert sites along the State highways and will participate in the joint development of GIS data layers depicting resource and facility information needed to assess, prioritize, develop, and monitor fish passage restoration.

6. Caltrans will pursue funding to address fish passage impediments at highway road crossings based on priorities for remediation.

7. Caltrans will participate with private organizations, and local, State, and Federal agencies to obtain grant funds for fish passage assessment and restoration as a means to affect a comprehensive strategy for corrective actions on a watershed scale.

8. Caltrans will train its staff in the proper identification, assessment, and design criteria for fish passage. Caltrans will pursue opportunities for development and execution of cross-training between agencies.

California Department of Water Resources,

DWR activities will be carried out by the Fish Passage Improvement Program staff within the Division of Planning and Local Assistance.

1. DWR will meet and coordinate fish passage activities with other MOU signatories and agencies.

2. DWR will carry out specific fish passage projects as specific funding and authorization become available.
3. DWR will work toward attaining funding for assessments, evaluations, and specific projects.
4. In cooperation with DFG, DWR will help to provide engineering and environmental documentation technical advice and support as appropriate and coordinate participation with other DWR resources.
5. DWR will coordinate hydrologic and other data acquisition from DWR sources for specific projects and regional or watershed assessments.

<u>U. S. Department of Agriculture, Forest Service</u>

The Pacific Southwest Region of the USDA Forest Service (Region 5) will:

1. Conduct an inventory of all road/stream crossings within the anadromous watersheds of the Klamath, Six Rivers, Shasta-Trinity, Mendocino, Lassen and Los Padres National Forests to determine if fish passage at any life stage is blocked or impeded. The inventory will be completed by the end of FY2002.
2. The inventory results will be entered into a standardized agency database.
3. The road/stream crossings will be prioritized based on impacts and extent of impacts on salmonid species. Region 5 will coordinate with local, State and Federal agencies, as well as private organizations, to identify critical watersheds in which to collectively focus activities to reduce fish blockage.
4. Region 5 will pursue funds to re-mediate blockage and impediment of fish passage at road/stream crossings.
5. Region 5 will coordinate internally with other Forest Service Regions and participate with local, State and Federal agencies as well as private organizations to develop consistent criteria for analyzing sites, collecting data, and storing information that is accessible to the participating organizations and to the public.
6. Region 5 will design stream crossings on new roads to provide adequate passage for all life stages of fish.
7. Region 5 will use the most recent research in training its staff in the proper identification, assessment, and design criteria for fish passage.

VIII. Contributing and Supporting Signatories

Contributing signatories will participate in the Work Group and contribute, as resources permit, to the implementation of goals, objectives, and work plans. Supporting signatories support the concept, goals and objectives of this MOU.

IX. Other Provisions and Agreements

This agreement is intended to be in furtherance of mutual goals for protecting watershed resources. This MOU is intended to embody general principles, and does not create Contractual relationships, rights, obligations, duties or remedies between or among signatories.

Agency actions are subject to statutory authority and regulatory requirements. Nothing in this MOU is intended to expand or limit the legal authority or responsibilities of any signatory agency, entity or organization.

Nothing in this MOU shall limit the participating agencies in carrying out their individual statutory responsibilities

This MOU does not modify or supersede other existing agreements, programs, MOU's, plans, regulations or executive orders.

Nothing herein alters the existing authorities or responsibilities of any party nor shall be considered as obligating any party in the expenditure of funds or the future payment of money or providing services. The commitments and obligations by state and federal agencies under this MOU are subject to the requirements of the federal Anti-Deficiency Act and to the availability of appropriated funds. The parties acknowledge that this MOU does not require any agency to expend its appropriated funds unless and until an authorized officer of that agency affirmatively acts to commit to such expenditures as evidenced in writing.

Consistent with federal law, nothing in this document constrains the discretion of the President or his or her successor from making whatever budgetary or legislative proposals he or his successors deem appropriate or desirable.

This MOU is not intended to, and does not, create any other right or benefit, substantive or procedural, enforceable at law or equity by a party against the United states, the State of California, any agencies thereof, any officers or employees thereof, or any other person.

Any party may withdraw from this MOU upon 30 days notice to the other parties.

This MOU may be amended only upon the written prior approval of each signatory.

Other entities may execute this Understanding and thereby become a Party.

This agreement is executed as of the date of the last signature and is effective through September 30, 2010, at which time it will expire unless extended.

X. Lead Signatory Agencies

California Resources Agency Date

California Department of Fish and Game Date

California Department of Transportation Date

California Department of Water Resources Date

National Marine Fisheries Service Date

U.S. Forest Service Date
(01-MU-11052008-221)

California State Coastal Conservancy Date

Contributing Signatories

Southern California Steelhead Coalition

California Trout

Five County Salmon Conservation Group

FishNet 4C

Supporting Signatories

____

Friends of the River

____

Humboldt State University

APPENDIX C(2)

PART IX

FISH PASSAGE EVALUATION AT STREAM CROSSINGS

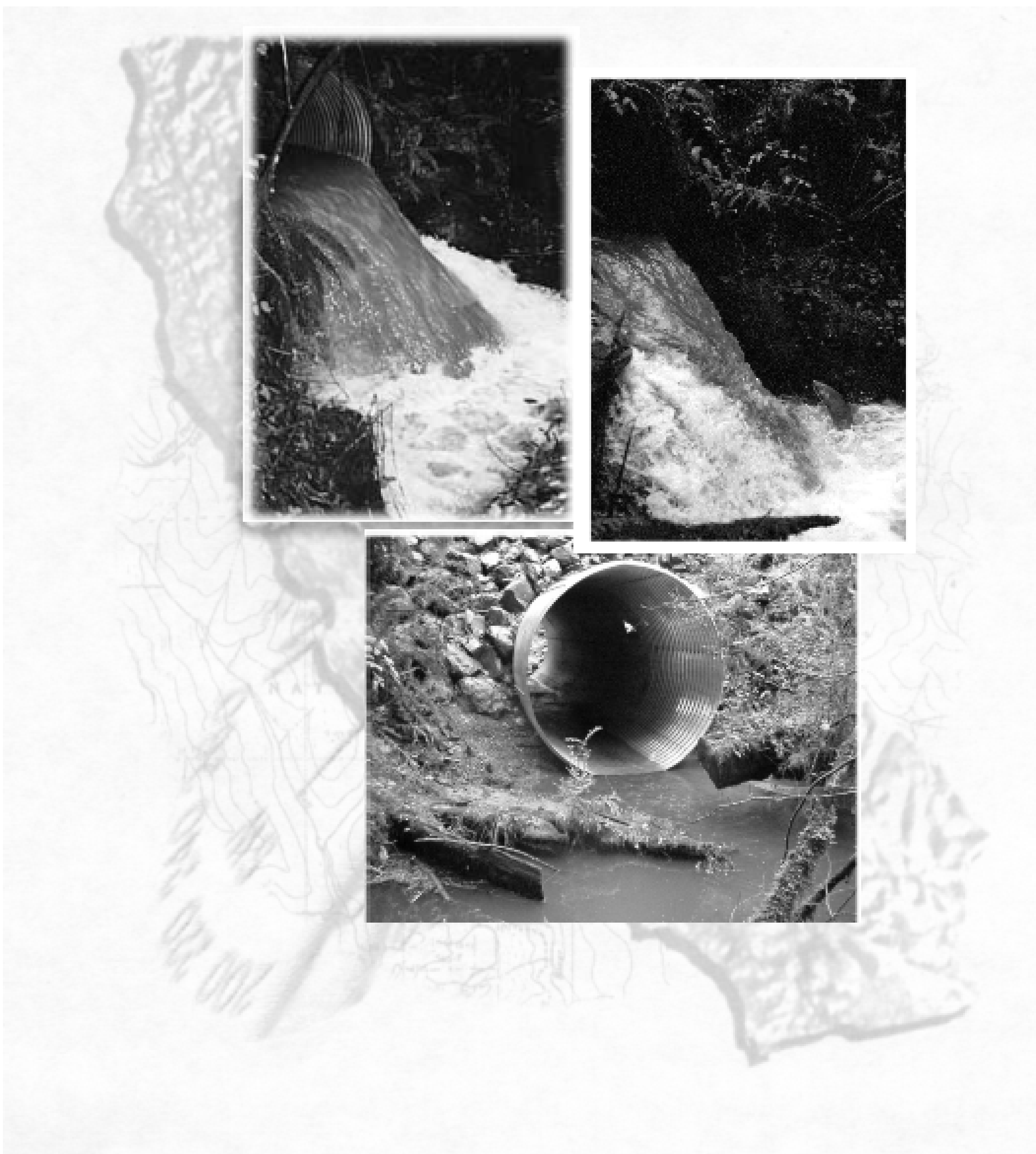


Table of Contents

Table of Figures iv
List of Tables v
ACKNOWLEDGMENTS vi
INTRODUCTION 1
Overview of evaluation process 4
FISH PASSAGE EVALUATION FIELD PREPARATION 7
Tools and Supplies Needed 7
FISH PASSAGE EVALUATION 8
Location of Stream Crossings 8
Site Visit 8
FISH PASSAGE INVENTORY DATA SHEET 9
Active Channel Widths 9
The active channel stage or ordinary high water level is the elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence on the landscape. Evidence of the active channel stage includes: 9
Fill Estimate 11
Longitudinal Survey 13
Tailwater Cross-Section 15
Site Sketch 15
Photography 16
Instructions for Completing the Fish Passage Inventory Data Sheet 17
Fisheries Information 17
Stream Crossing Information 17
Culvert Information 20
FISH PASSAGE INVENTORY DATA SHEET 26
PASSAGE ANALYSIS 28
Passage Evaluation Filter: GREEN-GRAY-RED 28
HYDROLOGY AND FLOW REQUIREMENTS 31
Flow Capacity 31
Fish Passage Flows 36
FishXing Analysis 38
Fisheries Inputs 38
Stream Crossing Inputs 39
Interpreting Results 41
Analysis of Retrofitted Stream Crossings 41
FISH HABITAT INFORMATION 41
RANKING OF STREAM CROSSINGS FOR TREATMENT 42
Ranking Criteria 42
Additional Ranking Considerations 44
PREFERred TREATMENT OPTIONS FOR UNIMPEDED FISH PASSAGE 45
STREAM CROSSING REMEDIATION PROJECT CHECKLIST 46
GUIDANCE TO MINIMIZE IMPACTS DURING STREAM CROSSING CONSTRUCTION 47
Measures to Minimize Disturbance From Instream Construction 47
Measures to Minimize Degradation of Water Quality 47

Measures to Minimize Loss or Disturbance of Riparian Vegetation 48
Measures to Minimize Impacts to Aquatic Habitat and Species During Dewatering of Project Site 48
Measures to Minimize Injury and Mortality of Fish and Amphibian Species During Dewatering 49
PROJECT MONITORING 50
Implementation Monitoring 50
Project Monitoring 50
FISH PASSAGE INVENTORY DATA SHEET 52
GLOSSARY 55
REFERENCES 60
Literature Cited 60
Personal Communications 62
APPENDIX IX-A 63
CULVERT CRITERIA FOR FISH PASSAGE 63
Introduction 63
Application of Criteria 64
Design Options 65
Active Channel Design Option 66
Culvert Setting & Dimensions 66
Stream Simulation Design Option 67
Culvert Setting & Dimensions 67
Substrate Configuration and Stability 67
Hydraulic Design Option 68
Hydrology 69
High Design Flow for Fish Passage 69
Low Design Flow for Fish Passage 69
Hydraulics 70
Culvert Setting & Dimensions 71
Considerations, Conditions, and Restrictions for All Designs Options 72
Anadromous Salmonid Spawning Areas 72
High Design Flow for Structural Integrity 72
Headwater Depth 72
Oversizing for Debris 72
Inlet Transitions 72
Interior Illumination 72
Adverse Conditions to be Avoided: 72
Multiple culverts 73
Bottomless Culverts 73
Culvert Retrofits for Fish Passage 73
Gradient Control Weirs 73
Baffles 74
Fishways 74
Select References and Internet Web Sites 75
APPENDIX IX-B 76
INTRODUCTION 76

PREFERred ALTERNATIVES AND CROSSINGS 77
DESIGNING NEW AND REPLACEMENT CULVERTS 77
Active Channel Design Method 77
Stream Simulation Design Method 77
Hydraulic Design Method 78
Hydrology for Fish Passage under the Hydraulic Design Method 78
Maximum Average Water Velocities in the Culvert at the High Fish Passage Design Flow 79
Minimum Water Depth at the Low Fish Passage Design Flow 79
Juvenile Upstream Passage 79
Maximum Hydraulic Drop 79
Structural Design and Flood Capacity 80
Other Hydraulic Considerations 80
RETROFITTING CULVERTS 81
OTHER GENERAL RECOMMENDATIONS 82
POST-CONSTRUCTION EVALUATION AND LONG TERM MAINTENANCE AND ASSESSMENT 83
REFERENCES 84
Internet Resources 86
APPENDIX IX-C 88
EXAMPLE FISH PASSAGE FLOWS CALCULATION 88
Step 1: 88
Step2: 89
Step 3: 90
Step 4: 90
Step 5: 91

Table of Figures

Common conditions that block fish passage (Evans and Johnson 1980). 3
Framework for inventory and evaluation of fish passage through stream crossings. 6
Active channel width versus bankfull channel width. 10
Example of active and bankfull channel margin 10
Headwater depth and culvert height, HW/D=1 11
Measurements taken to calculate fill volume 12
Diagram of required survey points for a longitudinal profile through a culvert. 14
Site Sketch example. 16
Four standard inlet types (Norman et al. 1985). 18
Culvert type and dimensions 20
Measuring corrugations. 21
Rustline measurements (Oxidation line is whitish or silver line, not to be confused with the rustline). (Adapted from Flannigan). 22
Measurements taken at embedded culverts 22
Measurements required to generate a rough fill volume estimate. 23
Surveyed elevations. 25
. Measurements used in filtering criteria 29
GREEN-GRAY-RED first-phase passage evaluation filter. 30

California regional regression equation for estimating peak flows associated with a 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year recurrence interval (Waananen and Crippen 1977).35
Example of a flow duration curve.....36
Varying velocity measurements within a culvert on Quarry Road at Morrison Gulch, tributary to Jacoby Creek, Humboldt Bay watershed.....40
Stream simulation strategy option. 45

List of Tables

Definitions of barrier types and their potential impacts (adapted from Robison, et al. 2000)..........1
Flow capacity for circular metal culverts at a HW/D=1.....32
Flow capacity for metal pipe-arch culverts at a HW/D = 1.....33
Flow capacity for concrete box culverts at a HW/D = 1.....33
Upper and lower fish passage flows for stream crossings (DFG 2002).....37
Minimum water depth requirements and swimming and leaping ability inputs for *FishXing* (These values are used to assist in prioritizing stream crossing for treatment and do not represent whether or not a stream crossing currently meets DFG or NMFS passage criteria).....39
Alternative methods available in *FishXing* for defining tailwater elevation below a stream crossing.....40

ACKNOWLEDGMENTS

The primary authors for Part IX, *Fish Passage Evaluation at Stream Crossings* were Ross N. Taylor and Michael Love. Ross N. Taylor, Ross Taylor and Associates, is a private consulting fishery biologist, with his business based in McKinleyville, CA. He has completed an inventory and fish passage evaluation for culverts located within fish bearing streams in Humboldt, Mendocino, Del Norte, Siskiyou, and Trinity Counties and is currently working on similar inventories for tributaries to the Russian River. Michael Love, Michael Love and Associates, specializes in hydrologic and hydraulic analysis for natural resources management. Michael has completed projects involving the design of stream crossings for fish passage, road and culvert assessments, effectiveness monitoring of stream crossings for fish passage, and flow frequency analysis for fish passage design. Michael is also a co-author of the FishXing software for analysis of fish crossings. Ross and Michael, under contract with the For Sake of Salmon program completed five fish passage workshops in the fall of 2001. Funding for the development of Part IX was provided by the Salmon and Steelhead Trout Restoration Account Citizen Advisory Committee (SB 271) and the Coastal Salmon Recovery Program Advisory Committee.

The editors of Volume II of the Manual wish to give special recognition to three hydraulic engineers that contributed throughout the process in developing the protocols included in Part IX. These three engineers include Marcin Whitman, George Heise (DFG) and Jonathon Mann (NMFS). Reviewers from DFG included Doug Albin, Bob Snyder, Marty Gingras, Derek Acomb, and Phil Warner. Special thanks goes to Chris Ramsey, Shirley Lipa and Vikki Avara-Snider (DFG) for their work in organizing and formatting. Other people who contributed include Steve Thompson and Mike Devany (NMFS), Bill Weaver (PWA), Richard Harris (University of California, Cooperative Extension), and Susan Firor (Thunder Applications).

Special recognition goes to the members of the Coastal Salmon Recovery Program Advisory Committee for recommending funding the printing of Part IX. Without the financial support of the above recognized advisory committees the development and printing of Volume II of the Manual would not be possible.

The authors want to thank Ross Taylor and Michael Love for the use of the title page photos. The photo on the upper left shows the old five foot culvert on Morrison Gulch, on November 20, 1998. The upper right photo shows a salmon trying to pass the culvert. The lower photo is of the nine foot culvert installed in the summer of 2001.

INTRODUCTION

A stream crossing is any human-made crossing over or through a stream channel including: paved roads, unpaved roads, railroads, trails, and paths. Stream crossings include culverts, bridges, and low-water crossings such as paved and unpaved fords. A stream crossing encompasses any structure or device designed to pass stream flow, and includes the approach and surface fill material within the crossing prism. The distinction between types of stream crossings is not as important as the effect the crossing has on the form and function of the stream.

An individual stream crossing may impact a relatively short length of upstream anadromous fish habitat, sometimes one or two miles or less. Throughout California, possibly thousands of stream crossings functioning as barriers exist. The cumulative effect of blocked habitat is thought to be substantial. Many stream crossings create temporal, partial, or complete barriers for adult anadromous salmonids during spawning migrations and create flow barriers for juvenile salmonids during seasonal movements (Table IX-1).

Barrier Category	Definition	Potential Impacts
Temporal	Impassable to all fish at certain flow conditions (based on run timing and flow conditions).	Delay in movement beyond the barrier for some period of time.
Partial	Impassable to some fish specie, during part or all life stages at all flows.	Exclusion of certain species furing their life stages from portions of a watershed.
Total	Impassable to all fish at all flows.	Exclusion of all species from portions of a watershed.

Table IX- 1. Definitions of barrier types and their potential impacts (adapted from Robison, et al. 2000).

At temporal barriers, the delay imposed by a stream crossing can limit the distance adult fish migrate upstream before spawning. This may result in under-utilization of upstream habitat and superimposition of redds in lower stream reaches. Even if stream crossings are eventually negotiated by adult fish, excess energy expended may result in their death prior to spawning, or reductions in viability of eggs and offspring. Migrating adults and juveniles concentrated below impassable stream crossings are vulnerable to predation by a variety of avian and mammalian species, and to poaching by humans. In addition, this reduction in stream habitat creates competition for space and food among adult and juvenile salmonids and other aquatic species, year round.

Both resident and anadromous salmonids make upstream and downstream migrations. Juvenile coho salmon spend approximately one year in freshwater before migrating to the ocean, and juvenile steelhead may rear in freshwater up to four years. Thus, both species are highly dependent on stream habitat throughout the year. Seasonal upstream movement into tributaries by juvenile salmonids has also been observed during the summer. These fish are thought to be seeking cool water refugia from stressful or lethal temperatures in larger river channels. A common strategy for over-wintering juvenile coho is to migrate from large rivers into smaller tributaries during late-fall and early-winter storms to seek refuge from high water velocities and turbidity levels in mainstem channels (Skeesick 1970; Cederholm and Scarlett 1981; Tripp and McCart 1983; Tschaplinski and Hartman 1983; Scarlett and Cederholm 1984; Sandercock 1991; Nickelson et al. 1992). Shapovalov and Taft (1954) reported seasonal movements by juvenile steelhead both upstream and downstream. Recent research conducted in coastal northern California suggests that juvenile salmonids migrate into smaller tributaries in the fall and winter to feed on eggs deposited during spawning, and on the flesh of adult carcasses (Roelofs, personal communication). Direct observation at numerous culverts in northern California confirmed similar upstream movements of three year-classes of juvenile steelhead (Taylor 2000).

Recent studies in coastal Washington streams documented the movement of juvenile coho, steelhead, and coast cutthroat trout and determined that movers grew faster than non-movers. Most summer, fall, and winter movement occurred in an upstream direction; however some marked individuals moved more than once and in both directions. Movement of juvenile salmonids is also a vital life history strategy in streams that naturally de-water during the summer, triggered by declining discharge (Kahier et al. 2001).

Characteristics of stream crossings with poor fish passage include:

- Crossings that constrict the natural channel width
- Crossings with hardened bottoms lacking diverse stream substrate
- Paved crossing invert set above the channel bottom
- Crossings not in alignment with stream channel
- Crossings requiring baffles or weirs inside to meet hydraulic criteria
- Channel bed and banks showing signs of instability upstream or downstream
- Crossings with projecting culvert inlets
- Crossings with trash rack installed at culvert inlet.

Such characteristics cause these typical types of passage problems (Figure IX-1):

- Excessive water velocities within a culvert
- Excessive drop at the outlet, resulting in a too high entry leap, or too shallow of a jump pool below a crossing
- Lack of water depth within culvert or over crossing
- Excessive water velocity or turbulence at a culvert inlet
- Debris accumulation at a culvert inlet or within a culvert barrel

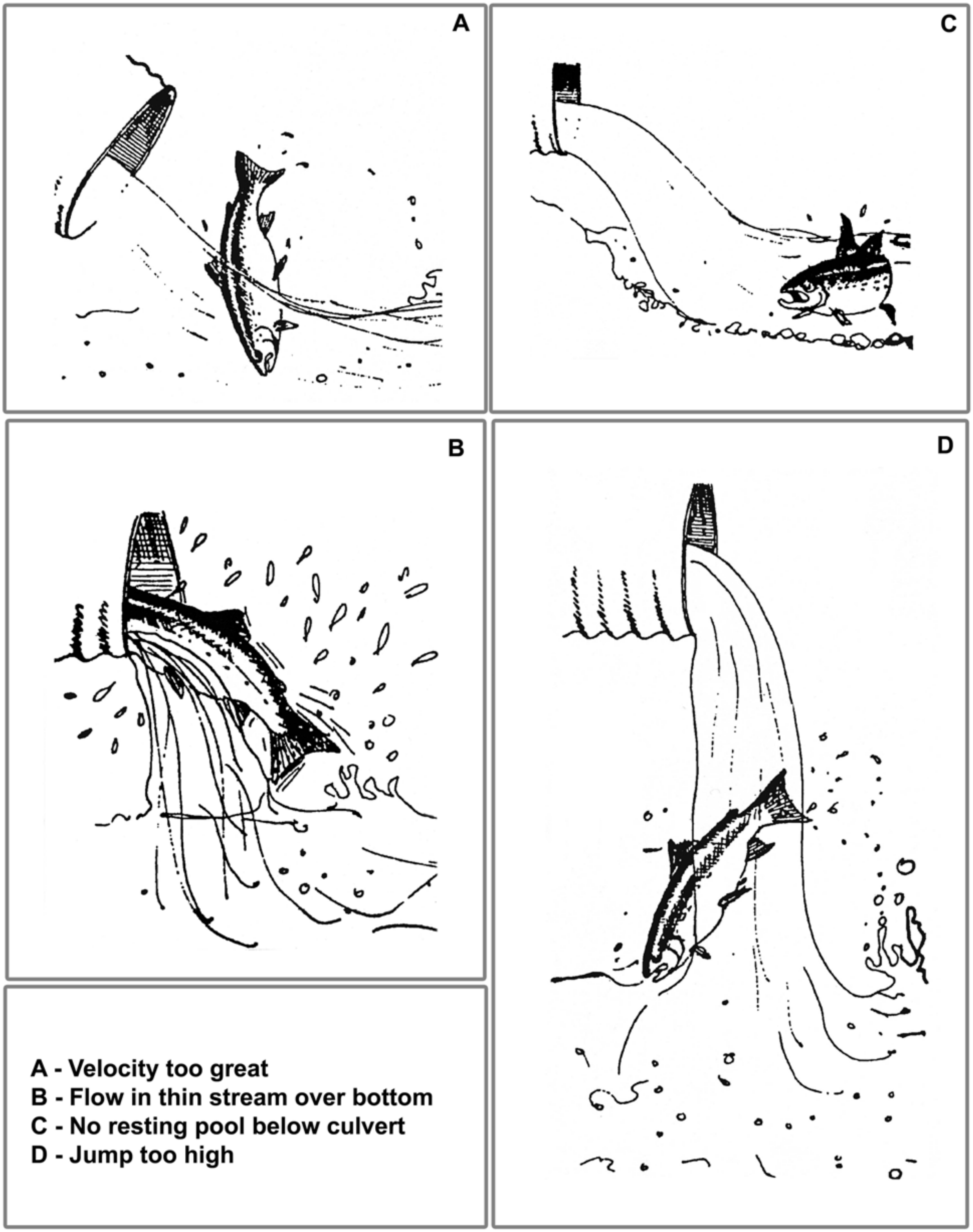


Figure 1: IX Common conditions that block fish passage.

Figure IX- 1. Common conditions that block fish passage (Evans and Johnson 1980).

Current State and Federal guidelines for new crossing installation aim to provide unimpeded passage for both adult and juvenile salmonids (Appendix IX-A and IX-B). However, many existing crossings are barriers to anadromous adults, more so to resident and juvenile salmonids whose smaller size significantly limits their leaping and swimming abilities. For decades, these existing crossings have effectively disrupted the spawning and rearing behavior of all four species of anadromous salmonids commonly found in California: chinook salmon, coho salmon, steelhead, and coastal cutthroat trout.

Characteristics of fish friendly crossings include:

- Crossing width at least as wide as the active channel. This reduces the constriction of flows at the inlet.
- Culvert passes a 100-year storm flow at less than 100% of the culvert's height. This allows for passage of other watershed products (large wood, debris, and substrate) during extremely high flows.
- Crossing bottom buried below the stream bed.
- Natural bed material 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.
- Stable streambanks upstream and downstream of the crossing.

OVERVIEW OF EVALUATION PROCESS

The objective of Part IX is to provide the user with:

- Consistent methods for collecting and analyzing data to evaluate passage of juvenile and adult salmonids through stream crossings (pages IX-8 to IX-42)
- Ranking criteria for prioritizing stream crossing sites for treatment according to the degree to which the barrier impedes species life stages trying to negotiate them, and considers the quality and quantity of available habitat upstream of the crossing (pages IX-42 to IX-44).
- Treatment options to provide unimpeded fish passage for all adult and juvenile age classes (pages IX-45 to IX-46)
- A stream crossing remediation project checklist (pages IX-46 to IX-47)
- Guidance measures to minimize impacts during stream crossing remediation construction (pages IX-47 to IX-50)
- Methods for monitoring effectiveness of corrective treatments (pages IX-50 to IX-51).

The fish passage evaluation protocol provides consistent methods for evaluating fish passage through culverts at stream crossings, and will aid in assessing fish passage through other types of stream crossings, such as bridges, and paved or hardened fords. Consistent evaluation of stream crossings enables managers to rank and prioritize sites for treatment. This is not a design protocol for constructing replacement structures. However, general aspects of design options, permits, water management, and measures to minimize construction impacts to salmonids and stream habitat are included.

The stream crossing inventory and fish passage evaluation is generally conducted as a series of tasks completed in the following order (Figure IX-2):

- Location of stream crossings and identification of crossing sites for passage evaluation (page IX-8).
- Fish Passage Inventory Data Sheet (pages IX-26 and IX-27).
- First-phase passage evaluation using the filtering process to assist in identifying sites which either meet or fail to meet fish passage criteria (the filtering process reduces the number of crossings which require an in-depth passage evaluation) (pages IX-28 to IX-30).
- Estimation of stream-specific hydrology, flow capacity of crossings, and fish passage flows (pages IX-31 to IX-40).
- In-depth passage analysis at sites identified by the first-phase passage evaluation as possible temporal or partial barriers (pages IX-36 to IX-39).
- Collection and interpretation of existing habitat information (pages IX-41 to IX-42).
- Ranking of sites for corrective treatment (pages IX-42 to IX-44).

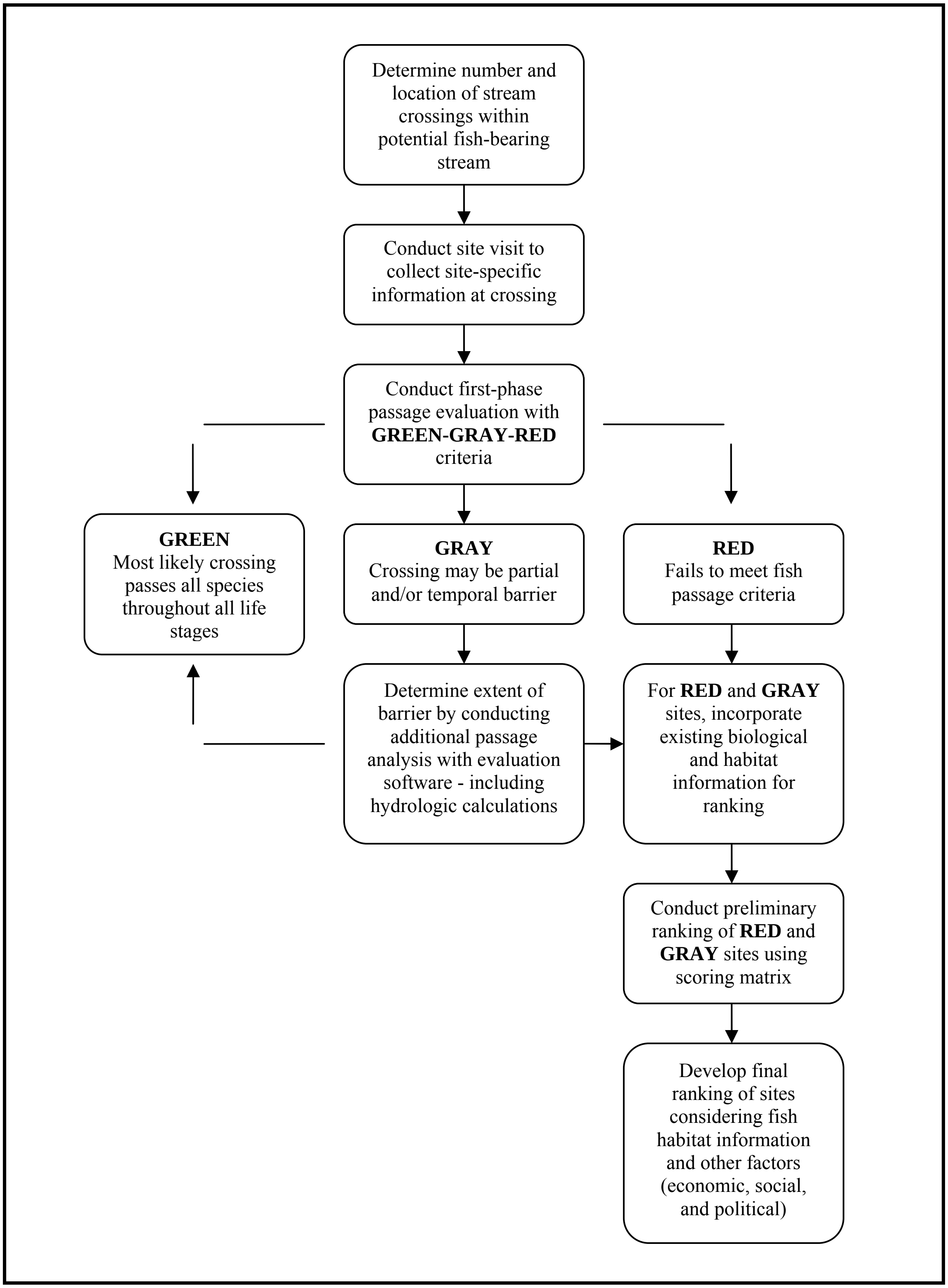


Figure IX- 2. Framework for inventory and evaluation of fish passage through stream crossings.

FISH PASSAGE EVALUATION FIELD PREPARATION

Prior to conducting field inventories, the project manager must consider special training requirements, minimum crew-size restrictions, or permits that may be required to legally work within road easements or confines of culverts. Always obtain landowner permission before accessing private property. Use proper safety equipment and carefully assess the site-specific characteristics of each stream crossing before conducting longitudinal surveys.

At each site place bright orange safety cones with signs marked “Survey Party” to alert oncoming traffic from both directions. Crew members should wear bright orange vests to increase one’s visibility to traffic. Two-way radios with headsets enable effective communication between crew members in spite of noise from road traffic and stream flow.

Use extreme caution when wading through culverts. In older corrugated steel culverts, check the floor carefully for rusted-through areas and/or jagged edges. A hard hat with a chin strap, protective footwear, and flashlight should be required items for any crew members that enter a culvert.

Prior to initiating stream crossing inventories field crews should become familiar with the protocol by participating in a DFG-sponsored or approved training session. Project supervisors should assure quality control of data collected by crews.

Tools and Supplies Needed

Prior to conducting field inventories, the following equipment and supplies should be assembled:

- Maps marked with site locations
- Names and phone numbers of property owners, along with copies of access agreements
- Data collection sheets, printed on water-proof paper
- Pencils
- Global Positioning System (GPS) unit (optional)
- Safety vests, signs, and cones
- Hard hat with chin strap
- Flashlight or headlamp
- Two-way radios with headset
- Waders, hip boots, and wading shoes (non-slip soled)
- Survey-level, auto-level equivalent or better (such as total station)
- Tripod, domed head preferred
- Tapes (one each): 300' and 100' in 0.1' increments
- Clamps to secure tapes for longitudinal profiles and cross section surveys
- Leveling rod: 25' in 1/100' increments
- Pocket leveling rod - to measure breaks-in-slopes within small diameter culverts
- Compass

- Clinometer - for measuring road prism slopes
- Camera, film (or discs for digital), and extra batteries
- Machete or pruners for clearing brush
- First-aid kit
- Poison oak protection

FISH PASSAGE EVALUATION

The fish passage evaluation protocol is designed for conducting consistent evaluation of stream crossings. Evaluation results identify fish passage problems, and, considering additional fish habitat information, rank or prioritize treatment recommendations for the project area. This protocol was designed to be used in conjunction with *FishXing* software (Love 1999).

Location of Stream Crossings

The first task is to locate and define the number of existing stream crossings on fish-bearing stream reaches within the watershed or area of interest. Preliminary watershed assessment for potential crossing locations requires an examination of the road system from aerial photos or topographic maps, and identification of stream crossings on known historic and present fish-bearing stream reaches.

