FINAL REPORT: DEL NORTE COUNTY CULVERT INVENTORY AND FISH PASSAGE EVALUATION

By

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INTRODUCTION

The inventory and fish passage evaluation of culverts within the Del Norte County road system was conducted between August, 1998 and December, 2000 under contract with the California Department of Fish and Game (CDFG) (contract # **FG 8094 WR**). The primary objective was to assess passage of juvenile and adult salmonids and develop a project-scheduling document to prioritize corrective treatments to provide unimpeded fish passage at road/stream intersections. The inventory was limited to county-maintained crossings within anadromous stream reaches known to historically and/or currently support runs of coho salmon (*Oncorhynchus kisutch*), steelhead (*O. mykiss irideus*) and/or coastal cutthroat trout (*O. clarki clarki*).

The inventory and assessment process included:

1. locating stream crossings within anadromous stream reaches;
2. visiting each culvert location during both late-summer/early fall low flow and during winter storm events;
3. collecting information regarding culvert specifications;
4. assessing fish passage using culvert specifications and passage criteria for juvenile and adult salmonids (from scientific literature and FishXing computer software);
5. assessing quality and quantity of stream habitat above and below each culvert; and
6. assessing fish passage by direct observation at culvert sites during fall/winter migration period.

The prioritization process ranked culvert sites by assigning numerical scores for the following criteria:

1. Presumed species diversity within stream reach of interest (and federal listing status);
2. extent of barrier for each species and lifestage for range of estimated migration flows;
3. quality and quantity of potential upstream habitat gains;
4. sizing of current stream crossing (risk of fill failure); and
5. condition of current crossing (life expectancy).

The initial ranking was not intended to provide an exact order of priority, rather produce a first-cut rank in which sites could be grouped as high, medium, or low priority. Professional judgement was a vital component of the ranking process. Site-specific information that is difficult to assign a discrete numerical value was also considered.

Examples include:

1. Direct observations of attempted migration at known barriers. Treating these sites should result in a high probability of immediate utilization of re-opened habitat.

2. Fish behavior at culverts. Recent studies suggests salmonids experience migration difficulties at road crossings that exhibit hydraulic characteristics within the reported abilities of several salmonid species (Taylor 2000; Love et al. pers. comm.).

3. Physical stress or danger to migrating salmonids. Recent studies have revealed several sites where concentrations of migrating salmonids were subjected to decades of predation by birds and mammals or poaching by humans (Taylor 2000). Inability to enter coolwater tributaries to escape stressful/lethal mainstem water temperatures during summer months has also been observed. These factors should weigh heavily in priority ranking.

Additional physical, operational, social, and/or economic factors exist that may influence the final order of sites; but these are beyond the scope of this project.

Final Product of Culvert Inventory

A hard copy and a diskette of this project-scheduling document were distributed to the following agencies and departments: Del Norte County Community Development Center; CDFG- Inland Fisheries Division and Region 1 Office (copy for each office); and Five-Counties Salmon Group.

Final report includes:

1. A count and location of all culverted stream crossings. Locations were identified by stream name; road name; watershed name; mile marker or distance to nearest crossroad; Del Norte county road map #; Township, Range and Section coordinates; and lat/long coordinates. All location data were entered into a spreadsheet for potential database uses.

2. For each site, culvert specifications were collected, including: length, diameter, type, position relative to flow and stream gradient, amount of fill material, depth of jump pool below culvert, height of jump required to enter culvert, previous modifications (if any) to improve fish passage, and evaluate effectiveness of previous modifications. All site-specific data were entered into a spreadsheet for potential database uses.

3. Information regarding culvert age, wear, and performance was collected, including: overall condition of the pipe, height of the rust line, and ability to pass flow (and debris) during the past two winters of moderately large storm events. Presence or absence and condition of trash racks was also assessed. All culvert specifications were entered into a spreadsheet for potential database uses.

4. An evaluation of fish passage at each culvert location. Fish passage was evaluated by two methods. First, the information collected on culvert specifications was used to calculate hydraulic characteristics of each culvert over a range of expected migration flows. These values were compared to values cited in current scientific literature regarding the leaping and swimming abilities of juvenile and adult coho salmon, steelhead, and coastal cutthroat trout. FishXing (a computer software program) modeled culvert hydraulics over the range of migration flows and compared these values with leaping and swimming abilities of the fish species and lifestage of interest. Secondly, fish passage was assessed by on-site observations of fish movement during expected periods of migration; primarily during and after rain storms between the months of November and March.

5. Photo documentation of each culvert to provide visual information regarding inlet and outlet configurations. Site photographs were digitized and provided on diskettes for easy insertion into any future reports, proposals, or presentations

6. An evaluation of quantity and quality of fish habitat above and below each culvert location. Some information was obtained from habitat typing surveys previously conducted by CDFG, watershed groups, and/or timber companies. Where feasible, a first-hand inspection and evaluation of stream habitat occurred. Length of potential anadromous habitat was also estimated from USGS topographic maps. In situations where formal habitat typing surveys were not conducted and/or access to stream reaches was not permitted, professional judgement of biologists familiar with watershed conditions was utilized.

7. A ranked list of culverts that require treatment to provide unimpeded fish passage to spawning and rearing habitat. On a site-by-site basis, general recommendations for providing unimpeded fish passage were provided. For example, some stream crossings may require a bridge or properly-sized culvert set below stream grade to accommodate fish passage, whereas other locations may just require building up the outlet pool with rip rap to backflood the culvert inlet and/or baffles to reduce velocities within the culvert.

Project Justification

Fish passage through culverts is an important factor in the recovery of depleted salmonid populations throughout the Pacific Northwest. Although most fish-bearing streams with culverts tend to be relatively small in size with only a couple of miles or less of upstream habitat, thousands of these exist and the cumulative effect of blocked habitat is probably quite significant. Culverts often create temporal, partial or complete barriers for anadromous salmonids on their spawning migrations (Table 1) (adapted from Robison et al. 2000).

Typical passage problems created by culverts are:

- Excessive drop at outlet (too high of entry leap required);
- Excessive velocities within culvert;
- Lack of depth within culvert;
- Excessive velocity and/or turbulence at culvert inlet; and
- Debris accumulation at culvert inlet and/or within culvert.

Table 1. Definitions of barrier types and their potential impacts.

Barrier Category	Definition	Potential Impacts
Temporal	Impassable to all fish some of the time	Delay in movement beyond the barrier for some period of time
Partial	Impassable to some fish at all times	Exclusion of certain species and lifestages from portions of a watershed
Total	Impassable to all fish at all times	Exclusion of all species from portions of a watershed

Even if culverts are eventually negotiated, excess energy expended by fish may result in their death prior to spawning, or reductions in viability of eggs and offspring. Migrating fish concentrated in pools and stream reaches below road crossings are also more vulnerable to predation by a variety of avian and mammalian species, as well as poaching by humans. Culverts which impede adult passage limit the distribution of spawning, often resulting in underseeded headwaters and superimposition of redds in lower stream reaches.

Current guidelines for new culvert installation aim to provide unimpeded passage for both adult and juvenile salmonids (NMFS 2000). However many existing culverts on federal, state, county, and private roads are barriers to anadromous adults, and more so to resident and juvenile salmonids whose smaller sizes significantly limit their leaping and swimming abilities to negotiate culverts. For decades, “legacy” culverts on established roads have effectively disrupted the spawning and rearing behavior of all four species of anadromous salmonids in California: Chinook salmon, (*Oncorhychus tschawytschaw*), coho salmon, coastal rainbow trout (steelhead are anadromous coastal rainbow trout), and coastal cutthroat trout.

In recent years, there has been a growing awareness of the disruption of instream migrations of resident and juvenile salmonids caused at road/stream intersections. Instream movements of juvenile and resident salmonids are highly variable and still poorly understood by biologists. Juvenile coho salmon spend approximately one year in freshwater before migrating to the ocean, and juvenile steelhead may rear in freshwater for up to four years prior to out-migration (one to two years is most common in California). Thus, juveniles of both species are highly dependent on stream habitat. Many studies indicate that a common strategy for over-wintering juvenile coho is to migrate out of larger river systems into smaller streams during late-fall and early-winter storms to seek refuge from possibly higher flows and potentially higher 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). Recent research conducted in coastal, northern California watersheds suggests that juvenile salmonids migrate into smaller tributaries in the fall and winter to feed on eggs deposited by spawning adults as well as flesh of spawned-out adults (Roelofs, per. comm). Direct observation at numerous culverts in northern California confirmed similar upstream movements of three year-classes of juvenile steelhead (young-of-year, 1-year old and 2-year old) (Taylor 2000).