Seek input from people with intimate knowledge of the road systems and watersheds of concern including: road supervisors, maintenance and construction crews, fisheries biologists, restoration groups, watershed groups, public land managers and/or private landowners. Before entering private lands, access permission must be obtained from all private landowners.

Anadromous fish-bearing stream reaches may be initially identified from topographic maps by considering the limit of anadromy up to a sustained channel slope of eight to ten percent. Resident trout reaches are defined as channels with gradients up to 20 percent (Robison et al. 2000, SSHEAR 1998). DFG biologists or land managers may have knowledge of anadromy limits due to local features such as falls, debris jams, small dams, or other stream crossings that may act as migration barriers.

Site Visit

- A site visit at the stream crossing is conducted to collect physical measurements affecting fish passage. This information is recorded on the *Fish Passage Inventory Data Sheet*. Additional information collected for stream crossings include:
- A description of the type and condition of each crossing
- Qualitative comments describing stream habitat immediately above and below each crossing
- GPS waypoints
- Site sketch and photographs

When in the field, to the extent feasible, search for stream crossings that failed to appear on the maps. Note any locations where these additional crossings exist, as well as stream reaches not examined. If stream crossings on maps are classified as culverts, bridges, or fords, it is recommended to field verify each of these structures. It is not uncommon for large culverts to be labeled as bridges. If maps are outdated, record locations on the topographic map and assign a GPS waypoint where a crossing has been installed or replaced with another type of stream crossing.

FISH PASSAGE INVENTORY DATA SHEET

The *Fish Passage Inventory Data Sheet* (pages IX-26 and IX-27) is completed for all stream crossings visited. Culverted stream crossings will require more data taken. Most field time is spent traveling to and from stream crossing locations. Therefore, at each location fill out the appropriate information which includes: determining active channel width, calculating a fill estimate, surveying a longitudinal profile and a tailwater cross section, making a site sketch and taking photographs.

Active Channel Widths

The active channel stage or ordinary high water level is the elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence on the landscape. Evidence of the active channel stage includes:

- The bank elevation at which cleanly scoured substrate of the stream ends and terrestrial vegetation begins
- A break in rooted vegetation or moss growth on rocks along stream margins
- Natural line impressed on the bank
- Shelving or terracing
- Changes in soil character
- Presence of deposited organic debris and litter
- Natural vegetation changes from predominantly aquatic to predominantly terrestrial

An active channel discharge is less than a bankfull channel discharge. Figure IX-3 provides a basic sketch of active versus bankfull channel locations. Figure IX-4 illustrates an example of both active and bankfull channel margins; however in many situations these indicators are less apparent. Many culvert design guidelines utilize active channel widths in determining the appropriate widths of new crossing installations (DFG 2002; Robison et al. 2000; NMFS 2001; Bates et al. 1999).

Take at least five channel width measurements to determine the active channel width. The best measurement sites are above the crossing in a channel reach visually beyond any influence the crossing may have on channel width. If it is not possible to measure active channel width above the crossing, downstream measurements may be taken beyond the influence of the crossing. An average of these measurements should account for natural variations in channel width.

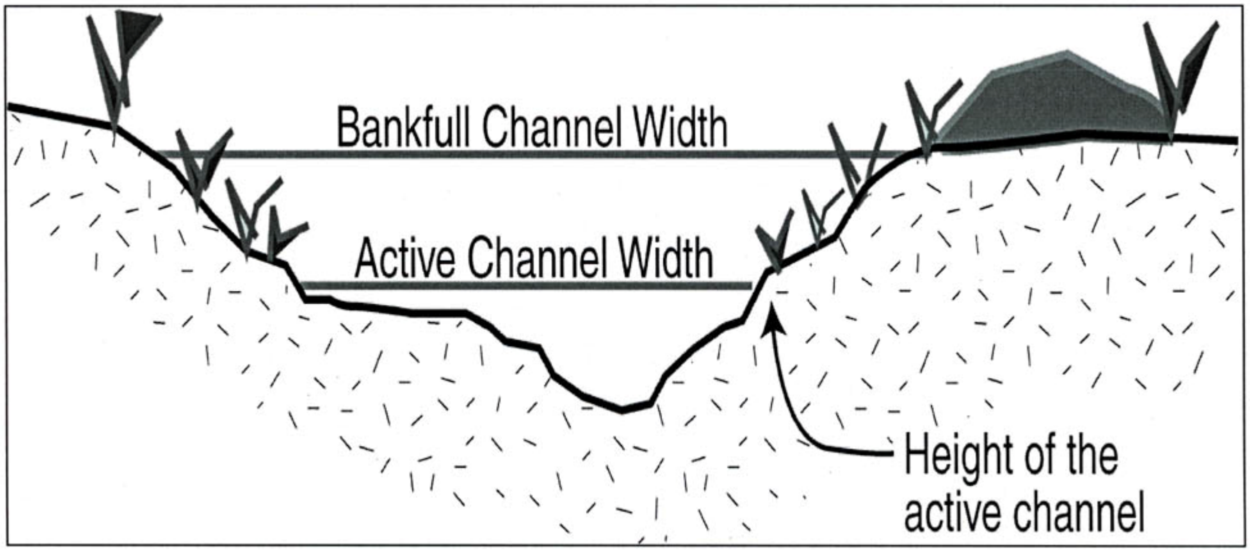


Figure IX- 3. Active channel width versus bankfull channel width.

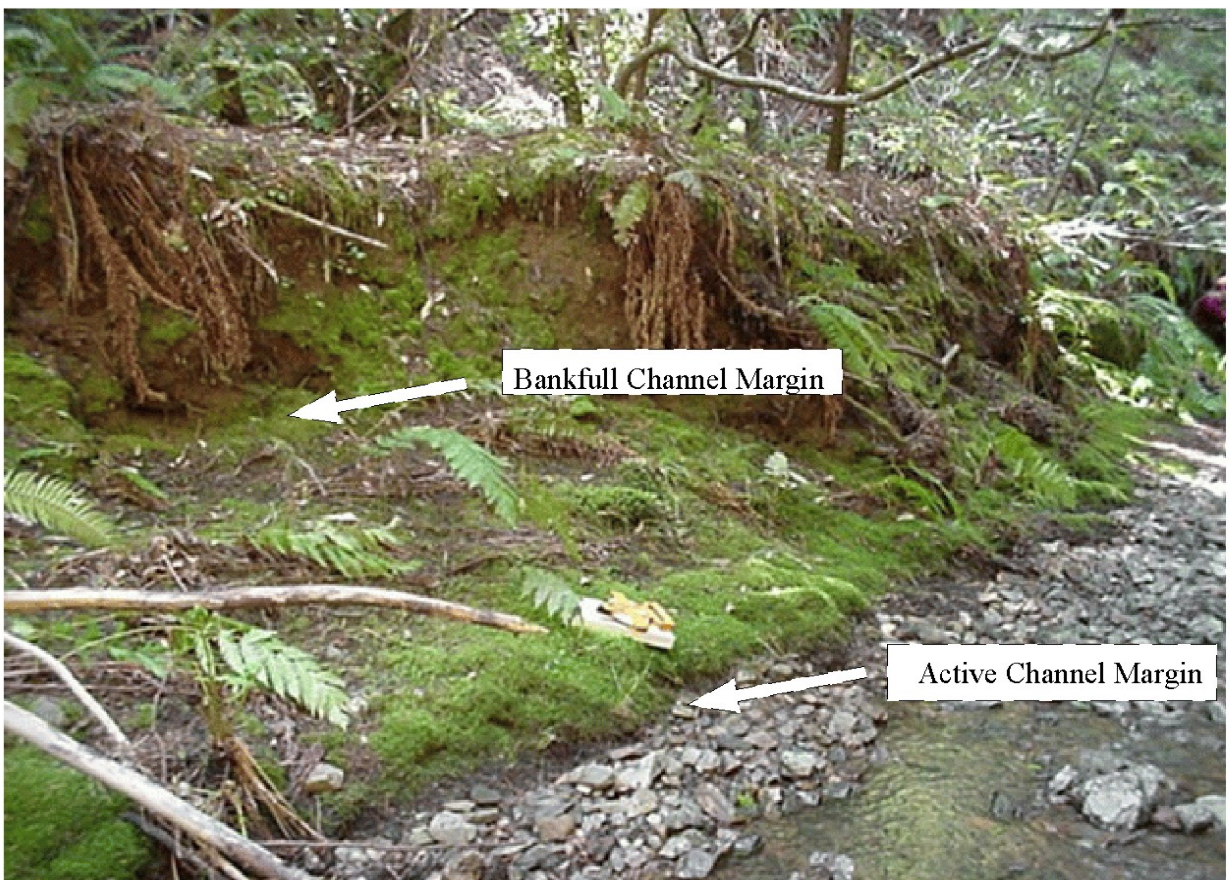


Figure IX- 4. Example of active and bankfull channel margin.

Fill Estimate

At each culvert, the volume of road fill is estimated from field measurements. These fill volume estimates are then incorporated into the ranking criteria for treatment and can assist in:

- Calculating culvert flood capacity at the headwater depth (HW) /culvert height (diameter - D) equal to one, HW/D =1 (Figure IX-5)
- Determining potential volume of sediment delivered to the stream if the stream crossing fails
- Developing rough cost estimates for barrier removal by estimating equipment time required for fill removal and disposal site space needed

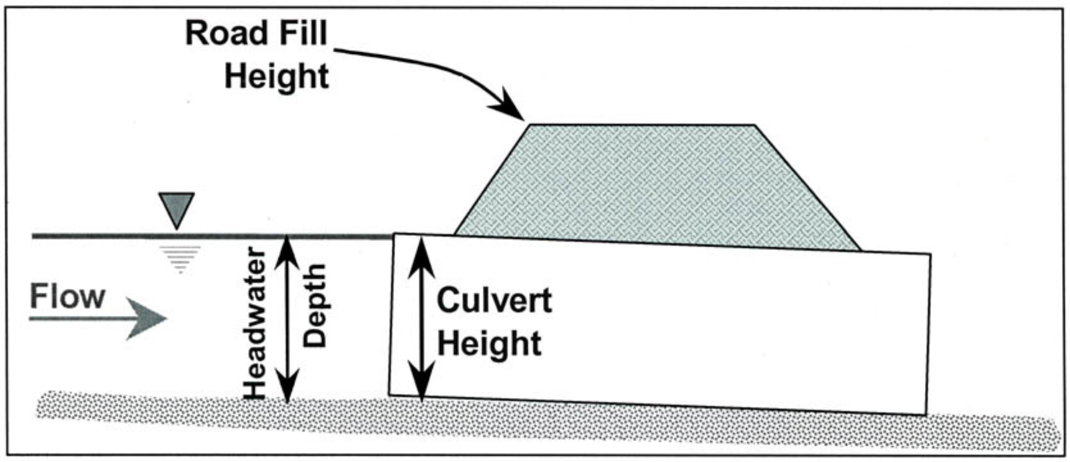


Figure IX- 5. Headwater depth and culvert height, HW/D=1.

Road fill volume is estimated using procedures outlined in Flannigan et al. (1998). The following measurements are taken to calculate the fill volume (Figure IX-6):

- Upstream and downstream fill slope lengths (L_d and L_u)
- Percent slope of upstream and downstream fill slopes (S_d and S_u)
- Width of road prism (W_r)
- Top fill length (L_f)
- Base fill width (W_c)

The fill measurements included in the *Fish Passage Inventory Data Sheet* generate rough fill volumes for comparison between sites while minimizing the amount of time required to collect the information. These volume estimates can contain significant error and should not be used for designing replacement structures.

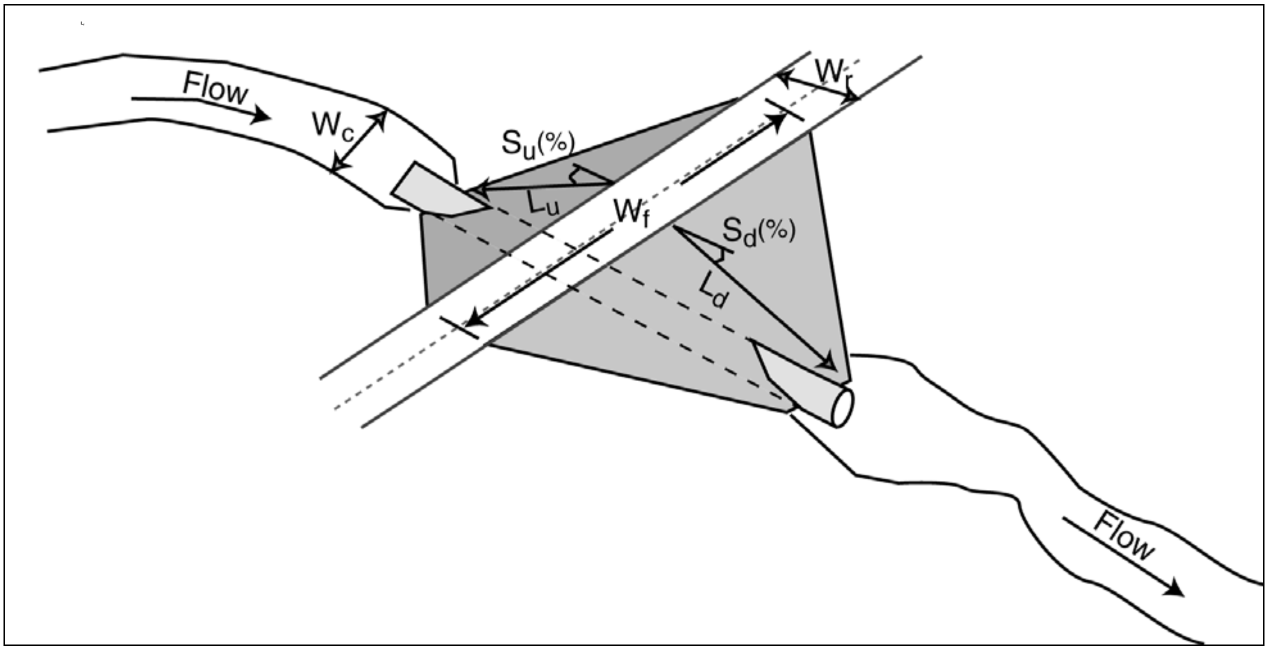


Figure IX- 6. Measurements taken to calculate fill volume.

Equations (1) through (4) are used to calculate the fill volume. To use the fill volume equations, convert slope from percent to degrees. This is accomplished by using the arc tangent function.

Upstream prism volume, V_u:

$$V_u = 0.25(L_f + W_c)(L_u \cos S_u)(L_u \sin S_u)$$

Downstream prism volume, V_d:

$$V_d = 0.25(L_f + W_c)(L_d \cos S_d)(L_d \sin S_d)$$

Volume below road surface, V_r:

$$V_r = 0.25(H_u + H_d)(L_f + W_c)\, W_r$$

where : $+H_u = L_u \sin S_u$, and $H_d = L_d \sin S_d$

Total fill volume, V:

$$V = V_u + V_d + V_r$$

Longitudinal Survey

A longitudinal survey is performed at each stream crossing to provide accurate elevation data for fish passage analysis. *Stream Channel Reference Sites: an Illustrated Guide to Field Technique* (Harrelson et al. 1994) provides basic surveying techniques. Because of the sensitivity of slope measurements when evaluating passage, slopes must be measured with surveying equipment that can accurately measure changes in elevation to 0.01 foot. It is not adequate to measure slopes with a handheld sight level or clinometer. The following steps should be followed when doing longitudinal surveys:

- Secure the end of a 300-foot tape on the upstream side of the crossing, usually at the tailwater control of the first resting pool above the crossing (Figure IX-7). This would be considered the first available resting habitat for fish after negotiating the crossing. The first resting pool location can be near the crossing inlet or a considerable distance upstream.
- Set the tape down the approximate center of the stream channel to reflect any major changes in channel direction. Continue the tape through the culvert or down the length of the crossing if possible. An elevation is recored at the tailwater control of the pool immediately below the crossing. If several downstream weirs create “stair-stepped” pools, take the elevation of the tailwater control of the most downstream pool. Extend the longitudinal tape downstream from the tailwater control until there is a noticeable change in slope or channel width. This channel reach often extends downstream to termination of the riffle below the outlet pool. Record the elevation at the downstream end of the channel reach selected. Record the station locations at the tailwater control and the end of the channel reach (to determine distance). The change in elevations divided by the distance, multiplied by 100, calculates the percent channel slope below the tailwater control.
- Pull the tape taut along the length of the crossing. For culverts, clamp the tape securely to the culvert inlet and outlet for accurate length measurements. In situations where it is not feasible to lay the tape through the culvert, such as at small diameter or severely rusted culvert, attempt to measure the culvert length as accurately as possible from the road surface. Make note of where these measurements were taken and attempt to verify length from existing road databases or as-built plans.
- Set the survey-level in a location to minimize or eliminate the number of times it must be moved to complete the survey. If possible, a location on the road surface is optimal, allowing a complete survey from a single location. However, at sites with high road fills or with breaks-in-slope within the culvert, the best location for the survey-level and tripod is within the stream channel or culvert.
- Establish and survey a temporary benchmark (TBM).
- Place the leveling rod in the thalweg at various stations along the center tape to capture visible breaks in slope along the stream channel and through the stream crossing.

At all stream crossings, a minimum of six elevations and corresponding stations along the center tape are required (Figure IX-7). These are:

1. Culvert inlet, or upstream end of the crossing
2. Culvert outlet, or downstream end of the crossing
3. Maximum depth within five feet downstream of the culvert
4. Maximum pool depth upstream of the crossing
5. Outlet pool's tailwater control
6. Active channel margin between the culvert outlet and the outlet pool's tailwater control. This elevation should correspond to the height of flow during an active channel discharge event.

On a site-specific basis, the following additional survey points provide useful information for evaluating fish passage:

- Steep changes in the stream channel profile immediately upstream of the culvert inlet or at the upstream end of the crossing, measure the elevation at the tailwater control of the first upstream resting pool to estimate the channel slope upstream of the crossing (Figure IX-7). In some cases, a fish may negotiate a culvert only to encounter a velocity barrier upstream of the inlet entrance.
- Slope of inlet and outlet aprons: To increase flood capacity and prevent scour, some crossings have concrete aprons lining the stream channel at the upstream and/or downstream end. These aprons are often steep, creating velocity and lack of depth barriers. Measure elevations at upstream and downstream ends of each apron and the length of the apron to calculate slope.

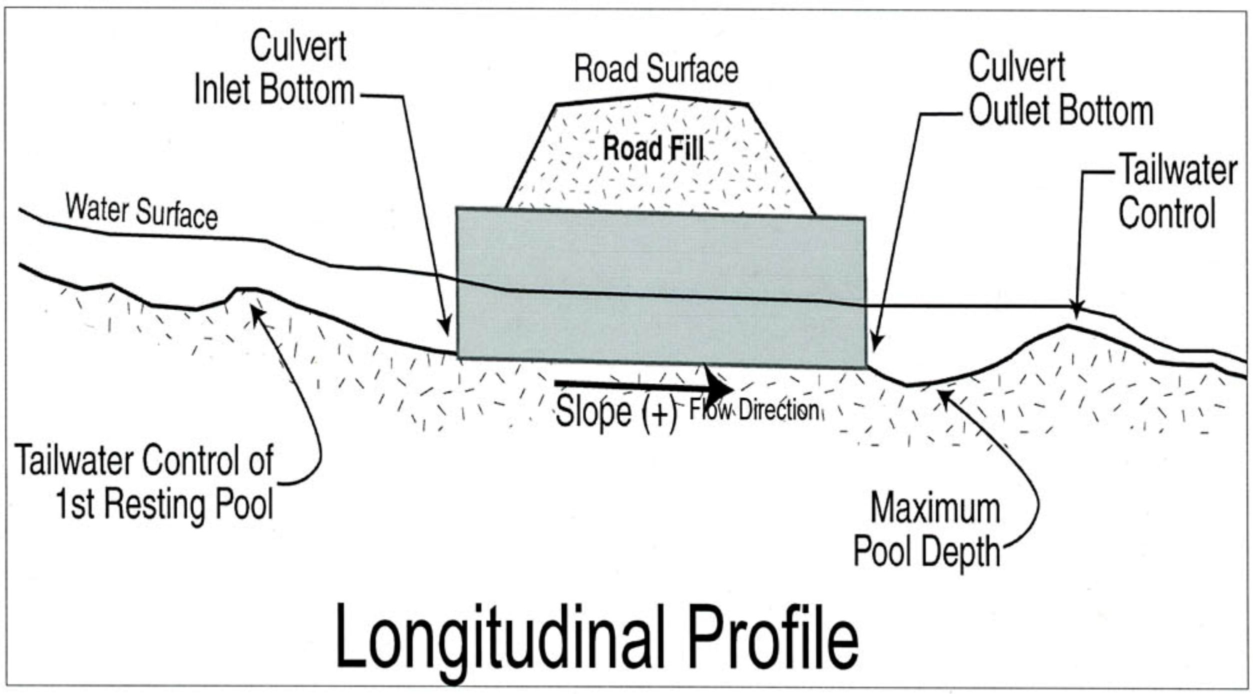


Figure IX- 7. Diagram of required survey points for a longitudinal profile through a culvert.

- Apparent breaks in slope within the crossing: Older culverts can sag when road fills slump, creating steeper sections within a culvert. If only inlet and outlet elevations are measured in a sagging culvert, steeper sections that may act as barriers will be missed.

Measure all elevations to the nearest 0.01' and enter each surveyed point with a corresponding station location (distance along tape) to the nearest 0.1 foot. Conventional survey standards start with station 0.0' at the downstream end of the tape; however, it is usually more feasible to work through a culvert from an upstream-to-downstream direction.

Tailwater Cross-Section

Although not required, in some cases a cross section survey across the bankfull channel width at the downstream tailwater control increases the accuracy of passage analysis. Space is provided on the *Fish Passage Inventory Data Sheet* to conduct this survey. For more detail, please refer to the extensive “Help files” provided with *FishXing* (Love 1999).

With no apparent outlet pool, locate the cross section three feet from the culvert outlet, perpendicular to the channel. For slightly perched culverts, locate the cross section at the tailwater control, perpendicular to the stream channel. Cross sections typically start (station 0.0N) on the left bank (looking downstream). Securely place the 100-foot tape across the channel. If feasible, conduct cross section survey with survey level still set in place for the longitudinal survey, otherwise a turning point is required.

Locate the first survey point at approximately the bankfull channel margin. Proceed to survey from left to right, taking elevations at obvious breaks in slope. Record the station number of each surveyed point (distance indicated on cross tape). Rod heights must be converted to elevations relative to established benchmark. Record points of interest such as location of bankfull channel margin, active channel margin, tailwater control, mid-channel bar formation, and/or wetted edges.

Site Sketch

A site sketch of the stream crossing should be included on the back of the *Fish Passage Inventory Data Sheet*. Figure IX-8 illustrates a typical site sketch. Features to consider in site sketches include:

- A “North Arrow”. Use a compass to determine direction of north. Orient the sketch so that north is towards the top of data sheet.
- Label direction of stream flow, road name, and stream name
- Mark TBM location and type
- Mark location(s) where survey level and tripod were placed to complete the longitudinal survey
- Mark locations of photo points
- Accurately depict orientation of stream channel to culvert inlet
- Include unique features such as wingwalls, riprap for bank armoring or jump pool formation, baffles, debris jams, location of any bends in the culvert, etc.

Photography

Take photographs of all stream crossing locations, including the inlet and outlet of each culvert. Photograph any unique site features, such as steep drops at inlets, perched outlets, breaks-in-slope, poor or damaged crossings, outlet pool conditions, debris blocked inlets, and/or habitat conditions above and below the site.

Photograph the outlet pool and tailwater control while facing in a downstream direction to capture stream bank configuration and channel slope. These photos provide a clear picture of the crossing's tailwater control to aid in passage evaluation.

Digital cameras are highly recommended, especially models with a variable aperture setting and flash. Digital technology allows preview of pictures while at the site. Delete and re-take unsuccessful photos.

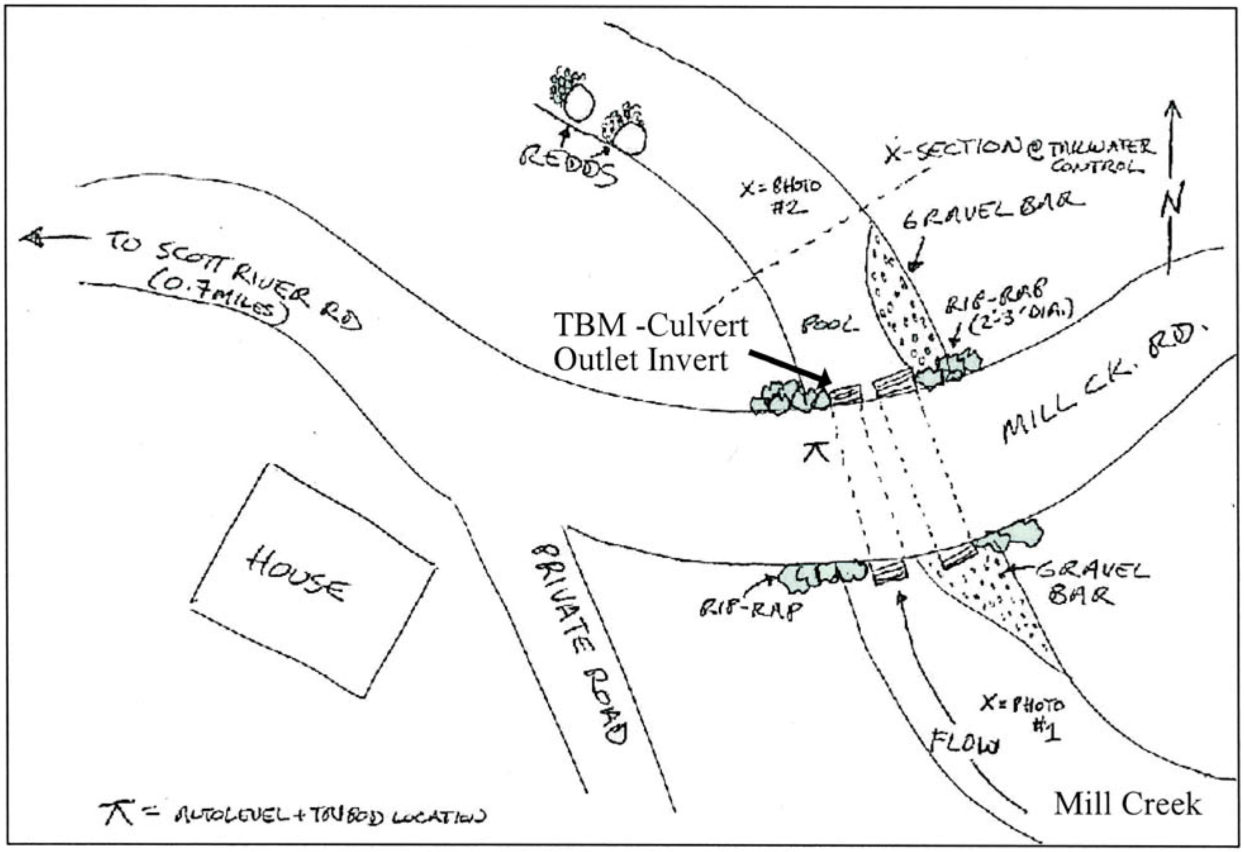


Figure IX- 8. Site Sketch example.

Instructions for Completing the Fish Passage Inventory Data Sheet

***Stream Crossing Type*:** Check bridge, ford, culvert, or other. If other, describe the type of stream crossing.

Date: Enter the day's date (mm/dd/yy).

***Surveyors*:** Enter the names of people operating the surveying-level (scope) and leveling rod.

Culvert #____ of _____: Required if a stream crossing is comprised of multiple pipes or a box culvert with two or more bays. Number from the left bank to the right bank (determined when facing downstream).

***Road*:** Enter road name and/or number.

***Mile Post*:** Enter the mile post where crossing is located. If the mileage is not posted at the crossing, use the vehicle's odometer to estimate the mile post to the nearest 0.1 mile by driving to the nearest posted mile-marker or the beginning of the road. Also record the direction driven.

Cross Road: Enter the name, direction and distance (0.1 miles) to the nearest named or numbered crossroad.

Stream Name: Enter the stream name as it appears on the 7.5 minute USGS quadrangle. If the stream is unnamed, enter *unnamed.* If a road crosses a stream in multiple locations, assign a number to the stream name with the stream #1 crossing located farthest downstream.

Tributary to: Enter the name of the receiving stream, river, lake or ocean.

Basin: Enter the main drainage system.

Quad: Enter the name of the USGS 7.5 Minute Series Quadrangle where the stream crossing is located.

T-R-S: From the USGS quadrangle, enter the Township, Range and Section the stream crossing is located in.

Lat/Long: Enter the latitude and longitude coordinates of stream crossing location in decimal degrees to the five figures right of the decimal place. DFG standard is NAD27. If the datum is other than NAD27, such as WSG84, record the horizontal datum used in the comments section. Determine location with either a global positioning system unit at the site, or later with a digitized, geo-referenced USGS quadrangle.

Flow Conditions During Survey: Check the box that best describes the flow conditions.

Fisheries Information

Fish Presence Observed During Survey: When initially approaching the crossing, carefully look for salmonids in the stream above and below the crossing. Check the appropriate choices.

Location: upstream and/or downstream, or none;
Age classes: adults, juveniles;
Species: steelhead, coho, chinook, coastal cutthroat, resident trout species, or unknown;
Juvenile Size Classes: <3", 3" - 6", >6";
Number of Fish Observed: Estimate the number of fish observed.

Stream Crossing Information

Inlet Type: Check the box that best describes inlet configuration (Figure IX-9).

Projecting: Culvert barrel projects upstream out of the road fill.

Headwall: Culvert barrel is flush with road prism, that is often set within a vertical concrete or wooden headwall.

Wingwall: Concrete walls that extend out from the culvert inlet in an upstream direction. In a downstream direction, wingwalls taper towards the inlet and usually increase a crossings flow capacity

Mitered: Culvert inlet is cut on an angle similar to angle of the road prism, increasing the size of the opening and the flow capacity.

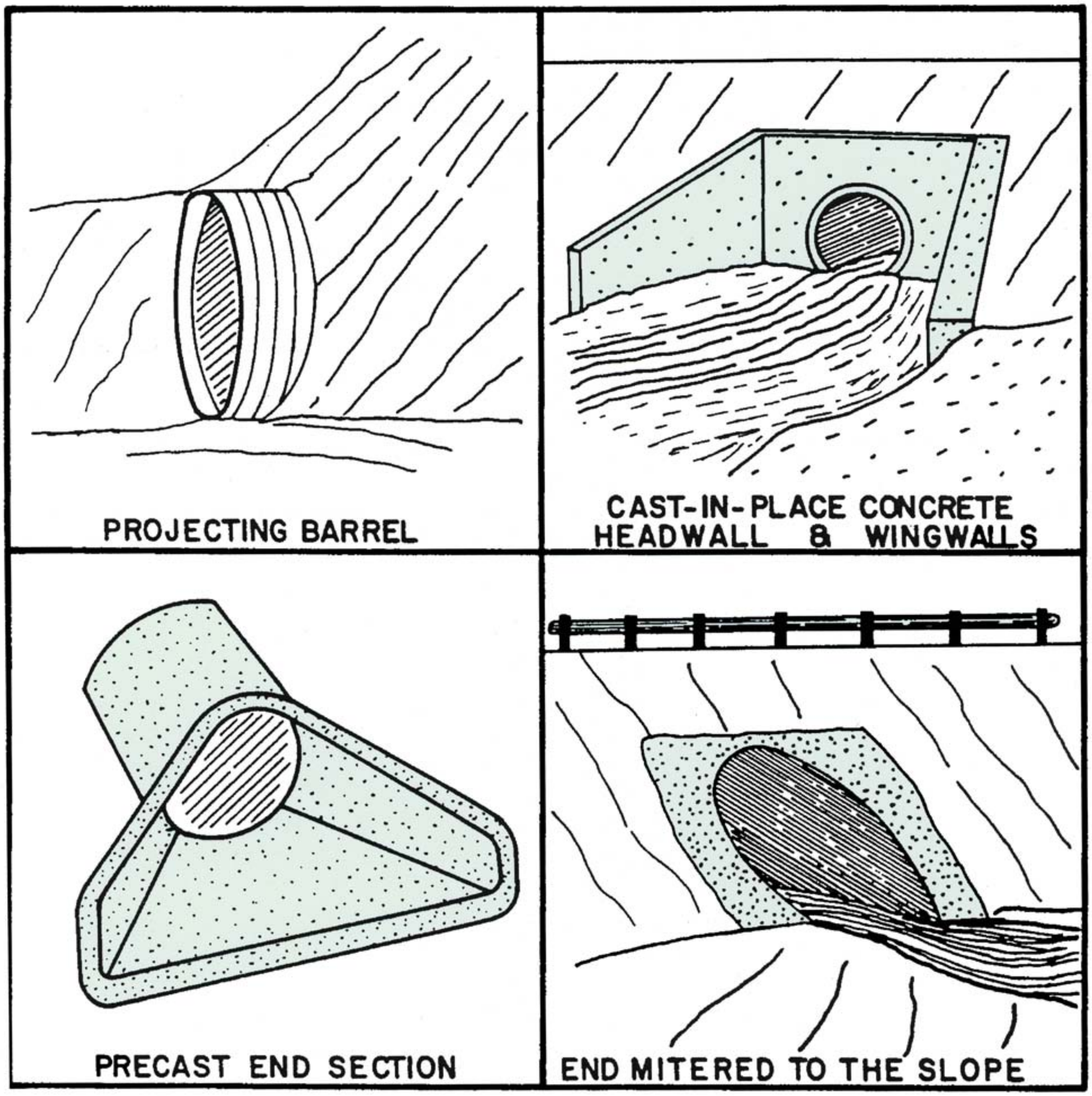


Figure IX- 9. Four standard inlet types (Norman et al. 1985).

Alignment: While standing at the inlet and looking upstream, estimate the stream channel approach angle with respect to the inlet. Check: *<30E, 30 - 45E, >45E.* Include this feature in the site sketch. Channel approach angles greater than 30^{o} may increase the likelihood of a stream crossing plugging with debris during storm flows, which impedes fish passage and can result in catastrophic failure of the stream crossing and road prism. In some instances, poor channel alignment creates adverse hydraulic conditions that inhibit or prevent fish passage.

Inlet Apron: Check appropriate choice. If an apron exists, provide a brief description. Measure and record length, width, and slope and include in the site sketch. Aprons are usually constructed of concrete and are installed to increase flow capacity and prevent or reduce erosion at the toe of the stream crossing fill.

Outlet Configuration: Check box that best describes culvert outlet.

At Stream Grade: A swim through culvert that has no drop at the outlet.

Free-fall Into Pool: Culvert outlet is perched directly over the outlet pool. Requires migrating fish to leap into culvert from outlet pool.

Cascade Over Riprap: Culvert outlet is perched above the downstream channel and exiting water flows (or sheets) over riprap, concrete, and/or bedrock.

Outlet Apron: Follow same instructions as provided for inlet aprons.

Tailwater Control: Defined as the channel feature which influences the water surface immediately downstream of the crossing. Check the box that best describes the tailwater control.

Pool Tailout: Commonly referred to as the riffle crest. Deposition of substrate downstream of the outlet pool controls the pool elevation.

Full-Spanning Log or Debris Jam: Naturally deposited pieces of wood or trees that influence the outlet pool elevation.

Log, Boulder, or Concrete Weirs: These structures are often placed downstream of perched culverts to raise tailwater elevation and reduce the leap height required by migrating fish to enter a culvert.

Other: Describe the pooltail conditions if none of the above choices accurately classifies the feature influencing the outlet pool elevation. Include details in site sketch and also photograph the feature.

No Control Point (Channel Cross Section Recommended): Describes situations where there is no outlet pool, allowing water to flow unimpeded downstream. In this situation the channel roughness, slope, and cross-sectional shape govern the water elevation downstream of the outlet. When surveying a cross section at these sites, it should be located within five feet of the outlet.

Upstream Channel Widths: Measure and record five active channel widths. The active channel is identified by locating the height of annual scour along banks developed by annual fluctuations of stream flow and indicated by the following physical characteristics:

- natural line impressed on the stream banks
- shelving
- changes in soil character
- absence of terrestrial vegetation
- presence of deposited organic debris and litter (Figure IX-4)
- Space the five measurements out over approximately a 100N stream reach, well above any influence the stream crossing may have on channel width or tributaries. Avoid obvious discontinuities, such as a large root wad or boulder. Record the ***Average Width***.

Undersized culverts can influence the active channel width for several hundred feet upstream as a result of ponding storm runoff, causing substrate deposition.

Culvert Information

Culvert Type: Check the appropriate type of culvert. Figure IX-10 depicts the end-sections of four common culvert types. *Other* may include either *bridge* or *ford*.

Diameter (ft): For circular culverts measure to the nearest 0.1N of the culvert's inside diameter. If corrugated, measure from the outside edge of the corrugations. In some cases circular pipes are installed as slightly oval (elliptical) to compensate for settling, if so, measure rise and span as in a pipe arch culvert.

Height or Rise (ft): While inside the culvert, measure the culvert's height or rise, to the nearest 0.1 foot, measured vertically from inside the corrugations. If the culvert bottom is completely covered with bedload (embedded), estimate culvert height based on shape (e.g. assume height = width for circular culverts). For open-bottom arches and box culverts that appear bottomless, measure the rise from the streambed to top of culvert.

Width or Span (ft) Measure and enter the culvert's maximum width or span to the nearest 0.1 foot.

Length (ft) Measure and record the culvert length from inlet to outlet to the nearest 0.1 foot.

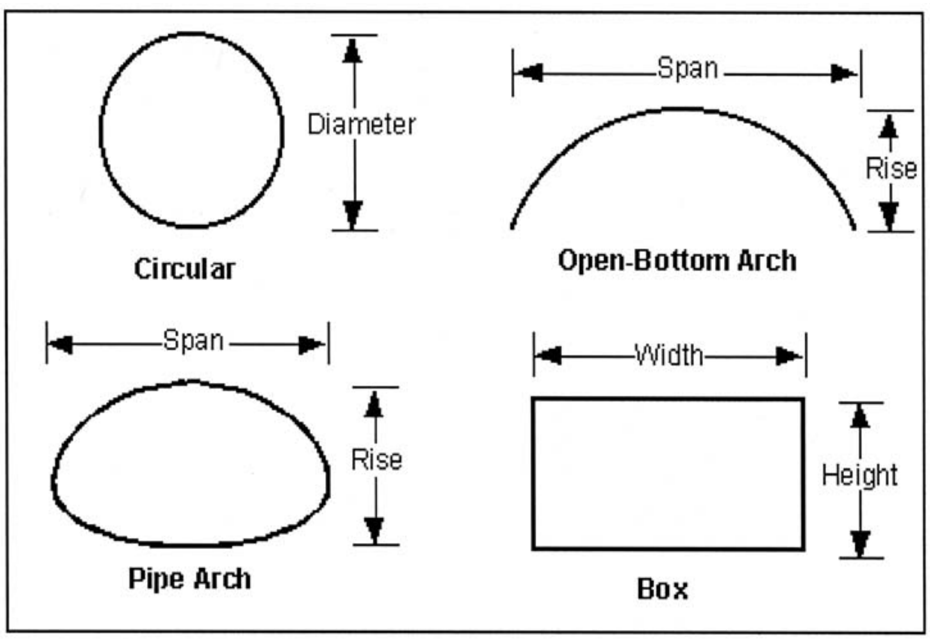


Figure IX- 10. Culvert type and dimensions.

Material: Check the box that most accurately describes the culvert's construction material. If none of the choices accurately describes the culvert material, provide a brief description of construction material and characterize the roughness of the material (a photograph is also recommended). Check multiple boxes if the culvert is a composite of two or more materials. Include a length measurement for each section of varying material.

Structural Steel Plate (SSP): Or "multi-plate" pipes constructed of multiple plates of corrugated galvanized steel, bolted together.

Corrugated Steel Pipe: (CSP) Pipes constructed of a single sheet of corrugated galvanized steel. Also referred to as corrugated metal pipes (CMP).

Aluminum: Corrugated aluminum, these pipes do not develop rustlines.

Plastic: Constructed of various types of high-impact plastics, usually with shallow corrugations.

Concrete: Most box culverts on county and state roads are constructed with concrete. However, some circular and arch pipes are made of concrete, generally with no corrugations.

Log/Wood: Includes old log stringer bridges and Humboldt crossings, but occasionally some box and old circular pipes too.

Other: Provide a brief description if none of the materials accurately describes the culvert.

Corrugations: Measure (in inches) and select the one of the standard corrugation dimensions (width x depth): 2bO x ½O; 3O x 1O; 5O x 1O; 6O x 2O or enter measurements if dimensions are not standard (Figure IX-11).

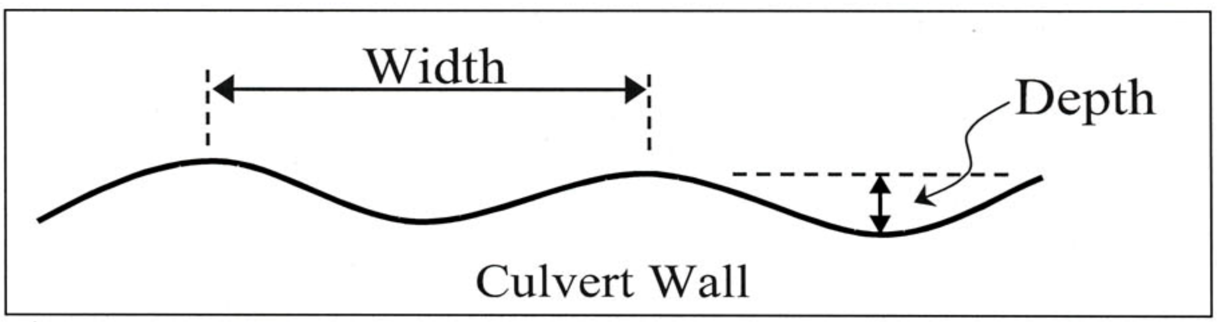


Figure IX- 11. Measuring corrugations.

Spiral: Check the appropriate choice if culvert has spiral (helical) corrugations because these reduce roughness.

Other: Describe corrugations if other than spiral.

Pipe Condition: Check the box that most accurately describes the culvert's condition. Also provide a brief description, if necessary. Photos of damaged crossings are recommended.

Good: No apparent damage, possibly slight rusting occurring.

Fair: Noticeable wear or rusting has occurred, but not rusted through the bottom yet.

Poor: Rusted or worn through, substantial leakage through bottom.

Extremely Poor:	Culvert floor is rusted through, sections are missing, crushed, slumping, or road fill is being undermined. High potential for imminent failure.
Describe Condition	Briefly describe any other type of apparent damage to culvert and/or road prism.
Rustline	If present, measure height (nearest 0.1N) of rustline peak inside culvert away from noticeable differences in rustline height affected by the inlet, outlet, baffles, or weirs (Figure IX-12). If no rustline is apparent enter *not present* (new CSP or SSP) or *not applicable (NA)* (concrete, aluminum, plastic).

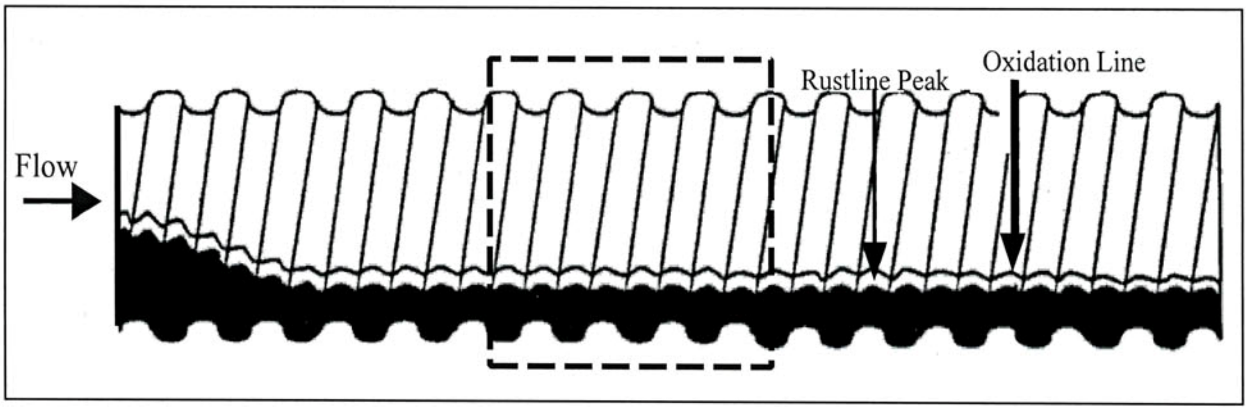


Figure IX- 12. Rustline measurements (Oxidation line is whitish or silver line, not to be confused with the rustline). (Adapted from Flannigan).

Embedded: Check yes if the culvert has substrate retained within at least a third of its length. Measure the depth of the substrate at the inlet and the outlet. If substrate is retained throughout the culvert, the start and end stations will be at the inlet and outlet If substrate cover is partial, record the depth as 0.0N at the appropriate location. For example, if the substrate coverage just begins within the culvert and continues through to the outlet, record the depth at the outlet and enter 0.0N for the inlet depth. Record station location of start and end of deposition (Figure IX-13). Describe the substrate as boulder, cobble, gravel, sand, silt/clay or bedrock (see Part III for substrate classifications).

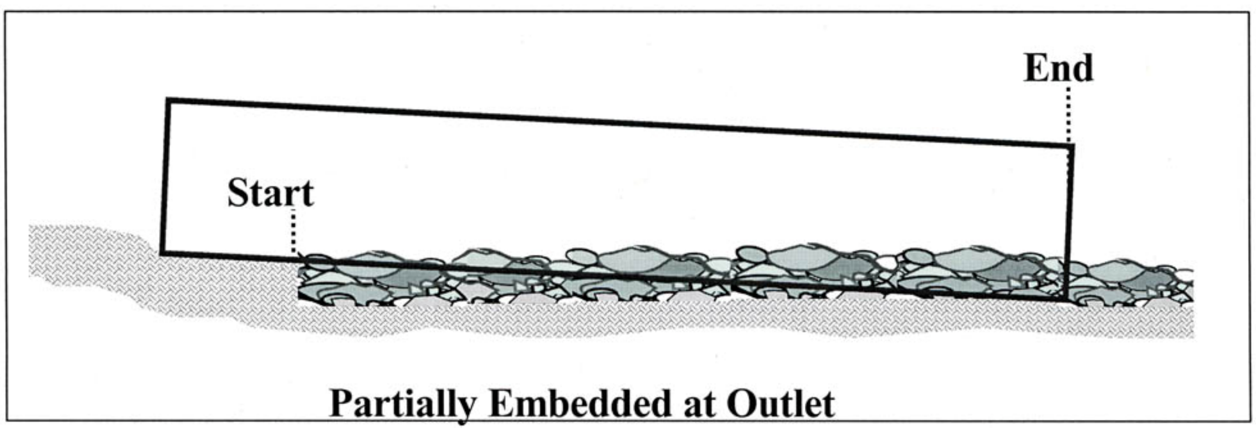


Figure IX- 13. Measurements taken at embedded culverts.

Barrel Retrofit: If culvert contains baffles or weirs inside the culvert, record the type, size, number, and spacing of the structures (see Part VII for baffle types).

Outlet Beam: If the stream crossing contains a beam within the outlet.

Notched: Note if structure is notched.

Breaks-in-Slope: Note the number and survey all noticeable breaks-in-slope between the culvert inlet and outlet. Record in the additional survey elevations section. Also note the station at which the break is located. In smaller culverts a pocket leveling rod is required. Surveying breaks-in-slope allows evaluation of the crossing in distinct sections to account for water velocities and depths influenced by the differing slopes.

Fill Volume: Seven measurements are required to generate a rough fill volume estimate (Figure IX-14).

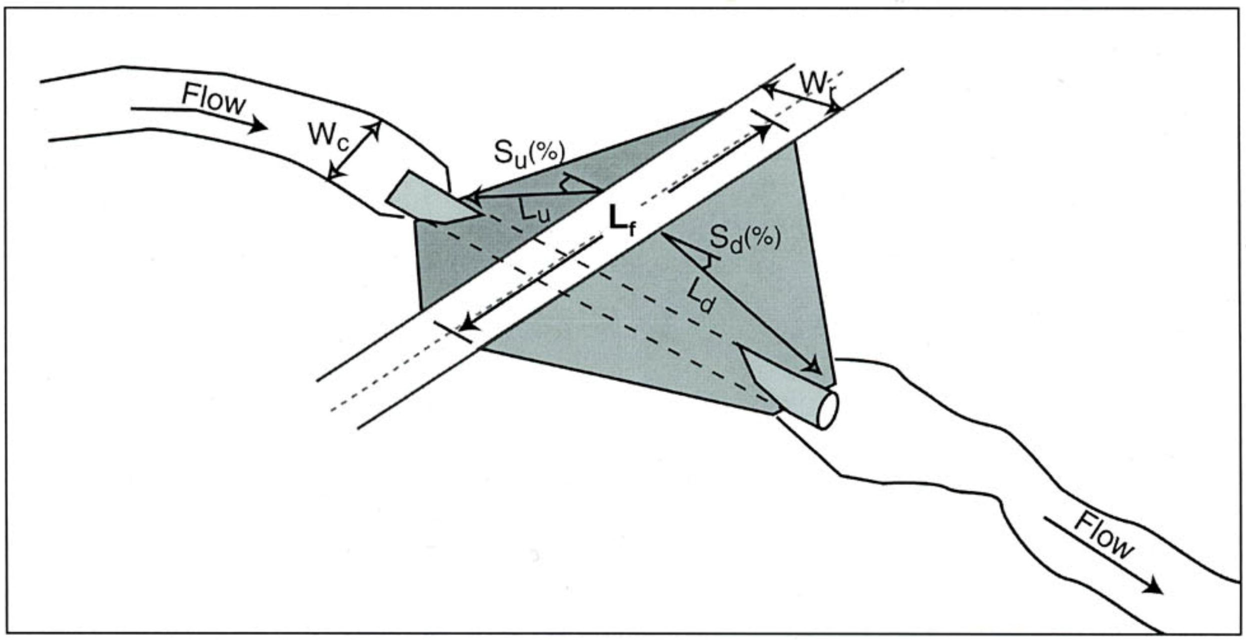


Figure IX- 14. Measurements required to generate a rough fill volume estimate.

Length of Upstream Fill (L_u): Measure and record to the nearest 0.1N the length of the road fill. To measure, one person stands at edge of road with tape held at waist level and the second crew member stands in channel at the toe of the road fill with tape at waist level.

Percent Slope of Upstream Fil (Su): The crew member on the road surface shoots from their eye-level to the eye-level of the crew member standing in channel at the toe of the fill.

Road Width (Wr): Measure and record to the nearest 0.1N the width of the road prism. Measure across the road surface at each edge where the break-in-slope down the fill prism occurs, this may include the paved road and/or shoulders and turn-outs on either side of the road.

Length of Downstream Fill (Ld): Same as measurement of *Lu*, but on downstream side of stream crossing fill slope.

Percent Slope of Downstream Fil (Sd): Same as measurement of *Su*, in percent, but on downstream side of stream crossing fill slope.

Top Fill Length (Lf): Measure and record to the nearest 0.1N the length of the road fill as it extends from left bank to right bank of the natural valley wall confinement of the stream channel.

Base Fill Width (Wc): Use the average active channel width calculated on the front of the data sheet.

Longitudinal Surveyed Elevations /Additional Surveyed Elevations : Record corresponding distance along tape (Station) with each survey point to the nearest 0.1 foot. Described below are the required survey points (Figure IX-15). If the channel is wetted at time of survey, measure water depths at all surveyed points and record in the Station Description column.The elevations of the backsight (BS), height of instrument (HI) and foresight (FS) in the longitudinal survey to the nearest 0.01 foot.

Temporary Benchmark: Record assigned elevation of the TBM.

*Tailwater Control of First Resting Habitat Upstream of Inlet:*Elevation at the start of the tape.

*Inlet Apron/Riprap:*If these features exist, survey the top of inlet apron and survey the toe of outlet aprons (even if submerged). Together with the elevations of the culvert's inlet and outlet, these points may be used to calculate the slopes of the inlet and outlet aprons.

*Inlet Depth:*Survey this point at the center of the culvert inlet. In embedded culverts, survey two elevations; at the center and at the channel thalweg. Use the "Additional Survey Points" section of the data sheet to enter the inlet thalweg data.

*Outlet Depth:*Survey this point at the center of the culvert outlet. In embedded culverts, survey two elevations; at the center and at the channel

Outlet Apron/Riprap: If these features exist. See above Inlet Apron/Riprap instructions.

*Maximum DepthWithin Five Feet ofOutlet:*Survey the maximum pool depth occurring within five feet of the culvert outlet. During migration flows, most adult salmonids will attempt their leaps within five feet of the outlet.

*Maximum Pool Depth:*Survey the deepest point of the outlet pool. Record depth at this point in addition to the maximum depth within five feet of outlet. If culvert is perched, this data determines if pool depth is adequate.

*Tailwater (TW) Control:*Survey the thalweg at the tailwater control (refer back to tailwater control for description). If no discernable control point exists, survey the channel thalweg within five feet of the culvert outlet. If concrete, boulder, or log weirs are in place, survey the lowest point along the weir. Photograph outlet pool and tailwater location to assist the data analyst running *FishXing*.

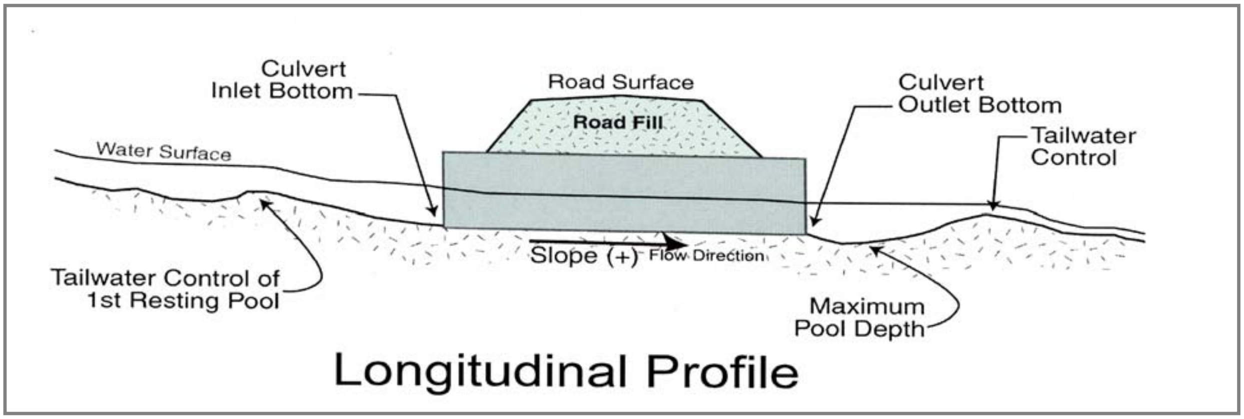


Figure IX- 15. Surveyed elevations.

Active Channel Stage: Surveyed anywhere in the outlet pool between the culvert outlet and the tailwater control location. Identify the active channel stage markings in at least two locations and compare elevations. A third elevation may be warranted if the first two are greater than 0.3’ apart. This elevation provides the minimum data required to roughly estimate the height of the outlet pool during upper migration flows (Figures IX-3 and IX-4).

Downstream Channel Percent Slope:Using the field inventory data, calculate the percent slope of the channel downstream of the stream crossing.

Tailwater Cross Section: (Optional) This cross section is used to estimate tailwater elevation at varying flows by constructing a flow-versus-tailwater elevation rating curve. This method is most appropriate for stream crossings with little or no outlet pool resulting in essentially unimpeded flow downstream of the outlet. A tailwater cross section is also useful at sites with slightly perched outlets (less than 2.0N high).

Substrate at Cross Section: Describe the streambed substrate composition at, and immediately downstream of the cross section. Substrate composition will determine the Manning’s roughness coefficient (Appendix H).

Suspected Passage Assessment: Based on your field observations and the definitions given in Table IX-1, check the boxes that in your judgement best describes the impact the stream crossing has on adult and juvenile salmonid fish passage.

Culvert Slope (%): Using the field inventory data, calculate percent culvert slope:

[(Elevation of Inlet Invert - Elevation of Outlet Invert)/(Culvert length)] X 100 = % Slope

FISH PASSAGE INVENTORY DATA SHEET

Stream Crossing Type: 9 bridge 9 ford 9culvert 9 other______________ **Date**:____/____/____
Surveyors: Scope: Rod: **Culvert #** **of** (left bank to right bank)

Road:	**Mile Post**:	**Crossroad**:
Stream Name:	**Tributary to**:	**Basin**:
Quad:	**T:** **R:** **S:**	**Lat/Long**:

Flow Conditions During Survey: ☐ continuous ☐ isolated pools ☐ dry

Fisheries Information

Fish Presence Observed During Survey: **Location**: ☐ upstream ☐ downstream ☐ none
Age Classes: ☐ adults ☐ juveniles Species: ______________________ ☐ unknown
Juvenile Size Classes: ☐ <3" ☐ 3"-6" ☐ >6" **Number of Fish Observed**:

Stream Crossing Information

Inlet Type: ☐ projecting ☐ headwall ☐ wingwall ☐ mitered
Alignment (deg): ☐ $<30^{o}$ ☐ 30^{o}- 45^{o} ☐ $>45^{o}$ **Inlet Apron**: ☐ yes ☐ no
Describe:

Outlet Configuration: ☐ at stream grade ☐ free-fall into pool ☐ cascade over rip rap
Outlet Apron: ☐ yes ☐ no Describe:

Tailwater Control: ☐ pool tailout ☐ full-spanning log or debris jam ☐ log weir ☐ boulder weir
☐ concrete weir ☐ other_________________________
☐ no control point (complete a channel cross-section)

Upstream Channel Widths (ft): (1) (2) (3) (4) (5) Average Width:

Culvert Information

Culvert Type: ☐ circular ☐ pipe arch ☐ box ☐ open-bottom arch ☐ other___________________
Diameter (ft):______ Height or Rise (ft):________ Width or Span (ft):_______ Length (ft):________

Material: ☐ SSP ☐ CSP ☐ aluminum ☐ plastic ☐ concrete ☐ log/wood ☐ other__________
Corrugations (width x depth): ☐ $2\,^{2}/_{3}$" x ½ ☐ 3" x 1" ☐ 5" x 1" ☐ 6" x 2" ☐ spiral
☐ other__________
Pipe Condition: ☐ good ☐ fair ☐ poor ☐ extremely poor
Describe:____ Rustline Height (ft):

Embedded: ☐ yes ☐ no Depth (ft): inlet_____ outlet_____ Station (ft): start:________ end:_______
Describe Substrate:

Barrel Retrofit (weirs/baffles): ☐ yes ☐ no
Type: ☐ steel ramp baffles ☐ Washington ☐ corner ☐ other:____________________________
Describe (number, placement, materials):
Outlet Beam: ☐ yes ☐ no Notched: ☐ yes ☐ no

Breaks-in-Slope: ☐ yes ☐ no Number:

Fill Volume: L_u (ft):_____ S_u (%):_____ W_r (ft): _____ L_d (ft): _____ S_d (%):_____ L_f (ft):_____
W_c (use average channel width) (ft):

Longitudinal Surveyed Elevations					Station Description and Water Depth (**Bold** = required)	**Tailwater Cross Section** (optional)					
Station (ft)	BS (+)	HI (ft)	FS (-)	Elevation (ft)		Station (ft)	BS (+)	HI (ft)	FS (-)	Elevation (ft)	Notes
					TBM:						
					TW Control of 1st resting habitat u/s of inlet						
					Inlet Apron/Riprap						
					Inlet Depth=						
					Outlet Depth=						
					Outlet Apron/Riprap						
					Max. Depth within 5' of outlet=						
					Max. Pool Depth						
					TW Control Depth=						
					Active Channel Stage						
					Downstream Channel Slope (%)	**Substrate at X-Section**:					
Additional Surveyed Elevations (including Breaks-in-Slope)						**Suspected Passage Assessment** Adults: 9 100% barrier 9 partial barrier 9 no barrier Juveniles: 9 100% barrier 9 partial barrier 9 no barrier					
						Culvert Slope:_____%					

Qualitative habitat comments

PASSAGE ANALYSIS

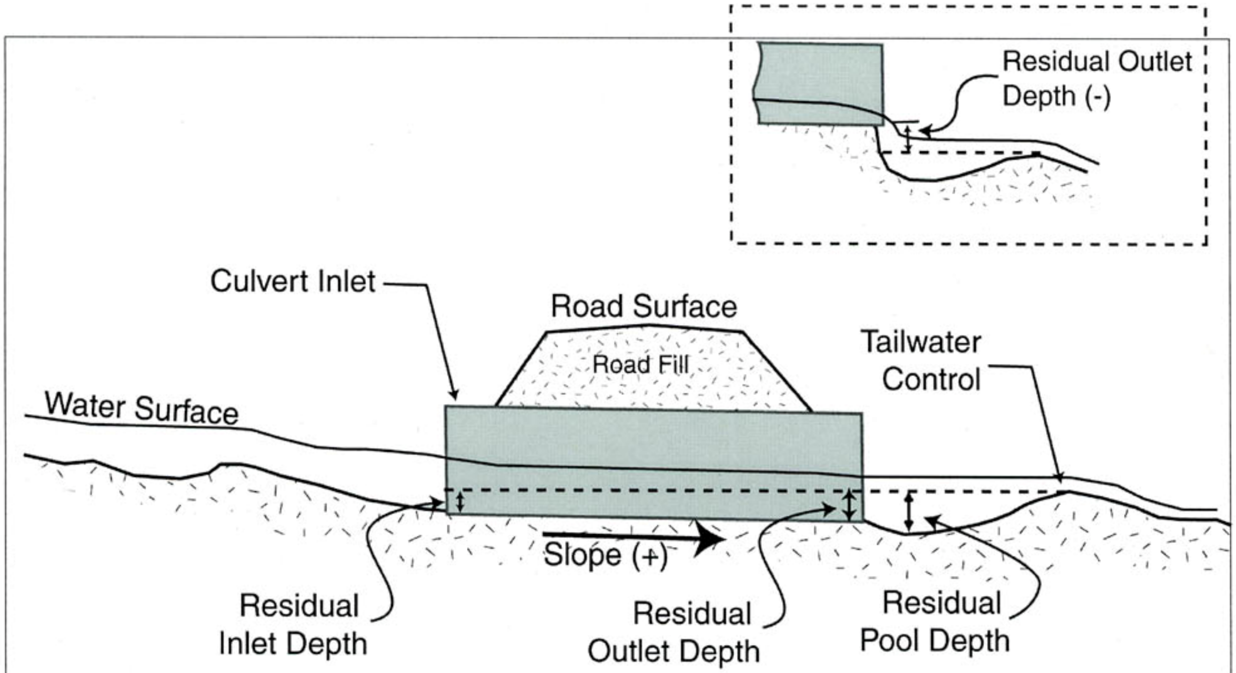
Enter data from the *Fish Passage Inventory Data Sheet* into a database or spreadsheet. From this, various calculations can be completed.

Passage Evaluation Filter: GREEN-GRAY-RED

A filtering process can be used to assist in identifying sites which either provide, or fail to provide, fish passage for all fish species and their life stages. From the *Fish Passage Inventory Data Sheet*, calculate average active channel width, culvert slope, residual inlet depth, and residual depth at the outlet (Figure IX-16). The passage evaluation filter (Figure IX-17) is used to reduce the number of crossings which require in-depth passage evaluation using *FishXing*. The filter classifies crossings into one of three categories:

- **GREEN**: Condition assumed adequate for passage of all salmonid life stages or throughout all salmonid life stages.
- **GRAT** Condition may not be adequate for all salmonid species at all their life stages. *FishXing* is used to determine the extent of barriers for each salmonid life stage.
- **RED**: Condition fail to meet DFG passage criteria (DFG 2002, Appendix IX-A) at all flows for strongest swimming species presumed present. Analysis of habitat quantity and quality upstream of the barrier is necessary to assess the priority of this crossing for treatment.

Some stream crossings have characteristics which may hinder fish passage, yet they are not recognized in the filtering process, such as breaks in-slope, inlet and outlet aprons, crushed inlets, or damage to the crossing invert. For crossings meeting the GREEN criteria, a review of the inventory data and field notes is necessary to ensure no unique passage problems exist before classifying the stream crossings as "passable".



Residual Pool Depth = $(\text{Elev}_{\text{Tailwater Control}} - \text{Elev}_{\text{Pool Bottom}})$

Residual Outlet Depth = $(\text{Elev}_{\text{Tailwater Control}} - \text{Elev}_{\text{Culvert Outlet}})$ (If Residual Outlet Depth is less than zero it is referred to as the Residual Outlet Drop)

Residual Inlet Depth = $(\text{Elev}_{\text{Tailwater Control}} - \text{Elev}_{\text{Culvert Inlet}})$

Figure IX- 16. Measurements used in filtering criteria.

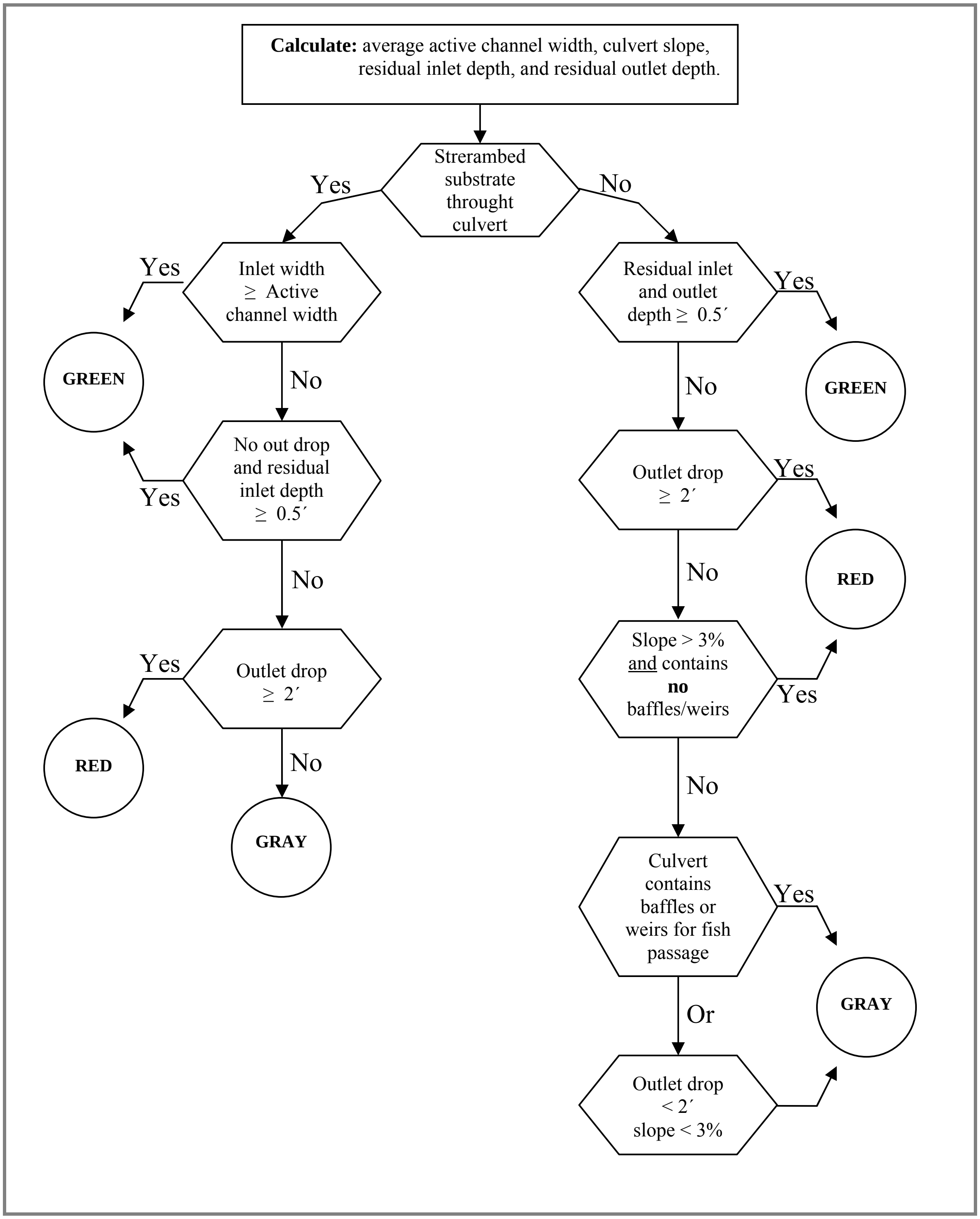


Figure IX- 17. GREEN-GRAY-RED first-phase passage evaluation filter.