Coastal cutthroat trout are present in many smaller tributaries in northern California, including nearly all watersheds within Del Norte County. This unique species is known for a wide variety of life-history strategies that encompass headwater resident populations, resident fish that migrate to and from mainstem channels for foraging and into small tributaries for spawning, and sea/estuary-run fish. In Del Norte County, significant sea-run populations of coastal cutthroat trout are in present in Lake Earl, Smith River, and lower Klamath River. Spawning migrations of all three life-history types often occur into the upper reaches of a watershed's smallest tributaries, often the tributaries where culverts are located. Numerous studies suggest that coastal cutthroat trout require spatial separation of spawning and rearing to reduce direct competition with larger (and more aggressive) steelhead and coho salmon (Behnke 1972, 1992; Campton and Utter 1985; Taylor 1997).

The variable life history of resident coastal rainbow trout is similar to coastal cutthroat trout, exhibited by seasonal movements in and out of one or more tributaries within a watershed. Again, smaller tributaries are where most culverts are still located since larger channels tend to be spanned by bridges.

In response to the 1994 federal listing of coho salmon as threatened in northern California, five counties (Humboldt, Del Norte, Trinity, Mendocino, and Siskiyou) formed the Five-Counties Salmon Group to examine various land-use activities conducted or permitted under county jurisdiction that may impact coho salmon habitat. Initial meetings identified causative factors of potential impacts, information gaps, and priority tasks required to obtain missing information. A high-priority task included conducting culvert inventories on county roads to evaluate fish passage and prioritize treatments.

Anadromous salmonids will benefit from this planning effort because the final document will provide Del Norte County's Community Development Department with a prioritized list of culvert locations to fix that will provide unimpeded passage for all species (and life stages) of salmonids. Report information will assist in proposal development to seek State and Federal money to implement treatments. The inventory will also provide the County with a comprehensive status evaluation of the overall condition and sizing of culverts within fish-bearing stream reaches, providing vital information to assist the County's general planning and road's maintenance needs.

METHODS AND MATERIALS

Methods for conducting the culvert inventory and fish passage evaluation included eight tasks; accomplished generally in the following order:

1. Location of culverts.
2. Initial site visits and data collection.
3. Estimation of tributary-specific hydrology and design flows for presumed migration period.
4. Data entry and passage analyses with FishXing.
5. Site visits for migration observations during fall/winter migration flows.
6. Collection and interpretation of existing habitat information.
7. Prioritization of sites for corrective treatment.
8. Site-specific recommendations for unimpeded passage of both juvenile and adults salmonids.

Location of Culverts

Preliminary project scoping included examination of Del Norte County road system maps and counting road/stream intersections on known anadromous stream reaches. The National Marine Fisheries Service (NMFS) coho salmon stock questionnaire list was used to identify and locate coho and steelhead streams on the Del Norte County road maps. NMFS's list of current and historic coho streams was based heavily on a compilation of field and survey reports produced by Brown and Moyle (1989). Nineteen county culverts were initially identified on coho-bearing reaches of streams, primarily within three major watersheds: Smith River, Lake Earl and the lower Klamath River. The remaining culverts were located on smaller coastal streams that drain directly into the Pacific ocean.

Because the use of maps was considered a rough, first-cut at locating potential culvert locations, additional sites were also investigated once the project started. Most of these sites were identified by fisheries biologists, restoration groups, or watershed groups with intimate knowledge regarding their local streams (Burgess, Schlotter, McLeod, Waldvogel, and Perry pers. com.) .

Initial Site Visits

The objective of the initial site visits was to collect physical measurements at each crossing to utilize with the fish passage evaluation computer software (FishXing). Notes describing the type and condition of each culvert, as well as qualitative comments describing stream habitat immediately above and below each culvert were also included. Photographs of the outlet and inlet were taken at each site.

Culvert Location

The location of each culvert was described by: Del Norte County road system map # ; road name; stream name; watershed name; Township, Range, and Section; latitude and longitude; and mile marker or distance to nearest cross-road. If more than one county road culvert crossed single stream, a number was assigned to the stream name with the #1 culvert located farthest downstream (numbering then proceeded in an upstream direction). Lat/long coordinates were determined using Terrain Navigator (Version 3.01 by MapTech), a geo-referenced mapping software program (North American 1927 datum).

Longitudinal Survey

A longitudinal survey was shot at each culvert to provide accurate elevation data for FishXing passage analyses. We utilized an auto-level (Topcon AT-G7) with an accuracy of ± 2.5 mm, a domed-head surveyor's tripod, and a 25' leveling rod in 1/100' increments. All data and information were written into a bound, water-proof, field data sheets or on water-proof data sheets with a pencil. On a weekly basis, fieldbook notes or data sheets were photocopied to provide a back-up in case of loss or destruction of originals.