HYDROLOGY AND FLOW REQUIREMENTS

When examining stream crossings for fish passage, three specific flows are considered: the peak flow capacity of the crossing, and the upper and lower fish passage flows. Peak flow capacity defines the ability of a crossing to accommodate a one-hundred year flow event, while fish passage flows define the upper and lower migration flows at the crossing. Fish passage flows will vary by species and lifestage so a complete analysis of a culvert often involves deriving several pairs of these high and low fish flows.

Because flow is not gaged on most small streams, it must be estimated using techniques that often require hydrologic information about the stream crossing's contributing watershed. Information needed includes:

- Drainage area
- Mean annual precipitation
- Average basin elevation

Most of this information can be obtained from USGS topographic maps, precipitation records, and water resources publications by various agencies.

Flow Capacity

Determination of peak flow capacity at a crossing can assist in prioritizing sites for treatment. Undersized crossings have a higher risk of catastrophic failure, which often results in the immediate delivery of sediment from the road fill to the downstream channel. Undersized crossings can also adversely affect sediment transport and downstream channel stability through frequent ponding of water upstream of the crossing and excessive scour of the downstream channel bed. This often leads to conditions that hinder fish passage and degrade habitat, such as upstream sediment deposition, perched crossing outlets, and downstream bank erosion.

Estimate the flow capacity of the stream crossing. Capacity is generally a function of the shape and cross-sectional area of the inlet. Additionally, the flow capacity increases as water ponds and the headwater depth increases. For existing stream crossings, determine the flow capacity at a headwater depth equal to the height of the culvert (Figure IX-5). This is commonly referred to as a headwater-to-diameter ratio equal to one (HW/D = 1).

Several methods are available for determining flow capacity of culverts, depending on the culvert shape and the level of accuracy required. Tables IX-2 through IX-4 offer flow capacity estimates at HW/D = 1 for standard metal circular, metal pipe-arch, and concrete box culverts. These values assume an unimpeded stream flow through the crossing with no reduction in velocity from outlet controls. Flow capacity for other types of stream crossings can be estimated using nomographs presented in the *Hydraulic Design of Highway Culverts* manual by the US Federal Highways Administration (Normann et al. 1985), available on-line at **http://www.fhwa.dot.gov.**

Diameter (inches)	Area (ft^2)	Flow Capacity[1]		
		Projecting (cfs)	Mitered (cfs)	Headwall (cfs)
24	3.1	11	12	14
30	4.9	20	22	24
36	7.1	31	34	38
42	9.6	46	51	55
48	12.6	64	71	77
54	15.9	86	95	104
60	19.6	112	123	135
66	23.8	142	157	171
72	28.3	177	195	213
78	33.2	216	238	260
84	38.5	260	286	313
90	44.2	309	340	372
96	50.3	363	400	437
102	56.7	422	465	509
108	63.6	487	536	587
114	70.9	557	614	672
120	78.5	634	698	763
132	95	804	886	969
144	113	1,000	1,101	1,204

[1] Flow capacity using equations presented in (Piehl et al. 1998).

Table IX- 2. Flow capacity for circular metal culverts at a HW/D=1.

Span IX Rise (feet - inches)	Area (ft^2)	Flow Capacity[1]		
		Projecting (cfs)	Mitered (cfs)	Headwall (cfs)
3-0 IX 1-10	41.3	16	17	18
3-7 IX 2-3	6.4	26	28	29
4-2 IX 2-7	8.5	37	40	42
4-10 IX 3-0	11.4	55	59	61
5-5 IX 3-4	14.2	70	77	79
6-0 IX 3-8	17.3	90	98	100
6-1 IX 4-7	22	130	138	142
7-0 IX 5-1	28	170	182	190
8-2 IX 5-9	38	240	258	270
9-6 IX 6-5	48	330	350	370
11-5 IX 7-3	63	470	520	550
12-10 IX 8-4	58	650	720	800
15-4 IX 9-3	107	920	980	1,020

1. Flow capacity estimated from Chart 34 in *Hydraulic Desgn of Highway Culverts* (Normann et al. 1985).

Table IX- 3. Flow capacity for metal pipe-arch culverts at a HW/D = 1.

Box Height (ft^2)	Flow Capacity[1]	
	Headwall (cfs/ft)	Wingwall (cfs/ft)
2	7.2	8.2
3	13	15
4	20	23
5	29	33
6	38	44
7	48	55
8	59	68
3	70	80
10	81	93
11	93	107
12	108	123

1. Flow capacity estimated from Chart 34 in *Hydraulic Design of Highway Culverts* (Normann et al. 1985).

Table IX- 4. Flow capacity for concrete box culverts at a HW/D = 1.
To calculate flow capacity, multiply value in the table by the culvert width.

Estimate the peak flows at each crossing. Peak flows are often reported in terms of a recurrence interval. The recurrence interval defines the average length of time between occurrences of a specific peak flow. For example, a 100-year peak flow has a 1% chance of occurring in any given year and occurs, on average, once in 100-years.

Current guidelines recommend all stream crossings pass the flow associated with the 100-year flood without causing structural damage (DFG 2002; NMFS 2001). Because of the high potential for debris clogging, infrequently maintained culvert crossings should accommodate the 100-year flood without overtopping the culverts inlet. The ranking analysis requires estimating the 5-year, 10-year, 25-year, 50-year, and 100-year peak flows. Three methods are commonly employed:

1. regional flood estimation equations for various recurrence intervals
2. the rational method
3. and estimates using local stream gaging data

Flood estimators have been developed for regions throughout California by the United States Geological Survey (USGS), the US Forest Service, California Department of Water Resources, and many county and city planning agencies. In some cases flood, estimations have a high degree of error, as much as a 40% to 50% mean standard error of estimate. These equations typically require general hydrologic information pertaining to the watershed, such as drainage area and mean annual precipitation.

Figure IX-18 contains the flood estimation equations developed by the USGS for regions throughout California. To determine if newer or more reliable flood estimation equations have been developed for a region, consult with local road managers and water resources professionals.

Compare the stream crossing's flow capacity to peak flow estimates. To assess the risk of failure, compare the stream crossing's flow capacity with the estimated peak flow for each recurrence interval. Then place each crossing into one of six categories:

- flow capacity equal to or greater than the 100-year flow
- between the 50-year and 100-year flows
- between the 25-year and 50-year flows
- between the 10-year and 25-year flows
- between the 5-year and 10-year flows
- or less than the 5-year flow

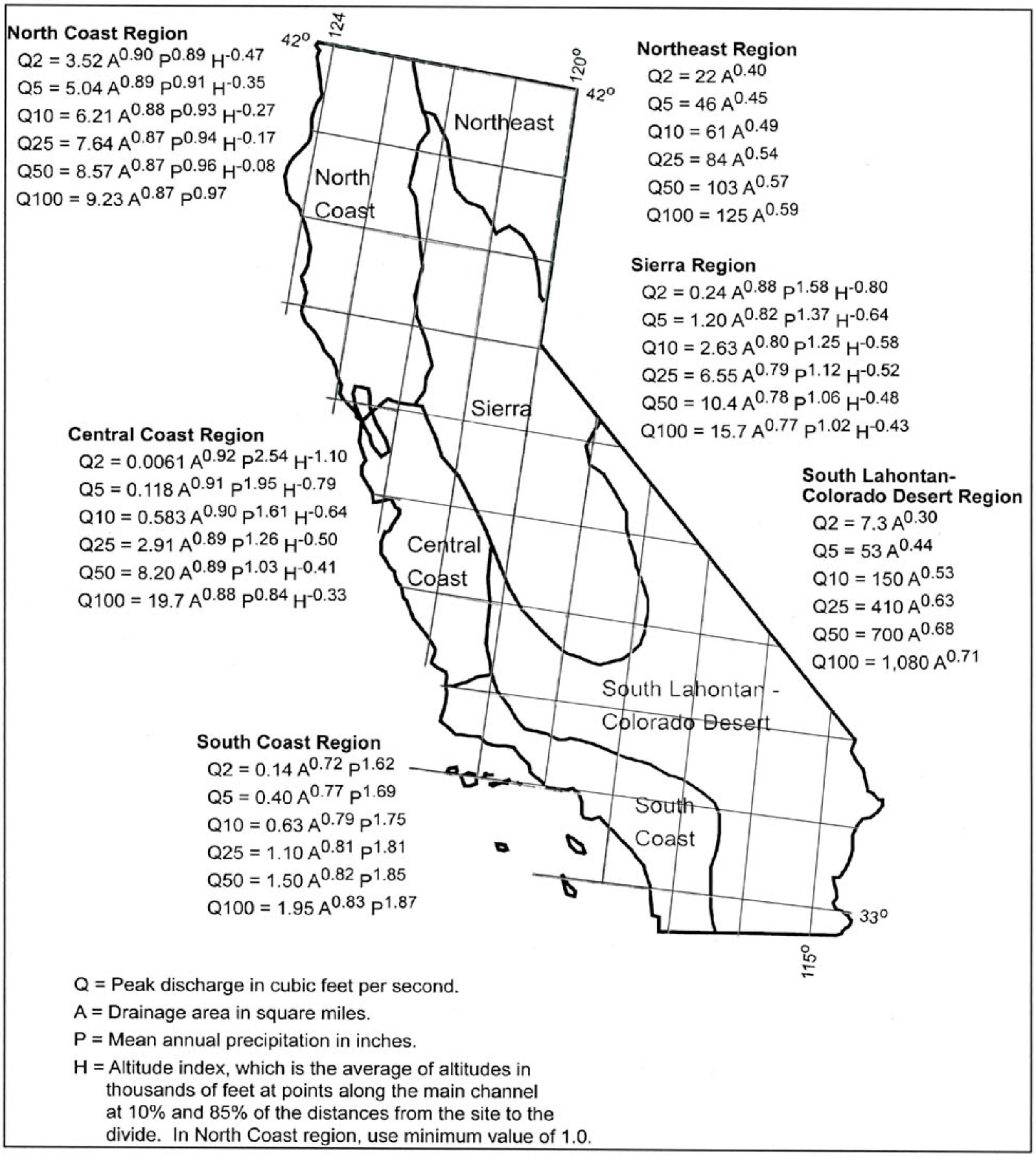


Figure IX- 18. California regional regression equation for estimating peak flows associated with a 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year recurrence interval (Waananen and Crippen 1977).

Fish Passage Flows

Although adult anadromous salmonids typically migrate upstream during higher flows triggered by hydrologic events, it is presumed that migration is naturally delayed during extreme large flood events. Conversely, during low flow periods water depths within the channel can become impassable for adult and/or juvenile salmonids (Figure IX-19). It is widely agreed that designing stream crossings to pass fish at high flood flows is impractical (Robison et al. 2000; SSHEAR, 1998). To identify the range of flows that stream crossings should accommodate for fish passage, lower and upper flow limits have been defined specifically for streams within California (Table IX-5, DFG 2002).

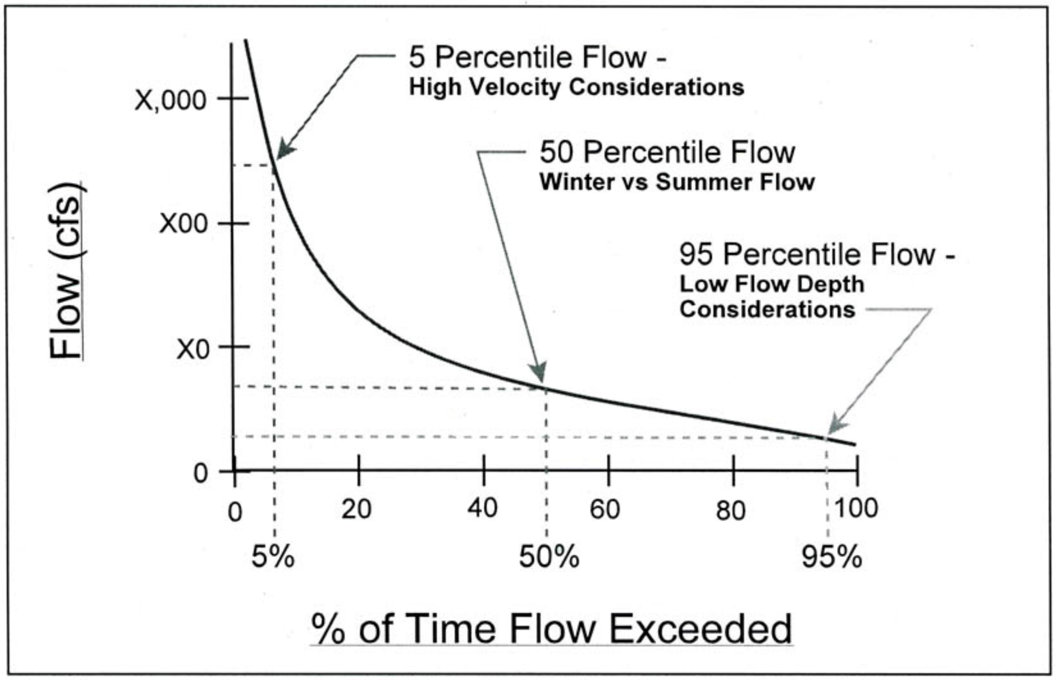


Figure IX- 19. Example of a flow duration curve.

The upper fish passage flow limit for adult anadromous salmonids (Q_{hp}) is defined as the 1% exceedance flow (the flow equaled or exceeded 1% of the time) during an average year. For all adult salmonids, the lower fish passage flow (Q_{lp}) equals the 50% exceedance flow. Table IX-5 lists the upper and lower passage flows for all species and life stages. Between the lower and upper passage flows stream crossings should allow unimpeded passage.

Fish passage flows are required for assessing passage at the GRAY stream crossings. To evaluate the extent to which a crossing is a barrier to fish, passage is assessed between the lower and upper passage flows for each fish species and lifestage of concern.

Species/Lifestage	Upper Passage Flow	Lower Passage Flow	
	Exceedance Flow	Exceedance Flow	Alternate Minimum Flow (cfs)
Adult Anadromous Salmonids	1%	50%	3
Adult Non-Anadromous Salmonids	5%	90%	2
Juvenile Salmonids	10%	95%	1
Native Non-Salmonids	5%	90%	1
Non-Native Species	10%	90%	1

Table IX- 5. Upper and lower fish passage flows for stream crossings (DFG 2002).

Identifying exceedance flows requires obtaining average daily stream flow data from nearby gaged basins. Most stream gages are operated by the USGS and the California Department of Water Resources, with much of the data available on-line. Use the following steps to estimate the needed upper and lower passage flows (see Appendix IX-C for a sample calculation):

1. Obtain flow records from local stream gages that meet the following requirements:
   a) At least 5-years of recorded daily average flows, and preferably more than 10-years (do not need to be consecutive years).
   b) A drainage area less than 50 square miles, and preferably less than 10 square miles.
   c) Unregulated flows (no upstream impoundment or water diversions). If feasible, use several gaged streams to determine which ones have flow characteristics that best resemble stream flows observed throughout the project area.

Rank the flows from highest to lowest (a rank of i = 1 given to the highest flow). The lowest flow will have a rank of ***n***, which equals the total number of flows considered.

To identify the rank associated with a particular exceedance flow, such as the 50% and 1% exceedance flows ($i_{50\%}$ and $i_{1\%}$ respectively), use the following equations:

$$i_{50\%} = 0.50(n+1) \qquad i_{1\%} = 0.01(n+1)$$

Round to the nearest whole number, the flows corresponding to those ranks are the 50% and 1% exceedance flows for the gaged stream.

To apply these flows to the ungaged stream, multiply the flows obtained in above step, $Q_{50\%}$ and $Q_{1\%}$, by the ratio of the gauged stream's drainage area (*DA*) to the drainage area of the ungaged stream at the stream crossing. Multiplying by this ratio adjusts for the differences in drainage area between watersheds. Other methods for determining exceedance flows for ungaged streams can also be used. These methods typically take into account differences in precipitation between watersheds.

In *FishXing* analysis, these flows will be used to determine the extent to which the crossing is a barrier. The stream crossing must meet water velocity and depth criteria between Q_{lp} and Q_{hp} to be considered 100% passable.

When flows from several different gaging stations are available, use knowledge of the local hydrology and rainfall patterns to decide which one offers the best estimate. For inventory and assessment purposes, the method described above is often sufficient. More detailed or accurate flow measurement techniques may be necessary in the design of new or replacement stream crossings.

FishXing Analysis

The subset of stream crossings identified as GRAY will require additional analysis to determine the extent to which they are barriers. At these stream crossings, water depths, velocities and outlet conditions should be calculated between the lower and upper passage flows to ascertain whether fish passage requirements are being met. Fish passage conditions can be analyzed using *FishXing*, a computer software program developed by the Six Rivers National Forest Watershed Interactions Team (USDA Forest Service, 1999). *FishXing* models culvert hydraulics (including open-bottom structures) and compares the predicted values with data regarding swimming and leaping abilities and minimum water depth requirements for numerous fish species. *FishXing* is available on-line at: **http://www.stream.fs.fed.us/fishxing/**.

FishXing inputs are divided into two categories:

1. Swimming capabilities and requirements for the fish species of concern
2. Site-specific information about the stream crossing

The following are general instructions for using *FishXing* to analyze passage conditions at a stream crossing. For detailed instructions and background information about using the software, consult the “Help Files” contained within *FishXing* and available from the home-page in a user manual format.

Fisheries Inputs

For each stream crossing that was placed in the GRAY category, conduct a separate passage analysis for all salmonids and their life stages. At many sites this may include different life stages of anadromous salmonids and resident trout. For each lifestage, a prolonged and burst swim speeds must be entered into the software. Prolonged swim speeds can be sustained for extended periods of time, ranging from one to sixty minutes. Fish often swim in this mode when passing through the barrel of a culvert. Burst swim speeds are higher than prolonged but can only be sustained for a few seconds. Fish swim in burst mode when faced with challenging situations, such as the inlet and outlet regions of a typical culvert. Table IX-6 lists swimming and leaping speeds along with corresponding endurance times for several salmonid life stages.

Species or Lifestage	Minimum Water Depth	Prolonged Swimming Mode		Burst Swimming Mode		
		Maximum Swim Speed	Time to Exhaustion	Maximum Swim Speed	Time to Exhaustion	Maximum Leap Speed
Adult anadromous salmonids	0.8 feet	6.0 ft/sec	4.0 ft/sec	10.0 ft/sec	5.0 ft/sec	3.0 ft/sec
Resident trout and juvenile steelhead >6"	0.5 feet	30 minutes	30 minutes	5.0 sec	5.0 sec	5.0 sec
Juvenile salmonids <6"	0.3 feet	1.5 ft/sec	30 minutes	15 ft/sec	6 ft/sec	4 ft/sec

Table IX- 6. Minimum water depth requirements and swimming and leaping ability inputs for *FishXing* (These values are used to assist in prioritizing stream crossing for treatment and do not represent whether or not a stream crossing currently meets DFG or NMFS passage criteria).

FishXing and other hydraulic models report the average cross-sectional water velocity, not accounting for spatial variations. Stream crossings with natural substrate or deep corrugations will have regions of reduced velocities that can be utilized by migrating fish (Figure IX-20). These areas are often too small for larger fish to use, but can enhance juvenile passage success. *FishXing* allows the use of reduction factors that decrease the calculated water velocities proportionally. Accounting for areas of reduced velocities may be appropriate for the analysis of juvenile passage through certain types of stream crossing structures. *FishXing* also requires a lower and upper fish passage flow. To calculate these flows refer to the previous “Hydrology and Flow Requirements” section.

Stream Crossing Inputs

During the site visit, all required stream crossing information will have been collected for the passage analysis. Input the appropriate stream crossing type, material and length, whether it’s embedded, corresponding roughness values, and the bottom elevations of the inlet and outlet.

Next, define the tailwater elevation with respect to the stream crossing outlet. The tailwater elevation often determines whether the culvert is a barrier. A high tailwater can backwater the culvert for easy passage. Too low of a tailwater elevation will leave the outlet perched above the downstream channel. There are three different methods to choose from, depending on the type of information collected during the field survey (Table IX-7).

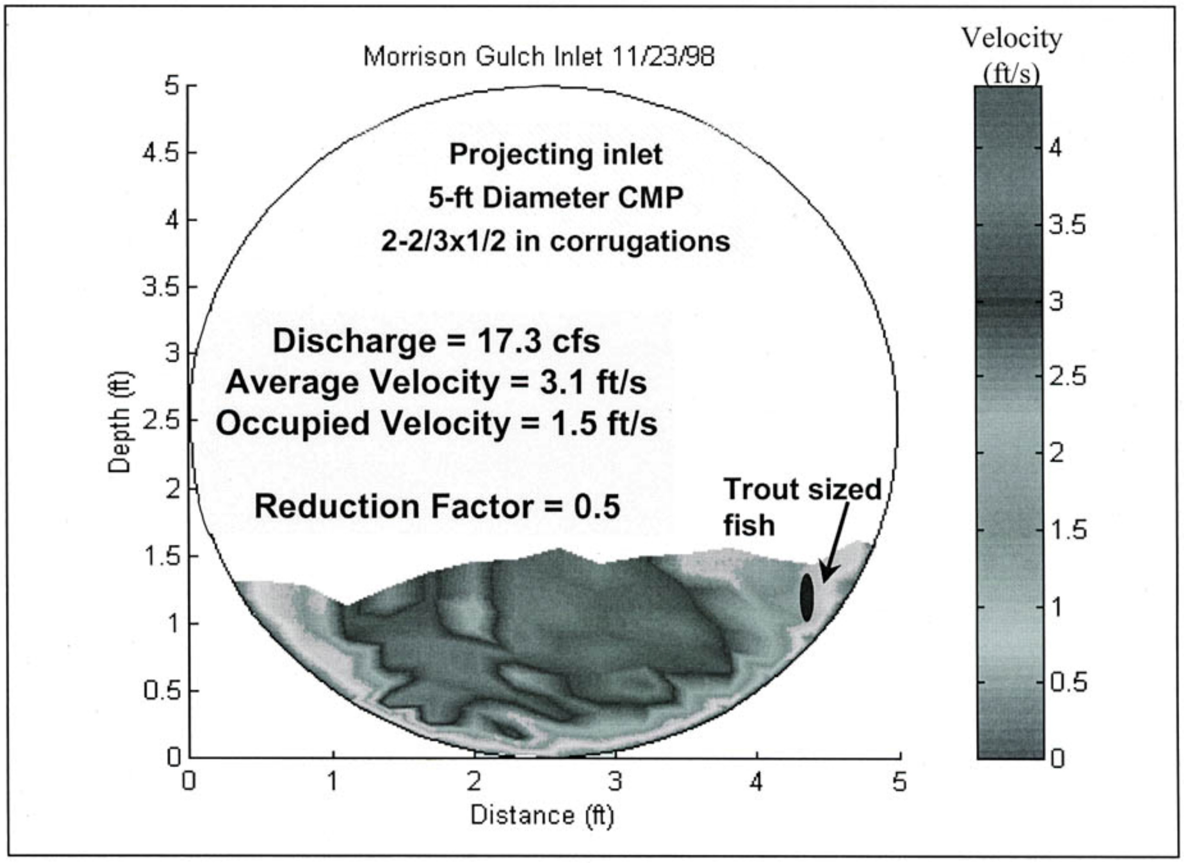


Figure IX- 20. Varying velocity measurements within a culvert on Quarry Road at Morrison Gulch, tributary to Jacoby Creek, Humboldt Bay watershed.

Method	Description	Advantages	Disadvantages
Constant Tailwater	Enter one tailwater elevation, often the height of the active channel margins at the tailwater control downstream of the culvert.	Requires least amount of data and may be adequate for first-cut assessments.	Does not accurately describe conditions at most sites.
Tailwater Rating Curve	Generates curve relating tailwater elevation to flow, requiring a minimum of two points. For the first point, set the flow equal to zero and enter the tailwater control elevation. The second point is approximated at the adult high passage flow using the surveyed elevation of active channel. A more accurate curve can be constructed by taking actual flow measurements.	Approximating the rating curve requires less data than Cross-sectional method, but is more accurate than Constant Tailwater method.	Requires making assumptions about tailwater elevation **or** taking direct measurements of stream flow.
Cross-sectional Analysis	Creates a tailwater-rating curve using a channel cross-section surveyed at the tailwater control, the downstream channel slope, and an estimate of channel roughness.	Creates a rating curve that adequately describes tailwater conditions.	Data intensive and requires estimate of channel roughness.

Table IX- 7. Alternative methods available in *FishXing* for defining tailwater elevation below a stream crossing.

Interpreting Results

Run *FishXing* at the lower, middle and upper passage flows. After running the model, use the "Water Surface Profile" (WSP) results to determine if the stream crossing is passable at the lower, middle, and upper flows. Use the "Barrier Code" to identify potential passage problems. The "Uniform Flow" results can be used to identify crossings with outlets perched too high for fish passage. Refer to the *FishXing* Help Files for additional information on interpreting results. Because "Uniform Flow" results do not account for backwatering nor depth and velocity changes at the inlet and outlet, these results should only be used to identify potential vertical barriers.

If results indicate desired conditions for passage do not exist at the lower or upper passage flow, use a trial-and-error approach (by changing input flows) to identify the flows that are passable, if any. Record these cut-off flows and note the passage requirement(s) that are not being met.

To assess the extent to which the crossing is a barrier to adult anadromous, resident, and juvenile salmonids compare the actual range of passable flows to the desired range (the upper and lower passage flows) and calculate the "percent passable". These values are utilized in the matrix for ranking sites for treatment. Additionally, on a site-by site basis, the identified range of passage flows can aid in developing treatment options.

Analysis of Retrofitted Stream Crossings

Evaluating passage conditions at crossings that have been retrofitted with baffles or weirs to increase water depths and decrease velocities is difficult and beyond the capabilities of FishXing. These sites require field monitoring during migration flows. Visit the site at several different flow conditions and observe the hydraulics within the crossing. Measure water depths between the baffles or weirs within the culvert and at the inlet and outlet. Water velocities can be estimated using a timed float. Also note if there appears to be insufficient resting areas behind baffles, excessive turbulence, debris clogging, or other conditions that may help or hinder passage of adult and juvenile fish. Based on these observations, for each fish species and lifestage present, estimate whether the crossing meets the passage criteria at migration flows. If the stream crossing provides adequate passage conditions for adults but not juveniles, then it would be considered 100% passable for adults and 0% passable for juveniles.

The observation of fish upstream does not necessarily indicate the stream crossing meets desired fish passage criteria. The crossing may remain a barrier at most flows or to most life stages, allowing passage for only a limited number of fish. Salmonids observed above a suspected barrier may also be resident fish.

FISH HABITAT INFORMATION

When ranking stream crossings for treatment, both quality and quantity of upstream habitat should be considered so that restoration funds are devoted to the greatest benefit of the fisheries resource. Following are fish habitat criteria to be considered.

Assessment of habitat conditions upstream and downstream of stream crossings can rely on previously conducted habitat typing or fisheries surveys. Communication with agency and private-sector biologists, watershed groups, coordinators, restorationists, and large landowners may assist in acquiring additional information on watershed assessment and evaluation. Historical information is often available in reports on file at DFG offices; check with the local DFG biologists or watershed planners for assistance in obtaining recent habitat information. If the road system intersects streams lacking recent habitat inventory information, field reconnaissance may be utilized to quantify habitat quality and quantity.

To estimate length of potential salmonid habitat upstream of each stream crossing use:

- Completed Stream Inventory Reports (see Part III)
- Conduct a stream inventory as a part of the fish passage inventory
- Use USGS 7.5 Minute Series topographic maps to define the upper limit of anadromous habitat when the channel exceeds a sustained eight to ten percent slope for approximately 1,000 feet. Upper limits of resident fish habitat may include channel reaches with slopes up to 20 percent. Consult with the local DFG biologist for additional guidance. This method should be considered a rough estimate. If possible verify results in the field.

RANKING OF STREAM CROSSINGS FOR TREATMENT

The primary objective of the ranking is to arrange stream crossings classified as GRAY and RED in order from high to low priority, using fish habitat information as the primary criteria. This should be done using site-specific information weighted heavily towards the biological and physical habitat considerations. The rankings generated are categorical and not intended to be absolute in deciding the exact order of scheduling remediations. Professional judgement plays an important part in deciding the order of treatment. As noted by Robison et al. (2000) numerous social and economic factors influence the exact order of sites to be treated, as well as treatment options considered.

Ranking Criteria

The ranking method assigns scores or values for the following five parameters at each GREEN, GRAY and RED stream crossing location:

1. *Species Diversity* - Number of salmonid species currently present (or historically present which could be restored) within the stream reach at each crossing location.

   Score: For each Federally or State listed salmonid species; Endangered = **4** points; Threatened or Candidate = **2** points; not listed = **1** point. Consult DFG or NMFS for historic species distribution and listing status information.

Extent of Barrier - Over the range of estimated migration flows, assign one of the following values from the "percent passable" results generated with *FishXing*. GREEN crossings are considered 100% passable for all fish, while RED crossings are considered 0% passable for all fish. Do this for adult anadromous, resident, and juvenile salmonids for each culvert.

   Score: 0 = 80% or greater passable; **1** = 79-60% passable; **2** = 59-40% passable; **3** = 39-20% passable; **4** = 19% or less passable; **5** = 0% passable (RED). For a total score, sum the values for all three.

Habitat Value - Multiply habitat quantity score by habitat quality score.

a) Habitat Quantity - Above each crossing, length in feet to a sustained 8% gradient or field-identified limit of anadromy.

   Score: 0.5 points for each 500 feet of stream (example: **0.5** points for <500N; **1** point for 1,000N; **2** points for 2,000N; and **5.5** points for 5,500N). The maximum possible score for *Habitat Quantity* is **10**.

b) Habitat Quality - For each stream, assign a score of quality after reviewing available habitat information. Consultation with local DFG biologists to assist in assigning habitat quality score is recommended.

   Score:
   - ***1.0*** *= Excellent* - Relatively undeveloped, with pristine watershed conditions. Habitat features include dense riparian zones with mix of mature native species, frequent pools, high-quality spawning areas, cool summer water temperatures, complex instream habitat, floodplain relatively intact.
   - ***0.75*** *= Good* - Habitat is mostly intact but erosional processes or other factors have altered the watershed with a likelihood of continued occurrence. Habitat includes dense riparian zones of native species, frequent pools, spawning gravels, cool summer water temperatures, complex instream habitat, floodplain relatively intact.
   - ***0.5*** *= Fair* - Erosional processes or other factors have altered the watershed with negative affects on watershed processes and features, with the likelihood of continued occurrence. Indicators include:
     a) riparian zone lacking mature conifers
     b) infrequent pools
     c) sedimentation evident in spawning areas (embeddedness ratings of 3)
     d) summer water temperatures periodically exceed stressful levels for salmonids
     e) sparse instream complex habitat, and floodplain intact or slightly modified
   - ***0.25*** *= Poor* - Erosional processes or other factors have significantly altered the watershed. There is a high likelihood of increased erosion and apparent effects to watershed processes. Habitat impacts include riparian zones absent or severely degraded, little or no pool habitat, excessive sedimentation evident in spawning areas (embeddedness ratings of 4), stressful to lethal summer water temperatures common, lack of instream habitat, floodplain severely modified with levees, riprap, and/or residential or commercial development.

Sizing (risk of failure) - For each crossing, assign one of the following values as related to flow capacity.

Score: 0 = sized for at least a 100-year flow, low risk; **1** = sized for at least a 50-year flow, low/moderate risk; **2** = sized for at least a 25-year flow, moderate risk of failure; **3** = sized for at least a 10-year flow, moderate/high risk of failure; **4** = sized for less than a 10-year flow, high risk of failure; **5** = sized for less than a 5-year flow, extreme risk of failure.

Current Condition - For each crossing, assign one of the following values.

Score: 0 = good condition; **1** = fair, showing signs of wear; **3** = poor, floor rusting through, crushed by roadbase, etc.; **5** = extremely poor, floor rotted-out, severely crushed, damaged inlets, collapsing wingwalls, slumping roadbase, etc.

For each stream crossing, enter criteria values into a spreadsheet, sum the five ranking criteria values, and compute the total scores. Then sort the list of crossings by total scores to determine a first-cut ranking for the project area.

Additional Ranking Considerations

The results of the ranking matrix provide a rough, first-cut evaluation of GRAY and RED stream crossings. There are other important factors that should be considered when deciding the exact scheduling of remediation efforts.

The following list provides guidance that should assist in rearranging the first-cut ranking. On a site-specific basis, some or all of these factors should be considered:

- *Presence or absence of other stream crossings* - In many cases, a single stream may be crossed by multiple roads. If migration barriers exist at multiple stream crossings, a coordinated effort is required to identify and treat them in a logical manner, generally in an upstream direction starting with the lowest crossing in the stream.
- *Fish observations at crossings* - Sites where fish are observed holding during migration periods should receive high consideration for remediation. Identify the species present, count the number of fish, and record failed versus successful passage attempts. Consider the potential for predation and/or poaching. Sites with holding fish are areas where immediate recolonization of upstream habitat is likely to occur.
- *Amount of road fill* - At stream crossings that are undersized and/or in poor condition, consider the volume of fill material within the road prism. This is material which is directly deliverable to the stream channel if the crossing were to fail. Also determine if there is a potential for water to divert down the road if the crossings capacity is overwhelmed (refer to Part X).
- *Remediation project cost* - The range of treatment options and associated costs must be examined when determining the order in which to proceed. In cases where Federal or State listed fish species are present, costs must be weighed against the consequences of not providing unimpeded passage.
- *Opportunity* - Road managers should consider upgrading all migration barriers during road maintenance activities. The ongoing costs of maintaining an undersized or improperly installed culvert may exceed the cost of replacing it with a properly sized and installed crossing. When undersized or older crossings fail during storms, road managers should be prepared to install properly-sized crossings that provide unimpeded passage for all species and life stages of fish.

PREFERRED TREATMENT OPTIONS FOR UNIMPEDED FISH PASSAGE

The following general guidance draws from design standards currently employed in Oregon and Washington, and are consistent with current guidelines for stream crossings in California. However, site-specific characteristics of the stream crossing location should always be carefully reviewed prior to selecting the type of crossing to install. These characteristics include local geology, slope of natural channel, channel confinement, and extent of channel incision likely to occur from removal of a perched culvert. Providing unimpeded passage for the salmonid species of concern will often dictate the design of a culvert upgrade or replacement. Bates et al. (1999) is a reference for stream crossing installation options. Robison et al. (2000) provides a comprehensive review of the advantages and disadvantages of various treatment alternatives based on channel slope and confinement.

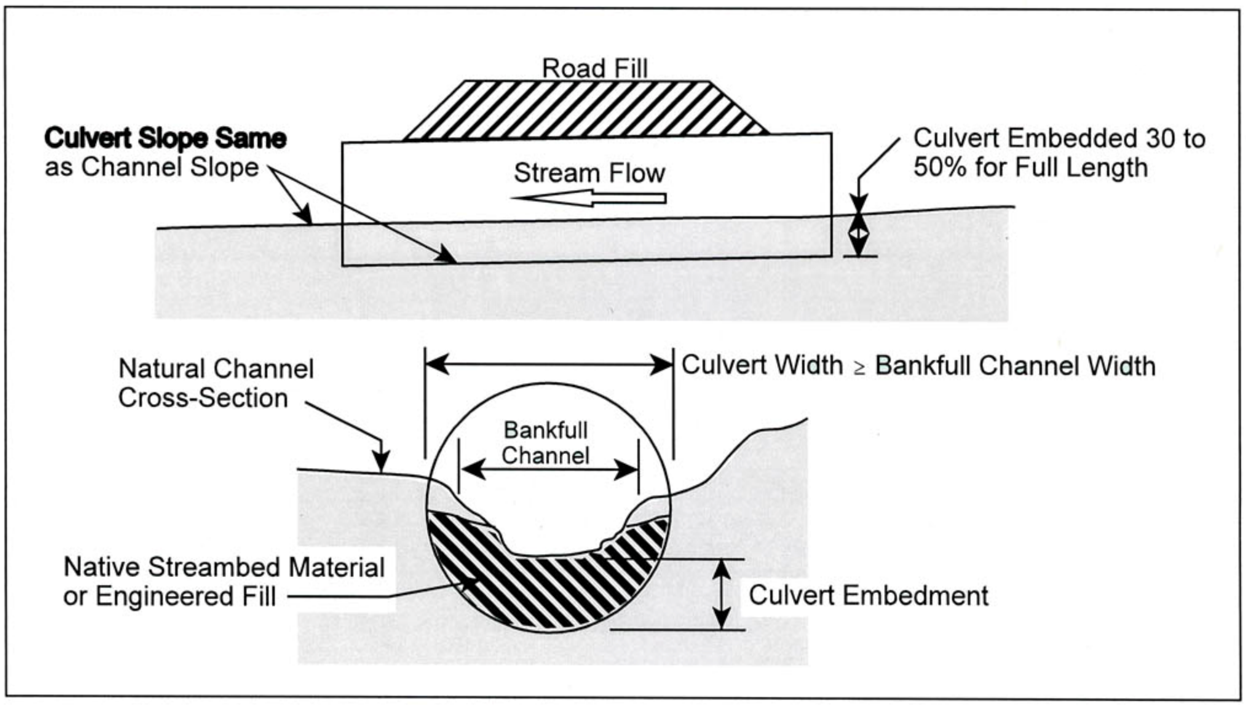


Figure IX- 21. Stream simulation strategy option.

NMFS *Guidelines for Salmonid Passage at Stream Crossings* (NMFS 2001) lists the following recommendations for new or replacement crossings, in order of preference. For additional information obtain the NMFS Guidelines at **http://swr.nmfs.noaa.gov/hcd/NMFSSCG.PDF.**

1. Nothing - Road realignment to avoid crossing the stream.
2. Bridge - Spanning the stream to allow for long term dynamic channel stability.
3. Streambed simulation strategies - Bottomless arch, embedded culvert design, or ford (Figure IX-21).
4. *Non-embedded culvert* - This is often referred to as hydraulic design, associated with more traditional culvert design approaches and is limited to low slopes for fish passage.
5. *Baffled culvert or structure designed with a fishway* - For steeper slopes.

STREAM CROSSING REMEDIATION PROJECT CHECKLIST

The following list briefly describes the general phases of a stream crossing remediation project, factors to consider at each site, and permits required:

1. Project budget - Once a treatment option is selected, develop a detailed project budget, including:
   a) Engineering design
   b) Project management
   c) Permit application preparation and fees
   d) CEQA compliance - including required botanical, wildlife, fisheries, and archeological surveys
   e) Construction labor - In-house or subcontracted
   f) Heavy equipment - In-house, subcontracted, or rented
   g) Materials and delivery to site
   h) Traffic bypass
   i) Water management plan
   j) Fish relocation from project site
   k) Construction-phase quality control monitoring
   l) Revegetation
   m) Paving and re-striping of roadway
   n) Post-project monitoring

Project Design - Designs consistent with current DFG (APPENDIX IX-A) and NMFS (Appendix IX-B) guidelines.

Project Permits - The permit application process should be initiated as soon as possible. Accurately provide all information required on permits, contact appropriate agency for applications and questions regarding permit information. The following are the minimum required agencies' permits and contact information:

   o) DFG - Lake and Streambed Alteration Agreement (Fish and Game Code § 1600 *et seq.*). Available on DFG website: **www.dfg.ca.gov/1600**
   p) US Army Corp of Engineers (USACOE) Section 404 Permit - Check USACOE Homepage at: **www.usace.army.mil** or if within San Francisco District check: **www.spn.usace.army.mil/regulatory/**
   q) NMFS reviews applications submitted to USACOE - For more information on permits, 4(d) rules and species distribution; check: **http://swr.nmfs.noaa.gov**
   r) California Regional Water Quality Control Board 401 Permit - Check homepage of State Water Resources Control Board to select link to appropriate regional water quality control board: **www.swrcb.ca.gov**.

GUIDANCE TO MINIMIZE IMPACTS DURING STREAM CROSSING CONSTRUCTION

Project planners should incorporate appropriate measures to minimize impacts during stream crossing construction. Listed are some general measures to minimize impacts from instream construction, degradation of water quality, loss or disturbance of riparian vegetation, impacts to aquatic habitat and species during de-watering, and injury and mortality of fish and amphibian species during de-watering. Local conditions and more specific conditions may require additional protective measures be implemented.

Measures to Minimize Disturbance From Instream Construction

- Construction should generally occur during the lowest flow period of the year.
- Construction should occur during the dry period if the channel is seasonally dry.
- Prevent any construction debris from falling into the stream channel. Any material that does fall into a stream during construction should be immediately removed in a manner that has minimal impact to the streambed and water quality.
- Where feasible, the construction should occur from the bank, or on a temporary pad underlain with filter fabric.
- Temporary fill must be removed in its entirety prior to close of work-window.
- Areas for fuel storage, refueling, and servicing of construction equipment must be located in an upland location.
- Prior to use, clean all equipment to remove external oil, grease, dirt, or mud. Wash sites must be located in upland locations so that dirty wash water does not flow into stream channel or wetlands.
- All construction equipment must be in good working condition, showing no signs of fuel or oil leaks.
- Petroleum products, fresh cement, or deleterious materials must not enter the stream channel.
- Operators must have spill clean-up supplies on site and be knowledgeable in their proper use and deployment.
- In the event of a spill, operators must immediately cease work, start clean-up, and notify the appropriate authorities.

Measures to Minimize Degradation of Water Quality

- Isolate the construction area from flowing water until project materials are installed and erosion protection is in place.
- Erosion control measures shall be in place at all times during construction. Do not start construction until all temporary control devices (straw bales, silt fences, etc.) are in place downslope or downstream of project site.
- Maintain a supply of erosion control materials onsite, to facilitate a quick response to unanticipated storm events or emergencies.

- Use erosion controls to protect and stabilize stockpiles and exposed soils to prevent movement of materials. Use devices such as plastic sheeting held down with rocks or sandbags over stockpiles, silt fences, or berms of hay bales to minimize movement of exposed or stockpiled soils.
- Stockpile excavated material in areas where it cannot enter the stream channel. Prior to start of construction, determine if such sites are available at or near the project location. If unavailable, determine location where material will be deposited. If feasible, conserve topsoil for reuse at project location or use in other areas.
- Minimize temporary stockpiling of excavated material.
- When needed, utilize instream grade control structures to control channel scour, sediment routing, and headwall cutting.
- Immediately after project completion and before close of seasonal work-window, stabilize all exposed soil with mulch, seeding, and/or placement of erosion control blankets.

Measures to Minimize Loss or Disturbance of Riparian Vegetation

- Prior to construction, determine locations and equipment access points that minimize riparian disturbance. Avoid affecting less stable areas.
- Retain as much understory brush and as many trees as feasible, emphasizing shade producing and bank stabilizing vegetation.
- Minimize soil compaction by using equipment with a greater reach or that exerts less pressure per square inch on the ground, resulting in less overall area disturbed or less compaction of disturbed areas.
- If riparian vegetation is to be removed with chainsaws, consider using saws currently available that operate with vegetable-based bar oil.
- Decompact disturbed soils at project completion as the heavy equipment exits the construction area.
- Revegetate disturbed and decompacted areas, with native species specific to the project location that comprise a diverse community of woody and herbaceous species.

Measures to Minimize Impacts to Aquatic Habitat and Species During Dewatering of Project Site

When construction work must occur within a year-round flowing channel, the work site must be dewatered. Dewatering can result in the temporary loss of aquatic habitat, and the stranding, displacement, or crushing of fish and amphibian species. Increased turbidity may occur from disturbance of the channel bed. Following these general guidelines will minimize impacts.

- Prior to dewatering, determine the best means to bypass flow through the work area to minimize disturbance to the channel and avoid direct mortality of fish and other aquatic vertebrates.
- Coordinate project site dewatering with a fisheries biologist qualified to perform fish and amphibian relocation activities.
- Minimize the length of the dewatered stream channel and duration of dewatering.

- Bypass stream flow around work area, but maintain streamflow to channel below construction site.
- The work area must often be periodically pumped dry of seepage. Place pumps in flat areas, well away from the stream channel. Secure pumps by tying off to a tree or stake in place to prevent movement by vibration. Refuel in area well away from stream channel and place fuel absorbent mats under pump while refueling. Pump intakes should be covered with 1/8" mesh to prevent entrainment of fish or amphibians that failed to be removed. Check intake periodically for impingement of fish or amphibians.
- Discharge waste water from construction area to an upland location where it will not drain sediment-laden water back to stream channel.

Measures to Minimize Injury and Mortality of Fish and Amphibian Species During Dewatering

Prior to dewatering a construction site, fish and amphibian species should be captured and relocated to avoid direct mortality and minimize take. This is especially important if listed species are present within the project site. The following measures are consistent with those defined as *reasonable and prudent* by NMFS for projects concerning several northern California Evolutionary Significant Units for coho salmon, chinook salmon, and steelhead.

- Fish relocation activities must be performed only by qualified fisheries biologists, with a current DFG collectors permit, and experience with fish capture and handling. Check with your local DFG biologist for assistance.
- In regions of California with high summer air temperatures, perform relocation activities during morning periods.
- Periodically measure air and water temperatures. Cease activities when water temperatures exceed temperatures allowed by DFG and NMFS

Exclude fish from re-entering work area by blocking the stream channel above and below the work area with fine-meshed net or screens. Mesh should be no greater than 1/8 inch. It is vital to completely secure bottom edge of net or screen to channel bed to prevent fish from re-entering work area. Exclusion screening should be placed in areas of low water velocity to minimize impingement of fish. Screens should be checked periodically and cleaned of debris to permit free flow of water.

- Prior to capturing fish, determine the most appropriate release location(s). Consider the following when selecting release site(s):
  1. similar water temperature as capture location
  2. ample habitat for captured fish
  3. low likelihood of fish re-entering work site or becoming impinged on exclusion net or screen
- Determine the most efficient means for capturing fish. Complex stream habitat generally requires the use of electrofishing equipment, whereas in outlet pools, fish may be concentrated by pumping-down pool and then seining or dip-netting fish.
- Electrofishing should only be conducted by properly trained personnel following DFG and NMFS guidelines.

- Minimize handling of salmonids. However, when handling is necessary, always wet hands or nets prior to touching fish.
- Temporarily hold fish in cool, shaded, aerated water in a container with a lid. Provide aeration with a battery-powered external bubbler. Protect fish from jostling and noise and do not remove fish from this container until time of release.
- Place a thermometer in holding containers and, if necessary, periodically conduct partial water changes to maintain a stable water temperature. If water temperature reaches or exceeds those allowed by DFG and NMFS, fish should be released and rescue operations ceased.
- Avoid overcrowding in containers. Have at least two containers and segregate young-of-year (YOY) fish from larger age-classes to avoid predation. Place larger amphibians, such as Pacific giant salamanders, in container with larger fish.
- If fish are abundant, periodically cease capture, and release fish at pre-determined locations.
- Visually identify species and estimate year-classes of fish at time of release. Count and record the number of fish captured. Avoid anesthetizing or measuring fish.
- Submit reports of fish relocation activities to DFG and NMFS in a timely fashion.
- If feasible, plan on performing initial fish relocation efforts several days prior to the start of construction. This provides the fisheries biologist an opportunity to return to the work area and perform additional electrofishing passes immediately prior to construction. In many instances, additional fish will be captured that eluded the previous days efforts.
- If mortality during relocation exceeds 5%, stop efforts and immediately contact the appropriate agencies.

PROJECT MONITORING

The process of integrating watershed hydrology, modeling of hydraulic dynamics through culverts, and passage evaluation for fish migration is still developing. There is a vital need to monitor newly constructed stream crossings to ensure design standards are adequate for both flow conveyance and unimpeded fish passage.

Implementation Monitoring

Many stream crossings are being replaced specifically to permit unimpeded passage of fish. Implementation monitoring is required to ensure that design specifications of projects are being correctly implemented. Engineering firms who design the new stream crossings should have staff on-site during critical phases of construction. Quality control will ensure that design specifications are utilized and accurately measured. Additional monitoring is needed to ensure construction crews follow other project stipulations, such as the water management plan, erosion control plan, traffic bypass plan, emergency spill plan and riparian revegetation plan.

Project Monitoring

The following monitoring activities may be used to evaluate the effects of a newly constructed stream crossing:

- *Changes in channel longitudinal profile and cross section* - Conducting channel profiles and cross sections before and after stream crossing replacement should provide information on reducing or eliminating perched outlets, channel response at sites where upstream channel incision is possible, the formation and stability within embedded crossings and impacts on downstream channel stability.
- *Spawning surveys during periods of presumed activity* - Pre- and post-project data concerning fish species and redd distribution within the stream reach of interest, both upstream and downsteam of a stream crossing site, will allow an evaluation of changes in spawner distribution.
- *Direct observation of fish migration at site* - Pre- and post-project data could be collected which would allow comparisons of observations of leap attempts in order to demonstrate the successful establishment of unimpeded passage.
- *Measurements of culvert hydraulic characteristics over the range of estimated migration flows* - An effort should be made to determine if the *FishXing* hydraulic modeling for the project design used in the remediation project accurately predict water depth, velocities, and tailwater conditions. This will help determine if the newly installed stream crossing will perform as expected in providing passage.
- *Photo and/or video documentation of pre-project, construction phases, and post-project* - A variety of established photo points can be used to visually document changes at a particular site.

FISH PASSAGE INVENTORY DATA SHEET

Stream Crossing Type: 9 bridge 9 ford 9culvert 9 other______________ **Date**:____/____/____
Surveyors: Scope: Rod: **Culvert #** **of** (left bank to right bank)

Road:	**Mile Post**:	**Crossroad**:
Stream Name:	**Tributary to**:	**Basin**:
Quad:	**T:** **R:** **S:**	**Lat/Long**:

Flow Conditions During Survey: ☐ continuous ☐ isolated pools ☐ dry

Fisheries Information

Fish Presence Observed During Survey: **Location**: ☐ upstream ☐ downstream ☐ none
Age Classes: ☐ adults ☐ juveniles Species: ______________________ ☐ unknown
Juvenile Size Classes: ☐ <3" ☐ 3"-6" ☐ >6" **Number of Fish Observed**:

Stream Crossing Information

Inlet Type: ☐ projecting ☐ headwall ☐ wingwall ☐ mitered
Alignment (deg): ☐ $<30^o$ ☐ 30^o- 45^o ☐ $>45^o$ **Inlet Apron**: ☐ yes ☐ no
Describe:

Outlet Configuration: ☐ at stream grade ☐ free-fall into pool ☐ cascade over rip rap
Outlet Apron: ☐ yes ☐ no Describe:

Tailwater Control: ☐ pool tailout ☐ full-spanning log or debris jam ☐ log weir ☐ boulder weir
☐ concrete weir ☐ other_________________________
☐ no control point (complete a channel cross-section)

Upstream Channel Widths (ft): (1) (2) (3) (4) (5) Average Width:

Culvert Information

Culvert Type: ☐ circular ☐ pipe arch ☐ box ☐ open-bottom arch ☐ other___________________
Diameter (ft):______ Height or Rise (ft):________ Width or Span (ft):_______ Length (ft):________

Material: ☐ SSP ☐ CSP ☐ aluminum ☐ plastic ☐ concrete ☐ log/wood ☐ other__________
Corrugations (width x depth): ☐ 2 $^2/_3$" x ½ ☐ 3" x 1" ☐ 5" x 1" ☐ 6" x 2" ☐ spiral
☐ other___________
Pipe Condition: ☐ good ☐ fair ☐ poor ☐ extremely poor
Describe:____ Rustline Height (ft):

Embedded: ☐ yes ☐ no Depth (ft): inlet_____ outlet_____ Station (ft): start:________ end:_______
Describe Substrate:

Barrel Retrofit (weirs/baffles): ☐ yes ☐ no
Type: ☐ steel ramp baffles ☐ Washington ☐ corner ☐ other:_____________________________
Describe (number, placement, materials):
Outlet Beam: ☐ yes ☐ no Notched: ☐ yes ☐ no

Breaks-in-Slope: ☐ yes ☐ no Number:

Fill Volume: L_u (ft):_____ S_u (%):_____ W_r (ft): _____ L_d (ft): _____ S_d (%):_____ L_f (ft):_____
W_c (use average channel width) (ft):

Site Sketch

Longitudinal Surveyed Elevations					Station Description and Water Depth (**Bold** = required)	**Tailwater Cross Section** (optional)					
Station (ft)	BS (+)	HI (ft)	FS (-)	Elevation (ft)		Station (ft)	BS (+)	HI (ft)	FS (-)	Elevation (ft)	Notes
					TBM:						
					TW Control of 1st resting habitat u/s of inlet						
					Inlet Apron/Riprap						
					Inlet Depth=						
					Outlet Depth=						
					Outlet Apron/Riprap						
					Max. Depth within 5' of outlet=						
					Max. Pool Depth						
					TW Control Depth=						
					Active Channel Stage						
					Downstream Channel Slope (%)	**Substrate at X-Section**:					
Additional Surveyed Elevations (including Breaks-in-Slope)						**Suspected Passage Assessment** Adults: 9 100% barrier 9 partial barrier 9 no barrier Juveniles: 9 100% barrier 9 partial barrier 9 no barrier					
						Culvert Slope:_____%					

Qualitative habitat comments

GLOSSARY

Active Channel Stage: The active channel or ordinary high water level is an elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence on the landscape, such as the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial or the bank elevation at which the cleanly scoured substrate of the stream ends and terrestrial vegetation begins (Figure IX-3 and IX-4).

Anadromous Fish: A group of fish that migrate from the ocean into fresh water to breed. Includes salmon and steelhead, as well as many other fish.

Apron: A hardened surface (usually concrete or grouted riprap) placed at either the invert of the culvert inlet or outlet to protect structure from scour and storm damage. Aprons often are migration barriers because flow is often shallow with high velocities. Aprons at outlet may also create turbulence and increase stream power that often down cuts the channel, resulting in perched outlets and/or de-stabilized stream banks.

Baffles: Wood, concrete or metal panels mounted in a series on the floor and/or wall of a culvert to increase boundary roughness and thereby reduce the average water velocity in the culvert.

Bankfull Stage: Corresponds to the stage at which channel maintenance is most effective, that is, the discharge at which the stream is moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels. The bankfull stage is most effective or is the dominate channel-forming flow, and has a recurrence interval of 1.5 years (Dunne & Leopold 1978) (Figures IX-3 and IX-4).

Bedload: Sand, silt, and gravel, or soil and rock debris rolled along the bottom of a stream by the moving water. The particles of this material have a density or grain size which prevents movement far above or for a long distance out of contact with the streambed under natural flow conditions.

Bottomless-arch: A type of culvert with rounded sides and top attached to concrete or steel footings set below stream grade. The natural stream channel and substrate run through the length of the culvert, providing streambed conditions similar to the actual stream channel.

Breaks-in-slope: Steeper sections within a culvert. As culverts age they often sag when road fills slump. FishXing is able to model changes in velocity created by varying slopes within several culvert sections.

CFS: Cubic feet per second.

Corrugations: Refers to the undulations present in CSP and SSP culvert material. Corrugations provide surface roughness which increases over the width and depth of standard dimensions.

CSP: Corrugated steel pipe. Pipe diameter is comprised of a single sheet of material.

Culvert: A specific type of stream crossing, used generally to convey water flow through the road prism base. Typically constructed of either steel, aluminum, plastic, or concrete. Shapes include circular, oval, squashed-pipe (flat floor), bottomless-arch, square, or rectangular (Figure IX-10).

Culvert Entrance: The downstream end of a culvert through which a fish enter to pass upstream.

Culvert Exit: The upstream end of a culvert through which a fish exit to pass upstream.

Culvert Inlet: The upsteam end of a culvert through which stream flow enters.

Culvert Outlet: The downstream end of a culvert through which stream flow discharges.

Embedment: The depth to which a culvert bottom is buried into the streambed. It is usually expressed as a percentage of the culvert height or diameter.

Exceedance Flow: N% exceedance flow is the flow that is equaled or exceeded n% of the time.

Fish Passage: The ability of both adult and juvenile fish to move both up and down stream.

Fishway: A structure for passing fish over vertical impedments. It may include special attraction devices, entrances, collection and transportation channels, a fish ladder and exit.

FishXing: A computer software program developed by the Six Rivers National Forest Watershed Interactions Team. *FishXing* models culvert hydraulics (including open-bottom structures) and compares the predicted values with data regarding swimming and leaping abilities and minimum water depth requirements for numerous fish species.

Flood Frequency: The frequency with which a flood of a given discharge has the probability of recurring. For example, a "100-year" frequency flood refers to a flood discharge of a magnitude likely to occur on the average of once every 100 years or, more properly, has a one-percent chance of being exceeded in any year. Although calculation of possible recurrence is often based on historical records, there is no guarantee that a "100-year" flood will occur at all within the 100-year period or that it will not recur several times.

Floodplain: The area adjacent to the stream constructed by the river in the present climate and inundated during periods of high flow.

Flood Prone Zone: Spatially, this area generally corresponds to the modern floodplain, but can also include river terraces subject to significant bank erosion. For delineation, see definition for floodplain.

Flow Duration (or Annual Exceedance Flow): 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, or migration period). Flow exceedance values are important for describing the flow conditions under which fish passage is required.

Gradient Control Weirs: Stabilizing weirs constructed in the streambed to prevent lowering of the channel bottom.

Hydraulic Capacity: The maximum amount of flow (in cfs) that a stream crossing can convey at 100% of inlet height.

Hydraulic Controls: Weirs constructed primarily of rocks or logs, in the channel below a culvert for the purpose of controlling water depth and water velocity within the crossing.

Hydraulic Jump: An abrupt transition in streamflow from shallow and fast (supercritical flow) to deep and slow (subcritical flow).

Inlet: Upstream entrance to a culvert.

Inlet Invert: Location at inlet, on the culvert floor where an elevation is measured to calculate culvert slope.

Invert: Lowest point of the crossing.

Maximum Average Water Velocity in Culvert: The highest average water velocity for any cross section along the length of the culvert, excluding the effects of water surface drawdown at the culvert outlet.

Outlet: Downstream opening of a culvert.

Outlet Invert: Location at outlet, on the culvert floor, where an elevation is measured to calculate culvert slope.

Ordinary High Water Mark: The mark along the bank or shore up to which the presence and action of the water are common and usual, and so long continued in all ordinary years, as to leave a natural line impressed on the bank or shore and indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics.

Passage Flow: Migration flows.

Peak Flow: One-hundred year flow event.

Perched Outlet: A condition in which a culvert outlet is suspended over the immediate downstream pool, requiring a migrating fish to leap into culvert.

Pipe-arch: A type of culvert with a flat floor and rounded sides and top, usually created by shaping or squashing a circular CSP or SSP pipe.

Q_{hp}: Stream discharge (in cfs) at high passage flow. For adult salmonids, in California defined as the 1% exceedance flow (the flow equaled or exceeded 1% of the time) during the period of expected migration.

Q_{lp}: Stream discharge (in cfs) at low passage flow. For adult salmonids, in California defined as the 90% exceedance flow for the migration period.

Recurrence Interval: Also referred to as flood frequency, or return period. It is the average time interval between actual occurances of a hydrological event of a given or greater magnitude. A flood event with a two-year recurrence interval has a 50% chance of occurring in any given year.

Roads: For purposes of these guidelines, roads include all sites of intentional surface disturbance for the purpose of vehicular or rail traffic and equipment use, including all surfaced and unsurfaced roads, temporary roads, closed and inoperable roads, legacy roads, skid trails, tractor roads, layouts, landings, turnouts, seasonal roads, fire lines, and staging areas.

Riffle Crest: See "tailwater control".

Salmonids: A taxonomic group of fish that includes salmon and steelhead, amoung others.

Section 10 and 404 Regulatory Programs: The principal federal regulatory programs, carried out by the US Army Corps of Engineers, affecting structures and other work below mean high water. The Corps, under Section 10 of the River and Harbor Act of 1899, regulates structures in, or affecting, navigable waters of the US as well as excavation or deposition of materials (e.g., dredging or filling) in navigable waters. Under Section 404 of the Federal Water Pollution Control Act Amendments (Clean Water Act of 1977), the Corps is also responsible for evaluating application for Department of the Army permits for any activities that involve the placement of dredged or fill material into waters of the United States, including adjacent wetlands.

SSP: Structural steel plate. Pipe diameter is comprised of multiple sheets of material which are usually bolted together.

Stream Crossing: Any human-made structure generally used for transportation purposes that crosses over or through a stream channel including: a paved road, unpaved road, railroad track, biking or hiking trail, golf-cart path, or low-water ford. A stream crossing encompasses the structure employed to pass stream flow as well as associated fill material within the crossing prism.

Supercritical Flow: Fast and shallow flowing water that is usually associated with a hydraulically steep, smooth surface.

Tailwater Control: The channel feature which influences the water surface elevation immediately downstream of the culvert outlet. The location controlling the tailwater elevation is often located at the riffle crest immediately below the outlet pool. Tailwater control is also the channel elevation that determines residual pool depth.

Thalweg: The line connecting the lowest or deepest points along a stream bed.

Waters of the United States: Currently defined by regulation to include all navigable and interstate waters, their tributaries and adjacent wetlands, as well as isolated wetlands and lakes and intermittent streams.

Weir: a) A notch or depression in a levee, dam, embankment, or other barrier across or bordering a stream, through which the flow of water is measured or regulated; b) A barrier constructed across a stream to divert fish into a trap; c) A dam (usually small) in a stream to raise the water level or divert its flow.

REFERENCES

Literature Cited

Bates, K, B. Barnard, B. Heiner, P. Klavas, and P. Powers. 1999. Fish passage design at road culverts: a design manual for fish passage at road crossings. WA Department of Fish and Wildlife. Olympia, Washington. 44 p.

DFG. 2002. Culvert Criteria for Fish Passage. State of California, Resources Agency, Department of Fish and Game. Sacramento, CA. 15p.

Cederholm, C.J. and W.J. Scarlett. 1981. Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977-1981, p. 98-110. *In* E.L. Brannon and E.O. Salo, editors. Proceedings of the Salmon and Trout Migratory Behavior Symposium. School of Fisheries, University of Washington, Seattle, WA.

Dunn, T. and L.B. Leopold. 1978. Water In Environmental Planning. W.H. Freeman and Company, New York, 877 p.

Evan,W., Johnson, F.Beryl. Fish migration and fish passage. A practical guide to solving fish passage problems. USDA- Forest Service, Washington, D.C. 1972 Revised 1980.

Flannigan, S.A., M.J. Furniss, T.S. Ledwith, S. Thiesen, M. Love, K. Moore, and J. Ory.1998. Methods for inventory and environmental risk assessment of road drainage crossings. USDA Forest Service, Six Rivers National Forest. 45 p.

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, B. Collins. 1998. *California Salmonid Stream Habitat Restoration Manual*. Inland Fisheries Division, DFG, Sacramento, California.

Harrelson, Cheryl C., C.L. Rawlins, and John P. Potyondy. 1994. Stream Channel Reference Sites: an Illustrated Guide to Field Technique. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-245.

Hunter, Larry A., and Lesley Mayor. 1986. Analysis of Fish Swimming Performance Data: Volume I. North/South Consultants Inc., Winnipeg, Manitoba. 33 pages.

Kahier, T.H., P. Roni and T.P. Quinn. 2001. Summer movement and growth of juvenile anadromous salmonids in small western Washington streams. Canadian Journal of Fish and Aquatic Science. 58: 1947-1956.

Love, Michael. 1999. FishXing User Manuel. USDA Forest Service, SiIX Rivers National Forest. 45 pages.

Nickelson, T.E., J.D. Rogers, S.L. Johnson, and M.F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Can. J. Aquat. Sci. 49: 783-789.

NMFS. 2001. Guidelines for salmonid passage at stream crossings. National Marine Fisheries Service, Southwest Region, Santa Rosa, California. www.swr.nmfs.noaa.gov/habitat.htm

Norman, Jerome M., Robert J. Houghtalen, and William J. Johnston. 1985. Hydraulic Design of Highway Culverts. US Department of Transportation, Federal Highway Administration, Report no. FHWA-IP-85-15, HDS no. 5. 272 pages.

Piehl, B.T., M.R. Pyles, R.L. Beschta. 1988. Flow capacity of culverts on Oregon coast range forest roads. Water Resources Bulletin Vol. 24, (3): 91-98.

Robison, E.G., A. Mirati, and M. Allen. 2000. Oregon road/stream crossing restoration guide: spring 1999. Advanced Fish Passage Training Version. 75 p.

Sandercock, R.K. 1991. Life history of coho salmon (Oncorhynchus kisutch). Pages 395-445 in C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver.

Scarlett, W.J. and C.J. Cederholm. 1984. Juvenile coho salmon fall-winter utilization of two small tributaries of the Clearwater River, Jefferson County, Washington, p. 227-242. *In* J.M. Walton and D.B. Houston, editors. Proceedings of the Olympic Wild Fish Conference, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Shapovalov, L. and Taft, A. 1954. The Life Histories of the Steelhead Rainbow Trout (*Salmon gairdneri gairdneri*) and Silver Salmon (*Oncorhynchus kisutch*) with Special Reference to Waddell Creek, California, and Recommendations Regarding Their Management. State of California Department of Fish and Game Fish Bulletin No. 98. 375 p.

Skeesick, D.B. 1970. The fall immigration of juvenile coho salmon into a small tributary. Res. Rep. Fish Comm. Oregon 2: 90-95.

SSHEAR. 1998. Fish passage barrier assessment and prioritization manual. Washington Department of Fish and Wildlife, Salmonid Screening, Habitat Enhancement, and Restoration (SSHEAR) Division. 57 p.

Taylor, R. N. 2000. Culvert inventory and fish passage evaluation of the Humboldt County road system. Final report for CA. Dept. Fish and Game, Fortuna, CA. 37 p and appendices.

Tripp, D. and P. McCart. 1983. Effects of different coho stocking strategies on coho and cutthroat trout production in isolated headwater streams. Can. Tech. Rep. Fish. Aquat. Sci. 40: 452-461.

Tshaplinski, P.J. and G.F. Hartman. 1983. Winter distribution of juvenile coho salmon (Oncorhynchus kisutch) before and after logging in Carnation Creek, British Columbia, and some implications for over-wintering survival. Can J. Fish Aquat. Sci. 40: 452-461.

Waananen, A.O. and J.R. Crippen. 1977. Magnitude and frequency of floods in California. U. S. Geological Survey, Water Resources Investigation 77-21, Menlo Park, CA . 96 p.

Personal Communications

Roelofs, T.D. Fisheries Department, Humboldt State University, Arcata, CA. 95519.

Taylor, Ross. Ross Taylor and Associates, McKinleyville, CA 95519.

APPENDIX IX-A

STATE OF CALIFORNIA
RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

CULVERT CRITERIA FOR FISH PASSAGE

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

INTRODUCTION

The following criteria have been adopted by the California Department of Fish and Game (DFG) to provide for upstream fish passage at culverts. This is not a culvert design manual, rather it is supplemental criteria to be used by qualified professionals for the design of culverts that meet both hydraulic and fish passage objectives while minimizing impacts to the adjacent aquatic and riparian resources. The objective of these criteria is to provide unimpaired fish passage with a goal of providing ecological connectivity.

Previous versions of the DFG Culvert Criteria were based on hydraulic design of culverts to match the swimming performance of adult anadromous salmonids. This revision of the criteria has been expanded to include considerations for juvenile anadromous salmonids, non-anadromous salmonids, native non-salmonids, and non-native fish. While criteria are still included for the hydraulic design option, criteria have been added for two additional design options that are based on the principles of ecological connectivity. The two additional design methods are:

- Active Channel Option
- Stream Simulation Option

The criteria contained in this document are based on the works of several organizations including state and federal agencies, universities, private organizations and consulting professionals. These criteria are intended to be consistent with the National Marine Fisheries Service, Southwest Region (NMFS-SWR) *Guidelines for Salmonid Passage at Stream Crossings*, as well as being in general agreement with Oregon and Washington Departments of Fish and Wildlife culvert criteria for fish passage. This document is considered a “Work in Progress” and will be revised as new information warrants.

The Caltrans Highway Design Manual defines a culvert as "A closed conduit which allows water to pass under a highway," and in general, has a single span of less than 6.1 meters (20 feet) or multiple spans totaling less than 6.1 meters. For the purpose of fish passage, the distinction between bridge, culvert or low water crossing is not as important as the effect the structure has on the form and function of the stream. To this end, these criteria conceptually apply to bridges and low water crossings, as well as culverts.

The primary factors that determine the extent to which fish passage will be impacted by the construction of a crossing are:

a. The degree of constriction the crossing has on the stream channel
b. The degree to which the streambed is allowed to adjust to vertically
c. The length of stream channel impacted by the crossing
d. The degree to which the stream velocity has been increased by the crossing

For unimpaired fish passage, it is desirable to have a crossing that is a large percentage of the channel bankfull width, allows for a natural variation in bed elevation, and provides bed and bank roughness similar to the upstream and downstream channel.