Once a site was located in the field by the two-person survey crew, bright orange safety cones with signs marked "Survey Party" were placed to warn oncoming traffic from both directions. Bright orange vests were also worn by the survey crew. Vests increased one's visibility to traffic, and decreased suspicions of nearby property owners to our unannounced presence in the roadside stream channel. If sites were close to private residences, we attempted to contact the property owners to inform them of our survey of the county-maintained road crossing.

To start the survey, a 300-foot tape (in 1/10' increments) was placed down the approximate center of the stream channel. The tape was started on the upstream side of the culvert, usually in the riffle crest of the first pool or run habitat unit above the culvert. This pool or run would be considered the first available resting habitat for fish negotiating the culvert. The tape was set to follow any major changes in channel direction. The tape was set through the culvert and continued downstream to at least the riffle crest (or control) of the pool immediately downstream of the culvert outlet. If several "stair-stepped" pools led up to the culvert inlet, then the tape was set to the riffle crest of the lower-most pool. Extreme caution was used when wading through culverts. A hardhat and flashlight were standard items used during the surveys.

The tripod and mounted auto-level were set in a location to eliminate or minimize the number of turning points required to complete the survey. If possible, a location on the road surface was optimal, allowing a complete survey to be shot from one location. The leveling rod was placed at the thalweg at various stations along the center tape, generally capturing visually noticeable breaks in slope along the stream channel.

At all sites, five required elevations were measured:

- culvert inlet,
- culvert outlet,
- maximum pool depth within five feet of the outlet,
- outlet pool control, and
- ordinary high water (OHW) mark at the outlet pool control. The OHW mark should correspond to the height of flow during an active channel discharge event. An active channel flow is less than a bankfull channel flow.

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

- Apparent breaks-in-slope within the crossing. Older culverts can bend when road fills slump, creating steeper sections within a culvert. If only inlet and outlet elevations are measured, the overall slope will predict average velocities less than actual velocities within steeper sections. These breaks-in-slope may act as velocity barriers, which are masked if only the overall slope of the culvert is measured.

- Steep drops in the stream channel profile immediately upstream of the culvert inlet. Measure the elevation at the tail of the first upstream holding water (where the tape was set) to estimate the channel slope leading into the culvert. In some cases, a fish may negotiate the culvert only to fail at passing through a velocity chute upstream of the inlet entrance. Inlet drops often create highly turbulent conditions during elevated flows.

All elevations were measured to the nearest 1/100' and entered with a corresponding station location (distance along tape) to the nearest 1/10'.

<u>Channel widths</u>

Where feasible, at least five measurements of the active channel width above the culvert (visually beyond any influence the crossing may have on channel width) were taken. Active channel is defined as the portion of channel commonly wetted during and above winter base flows and is identified by a break in rooted vegetation or moss growth on rocks along stream margins. Some culvert design guidelines utilize active channel widths in determining the appropriate widths of new culvert installations (Robison et al 2000; NMFS 2000; Bates et al. 1999).

Although not required, in many cases a cross-section survey of at least the bankfull channel width at the outlet pool control was measured to increase the accuracy of passage analyses. For more detail, refer to the extensive “Help files” provided with FishXing (Love 2000).

Fill Estimate

At each culvert, the amount of road fill was estimated by calculating the volume of fill prism between the road surface and the culvert (Figure 1) (from Flannigan et al 1999).

Fill volume was estimated to:

1. assist in development of cost estimates for barrier removal by estimating equipment time required for fill removal and disposal site space needed;
2. calculating culvert capacity at HW/D = fill height; and
3. evaluating the consequences of fill failure by: Sediment volume + risk of failure = consequence to stream habitat.

The fill prism was calculated from the following measurements:

1. Upstream and downstream fill slope measurements (L_d and L_u).
2. Slope (%) of upstream and downstream fill slopes.
3. Width of road prism (W_r).
4. Length of road prism (W_u).
5. Channel width (flood prone width) (W_c).