In general, bridges are preferred over culverts because they typically do not constrict a stream channel to as great a degree as culverts and usually allow for vertical movement of the streambed. Bottomless culverts may provide a good alternative for fish passage where foundation conditions allow their construction and width criteria can be met. In all cases, the vertical and lateral stability of the stream channel should be taken into consideration when designing a crossing.

APPLICATION OF CRITERIA

These criteria are intended to apply to **new and replacement** culverts where fish passage is legally mandated or is otherwise important to the life histories of the fish and wildlife that utilize the stream and riparian corridor. Not all stream crossings may be required to provide upstream fish passage, and of those that do, some may only require passage for specific species and age classes of fish.

Where existing culverts are being modified or retrofitted to improve fish passage, the Hydraulic Design Option criteria should be the design objective for the improvements. However, it is acknowledged that the conditions that cause an existing culvert to impair fish passage may also limit the remedies for fish passage improvement. Therefore, short of culvert replacement, the Hydraulic Design Option criteria should be the goal for improvement and not the required design threshold.

To determine the biological considerations and applicable criteria for a particular culvert site, the project sponsors should contact the Department of Fish and Game, the National Marine Fisheries Service (for projects in marine and anadromous waters) and the US Fish and Wildlife Service (for projects in anadromous and fresh waters) for guidance.

It is the responsibility of the project sponsor to obtain the most current version of the culvert criteria for fish passage. Copies of the current criteria are available from the Department of Fish and Game through the appropriate Regional office, which should be the first point of contact for any stream crossing project. Addresses and phone numbers for the California Department of Fish and Game Regional Offices are shown in Table IX A-1.

California Dept. of Fish and Game Regional Offices		
Region	**Address**	**Phone Number**
Northern California -North Coast Region	601 Locust Street redding, CA 96001	(530) 225-2300
Sacramento Valley -Central Sierra Region	1701 Nimbus Drive Rancho Cordova, CA 95670	(916) 358-2900
Central Coast Region	7329 Silverado Trail P.O. Box 47 Yountville, CA 94599	(707) 944-5500
San Joaquin Valley - Southern Sierra Region	1234 E. Shaw Avenue Fresno, CA 93710	(559) 243-4005 x151
South Coast Region	4649 Viewridge Avenue San Diego, CA 92123	(858) 467-4200
Eastern Sierra - Inland Deserts Region	4775 Bird Farm Road Chino Hills, CA 9709	(909) 597-9823

Table IX-A- 1. California Department of Fish and Game Regional offices.

DESIGN OPTIONS

All culverts should be designed to meet appropriate hydraulic capacity and structural integrity criteria. In addition, where fish passage is required, the culvert shall be designed to meet the criteria of the Active Channel Design Option, Stream Simulation Design Option or the Hydraulic Design Option for Upstream Fish Passage. The suitability of each design option is shown in Table IX-A-2.

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 IX-A- 2. Suitability design options.

Active Channel Design Option

The Active Channel Design Option (Figure IX-A-1) is a simplified design method that is intended to size a crossing sufficiently large and embedded deep enough into the channel to allow the natural movement of bedload and formation of a stable bed inside the culvert. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this option since the stream hydraulic characteristics within the culvert are intended to mimic the stream conditions upstream and downstream of the crossing.

The Active Channel Design Option is suitable for the following conditions:

- New and replacement culvert installations
- Simple installations with channel slopes less than 3%
- Short culvert length (less than 100 feet)
- Passage required for all fish

Culvert Setting & Dimensions

e. Culvert Width - The minimum culvert width shall be equal to, or greater than, 1.5 times the active channel width.

f. Culvert Slope - The culvert shall be placed level (0% slope).

g. Embedment - The bottom of the culvert shall be buried into the streambed not less than 20% of the culvert height at the outlet and not more than 40% of the culvert height at the inlet.

h. Embedment does not apply to bottomless culverts.

See section on Considerations, Conditions, and Restrictions for all design options.

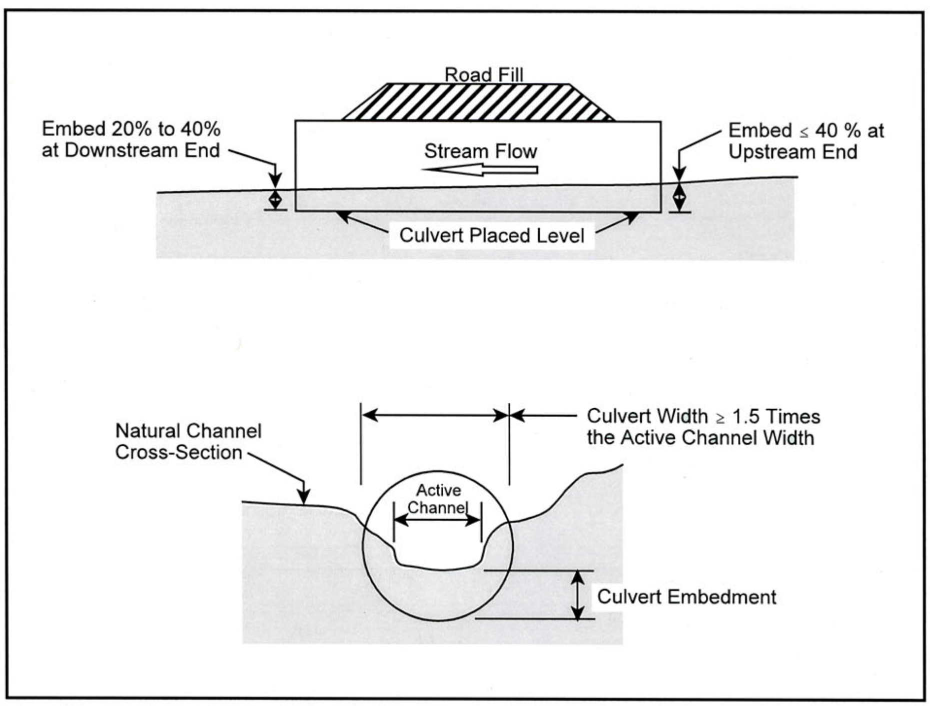


Figure IX-A- 1. Active channel design option.

Stream Simulation Design Option

The Stream Simulation Design Option (Figure IX-A-2)is a design process that is intended to mimic the natural stream processes within a culvert. Fish passage, sediment transport, flood and debris conveyance within the crossing are intended to function as they would in a natural channel. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this options since the stream hydraulic characteristics within the culvert are designed to mimic the stream conditions upstream and downstream of the crossing.

Stream simulation crossings are sized as wide, or wider than, the bankfull channel and the bed inside the culvert is sloped at a gradient similar to that of the adjacent stream reach. These crossings are filled with a streambed mixture that is resistant to erosion and is unlikely to change grade, unless specifically designed to do so. Stream simulation crossings require a greater level of information on hydrology and topography and a higher level of engineering expertise than the Active Channel Design Option.

The Stream Simulation Design Option is suitable for the following conditions:

- New and replacement culvert installations
- Complex installations with channel slopes less than 6%
- Moderate to long culvert length (greater than 100 feet)
- Passage required for all fish
- Ecological connectivity required

Culvert Setting & Dimensions

i. Culvert Width - The minimum culvert width shall be equal to, or greater than, the bankfull channel width. The minimum culvert width shall not be less than 6 feet.

j. Culvert Slope - The culvert slope shall approximate the slope of the stream through the reach in which it is being placed. The maximum slope shall not exceed 6%.

k. Embedment - The bottom of the culvert shall be buried into the streambed not less than 30% and not more than 50% of the culvert height. Embedment does not apply to bottomless culverts.

Substrate Configuration and Stability

- Culverts with slopes greater than 3% shall have the bed inside the culvert arranged into a series of step-pools with the drop at each step not exceeding the limits shown in Table IX-A-7.
- Smooth walled culverts with slopes greater than 3% may require bed retention sills within the culvert to maintain the bed stability under elevated flows.
- The gradation of the native streambed material or engineered fill within the culvert shall address stability at high flows and shall be well graded to minimize interstitial flow through it.

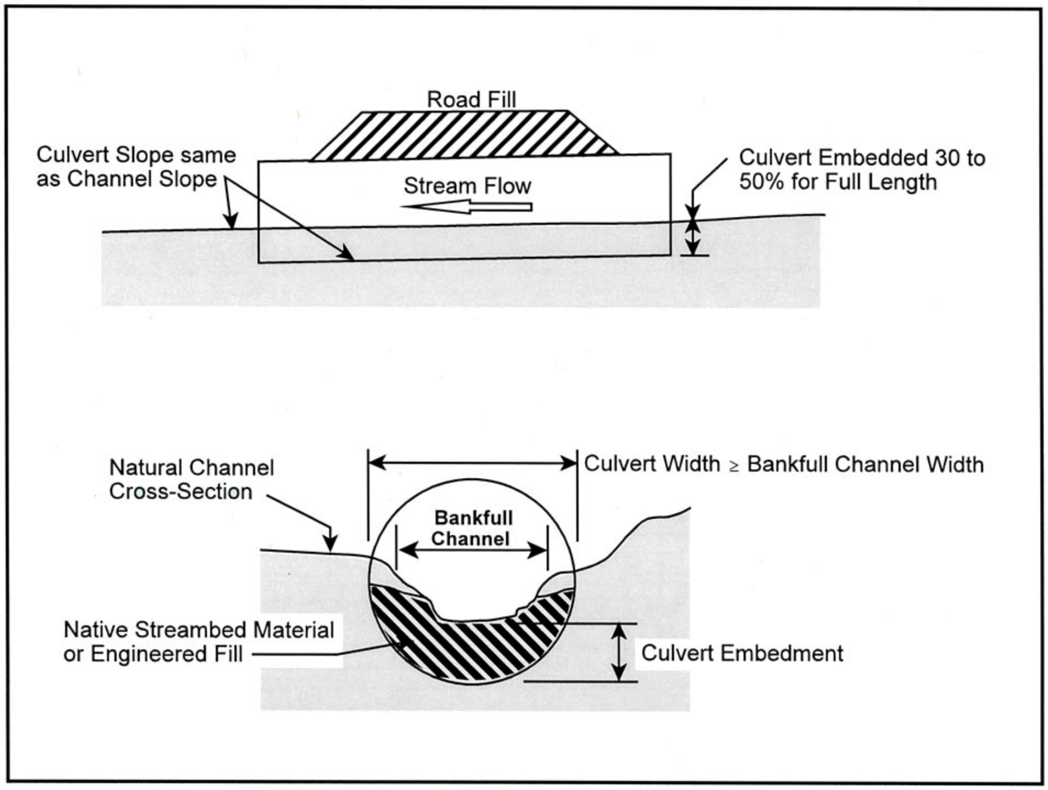


Figure IX-A- 2. Stream simulation design option.

Hydraulic Design Option

The Hydraulic Design Option is a design process that matches the hydraulic performance of a culvert with the swimming abilities of a target species and age class of fish. This method targets distinct species of fish, therefore it does not account for ecosystem requirements of non-target species. There can be significant errors associated with estimation of hydrology and fish swimming speeds that are mitigated by making conservative assumptions in the design process. Determination of the high and low fish passage design flows, water velocity, and water depth are required for this option.

The Hydraulic Design Option requires hydrologic data analysis, open channel flow, hydraulic calculations, and information on the swimming ability and behavior of the target group of fish. This design option can be applied to the design of new and replacement culverts and can be used to evaluate the effectiveness of retrofits for existing culverts.

The Hydraulic Design Option is suitable for the following conditions:

- New, replacement, and retrofit culvert installations
- Low to moderate channel slopes (less than 3%)
- Active Channel Design or Stream Simulation Options is not physically feasible
- Swimming ability and behavior of target species of fish is known
- Ecological connectivity not required
- Evaluation of proposed improvements to existing culverts

HYDROLOGY

High Design Flow for Fish Passage

- The high design flow for fish passage is used to determine the maximum water velocity within the culvert. Where flow duration data is available or can be synthesized, use the values for Percent Annual Exceedance Flow shown in Table IX-A-3. If flow duration data is not available the values shown for Percentage of 2-yr Recurrence Interval Flow may be used as an alternative.

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 IX-A- 3.

Low Design Flow for Fish Passage

The low design flow for fish passage is used to determine the minimum depth of water within a culvert. Where flow duration data is available or can be synthesized, use the values for Percent Annual Exceedance Flow shown in Table IX-A-4. If the Percent Annual Exceedance Flow is determined to be less than the Alternate Minimum Flow, use the Alternate Minimum Flow. If flow duration data is not available, the values shown for Alternate Minimum Flow may be used.

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 IX-A- 4.

Hydraulics

Maximum Average Water Velocity in Culvert (At high design flow) - Where fish passage is required, the maximum average water velocity within the culvert shall not exceed the values shown in Tables IX-A-5 and IX-A-6.

Minimum Water Depth in Culvert (At Low Design Flow) - Where fish passage is required, the minimum water depth within the culvert shall not be less than the values shown in Table IX-A-5.

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 IX-A- 5.

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 IX-A- 6.

Maximum Outlet Drop - Hydraulic drops between the water surface in the culvert to the pool below the culvert should be avoided for all cases. Where fish passage is required and a hydraulic drop is unavoidable, it's magnitude should be evaluated for both high design flow and low design flow and shall not exceed the values shown in Table IX-A-7. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth shall be provided.

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 IX-A- 7.

Hydraulic Controls - Hydraulic controls in the channel upstream and/or downstream of a crossing can be used to provide a continuous low flow path through the crossing and stream reach. They can be used to facilitate fish passage by establishing the following desirable conditions:

- Control depth and water velocity within the crossing
- Concentrate low flows
- Provide resting pools upstream and downstream of the crossing
- Control erosion of the streambed and banks

Baffles - Baffles shall not be used in the design of new or replacement culverts in order to meet the hydraulic design criteria.

Adverse Hydraulic Conditions - The following hydraulic conditions are generally considered to be detrimental to efficient fish passage and should be avoided. The degree to which they impede fish passage depends upon the magnitude of the condition. Crossings designed by the Hydraulic Design Option should be evaluated for the following conditions at high design flow for fish passage:

- Super critical flow
- Hydraulic jumps
- Highly turbulence conditions
- Abrupt changes in water surface elevation at inlet and outlet

Culvert Setting & Dimensions

l. Culvert Width - The minimum culvert width shall be 3 feet.

m. Culvert Slope - The culvert slope shall not exceed the slope of the stream through the reach in which the crossing is being placed. If embedment of the culvert is not possible, the maximum slope shall not exceed 0.5%.

n. Embedment - Where physically possible, the bottom of the culvert shall be buried into the streambed a minimum of 20% of the height of the culvert below the elevation of the tailwater control point downstream of the culvert. The minimum embedment should be at least 1 foot. Where physical conditions preclude embedment, the hydraulic drop at the outlet of a culvert shall not exceed the limits specified above.

See section on Considerations, Conditions, and Restrictions for all design options.

CONSIDERATIONS, CONDITIONS, AND RESTRICTIONS FOR ALL DESIGNS OPTIONS

Anadromous Salmonid Spawning Areas

The hydraulic design method shall not be used for new or replacement culverts in anadromous salmonid spawning areas.

High Design Flow for Structural Integrity

All culvert stream crossings, regardless of the design option used, shall be designed to withstand the 100-yr peak flood flow without structural damage to the crossing. The analysis of the structural integrity of the crossing shall take into consideration the debris loading likely to be encountered during flooding.

Headwater Depth

The upstream water surface elevation shall not exceed the top of the culvert inlet for the 10-yr peak flood and shall not be greater than 50% of the culvert height or diameter above the top of the culvert inlet for the 100-yr peak flood.

Oversizing for Debris

In some cases, it may be necessary to increase the size of a culvert beyond that calculated for flood flows or fish passage in order to pass flood-borne debris. Where there is significant risk of inlet plugging by flood borne debris, culverts should be designed to pass the 100-yr peak flood without exceeding the top of the culvert inlet. Oversizing for flood-borne debris may not be necessary if a culvert maintenance agreement has been effected and the culvert inlet can be safely accessed for debris removal under flood flow conditions.

Inlet Transitions

A smooth hydraulic transition should be made between the upstream channel and the culvert inlet to facilitate passage of flood borne debris.

Interior Illumination

Natural or artificial supplemental lighting shall be provided in new and replacement culverts that are over 150 feet in length. Where supplemental lighting is required, the spacing between light sources shall not exceed 75 feet.

Adverse Conditions to be Avoided:

- Excessive skew with stream alignment
- Changes in alignment within culvert
- Trash racks and livestock fences
- Realignment of the natural stream channel

Multiple culverts

Multiple culverts are discouraged where the design criteria can be met with a single culvert. If multiple culverts are necessary, a multi-barreled box culvert is preferred over multiple individual culverts. Site specific criteria may apply to multiple culvert installations.

Bottomless Culverts

Bottomless culverts are generally considered to be a good solution where fish passage is required, so long as culvert width criteria are met and the culvert footings are deep enough to avoid scour exposure. Site specific criteria may apply to bottomless culverts installations.

CULVERT RETROFITS FOR FISH PASSAGE

Culverts that have fish passage problems were generally designed with out regard for fish passage. While these culverts may convey stream flow, they are often undersized for the watershed hydrology, stream fluvial processes, have been placed at a slope that is too steep for fish passage, or have had the outlet raised above the channel bed in order to control the water velocity in the culvert. Most of these problems arise from the culvert being undersized. For undersized culverts it is difficult, if not impossible, to meet the objective of unimpaired fish passage without replacing the culvert. However, in many cases, fish passage can be significantly improved for some species and their life stages without fully meeting the hydraulic criteria for new culverts. In some cases a modest improvement in hydraulic conditions can result in a significant improvement in fish passage.

Where existing culverts are being modified or retrofitted to improve fish passage, the Hydraulic Design Option criteria should be the design objective for improvements. However, it is acknowledged that the conditions that cause an existing culvert to impair fish passage may also limit the remedies for fish passage improvement. Therefore, short of culvert replacement, the Hydraulic Design Option criteria should be the goal for improvement and not the required design threshold.

A protocol for fish passage evaluation at existing culverts is included in the Department of Fish and Game's *California Salmonid Stream Habitat Restoration Manual*. This manual also includes information methods for improving fish passage at road crossings.

Fish passage through existing non-embedded culverts may be improved through the use of gradient control weirs upstream or downstream of the culvert, interior baffles or weirs, or in some cases, fish ladders. However, these measures are not a substitute for good fish passage design for new or replacement culverts.

Gradient Control Weirs

- Downstream Channel - Control weirs can be used in downstream channel to backwater through culvert or reduce an excessive hydraulic drop at a culvert outlet. The maximum drop at the culvert outlet shall not exceed the values in Table IX-A-7.
- Upstream Channel - Control weirs can be used in the channel upstream of the culvert inlet to re-grade the bed slope and improve exit conditions.

- Hydraulic Drop - The individual hydraulic drop across a single control weir shall not exceed the values in Table IX-A-7, except that boulder weirs may drop 1 foot per weir for all salmonids, including juveniles.

Baffles

Baffles may provide incremental fish passage improvement in culverts with excess hydraulic capacity that can not be made passable by other means. Baffles may increase clogging and debris accumulation within the culvert and require special design considerations specific to the baffle type.

Fishways

Fishways are generally not recommended, but may be useful for some situations where excessive drops occur at the culvert outlet. Fishways require specialized site specific design for each installation.

SELECT REFERENCES AND INTERNET WEB SITES

Baker, C.O. and F.E. Votapka. 1990. *Fish Passage Through Culverts*. Federal Highways Administration & USDA Forest Service. FHWA-FL-90-006. (Available from USDA Forest Service publications, San Dimas Laboratory, CA)

Behlke, C.E., D.L. Kane, R.F. McLean, and M.D. Travis. 1991. *Fundamentals of Culvert Design for Passage of Weak-Swimming Fish, Final Report*. Alaska DOT&PF and USDT, Federal Highway Administration, FHWA-AK-RD-90-10.

California Department of Fish and Game: www.dfg.ca.gov

California Department of Fish and Game. 1998. *California Salmonid Stream Habitat Restoration Manual, 3rd Edition*. Habitat Conservation Division.

National Marine Fisheries Service, Southwest Region. *Stream Crossing Guidelines* http://swr.nmfs.noaa.gov/habitat.htm

FishXing software and learning systems for the analysis of fish passage through culverts. USD.A. Forest Service. 1999. *Fish Xing. Version 2.2*. Six Rivers National Forest Watershed Interactions Team, Eureka, CA. www.stream.fs.fed.us/fishxing/

USDA Forest Service Water-Road Interaction Technology Series Documents www.streamfs.fed.us/water-road/indexhtml

Washington Department of Fish and Wildlife Fish Passage Technical Assistance www.wa.gov/wdfw/hab/engineer/habeng.htm

Washington Department of Fish and Wildlife, 1999. *Fish Passage Design at Road Culverts*. www.wa.gov/wdfw/hab/engineer/cm/toc.htm

APPENDIX IX-B

National Marine Fisheries Service
Southwest Region
GUIDELINES FOR SALMONID PASSAGE AT STREAM CROSSINGS\

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 US 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.

Protocols for fish-barrier assessment and site prioritization are under development by the California Department of Fish and Game (DFG). These will be available in updated versions of the *California Salmonid Stream Habitat Restoration Manual*. Most streams in California also 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 and require "ecological connectivity" that dictate other design criteria not covered in this document. Therefore, the project applicant should check with the local Fish and Game office, the US Fish and Wildlife Service (USFWS), and/or tribal biologists to ensure other species are fully considered.

The California Department of Transportation Highway Design Manual defines a culvert as "A closed conduit which allows water to pass under a highway," and in general, has a single span of less than 20 feet or multiple spans totaling less than 20 feet. For the purpose of fish passage, the distinction between bridge, culvert or low water crossing is not as important as the effect the structure has on the form and function of the stream. To this end, these criteria conceptually apply to bridges and low water crossings, as well as culverts.

PREFERRED ALTERNATIVES AND CROSSINGS

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

Nothing - Road realignment to avoid crossing the stream.

Bridge - spanning the stream to allow for long term dynamic channel stability.

Streambed simulation strategies - bottomless arch, embedded culvert design, or ford.

Non-embedded culvert - this is often referred to as a hydraulic design, associated with more traditional culvert design approaches limited to low slopes for fish passage.

Baffled culvert, or structure designed with a fishway - for steeper slopes.

If a segment of stream channel where a crossing is proposed is in an active salmonid spawning area then only full span bridges or streambed simulations are acceptable.

DESIGNING NEW AND REPLACEMENT CULVERTS

The guidelines below are adapted from culvert design criteria published by many federal and state organizations including the California Department of Fish and Game (DFG 2002). It is intended to apply to new and replacement culverts where fish passage is legally mandated or important.

Active Channel Design Method

The Active Channel Design method is a simplified design that is intended to size a culvert sufficiently large and embedded deep enough into the channel to allow the natural movement of bedload and formation of a stable bed inside the culvert. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this method since the stream hydraulic characteristics within the culvert are intended to mimic the stream conditions upstream and downstream of the crossing. This design method is usually not suitable for stream channels that are greater than 3% in natural slope or for culvert lengths greater than 100 feet. Structures for this design method are typically round, oval, or squashed pipes made of metal or reinforced concrete.

- Culvert Width - The minimum culvert width shall be equal to, or greater than, 1.5 times the active channel width.
- Culvert Slope - The culvert shall be placed level (0% slope).
- Embedment - The bottom of the culvert shall be buried into the streambed not less than 20% of the culvert height at the outlet and not more than 40% of the culvert height at the inlet.

Stream Simulation Design Method

The Stream Simulation Design method is a design process that is intended to mimic the natural stream processes within a culvert. Fish passage, sediment transport, flood and debris conveyance within the culvert are intended to function as they would in a natural channel. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this option since the stream hydraulic characteristics within the culvert are designed to mimic the stream conditions upstream and downstream of the crossing. The structures for this design method are typically open bottomed arches or boxes but could have buried floors in some cases. These culverts contain a streambed mixture that is similar to the adjacent stream channel. Stream simulation culverts require a greater level of information on hydrology and geomorphology (topography of the stream channel) and a higher level of engineering expertise than the Active Channel Design method.

- Culvert Width - The minimum culvert width shall be equal to, or greater than, the bankfull channel width. The minimum culvert width shall not be less than 6 feet.
- Culvert Slope - The culvert slope shall approximate the slope of the stream through the reach in which it is being placed. The maximum slope shall not exceed 6%.
- Embedment - The bottom of the culvert shall be buried into the streambed not less than 30% and not more than 50% of the culvert height. For bottomless culverts the footings or foundation should be designed for the largest anticipated scour depth.

Hydraulic Design Method

The Hydraulic Design method is a design process that matches the hydraulic performance of a culvert with the swimming abilities of a target species and age class of fish. This method targets distinct species of fish and therefore does not account for ecosystem requirements of non-target species. There are significant errors associated with estimation of hydrology and fish swimming speeds that are resolved by making conservative assumptions in the design process. Determination of the high and low fish passage design flows, water velocity, and water depth are required for this option.

The Hydraulic Design method requires hydrologic data analysis, open channel flow hydraulic calculations and information on the swimming ability and behavior of the target group of fish. This design method can be applied to the design of new and replacement culverts and can be used to evaluate the effectiveness of retrofits of existing culverts.

- Culvert Width - The minimum culvert width shall be 3 feet.
- Culvert Slope - The culvert slope shall not exceed the slope of the stream through the reach in which it is being placed. If embedment of the culvert is not possible, the maximum slope shall not exceed 0.5%.
- Embedment - Where physically possible, the bottom of the culvert shall be buried into the streambed a minimum of 20% of the height of the culvert below the elevation of the tailwater control point downstream of the culvert. The minimum embedment should be at least 1 foot. Where physical conditions preclude embedment, the hydraulic drop at the outlet of a culvert shall not exceed the limits specified above.

Hydrology for Fish Passage under the Hydraulic Design Method

o. **High Fish Passage Design Flow** - The high design flow for adult fish passage is used to determine the maximum water velocity within the culvert. Where flow duration data is available or can be synthesized the high fish passage design flow for adult salmonids should be the 1% annual exceedance. If flow duration data or methods necessary to compute them are not available then 50% of the 2 year flood recurrence interval flow may be used as an alternative. Another alternative is to use the discharge occupied by the cross-sectional area of the active stream channel. This requires detailed cross section information for the stream reach and hydraulic modeling. For upstream juvenile salmonid passage the high design flow should be the 10% annual exceedance flow.

p. **Low Fish Passage Design Flow** - The low design flow for fish passage is used to determine the minimum depth of water within a culvert. Where flow duration data is available or can be synthesized the 50% annual exceedance flow or 3 cfs, whichever is greater, should be used for adults and the 95% annual exceedance flow or 1 cfs, whichever is greater, should be used for juveniles.

Maximum Average Water Velocities in the Culvert at the High Fish Passage Design Flow

Average velocity refers to the calculated average of velocity within the barrel of the culvert. Juveniles require 1 fps or less for upstream passage for any length culvert at their High Fish Passage Design Flow. For adult salmonids use the following table to determine the maximum velocity allowed.

Culvert Length (ft)	Velocity (fps) - Adult Salmonids
<60	6
60-100	5
100-200	4
200-300	3
>300	2

Minimum Water Depth at the Low Fish Passage Design Flow

For non-embedded culverts, minimum water depth shall be twelve 12 inches for adult steelhead and salmon, and six 6 inches for juvenile salmon.

Juvenile Upstream Passage

Hydraulic design for juvenile upstream passage should be based on representative flows in which juveniles typically migrate. Recent research (NMFS, 2001, in progress) indicates that providing for juvenile salmon up to the 10% annual exceedance flow will cover the majority of flows in which juveniles have been observed moving upstream. The maximum average water velocity at this flow should not exceed 1 fps. In some cases, over short distances, 2 fps may be allowed.

Maximum Hydraulic Drop

Hydraulic drops between the water surface in the culvert and the water surface in the adjacent channel should be avoided for all cases. This includes the culvert inlet and outlet. Where a hydraulic drop is unavoidable, its magnitude should be evaluated for both high design flow and low design flow and shall not exceed 1 foot for adults or 6 inches for juveniles. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth should be provided.

Structural Design and Flood Capacity

All culvert stream crossings, regardless of the design option used, shall be designed to withstand the 100-year peak flood flow without structural damage to the crossing. The analysis of the structural integrity of the crossing shall take into consideration the debris loading likely to be encountered during flooding. Stream crossings or culverts located in areas where there is significant risk of inlet plugging by flood borne debris should be designed to pass the 100-year peak flood without exceeding the top of the culvert inlet (Headwater-to-Diameter Ratio less than one). This is to ensure a low risk of channel degradation, stream diversion, and failure over the life span of the crossing. Hydraulic capacity must be compensated for expected deposition in the culvert bottom.

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, and allow passage of bedload material.

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.

RETROFITTING 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 DFG biologists can help in selecting priorities and alternatives.

Where existing culverts are being modified or retrofitted to improve fish passage, the Hydraulic Design method criteria should be the design objective for the improvements. However, it is acknowledged that the conditions that cause an existing culvert to impair fish passage may also limit the remedies for fish passage improvement. Therefore, short of culvert replacement, the Hydraulic Design method criteria should be the goal for improvement but not necessarily the required design threshold.

Fish passage through existing non-embedded culverts may be improved through the use of gradient control weirs upstream or downstream of the culvert, interior baffles or weirs, or in some cases, fish ladders. However, these measures are not a substitute for good fish passage design for new or replacement culverts. The following guidelines should be used:

- Hydraulic Controls - Hydraulic controls in the channel upstream and/or downstream of a culvert can be used to provide a continuous low flow path through culvert and stream reach. They can be used to facilitate fish passage by establishing the following desirable conditions: Control depth and water velocity within culvert, concentrate low flows, provide resting pools upstream and downstream of culvert and prevent erosion of bed and banks. A change in water surface elevation of up to one foot is acceptable for adult passage conditions, provided water depth and velocity in the culvert meet other hydraulic guidelines. 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.
- Baffles - Baffles may provide incremental fish passage improvement in culverts with excess hydraulic capacity that cannot be made passable by other means. Baffles may increase clogging and debris accumulation within the culvert and require special design

considerations specific to the baffle type. Culverts that are too long or too high in gradient require resting pools, or other forms of velocity refuge spaced at increments along the culvert length.

- Fishways - Fishways are generally not recommended, but may be useful for some situations where excessive drops occur at the culvert outlet. Fishways require specialized site-specific design for each installation. A NMFS or DFG fish passage specialist should be consulted.
- Multiple Culverts - Retrofitting multiple barrel culverts with baffles in one of the barrels may be sufficient as long as low flow channel continuity is maintained and the culvert is reachable by fish at low stream flow.

OTHER GENERAL RECOMMENDATIONS

Trash racks and livestock fences should not be used near the culvert inlet. Accumulated debris may lead to severely restricted fish passage, and potential injuries to fish. 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 rise with increasing flow are highly recommended.

Natural or artificial supplemental lighting should be provided in new and replacement culverts that are over 150 feet in length. Where supplemental lighting is required, the spacing between lightsources shall not exceed 75 feet.

The NMFS and the DFG set instream 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.

Culverts shall only be installed in a de-watered site, with a sediment control and flow routing plan acceptable to NMFS or DFG. 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.

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

If pumps are used to temporarily divert a stream to facilitate construction, an acceptable fish screen must be used to prevent entrainment or impingement of small fish. Contact NMFS or DFG hydraulic engineering staff for appropriate fish screen specifications. Unacceptable wastewater associated with project activities shall be disposed of off-site in a location that will not drain directly into any stream channel.

POST-CONSTRUCTION EVALUATION AND LONG TERM MAINTENANCE AND ASSESSMENT

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:

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

NMFS and/or DFG 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.

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 in the annual cycle and corrected promptly.

REFERENCES

Baker, C.O. and F.E. Votapka. 1990. *Fish Passage Through Culverts*. Federal Highways Administration & USDA Forest Service. FHWA-FL-90-006. 67 pages. (Available from USDA Forest Service publications, San Dimas Laboratory, CA)

Bates, K. 1992. *Fishway Design Guidelines for Pacific Salmon*. Working paper 1.6. (Available from Ken Bates, Lands and Restoration Program Chief Engineer, Washington Dept. of Fish and Wildlife. 600 Capitol Way North, Olympia, WA, 98501-1091.)

Beechie, T., E. Beamer, and L. Wasserman. 1994. *Estimating Coho Salmon Rearing Habitat and Smolt Production Losses in a Large River Basin, and Implications for Habitat Restoration*. North Am. J. Fish. Mgt. 14:797 - 811.

Behlke, C.E., D.L. Kane, R.F. McLean, and M.D. Travis. 1991. *Fundamentals of Culvert Design for Passage of Weak-Swimming Fish, Final Report*. Alaska DOT&PF and USDT, Federal Highway Administration, FHWA-AK-RD-90-10. 177 pages.

California Department of Fish and Game. 1998. California Salmonid Stream Habitat Restoration Manual, 3rd Edition, Part IX Fish Passage Evaluation At Road Crossings.

California Department of Fish and Game. 2001. *Culvert Criteria for Fish Passage*.

Clay, C.H. 1995. *Design of Fishways and Other Fish Facilities, 2nd Edition*. Lewis Publishers, CRC Press (imprint), Boca Raton, FL. 248 pages.

Evans, W.A. and B. Johnston. 1980. *Fish Migration and Fish Passage: a Practical Guide to Solving Fish Passage Problems*. US Forest Service, EM - 7100 - 2, Washington, D.C.

Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. *Road Construction and Maintenance*. American Fisheries Society Special Publication 19:297-323.

Gebhards, S., and J. Fisher. 1972. *Fish Passage and Culvert Installations*. Idaho Fish and Game Rep. 12 pages.

Groot, C., and L. Margolis, editors. 1991. *Pacific Salmon Life Histories*. Univ. British Columbia Press, Vancouver. 564 pages.

Hassler, T.J. 1987. *Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) Coho Salmon*. US Fish Wildl. Serv. Biol. Rep. 82(11.70). US Army Corps of Engineers, TR EL-82-4. 19 pages.

Johnson, A. and J.F. Orsborn. Undated, circa 1990. *Welcome to Culvert College*. Washington Trout, Duvall, WA. 67 pages.

Kay, AR., and R.B. Lewis. 1970. *Passage of Anadromous Fish Through Highway Drainage Structures*. California Division of Highways, Dist. 01 Res. Rep. 629110. 28 pages.

Katopodis, C. 1992. *Introduction to Fishway Design*. Working Document from Fish Passageways and Diversion Structures Course presented by National Education and Training Center, USFWS.

Lauman, J.E. 1976. *Salmonid Passage at Stream-Road Crossings*. Oregon Dept. of Fish and Wildlife.

McClellan, T.J. 1970. *Fish Passage Through Highway Culverts*. US Dept. Trans., Federal Highway Administration and Oregon State Game Comm., Portland OR. 16 pages.

Meehan, W.R., editor. 1991. *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habita*ts. American Fisheries Society Special Publication 19.

ODFW, 1997. Oregon Department of Fish and Wildlife *Guidelines and Criteria for Stream-Road Crossings*. 7 pages.

Pearsons, T.N., G.A. McMichael, S.W. Martin, E.L. Bartrand, A. Long, and S.A. Leider. 1996. *Yakima Species Interactions Studies Annual Report 1994*. US Department of Energy, Bonneville Power Administration Annual Report 1994. No. DOE/BPB99852-3.

Poulin, V.A., and H.W. Argent. 1997. *Stream Crossing Guidebook for Fish Streams, a Working Draft*. Prepared for British Columbia Ministry of Forests. 80 pages.

Sandercock, F.K. 1991. *Life History of Coho Salmon*. Pages 397-445 *in* C. Groot and L. Margolis (ed.s.), Pacific salmon life histories. Univ. British Columbia Press, Vancouver. 564 pages.

Shirvell, C.S. 1994. Effect of changes in streamflow on the microhabitat use and movement of sympatric juvenile coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*O. tshawytscha*) in a natural stream. Can. J. Fish. Aquat. Sci. 51:1644-1652.

Salmonid Restoration Federation Conference. 1996. *Culvert Fish Passage Design and Retrofitting Workshop*. Fortuna, CA. 30 pages.

USD.A., Forest Service, 1999. *Water Road Interaction Series*.

US Fish and Wildlife Service. *1983-19__. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates*. US Fish Wildlife Service, Biol. Rep. 82(11). US Army Corps of Engineers, TR EL-82-4.

Waples, R.S. 1991. *Definition of "Species@ under the ESA: Application to Pacific Salmon*. US Dep. Commer., NOAA Tech. Memo., NMFS, F/NWC-194, 29 pages.

Washington State Department of Fish and Wildlife, 1999. Design Guidelines for Fish Passage Design at Road Culverts.

Washington State Department of Transportation. 1998. *Juvenile and Resident Salmonid Movement and Passage Through Culverts. Final Report. Rept. No. WA-RD 457.1*. (Available through the National Technical Information Service, Springfield, VA 22616).

Washington State Department of Transportation. 1997. *Fish Passage Program Department of Transportation Inventory Final Report.* G. Johnson (Project Leader) and nine others. 58 pages.

Washington State Department of Transportation. 1996. *Investigation o f Culvert Hydraulics Related to Juvenile Fish Passage. Final Report. Rept. No. WA-RD 388.1*. (Available through the National Technical Information Service, Springfield, VA 22616)

Weaver, W.E., and D.K. Hagans. 1994. *Handbook for Forest and Ranch Roads*. Mendocino County Resource Conservation District. 161 pages.

Wietkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. *Status Review of Coho Salmon from Washington, Oregon, and California*. US Dep. Commer., NOAA Tech. Memo., NMFS-NWFSC-24, Northwest Fisheries Science Center, Seattle, Washington. 258 pages.

Ziemer, G.L. 1961. *Fish Transport in Waterways*. Alaska Dept. of Fish and Game. 2 pages.

INTERNET RESOURCES

California Department of Fish and Game
http://www.dfg.ca.gov

National Marine Fisheries Service Southwest Region
http://swr.nmfs.noaa.gov

Washington Department of Fish and Wildlife Fish Passage Technical Assistance
http://www.wa.gov/wdfw/hab/engineer/habeng.htm

Oregon Road/Stream Crossing Restoration Guide, Spring 1999 (with ODFW criteria)
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/fishIXing/

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

Please direct questions regarding this material to:
National Marine Fisheries Service Phone: (707) 575-6050

Hydraulic Engineering Staff Fax: (707) 578-3425
777 Sonoma Avenue, Suite 325
Santa Rosa, CA 95404
Email: nmfs.swr.fishpassage@noaa.gov

APPENDIX IX-C

EXAMPLE FISH PASSAGE FLOWS CALCULATION

This is a step by step illustration of calculating fish passage flows for analyzing a stream crossing using *FishXing*. The calculations are for a fictitious culvert in a coastal drainage in the Santa Cruz area. The culvert has a drainage area of 3.56 mi^2 . The calculated fish passage flows in this example are for adult steelhead. Passage flows for other species or lifestages would be derived using a similar methodology.

This example uses data from the USGS website for gage 11161800. The identical data can be obtained at:
http://water.usgs.gov/nwis/discharge?site_no=11161800&agency_cd=USGS&format=rdb&begin_date=&end_date=&period=

Step 1:

Obtain gage data.

This example project has stream flow characteristics similar to that of San Vicente Creek, a small watershed where there was a USGS gage with a long flow history. In some cases data might need to be combined from several nearby gages.

Print the data in tabular form to the browser then copy and paste the entire file into a spreadsheet.

```
# US Geological Survey
# National Water Information System
# Retrieved: 2002-01-11 10:34:24 EST
#
# This file contains published daily mean streamflow data.
#
# This information includes the following fields:
#
#  agency_cd   Agency Code
#  site_no     USGS station number
#  dv_dt       date of daily mean streamflow
#  dv_va       daily mean streamflow value, in cubic-feet per-second
#  dv_cd       daily mean streamflow value qualification code
#
# Sites in this file include:
#  USGS 11161800 SAN VICENTE C NR DAVENPORT CA
#
#
agency_cd       site_no dv_dt   dv_va   dv_cd
5s      15s     10d     12n     3s
USGS    11161800        1969-10-01      1.7
USGS    11161800        1969-10-02      1.7
USGS    11161800        1969-10-03      1.7
USGS    11161800        1969-10-04      1.7
USGS    11161800        1969-10-05      1.8
USGS    11161800        1969-10-06      1.8
USGS    11161800        1969-10-07      1.8
```

USGS	11161800	1969-10-08	1.8
USGS	11161800	1969-10-09	1.9
USGS	11161800	1969-10-10	2.0
USGS	11161800	1969-10-11	2.1
USGS	11161800	1969-10-12	2.1
USGS	11161800	1969-10-13	2.3
USGS	11161800	1969-10-14	2.4
USGS	11161800	1969-10-15	8.9
USGS	11161800	1969-10-16	11
USGS	11161800	1969-10-17	3.3
USGS	11161800	1969-10-18	2.7
USGS	11161800	1969-10-19	2.5
USGS	11161800	1969-10-20	2.4
USGS	11161800	1969-10-21	2.4
USGS	11161800	1969-10-22	2.4
USGS	11161800	1969-10-23	2.4
USGS	11161800	1969-10-24	2.4

Continued for approximately 5,800 records to:

USGS	11161800	1985-09-27	1.5
USGS	11161800	1985-09-28	1.5
USGS	11161800	1985-09-29	1.4
USGS	11161800	1985-09-30	1.5

Step2:

Remove the verbiage in the header to get a uniform set of data columns.

USGS	11161800	1969-10-01	1.7
USGS	11161800	1969-10-02	1.7
USGS	11161800	1969-10-03	1.7
USGS	11161800	1969-10-04	1.7
USGS	11161800	1969-10-05	1.8
USGS	11161800	1969-10-06	1.8
USGS	11161800	1969-10-07	1.8
USGS	11161800	1969-10-08	1.8
USGS	11161800	1969-10-09	1.9
USGS	11161800	1969-10-10	2.0
USGS	11161800	1969-10-11	2.1
USGS	11161800	1969-10-12	2.1
USGS	11161800	1969-10-13	2.3
USGS	11161800	1969-10-14	2.4
USGS	11161800	1969-10-15	8.9
USGS	11161800	1969-10-16	11
USGS	11161800	1969-10-17	3.3
USGS	11161800	1969-10-18	2.7
USGS	11161800	1969-10-19	2.5
USGS	11161800	1969-10-20	2.4
USGS	11161800	1969-10-21	2.4
USGS	11161800	1969-10-22	2.4
USGS	11161800	1969-10-23	2.4
USGS	11161800	1969-10-24	2.4
USGS	11161800	1969-10-25	2.4
USGS	11161800	1969-10-26	2.4

USGS	11161800	1969-10-27	2.4
USGS	11161800	1969-10-28	2.3
USGS	11161800	1969-10-29	2.3
USGS	11161800	1969-10-30	2.3
USGS	11161800	1969-10-31	2.1
USGS	11161800	1969-11-01	2.1
USGS	11161800	1969-11-02	2.1
USGS	11161800	1969-11-03	2.1
USGS	11161800	1969-11-04	2.0
USGS	11161800	1969-11-05	4.0
USGS	11161800	1969-11-06	3.3
USGS	11161800	1969-11-07	2.9
USGS	11161800	1969-11-08	2.7
USGS	11161800	1969-11-09	2.6
USGS	11161800	1969-11-10	2.5
USGS	11161800	1969-11-11	2.5
USGS	11161800	1969-11-12	2.4
USGS	11161800	1969-11-13	2.4

Continued for approximately 5,800 records to:

USGS	11161800	1985-09-27	1.5
USGS	11161800	1985-09-28	1.5
USGS	11161800	1985-09-29	1.4
USGS	11161800	1985-09-30	1.5

Step 3:

Use the "Text to Columns" feature under the "Data" menu to sort the data into four columns in preparation for ranking. Select the flow column and use the sort function to sort and rank the flows from highest to lowest.

1	854
2	560
3	430
4	295
5	240
6	229
7	212
8	202
9	201
10	194
11	190

Continued for approximately 5, 800 records:

5,841	0.42
5,842	0.42
5,843	0.42
5,844	0.42
2917	0.42

Step 4:

Identify the rank of the 50% and 1% exceedance flows for the lower and upper fish passage flows for adult steelhead, as defined by the criteria. (For analyzing other species or life stages, use the appropriate exceedance percentage found in Table IX-5). Find what flow rate corresponds to the desired ranking.

We have 5,844 records, therefore:

Q50% rank is computed as: 0.50 IX 5,844 = 2,922

A rank of 2,922 corresponds to a flow of 3.3 cfs

Q1% rank is computed as: 0.01 IX 5,844 = 58.44

Rounding to the nearest whole number rank of 58 corresponds to a flow of 86 cfs

Step 5:

Multipy these fish passage flows by the ratio of the watershed area above our culvert (3.56 square miles) to the area of the gaged watershed (6.07 square miles). Note: several modern mapping programs make it easy to outline and determine the watershed area above any given point.

Lower Adult Fish Passage Flow

Q50% at the stream crossings: 3.3 cfs IX (3.56 mi^2 / 6.07 mi^2) = 1.9cfs

Upper Adult Fish Passage Flow

Q1% at the stream crossings: 86 cfs IX (3.56 mi^2 / 6.07 mi^2) = 50.4 cfs

If a gaged stream is nearby but has a different aspect or annual precipitation, ratios can be used to correct for this as well. Use these two numbers as the lower and upper fish passage flows in *FishXing* analysis.

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.

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 the *California Salmonid Stream Habitat Restoration Manual*. Most streams in California also 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 and require "ecological connectivity" that dictate other design criteria not covered in this document. 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.

The California Department of Transportation Highway Design Manual defines a culvert as "A closed conduit which allows water to pass under a highway," and in general, has a single span of less than 20 feet or multiple spans totaling less than 20 feet. For the purpose of fish passage, the distinction between bridge, culvert or low water crossing is not as important as the effect the structure has on the form and function of the stream. To this end, these criteria conceptually apply to bridges and low water crossings, as well as culverts.

2.0 PREFERRED ALTERNATIVES AND CROSSINGS

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

1. *Nothing* - Road realignment to avoid crossing the stream
2. *Bridge* - spanning the stream to allow for long term dynamic channel stabilty
3. *Streambed simulation strategies* - bottomless arch, embedded culvert design, or ford
4. *Non-embedded culvert* - this is often referred to as a hydraulic design, associated with more traditional culvert design approaches limited to low slopes for fish passage
5. *Baffled culvert, or structure designed with a fishway* - for steeper slopes

If a segment of stream channel where a crossing is proposed is in an active salmonid spawning area then only full span bridges or streambed simulations are acceptable.

3.0 DESIGNING NEW AND REPLACEMENT CULVERTS

The guidelines below are adapted from culvert design criteria published by many federal and state organizations including the California Department of Fish and Game (CDFG, 2001). It is intended to apply to new and replacement culverts where fish passage is legally mandated or important.

3.1 Active Channel Design Method

The Active Channel Design method is a simplified design that is intended to size a culvert sufficiently large and embedded deep enough into the channel to allow the natural movement of bedload and formation of a stable bed inside the culvert. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this method since the stream hydraulic characteristics within the culvert are intended to mimic the stream conditions upstream and downstream of the crossing. This design method is usually not suitable for stream channels that are greater than 3% in natural slope or for culvert lengths greater than 100 feet. Structures for this design method are typical round, oval, or squashed pipes made of metal or reinforced concrete.

- Culvert Width - The minimum culvert width shall be equal to, or greater than, 1.5 times the active channel width.
- Culvert Slope - The culvert shall be placed level (0% slope).
- Embedment - The bottom of the culvert shall be buried into the streambed not less than 20% of the culvert height at the outlet and not more than 40% of the culvert height at the inlet.

3.2 Stream Simulation Design Method

The Stream Simulation Design method is a design process that is intended to mimic the natural stream processes within a culvert. Fish passage, sediment transport, flood and debris conveyance within the culvert are intended to function as they would in a natural channel. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this option since the stream hydraulic characteristics within the culvert are designed to mimic the stream conditions upstream and downstream of the crossing. The structures for this design method are typically open bottomed arches or boxes but could have buried floors in some cases. These culverts contain a streambed mixture that is similar to the adjacent stream channel. Stream simulation culverts require a greater level of information on hydrology and geomorphology (topography of the stream channel) and a higher level of engineering expertise than the Active Channel Design method.

- Culvert Width - The minimum culvert width shall be equal to, or greater than, the bankfull channel width. The minimum culvert width shall not be less than 6 feet.
- Culvert Slope - The culvert slope shall approximate the slope of the stream through the reach in which it is being placed. The maximum slope shall not exceed 6%.
- Embedment - The bottom of the culvert shall be buried into the streambed not less than 30% and not more than 50% of the culvert height. For bottomless culverts the footings or foundation should be designed for the largest anticipated scour depth.

3.3 Hydraulic Design Method

The Hydraulic Design method is a design process that matches the hydraulic performance of a culvert with the swimming abilities of a target species and age class of fish. This method targets distinct species of fish and therefore does not account for ecosystem requirements of non-target species. There are significant errors associated with estimation of hydrology and fish swimming speeds that are resolved by making conservative assumptions in the design process. Determination of the high and low fish passage design flows, water velocity, and water depth are required for this option.

The Hydraulic Design method requires hydrologic data analysis, open channel flow hydraulic calculations and information on the swimming ability and behavior of the target group of fish. This design method can be applied to the design of new and replacement culverts and can be used to evaluate the effectiveness of retrofits of existing culverts.

$ Culvert Width - The minimum culvert width shall be 3 feet.

$ Culvert Slope - The culvert slope shall not exceed the slope of the stream through the reach in which it is being placed. If embedment of the culvert is not possible, the maximum slope shall not exceed 0.5%.

$ Embedment - Where physically possible, the bottom of the culvert shall be buried into the streambed a minimum of 20% of the height of the culvert below the elevation of the tailwater control point downstream of the culvert. The minimum embedment should be at least 1 foot. Where physical conditions preclude embedment, the hydraulic drop at the outlet of a culvert shall not exceed the limits specified above.

Hydrology for Fish Passage under the Hydraulic Design Method

$ **High Fish Passage Design Flow** - The high design flow for adult fish passage is used to determine the maximum water velocity within the culvert. Where flow duration data is available or can be synthesized the high fish passage design flow for adult salmonids should be the 1% annual exceedance. If flow duration data or methods necessary to compute them are not available then 50% of the 2 year flood recurrence interval flow may be used as an alternative. Another alternative is to use the discharge occupied by the cross-sectional area of the active stream channel. This requires detailed cross section information for the stream reach and hydraulic modeling. For upstream juvenile salmonid passage the high design flow should be the 10% annual exceedance flow.

$ **Low Fish Passage Design Flow** - The low design flow for fish passage is used to determine the minimum depth of water within a culvert. Where flow duration data is available or can be synthesized the 50% annual exceedance flow or 3 cfs, whichever is greater, should be used for adults and the 95% annual exceedance flow or 1 cfs, whichever is greater, should be used for juveniles.

Maximum Average Water Velocities in the Culvert at the High Fish Passage Design Flow - Average velocity refers to the calculated average of velocity within the barrel of the culvert. Juveniles require 1 fps or less for upstream passage for any length culvert at their High Fish Passage Design Flow. For adult salmonids use the following table to determine the maximum velocity allowed.

Culvert Length (ft)	Velocity (fps) - Adult Salmonids
<60	6
60-100	5
100-200	4
200-300	3
>300	2

Minimum Water Depth at the Low Fish Passage Design Flow - For non-embedded culverts, minimum water depth shall be twelve 12 inches for adult steelhead and salmon, and six 6 inches for juvenile salmon.

Juvenile Upstream Passage - Hydraulic design for juvenile upstream passage should based on representative flows in which juveniles typically migrate. Recent research (NMFS, 2001, in progress) indicates that providing for juvenile salmon up to the 10% annual exceedance flow will cover the majority of flows in which juveniles have been observed moving upstream. The maximum average water velocity at this flow should not exceed 1 fps. In some cases over short distances 2 fps may be allowed.

Maximum Hydraulic Drop - Hydraulic drops between the water surface in the culvert and the water surface in the adjacent channel should be avoided for all cases. This includes the culvert inlet and outlet. Where a hydraulic drop is unavoidable, its magnitude should be evaluated for both high design flow and low design flow and shall not exceed 1 foot for adults or 6 inches for juveniles. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth should be provided.

3.4 Structural Design and Flood Capacity

All culvert stream crossings, regardless of the design option used, shall be designed to withstand the 100-year peak flood flow without structural damage to the crossing. The analysis of the structural integrity of the crossing shall take into consideration the debris loading likely to be encountered during flooding. Stream crossings or culverts located in areas where there is significant risk of inlet plugging by flood borne debris should be designed to pass the 100-year peak flood without exceeding the top of the culvert inlet (Headwater-to-Diameter Ratio less than one). This is to ensure a low risk of channel degradation, stream diversion, and failure over the life span of the crossing. Hydraulic capacity must be compensated for expected deposition in the culvert bottom.

3.5 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, and allow passage of bedload material.

- 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.

4.0 RETROFITTING 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.

Where existing culverts are being modified or retrofitted to improve fish passage, the Hydraulic Design method criteria should be the design objective for the improvements. However, it is acknowledged that the conditions that cause an existing culvert to impair fish passage may also limit the remedies for fish passage improvement. Therefore, short of culvert replacement, the Hydraulic Design method criteria should be the goal for improvement but not necessarily the required design threshold.

Fish passage through existing non-embedded culverts may be improved through the use of gradient control weirs upstream or downstream of the culvert, interior baffles or weirs, or in some cases, fish ladders. However, these measures are not a substituted for good fish passage design for new or replacement culverts. The following guidelines should be used:

- **Hydraulic Controls -** Hydraulic controls in the channel upstream and/or downstream of a culvert can be used to provide a continuous low flow path through culvert and stream reach. They can be used to facilitate fish passage by establishing the following desirable conditions: Control depth and water velocity within culvert, concentrate low flows, provide resting pools upstream and downstream of culvert and prevent erosion of bed and banks. A change in water surface elevation of up to one foot is acceptable for adult passage conditions, provided water depth and velocity in the culvert meet other hydraulic guidelines. 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.

- **Baffles** - Baffles may provide incremental fish passage improvement in culverts with excess hydraulic capacity that can not be made passable by other means. Baffles may increase clogging and debris accumulation within the culvert and require special design considerations specific to the baffle type. Culverts that are too long or too high in gradient require resting pools, or other forms of velocity refuge spaced at increments along the culvert length.

- **Fishways** - Fishways are generally not recommended, but may be useful for some situations where excessive drops occur at the culvert outlet. Fishways require specialized site-specific design for each installation. A NMFS or CDFG fish passage specialist should be consulted.

- **Multiple Culverts** - Retrofitting multiple barrel culverts with baffles in one of the barrels may be sufficient as long as low flow channel continuity is maintained and the culvert is reachable by fish at low stream flow.

5.0 OTHER GENERAL RECOMMENDATIONS

Trash racks and livestock fences should not be used near the culvert inlet. Accumulated debris may lead to severely restricted fish passage, and potential injuries to fish. 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 rise with increasing flow are highly recommended.

Natural or artificial supplemental lighting should be provided in new and replacement culverts that are over 150 feet in length. Where supplemental lighting is required the spacing between light sources shall not exceed 75 feet.

The NMFS and the 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.

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.

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

If pumps are used to temporarily divert a stream 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. 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 AND LONG TERM MAINTENANCE AND ASSESSMENT

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.

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 in the annual cycle and corrected promptly.

8.0 DEFINITIONS

These definitions apply to terms used in this document. Meanings may differ when used in another context and are not legal unless otherwise noted. Definitions were shortened, paraphrased or adapted to fit regional conditions and for ease of understanding.

Active Channel: A waterway of perceptible extent that periodically or continuously contains moving water. It has definite bed and banks which serve to confine the water and includes stream channels, secondary channels, and braided channels. It is often determined by the "ordinary high water mark" which means that line on the shore established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.

Bankfull: The point on a streambank at which overflow into the floodplain begins. The floodplain is a relatively flat area adjacent to the channel constructed by the stream and overflowed by the stream at a recurrence interval of about one to two years. If the floodplain is absent or poorly defined, other indicators may identify bankfull. These include the height of depositional features, a change in vegetation, slope or topographic breaks along the bank, a change in the particle size of bank material, undercuts in the bank, and stain lines or the lower extent of lichens and moss on boulders. Field determination of bankfull should be calibrated to known stream flows or to regional relationships between bankfull flow and watershed drainage area.

Bedload: Sand, silt, and gravel, or soil and rock debris rolled along the bottom of a stream by the moving water. The particles of this material have a density or grain size which prevents movement far above or for a long distance out of contact with the streambed under natural flow conditions.

Fish Passage: The ability of both adult and juvenile fish to move both up and down stream.

Flood Frequency: The frequency with which a flood of a given discharge has the probability of recurring. For example, a "100-year" frequency flood refers to a flood discharge of a magnitude likely to occur on the average of once every 100 years or, more properly, has a one-percent chance of being exceeded in any year. Although calculation of possible recurrence is often based on historical records, there is no guarantee that a "100-year" flood will occur at all within the 100-year period or that it will not recur several times.

Flood Prone Zone: Spatially, this area generally corresponds to the modern floodplain, but can also include river terraces subject to significant bank erosion. For delineation, see definition for floodplain.

Floodplain: The area adjacent to the stream constructed by the river in the present climate and inundated during periods of high flow.

Flow Duration Curve: A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded. Flow duration curves are usually based on daily streamflow and describe the flow characteristics of a stream throughout a range of discharges without regard to the sequence of occurrence. If years of data are plotted the annual exceedance flows can be determined.

Ordinary High Water Mark: The mark along the bank or shore up to which the presence and action of the water are common and usual, and so long continued in all ordinary years, as to leave a natural line impressed on the bank or shore and indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics.

Roads: For purposes of these guidelines, roads include all sites of intentional surface disturbance for the purpose of vehicular or rail traffic and equipment use, including all surfaced and unsurfaced roads, temporary roads, closed and inoperable roads, legacy roads, skid trails, tractor roads, layouts, landings, turnouts, seasonal roads, fire lines, and staging areas.

Section 10 and 404 Regulatory Programs: The principal federal regulatory programs, carried out by the U.S. Army Corps of Engineers, affecting structures and other work below mean high water. The Corps, under Section 10 of the River and Harbor Act of 1899, regulates structures in, or affecting, navigable waters of the U.S. as well as excavation or deposition of materials (e.g., dredging or filling) in navigable waters. Under Section 404 of the Federal Water Pollution Control Act Amendments (Clean Water Act of 1977), the Corps is also responsible for evaluating application for Department of the Army permits for any activities that involve the placement of dredged or fill material into waters of the United States, including adjacent wetlands.

Waters of the United States: Currently defined by regulation to include all navigable and interstate waters, their tributaries and adjacent wetlands, as well as isolated wetlands and lakes and intermittent streams.

9.0 REFERENCES

Baker, C.O. and F.E. Votapka. 1990. *Fish Passage Through Culverts*. Federal Highways Administration & USDA Forest Service. FHWA-FL-90-006. 67 pages. (Available from USDA Forest Service publications, San Dimas Laboratory, CA)

Bates, K. 1992. *Fishway Design Guidelines for Pacific Salmon*. Working paper 1.6. (Available from Ken Bates, Lands and Restoration Program Chief Engineer, Washington Dept. of Fish and Wildlife. 600 Capitol Way North, Olympia, WA, 98501-1091.)

Beechie, T., E. Beamer, and L. Wasserman. 1994. *Estimating Coho Salmon Rearing Habitat and Smolt Production Losses in a Large River Basin, and Implications for Habitat Restoration*. North Am. J. Fish. Mgt. 14:797 - 811.

Behlke, C.E., D.L. Kane, R.F. McLean, and M.D. Travis. 1991. *Fundamentals of Culvert Design for Passage of Weak-Swimming Fish, Final Report*. Alaska DOT&PF and USDT, Federal Highway Administration, FHWA-AK-RD-90-10. 177 pages.

California Department of Fish and Game. 1998. *California Salmonid Stream Habitat Restoration Manual, 3rd Edition, Part X Fish Passage Evaluation At Road Crossings* (Part X is in preparation, expected fall 2001).

California Department of Fish and Game. 2001. *Culvert Criteria for Fish Passage*.

Clay, C.H. 1995. *Design of Fishways and Other Fish Facilities, 2nd Edition*. Lewis Publishers, CRC Press (imprint), Boca Raton, FL. 248 pages.

Evans, W.A. and B. Johnston. 1980. *Fish Migration and Fish Passage: a Practical Guide to Solving Fish Passage Problems*. U.S. Forest Service, EM - 7100 - 2, Washington, D.C.

Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. *Road Construction and Maintenance*. American Fisheries Society Special Publication 19:297-323.

Gebhards, S., and J. Fisher. 1972. *Fish Passage and Culvert Installations*. Idaho Fish and Game Rep. 12 pages.

Groot, C., and L. Margolis, editors. 1991. *Pacific Salmon Life Histories*. Univ. British Columbia Press, Vancouver. 564 pages.

Hassler, T.J. 1987. *Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) Coho Salmon*. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.70). U.S. Army Corps of Engineers, TR EL-82-4. 19 pages.

Johnson, A. and J.F. Orsborn. Undated, circa 1990. *Welcome to Culvert College*. Washington Trout, Duvall, WA. 67 pages.

Kay, AR., and R.B. Lewis. 1970. *Passage of Anadromous Fish Through Highway Drainage Structures*. California Division of Highways, Dist. 01 Res. Rep. 629110. 28 pages.

Katopodis, C. 1992. *Introduction to Fishway Design*. Working Document from Fish Passageways and Diversion Structures Course presented by National Education and Training Center, USFWS.

Lauman, J.E. 1976. *Salmonid Passage at Stream-Road Crossings*. Oregon Dept. of Fish and Wildlife.

McClellan, T.J. 1970. *Fish Passage Through Highway Culverts*. U.S. Dept. Trans., Federal Highway Administration and Oregon State Game Comm., Portland OR. 16 pages.

Meehan, W.R., editor. 1991. *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitat*s. American Fisheries Society Special Publication 19.

ODFW, 1997. Oregon Department of Fish and Wildlife *Guidelines and Criteria for Stream-Road Crossings*. 7 pages.

Pearsons, T.N., G.A. McMichael, S.W. Martin, E.L. Bartrand, A. Long, and S.A. Leider. 1996. *Yakima Species Interactions Studies Annual Report 1994*. U.S. Department of Energy, Bonneville Power Administration Annual Report 1994. No. DOE/BPB99852-3.

Poulin, V.A., and H.W. Argent. 1997. *Stream Ccrossing Guidebook for Fish Streams, a Working Draft*. Prepared for British Columbia Ministry of Forests. 80 pages.

Sandercock, F.K. 1991. *Life History of Coho Salmon*. Pages 397-445 *in* C. Groot and L. Margolis (ed.s.), Pacific salmon life histories. Univ. British Columbia Press, Vancouver. 564 pages.

Shirvell, C.S. 1994. Effect of changes in streamflow on the microhabitat use and movement of sympatric juvenile coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*O. tshawytscha*) in a natural stream. Can. J. Fish. Aquat. Sci. 51:1644-1652.

Salmonid Restoration Federation Conference. 1996. *Culvert Fish Passage Design and Retrofitting Workshop*. Fortuna, CA. 30 pages.

U.S.D.A., Forest Service, 1999. *Water Road Interaction Series*.

U.S. Fish and Wildlife Service. *1983-19__*. *Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates*. U.S. Fish Wildlife Service, Biol. Rep. 82(11). U.S. Army Corps of Engineers, TR EL-82-4.

Waples, R.S. 1991. *Definition of "Species@ under the ESA: Application to Pacific Salmon*. U.S. Dep. Commer., NOAA Tech. Memo., NMFS, F/NWC-194, 29 pages.

Washington State Department of Fish and Wildlife, 1999. Design Guidelines for Fish Passage Design at Road Culverts.

Washington State Department of Transportation. 1998. *Juvenile and Resident Salmonid Movement and Passage Through Culverts. Final Report. Rept. No. WA-RD 457.1*. (Available through the National Technical Information Service, Springfield, VA 22616).

Washington State Department of Transportation. 1997. *Fish Passage Program Department of Transportation Inventory Final Report.* G. Johnson (Project Leader) and nine others. 58 pages.

Washington State Department of Transportation. 1996. *Investigation o f Culvert Hydraulics Related to Juvenile Fish Passage. Final Report. Rept. No. WA-RD 388.1*. (Available through the National Technical Information Service, Springfield, VA 22616)

Weaver, W.E., and D.K. Hagans. 1994. *Handbook for Forest and Ranch Roads*. Mendocino County Resource Conservation District. 161 pages.

Wietkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. *Status Review of Coho Salmon from Washington, Oregon, and California*. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-NWFSC-24, Northwest Fisheries Science Center, Seattle, Washington. 258 pages.

Ziemer, G.L. 1961. *Fish Transport in Waterways*. Alaska Dept. of Fish and Game. 2 pages.

Internet Resources:

California Department of Fish and Game
http://www.dfg.ca.gov

National Marine Fisheries Service Southwest Region
http://swr.nmfs.noaa.gov

Washington Department of Fish and Wildlife Fish Passage Technical Assistance
http://www.wa.gov/wdfw/hab/engineer/habeng.htm

Oregon Road/Stream Crossing Restoration Guide, Spring 1999 (with ODFW criteria)
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

Please direct questions regarding this material to:

National Marine Fisheries Service
Hydraulic Engineering Staff
777 Sonoma Avenue, Suite 325
Santa Rosa, CA 95404

Phone: (707) 575-6050
Fax: (707) 578-3425

Email: nmfs.swr.fishpassage@noaa.gov

APPENDIX C(3)

Phase I-Reconnaissance
A preliminary reconnaissance study of the barriers to fish passage on California's coastal streams and rivers was completed on July 27, 2002. That report was an initial reconnaissance effort and the first phase in a longer term effort to identify projects that would presumably remove barriers and improve aquatic habitats along California's streams. The principal technique used in that study was interviews of individuals within organizations that are involved in the work of identifying barriers to fish passage or their removal. That study was conducted by the Institute for Fisheries Resources with a grant from the State Coastal Conservancy. Copies of that report are available upon request, but a summary follows.

Sponsored with a grant from the California State Coastal Conservancy ("SCC"), the Institute for Fisheries Resources ("IFR") undertook a project to provide the first comprehensive overview of the activities of individuals and local, state, and federal agencies affecting the barriers on coastal streams. That project identified and interviewed those individuals or agencies which have information or knowledge of, or are involved directly or indirectly in projects that would either lead to a greater knowledge about coastal barriers, or are actually engaged in projects to restore fish passage and habitat in coastal streams. As such, this project was a reconnaissance effort and the first phase of a longer term project to identify projects that would improve fish passage and aquatic habitat along California's coastal streams.

IFR contacted 333 people and conducted formal detailed interviews of 30 of those people. Another 213 people received informal interviews when it was determined in the interview process that the nature of their information about coastal barriers did not warrant a formal 40-minute interview. Seventy-seven of the people contacted (24%) declined to participate in the study or were not interviewed. All 46 of the coastal watersheds from the borders with Mexico to Oregon were analyzed. A list of the participants, their reponses, and the watersheds examined is included in appendices to that report. Based on the interviews and an analysis of maps and other information obtained in this project, the key observations of Phase I are:

- **There are thousands of barriers on California's coastal streams.** Some of those barriers are the result of natural processes in a watershed (e.g., erosion, landslides, tree falls and debris accumulations). Many others are the direct or indirect result of human activity, such as road construction, dams for water supply, or barriers caused by forestry practices. Appendix D to this project contains a list of the hundreds of barriers, organized according to the watershed in which they are located, that were identified in other research projects and assembled in the course of this project.

- **There are dozens of projects along the entire coast dedicated to improving stream conditions and water quality.** Some of those projects are focused on fisheries restoration—and anadromous fisheries in particular, and some of the projects focus on broader stream water quality improvements that could indirectly benefit anadromous fisheries. The Pacific States Marine Fisheries Commission, in cooperation with the California Department of Fish and Game, is presently assembling a spatial data base of those projects.

- **Removing barriers to fish passage is not the objective of many projects.** Often the existence of barriers is noted as part of a research or restoration project focused on another topic, but if any information is collected about the barrier itself the nature and quality of the information collected is inconsistent. As a result, the information about barriers that is available from those projects is generally anecdotal, qualitative in nature, and not at all systematically collected, standardized, stored, or accessible.

- **Overall, very little is known about coastal streams and the barriers on them.** It is almost certain, however, that there are many specific investment opportunities to improve or restore fish passage and habitat because of the important role of the streams in the coastal fishery and because barrier improvement or removal projects have typically received so little attention.

- **Existing data collection efforts are not coordinated or systematic. This results in inconsistent and non-standardized types and qualities of data.** In some cases the data is very detailed and focused on an assessment of a particular barrier as an impediment to fish passage and habitat. In most cases, however, the data is general and not specific to particular barriers. The data that is available does not provide enough information to help determine whether to make improvements to that barrier.

- **There is no consistent definition or agreement of what constitutes a barrier.**

- **Much information that is collected on streams pertains to factors that could be the consequence of barriers (e.g., changes in water quality, flows, habitat, etc.), but little of the information is directly focused on the barriers themselves.** The causal relationship between the barrier and downstream effects on fish and their habitat is not clearly established.

- **The form of data collected is highly variable, non-standardized, and difficult to assess.** For example, the data ranges from old undated photographs or field notes containing information about barriers to highly technical and accurate GIS data.

- **There is almost no information about the social, economic, or legal setting of the barriers.** Even those barriers for which considerable effort has been invested in studying the biological significance of the barrier generally have little information available that would indicate how difficult, expensive, or controversial a project to improve or remove a barrier might be. Correspondingly, there is generally very little information available on barriers about what “action-forcing” mechanisms might be available to help get a restoration project opportunity launched. For example, there is very little information about how old or safe barriers might be and whether there is a public health and safety concern that would necessitate a barrier modification or removal project.

- **<u>Our limited information about barriers does not provide enough information about the barrier relative to the stream, other barriers, or fish habitat.</u>** For example, there is very little information available about such basic questions as the relative upstream-downstream locations of barriers and which of them most impedes fish passage. The most complete information about the watershed impacts of barriers is the work available on culverts in the North Coast region. Similarly, the water quality studies do not presently provide enough information about the relationship between a specific structure, water quality, and the other barriers on the stream.

- **<u>The various agencies and organizations contacted have invested much more attention on North Coast streams than Central Coast or South Coast streams.</u>** Even then, however, the information regarding the north coast streams appears to be anecdotal and incomplete for purposes of identifying priority opportunities for improvement. Until the existing data resources have been "mined" of their useful information on coastal barriers, it is not possible to evaluate how complete or incomplete the specific information is.

- **<u>There are several research projects underway, or about to be launched, on the North, Central, and the South Coasts that will yield additional information about coastal barriers.</u>** If the sponsors of those projects are contacted promptly, it is possible that those projects could be modified to yield more and systematic information about the barriers on those streams.

- **<u>Some agencies and individuals regard barrier information and data as proprietary.</u>** We encountered resistance from some of the people interviewed to provide the data to anyone. The usual reason provided by the individual for not providing the information was that there is some understanding with the owner of the barrier or the land surrounding it that precludes sharing the information. In other cases, the individuals who have information related to barriers indicated that their studies are not yet finished and therefore, the individuals are reluctant to release even enough information which help to would characterize the information they have. Some individuals may be willing to release information for use by the Coastal Conservancy, however they indicated that they would not if the information would be part of a public database.

- **<u>The best project opportunities entail partnering with the local stakeholders and participating government agencies.</u>**

- **<u>There is substantial interest in this project and its subsequent phases. Numerous stakeholders would be interested and willing to collaborate in future work.</u>**

The Phase I Report, based on the findings above, made the following recommendations:

- Considering the lack of information about barriers on coastal streams, we recommend that the next phase of this project have two goals: First, establish priorities for barrier removal opportunities on specific streams and watersheds based on the information that is presently available. Second, concurrent with (1), we recommend that the Conservancy analyze the existing body of information, identify key data gaps, and undertake projects specifically designed to fill those gaps. For example, a "watershed-down" approach to priorities would help focus the next phase on:

-- **watersheds** with the most promise for restoring fish populations taking account of the water quantity and quality, present activities in the watershed, and present/potential fish populations;

-- **streams** and barriers where enough technical, scientific, and policy information is in place to guide decision making;

-- **barriers** where there is enough information about the structure itself and the impact of that structure on fish passage and habitat;

-- **project settings** where there are cooperating stakeholders, including the owner(s), and willing public agency partners (including situations where there is an identifiable "action-forcing" mechanism);

-- **projects** where the "risk-reward" ratio is high enough that a project could be undertaken and could yield significant results.

- A review process will help focus efforts on high-potential streams, reaches, and specific barriers. In addition, interested parties could then nominate projects that they believe warrant investments to improve fish passage and then those candidate projects could be screened in a timely manner so that the best early projects are discovered and evaluated as soon as possible.

- The next phase of the project should include a detailed mapping and inventory system that presently does not exist. This project has produced an initial identification of some of the thousands of barriers that exist. It is not possible to evaluate the significance of any of them in isolation.

- Data collection, analysis, and development of projects should continue in all watersheds; collaborative arrangements with the individuals, organizations, or agencies involved can help those efforts focus on critically important barrier issues early enough to complete the project as efficiently as possible.

APPENDIX D(1)

CALIFORNIA SALMONID STREAM HABITAT RESTORATION MANUAL

Permits That May Be Required

Access Agreement. This agreement is necessary to not only do the development work, but to enter onto property other than your own to do preliminary survey work. This agreement must be reached between the project sponsor and the landowner or manager.

Streambed Alteration Agreement. This agreement, issued by the Department of Fish and Game, is necessary to perform any physical manipulation of the stream, including vegetation, within the high water mark (Fish and Game Code, Sections 1601/1603).

U.S. Army Corps of Engineers 404 Permit. This permit, required pursuant to the Clean Water Act, may or may not be needed, but if the project proposes removal or placement of any materials in the stream area, or if the project area is a wetland, then the project proponent must apply to the Corps of Engineers to determine if a permit is necessary.

U.S. Army Corps of Engineers Section 10 Permit. This permit, required pursuant to the Harbors and Rivers Act, is to be obtained for any construction between high water marks of navigable rivers.

Section 401 of the Clean Water Act. Section 401 of the Clean Water Act requires that the California Regional Water Quality Control Board determine consistency between proposed projects, California water quality laws, and certain sections of the Clean Water Act. The California Regional Water Quality Control Board has established specific procedures for implementing this section. The project proponent may be required to submit a "Request for Certification" form to the California Regional Water Quality Control Board.

Department of Fish and Game Trapping and Rearing Permit. If the restoration project proposes to trap and rear fish, a trapping and rearing permit must be obtained from the Department before any fish may be handled. This permit process requires the applicant to have an approved five-year management plan before the permit will be issued (Appendix B). Contact the local DFG district fishery biologist.

County and State Right-of-Way permits. If the proposed project is near any public roads it could require agreements or permits with county and state public works departments. In addition, many counties have ordinances against working within a riparian corridor along a stream area. This usually falls under the county planning department.

State Lands Commission. State Lands Commission is a permitting agency responsible for riverbed lands owned in fee by the State as sovereign lands, subject to the public trust for water-related commerce, navigation, fisheries, recreation, open space, and habitat.

Project proponents should contact the State Lands Commission to determine if the project falls under Commission jurisdiction.

California Environmental Quality Act (CEQA). Anytime an individual or a group(including public agencies), contracts with the Department of Fish and Game for fish habitat restoration projects, an environmental review is necessary. Individuals or groups conducting habitat restoration projects in a volunteer capacity may also need to have an environmental review of proposed projects, and should discuss proposed projects with the DFG district fishery biologist during the planning stages.

National Environmental Policy Act (NEPA). This applies to projects which are carried out, financed, or approved in whole or part by federal agencies.

National Marine Fisheries Service (NMFS). Written authorization must be obtained for any activities that may impact a federally listed species.

APPENDIX D(2)

Additional Resources

ACTERRA http://www.acterra.org

Alameda Creek Alliance http://www.alamedacreek.com/

American Fisheries Society http://www.fisheries.org/

American Land Conservancy http://www.alcnet.org/

American River Conservancy http://www.coloma.com/arc/index.html

American River Watershed Group http://www.arwg.org/

American River Natural History Association http://www.arnha.org

American River Parkway Foundation http://www.arpf.org

American Rivers http://www.amrivers.org/

American Water Works Association http://www.awwa.org/utility/C.cfm

American Whitewater Affiliation http://www.americanwhitewater.org/

Aquatic Outreach Institute http://www.aoinstitute.org/

Arana Gulch Watershed Alliance http://www.aranagulch.org/

Bay Institute of San Francisco http://www.bay.org

Chico Creek Watershed http://www.csuchico.edu/watershed/bcc

Biodiversity Maps of Fishes in California

http://ice.ucdavis.edu/aquadiv/fishbio/biofish.html

Butte Creek Watershed Conservancy http://buttecreekwatershed.org/

Butte Environmental Council http://www.becnet.org

CALFED Watershed Program http://www.baydeltawatershed.org/

California Association of Resource Conservation Districts http://www.carcd.org/

California Coastal Commission http://www.coastalconservancy.ca.gov/

California Coordinated Resource http://www.cacrmp.org/

California County Websites

http://www.csac.counties.org/counties_close_up/county_web/index.html

Department of Fish and Game http://www.dfg.ca.gov

California Department of Fish and Game Anadromous Fish and Watershed Branch

http://www.dfg.ca.gov/nafwrb/index.html

California Department of Fish and Game <Threatened and Endangered Fishes
http://www.dfg.ca.gov/hcpb/species/t_e_spp/tespp.shtml

California Department of Water Resources Current River Conditions
http://cdec.water.ca.gov/river/rivcond.html

California Resources Agency Watershed Web http://www.ceres.ca.gov/watershed/

California Resource Conservation Districts http://www.nacdnet.org/resources/CA.htm

California Rivers Assessment http://endeavor.des.ucdavis.edu/newcara/

California Trout http://www.caltrout.org/

California Wild Heritage Campaign http://www.californiawild.org/

CalFish http://www.calfish.org

Carmel River Steelhead Association http://www.carmelriverwatershed.org/crsa.html

CEMAR http://www.cemar.org/index.html

Central Coast Salmon Enhancement, Inc http://www.centralcoastsalmon.com

Chico Creek Nature Center http://now2000.com/naturecenter/

Coastal Watershed Council http://www.coastal-watershed.org/

Committee for Green Foothills http://cgf.best.vwh.net/

Committee to Save the Kings River http://www.savethekings.org/

The Conservation Fund http://www.conservationfund.org/

Cosumnes River Preserve http://www.cosumnes.org

Cosumnes River Task Force http://www.cosumnesriver.org/

Coyote Creek-Ventura County Steelhead
http://www.dnai.com/%7Eccate/VenturaApr98.html

Deer Creek Watershed Council
http://www.csuchico.edu/watershed/deercreek/index.htm

Deltakeeper http://www.sfbaykeeper.org/index_ie.html

Eel River Watershed Improvement Group
http://www.applecreek.com/erwig/home.html

EPA office of Wetlands, Oceans & Watersheds http://www.epa.gov/OWOW/

Erosion Control http://www.forester.net/ecm_0209_stirring.html

The Environmental Defense Fund http://www.environmentaldefense.org/home.cfm

Environmental Organization Web Directory http://www.webdirectory.com/

Frequently Asked Questions Essential Fish Habitat	http://www.swr.ucsd.edu/hcd/efhqaca.htm
FishBase	http://ichtyonb1.mnhn.fr/search.cfm
FishXing	http://www.stream.fs.fed.us/fishxing/
Foothill Conservancy	http://karass.outdoingit.com/%7Efhc/
For the Sake of the Salmon	http://www.4sos.org/
Friends of the Eel River	http://www.eelriver.org/
Friends of Deer Creek	http://www.friendsofdeercreek.org/
Friends of Five Creeks	http://www.fivecreeks.org/index3.html
Friends of the Garcia River	http://www.frog.org/
Friends of Corte Madera Creek Watershed	http://www.cortemaderacreek.org/
Friends of the Napa River	http://www.friendsofthenapariver.org/
Friends of the Los Angeles River	http://www.calsur.com/folar/
Friends of the River	http://www.friendsoftheriver.org/
Friends of the Russian River	http://www.envirocentersoco.org/forr/index.html
Friends of San Leandro Creek	http://www.fslc.org/
Friends of the Santa Clara River	http://www.fscr.org/
Friends of the South Fork Kings River	http://sfkingsriver.org/
Friends of Temescal Creek	http://www.aoinstitute.org/temescal/activities.html"
Friends of the Trinity River	http://www.fotr.org/
Garrapata Creek Watershed Council	http://www.garrapatacreek.org/
GREEN	http://www.earthforce.org/green/
Greenwood Watershed Association	http://www.elksoft.com/gwa/
Guide to San Francisco Bay Creeks	http://www.museumca.org/creeks/
Humboldt Fish Action Council	http://www.humboldt.edu/%7Efish/council.htm
Ichthyology Web Resources	http://www.biology.ualberta.ca/jackson.hp/IWR/index.php
The International Rivers Network	http://www.irn.org/index.html
Klamath Forest Alliance	http://www.sisqtel.net/%7Eklamath/
Klamath Resource Information System	http://www.krisweb.com/
Know Your Watershed	http://ctic.purdue.edu/kyw/kyw.html
Marin Conservation League	http://www.conservationleague.org

Matilija Coalition http://www.rain.org/%7Epjenkin/matilija/

Mattole Restoration Council http://www.mattole.org/

Mattole Salmon Group http://www.humboldt.net/%7Esalmon/

Merced River Stakeholders http://www.mercedriverstakeholders.org/

Upper Merced River Watershed Council http://www.sierratel.com/watershed/

Mokelumne-Cosumnes Watershed Alliance http://www.mcwatershed.org

The Monterey Bay Salmon and Trout Project http://www.mbstp.org

National Marine Fisheries Service Southwest Region http://swr.ucsd.edu

Native Fish Conservancy http://www.nativefish.org/index.html

Native Fish Society http://home.teleport.com/%7Esalmo/

Natural Resource Conservation Service http://www.nrcs.usda.gov/

Natural Resources Defense Council

http://www.nrdc.org/water/conservation/default.asp

The Nature Conservancy http://www.tnccalifornia.org/index.asp

The Nature Conservancy-Cosumnes River Preserve

http://www.tnccalifornia.org/our_proj/cosumnes/index.asp

NOAA Fisheries http://www.nmfs.noaa.gov

NOAA Pacific Salmon and the Endangered Species Act

http://www.nwr.noaa.gov/1salmon/salmesa/index.htm

NOAA Northwest Fisheries Science Center http://www.nwfsc.noaa.gov/

NOAA Northwest Salmon Recovery Planning http://www.nwfsc.noaa.gov/cbd/trt/

Oregon Department of Fish and Wildlife Research Section

http://www.orst.edu/Dept/ODFW/index.html

Pacific Rivers Council http://www.pacrivers.org

Pacific States Marine Fisheries Commission http://www.psmfc.org/

Placer Land Trust and Nature Center http://www.pltpnc.org

Planning and Conservation League Foundation http://www.pcl.org

Protect American River Canyons http://www.parc -auburn.org/

Putah Creek Council http://www.putahcreek.org/pcc/

Redwood Coast Land Conservancy http://www.rc-lc.org/J.htm

Redwood Community Action Agency Natural Resources Services

http://www.rcaa.org/nrs/index.html

Restore Hetch Hetchy http://www.hetchhetchy.org/

River Network http://www.rivernetwork.org/

Rivers Reborn:Removing Dams and Restoring Rivers in California (Friends of the River)

http://www.friendsoftheriver.org/riversreborn/tuolumne.html

Russian River Watershed Council http://www.rrwc.net/

Sacramento River Watershed Program http://www.sacriver.org

Sacramento Watershed Action Group http://www.watershedrestoration.org/

Salmon and Steelhead Restoration Group http://www.silichip.org

Salmon Restoration Association https://www.salmonrestoration.com/home.html

Salmon River Restoration Council http://www.srrc.org/

Salmonid Restoration Federation http://www.northcoastweb.com/srf/

San Francisquito Creek CRMP http://www.pccf.org/crmp/index.html

San Francisco Estuary Institute http://www.sfei.org

San Joaquin River Conservancy http://www.sjriverconservancy.com

San Joaquin River Parkway and Conservation Trust http://www.riverparkway.org/

San Lorenzo River Restoration Institute http://gate.cruzio.com/%7Eslriver/

Santa Clara Water Management Initiative http://www.scbwmi.org/

Save our Wild Salmon http://www.wildsalmon.org/

The Sierra Club http://www.sierraclub.org/

Sierra Nevada Alliance http://www.sierranevadaalliance.org/

Sonoma County Conservation Council http://www.monitor.net/%7Eec/groups.htm

South Yuba River Citizens League http://www.syrcl.org/

The Southern California Coastal Watershed Inventory

http://www.regis.berke ley.edu/Coastalconserv/web2/

Stream Restoration Library http://www.gcswcd.com/stream/library/

Streamflow Research http://www.cwest.orst.edu/streamflow/mainpage/hydro.htm

STREAMNET http://www.streamnet.org/

Trout Unlimited http://www.tucalifornia.org/

United Anglers of California http://www.unitedanglers.org

Urban Creeks Council-Sacramento Chapter http://sacto_ucc.tripod.com/Sacto-UCC/

Army Corps of Engineers Sacramento District http://www.spk.usace.army.mil/

U.S Army Corps of Engineers San Francisco District http://www.spn.usace.army.mil/

Bureau of Reclamation Concrete Dams http://www.usbr.gov

U.S Bureau of Reclamation Tracking Ecosystem Restoration Activities-Central Projects
http://www.tera.mp.usbr.gov/projects_activities/central/index.htm

U.S Bureau of Reclamation Tracking Ecosystem Restoration Activities-Northern Projects
http://www.usbr.gov

U.S Bureau of Reclamation Tracking Ecosystem Restoration Activities-Southern Projects
http://www.tera.mp.usbr.gov/projects_activities/southern/index.htm

U.S Department of Agriculture Stream Systems Technology Center
http://www.stream.fs.fed.us/index.html

U.S EPA Adopt Your Watershed http://www.epa.gov/adopt/

U.S EPA Top 10 Watershed Lessons Learned
http://www.epa.gov/owow/lessons/index.html

U.S Fish and Wildlife Service http://www.fws.gov

U.S Fish and Wildlife Service Fish Passage Program
http://fisheries.fws.gov/FWSMA/FishPassage/index.htm

U.S Fish and Wildlife Service Pacific Region http://www.fws.gov

U.S Fish and Wildlife Service Endangered and Threatened Species
http://www.r1.fws.gov/es/endsp.htm

U.S.G.S. Water Resources of California http://water.wr.usgs.gov/

Water Forum http://www.waterforum.org/

The Water Education Foundation http://www.watereducation.org/

Watershed Groups in California http://www.4sos.org/wsgroups/wsgroups-ca.html

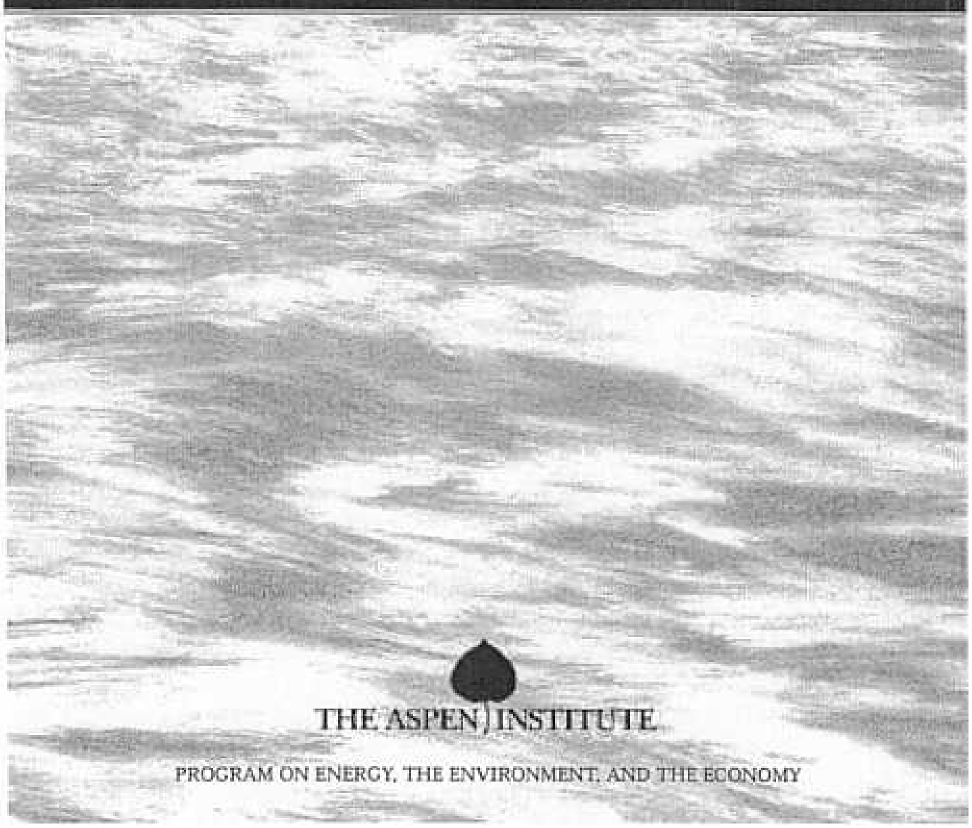
Watershed Management Council http://watershed.org/wmc/index.html

Watershed Projects Inventory http://endeavor.des.ucdavis.edu/wpi/

The Wild Salmon Center http://www.wildsalmoncenter.org

Yolo Basin Foundation http://www.yolobasin.org

Dam Removal ■ *A New Option For a New Century*



APPENDIX D (3)

Dialogue Participants

Margaret Bowman
American Rivers

Mark H. Capelli
National Marine Fisheries Service

R. Scott Carney
PA Fish & Boat Commission

David Clark
MA Dept. of Environmental Management

Kathryn Conant
NOAA, National Marine Fisheries Service

Shannon Cunniff
U.S. Bureau of Reclamation

Thomas F. Donnelly
National Water Resources Association

Wayne D. Edwards
HDR Engineering, Inc.

Forester Einarsen
U.S. Army Corps of Engineers

Meg M. Galloway
WI Dept. of Natural Resources

Jane Hannuksela
NOAA General Counsel

Joan Harn
National Park Service

Alex Hoar
U.S. Fish & Wildlife Service

Robert G. Hunter
Water Watch

Cleveland Kapala
PG&E National Energy Group

Julie A. Keil
Portland General Electric Company

Stephanie Lindloff
NH Dept. of Environmental Services

Steven Malloch
Trout Unlimited

Dave Munro
Skippers Cove Marina, CA

Joseph Pavel
Northwest Indian Fishery Commission

Karen I. Pelto
MA Dept. of Fish & Wildlife

Kyle Schilling
ASCE, Environment & Water Resources Institute

Robert Wengrzynek
USDA NRCS

Marcin Whitman
CA Dept. of Fish & Game

Laura A.S. Wildman
American Rivers

Eugene P. Zeizel
Federal Emergency Management Agency

Dam Removal – A New Option For a New Century is issued on the authority of The Aspen Institute and its Program on Energy, the Environment, and the Economy. It reflects the collective views of the diverse participants in the dialogue and the agreements they reached over two years and, as such, reflects numerous reconciliations. No individual should be presumed to endorse every word; nor should the participation of individuals imply the endorsement of their organizations. The organizations listed are those with which the participants were affiliated at the time of the last meeting.

Examples of barriers to dam removal and its appropriate consideration as a river management option:

- tendency to use inappropriate or one-size-fits-all analyses for what is in fact the unique context of every dam including its physical, ecological, social, economic, regulatory, and legal constraints
- difficulty in quantifying methods for assessing the full range of the costs and benefits of river management options, particularly social, ecological, and historic values
- inadequate inventories of existing and removed dams as a basis for decisionmaking
- absence of periodic, comprehensive evaluations of all dams
- inappropriateness of current regulatory regimes and levels of analyses required for permitting
- lack of clear guidance on the rights and responsibilities of dam owners and other beneficiaries
- shortage of funding, especially for soft costs such as inclusive decisionmaking processes involving all stakeholders
- lack of technical studies on dam removal impacts, benefits, and techniques
- lack of centralized information about the dam removal option
- lack of public understanding of dams and dam removal

Premises

During the initial dialogues that produced this report, the Aspen group agreed on a set of shared premises which provided grounds for further exploration and eventually for the recommendations and action items (detailed in Part I of the report). This agreement was reached only after consideration of the full range of dams, from abandoned mill dams to large, multipurpose dams, and after agreement that removal of a dam can be a reasonable approach to meeting a variety of economic, ecological, water resource, public safety and owner objectives.

The group also developed a list of opportunities that can set the consideration of dam removal in motion, priority issues to consider in dam removal, and lessons learned in the collective experience of the group in implementing dam removal (described in Part II of the report).

The Aspen Institute's new report, *Dam Removal – A New Option For A New Century*, is now available. The following summarizes the report and its recommendations. Please access the full report using the contact information on the back cover of this pamphlet.

The United States relies on dams and reservoirs. From the earliest settlements to today, communities have diverted and stored water for many uses. Now, however, along rivers and lakes from New England to California, some of the tens of thousands of dams in the United States are aging beyond their expected lifespan, and some are causing a variety of safety, environmental, and other problems. Dealing with these situations can be a costly and controversial task, complicated by society's changing views of dams. Once perceived as almost entirely beneficial, dams are seen more realistically today as having both positive and negative effects, some obvious and quantifiable, and others less so.

One possible solution to these dilemmas—and in some cases the best solution—is dam removal. The removal of some dams can be straightforward and inexpensive. But for many dams, evaluating and implementing this option can be difficult.

In September 2000, The Aspen Institute's Program on Energy, the Environment, and the Economy invited a group of twenty-six experts to address these issues in a series of intentional, values-based dialogues. This report offers the group's recommendations and practical advice aimed at integrating the dam removal option into river management decisions, evaluating the options fairly and, if appropriate, implementing the dam removal option effectively. The imprimatur of this diverse group, with interests that are often at odds, lends a unique weight to the recommendations.

Recommendations

The Aspen group recommends the following to policymakers and practitioners at the national, state, and local levels:

- Reflect the scale of the project and scope of the project's impacts in the depth and type of analysis associated with a decision about any dam.
- Integrate dam removal at appropriate levels as an option in decisionmaking regarding dams, including the regulatory process, watershed planning, and community decision making.
- Review all dam structures and operations periodically and within a reasonable time frame; reviews should address environmental, economic, and social benefits and impacts in addition to dam safety.
- Provide public notice and opportunity for comment regarding dam removal decisions when public resources are affected.
- Consider social, ecological, and historical values in decisionmaking about dam removal.
- Address the rights of dam owners and beneficiaries of dam services.
- Revise permitting processes to ensure that shortterm impacts of dam removal do not preclude projects for which restoration benefits outweigh those impacts.
- Coordinate policies and regulatory programs affecting dam removal.
- Expand, integrate, and where necessary establish dam inventories so that a comprehensive inventory of all dams (regardless of size) is available.
- Develop technical guidance and site-appropriate practices for implementing dam removal.
- Increase scientific research and educational curricula on dam removal.
- Provide public education on dams and dam removal.
- Establish and maintain a user-friendly, centralized, Web-based clearinghouse for dam removal information.
- Establish financial responsibility for dam removal.
- Improve funding opportunities for dam removal.

THE ASPEN INSTITUTE

Program on Energy, the Environment, and the Economy
One Dupont Circle, NW, Suite 700
Washington, DC 20036
www.aspeninst.org/damremovaloption

A full copy of the report can be found on-line or by contacting

The Aspen Institute
Publication Orders
109 Houghton Lab Lane
PO Box 222
Queenstown, MD 21658
410 820 5338

APPENDIX D(4)

FISH PASSAGE INVENTORY – FIRST PASS DATA SHEET

California Fish Passage Forum

[To be used for quick first pass simple inventories of all types of fish passage problems or during any other type of stream survey or restoration work. Provides standardized data entry sheet for collecting new barrier/stream structure information to be directly incorporated into Passage Assessment Database.]

I. GENERAL

Surveyor: | **Date:** / / | **Time:** AM/PM

Agency:

Weather: □ sunny □ overcast □ raining

Water Conditions: □ clear □ turbid

Flow Conditions: □ continuous □ isolated pools □ dry

Water Temperature (°C): | **Ambient Temperature (°C):**

II. LOCATION

Latitude: | **Longitude:** | **Quad Name:**

Stream Name: | **Tributary To:**

Bank Location (looking downstream)**:** □ left □ right □ both

Channel Type: □ **V** □ **U**

Road Name: **Milepost:** | **Photos Taken?** □ Yes □ No

Photo Description/Numbers:

Land Owner: | **Structure Owner:**

III. STRUCTURE

Structure Type: □ diversion □ dam □ natural □ culvert □ bridge □ other____________

Description:

IV. FISH

Fish Observed? □ Yes □ No | **Salmonids Observed?** □ Yes □ No

V. DIVERSION

Diversion Type: □ slant □ siphon □ vertical □ floodgate □ submersible □ centrifugal □ weir □ pump

Pipe Size: □ < 1 ft. □ 1 – 2 ft. □ > 2 ft.

Screened? □ Yes □ No | **Pump Running?** □ Yes □ No

VI. CULVERT

Culvert Type: □ box □ circular □ other___________ □ pipe arch

Culvert Material: □ concrete □ structural plate □ log/wood □ plastic □ other___________

Culvert Diameter: □ ≤ 2 ft. □ > 2 ft.

Outlet Drop Height: □ < 1 ft. □ 1 – 3 ft. □ > 3 ft.

Number of Culverts:

Weirs/Baffles? □ Yes □ No

VII. DAM

Dam Type: □ earth □ rock/cement □ other____________

Dam Width: | **Dam Height:**

□ **Seasonal** □ **Permanent**

Passage Facility? □ Yes □ No

VIII. BRIDGE

Bridge Type: □ free span □ instream structure

□ **Active** □ **Abandoned**

Apron? □ Yes □ No

IX. NATURAL

Natural Barrier Type: □ waterfall □ grade □ landslide □ log jam □ other___________

Waterfall Drop: □ ≤ 8 ft. □ > 8 ft.

ADDITIONAL NOTES:

TERMINOLOGY

I. GENERAL

Water Conditions

Clear-free from pollution or cloudiness
Turbid-muddy or cloudy water

Flow Conditions

Continuous-Free flowing water
Isolated pools-Pools are present but they are not connected by free flowing water
Dry-no water at all

II. LOCATION

Latitude/Longitude-North American Datum 1983.

Quad Name-U.S.G.S. 7.5 minute Quadrangle name if known

Bank Location-where in the stream the structure is located

Channel Type

V-For general description purposes, is the channel shaped like a V
U-For general description purposes, is the channel shaped like a U, bank slopes more gradual than V channel

Milepost-Generally, both State and County roads have markers located every half mile indicating the road/highway number, county it is located in, and the postmile or kilopost location of the marker. For north/south roads, the markers start at 0.00 from the southern end and progress upwards as you travel north. For west/east roads, the markers start at 0.00 from the western end and increase as you travel east.

Land Owner-may be private, public, tribal, or unknown-if known, put down owners name and contact info

Structure Owner-may be different from land owner- if known, put down owners name and contact info

III. STRUCTURE

Structure Type

Diversion- The transfer of water from a stream by a pipe, canal, well, or other conduit to another watercourse or to the land
Dam- A man-made barrier constructed across a stream and designed to control water flow or create a reservoir
Natural- A barrier that is not man-made, such as: waterfall, beaver dam, insufficient flow, landslide, velocity, etc.
Culvert- A pipe that allows streams, rivers, or runoff to pass under a road
Bridge-A structure conveying a road or pathway over a stream, river, or a depression
Other-Something that is not described in the above categories

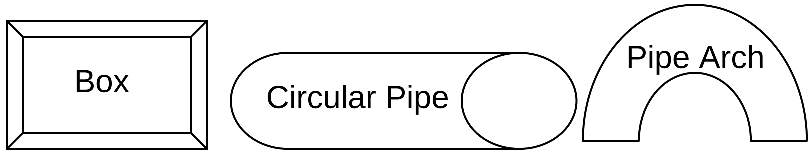
V. DIVERSION

Diversion Type

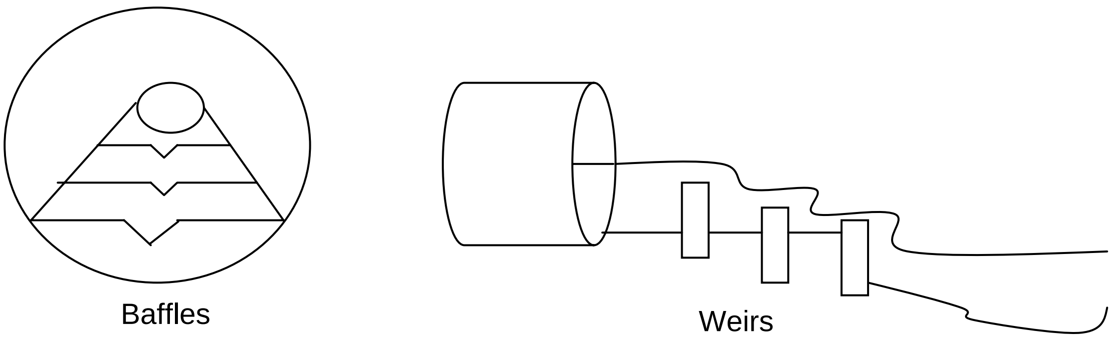
Slant-Both the pump and intake pipe are angled at a slant up the river the river bank
Submersible-The pump for diverting water is submerged under the water or bank and is not visible
Vertical-The pump is vertically oriented and pulls water straight up
Floodgate-Water diversion where water is diverted by gravity flow and controlled via a screwgate
Pump-Water diversion where type of pump used is unknown but use of a pump is certain
Centrifugal-Old style pump which has a similar visual appearance to a snail shell (spiral or circular)
Weir-Type of dam structure, usually spanning both banks, where flashboards are used to create head for the pump
Siphon-Intake pipe which bends from the river source over a levee into a discharge. No pump is involved, it diverts when the head differential is such that water automatically starts flowing into the discharge. It works by suction, or capillary action.

Screened-Fish screens are supposed to keep fish from being taken out of a stream or river by a water diversion.

VI. CULVERT
Culvert Type



Weirs/Baffles-These are generally structures that are added as a retrofit to a culvert (baffles), or placed in the stream (weirs) to reduce velocity or improve fish passage in some way.



VII. DAM
Passage Facility-Is there a fish ladder, natural fishway bypass, or some other structure in place to improve fish passage?

VIII. BRIDGE
Bridge Type

Free span-no part of the bridge is in the stream
Instream structure-an abutment, pier, or some other part of the bridge is in the stream

Active/Abandoned-Is the bridge still utilized for vehicular or pedestrian traffic, or is it abandoned

Apron-A protective shield, usually made of concrete, to protect against erosion, may be around piers or abutments or span the entire creek

IX. NATURAL
Natural Barrier Type

Waterfall- A sudden, nearly vertical drop in a stream, as it flows over rock
Grade-The topography of the streambed is too steep for fish to ascend
Landslide-Movement of earth down a steep slope into a stream that blocks fish passage
Log jam-Log debris in a stream such that it blocks fish passage