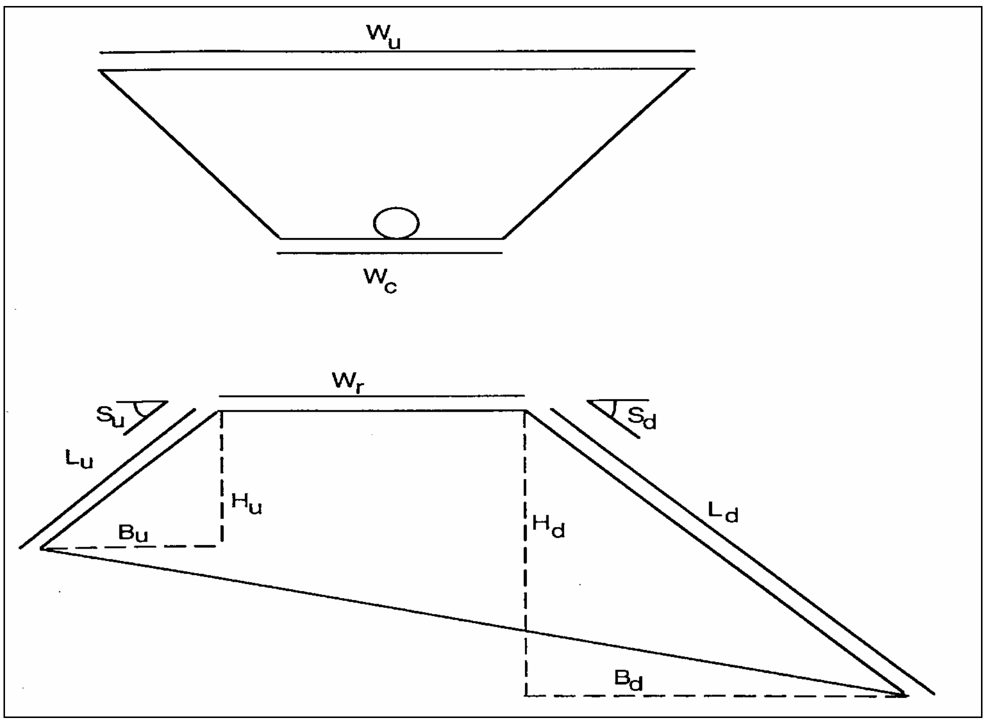

Figure 1. Fill measurements – solid lines were measured values, dashed lines were calculated.

Other Site-specific Measurements

For each site, the following culvert specifications were collected:
1. Length (to nearest 1/10 of foot);
2. Dimensions: diameter (circular), or height and width (box culverts), or span and rise (pipe arches);
3. Type: corrugated metal pipe (CSP), structural steel plate (SSP), concrete pipe, concrete box, bottomless pipe arch, squashed pipe-arch, or a composite of materials;
4. Overall condition of the pipe (good, fair, poor, extremely poor);
5. Height and width of the rust line (if present);
6. Position relative to flow and stream gradient;
7. Depth of jump pool below culvert;
8. Height of jump required to enter culvert;
9. Previous modifications (if any) to improve fish passage; and
10. Condition of previous modifications.

Qualitative notes describing stream habitat immediately upstream and downstream of each culvert were taken. Where feasible, variable lengths of the stream channel above and below crossings were walked to detect presence of salmonids and provide additional information regarding habitat conditions.

Data Entry and Passage Analyses

All survey and site visit data were recorded in either a bound, waterproof, field notebook; or on waterproof data sheets. Then data for each culvert were entered into a spreadsheet (Excel 97). A macro was created to calculate thalweg elevations of longitudinal profiles and compute culvert slopes.

NOTE: FishXing Overview, Hydrology and Design Flow, Peak Flow Capacity, and Fish Passage Flows sections were written by Michael Love under a separate contract administered by CDFG (Taylor and Love, 2001).

FishXing Overview

FishXing is a computer software program developed by Six Rivers National Forest's Watershed Interactions Team - a group of scientists with diverse backgrounds in engineering, hydrology, geomorphology, geology and fisheries biology. Mike Furniss, a Forest Service hydrologist for Six Rivers, managed program development. Test versions of FishXing were used during the Del Norte County culvert inventory, which provided an excellent testing ground for evaluating fish passage though a wide variety of culvert configurations, as well as catching glitches and bugs in the software.

A CD-ROM final version of FishXing was released in March, 2000. In-depth information regarding FishXing (or a copy) may be obtained at the Fish Crossing homepage on the internet (www.stream.fs.fed.us/fishxing/).

FishXing is an interactive software package that integrates a culvert design and assessment model for fish passage nested within a multimedia educational setting. Culvert hydraulics are well understood and model output closely resembles reality. FishXing successfully models (predicts) hydraulic conditions throughout the culvert over a wide range of flows for numerous culvert shapes and sizes. The model incorporates fisheries inputs including fish species, life stages, body lengths, and leaping and swimming abilities. FishXing uses the swimming abilities to determine whether the culvert installation (current or proposed) will accommodate fish passage at desired range of migration flows, and identify specific locations within the culvert that impede or prevent passage. Software outputs include water surface profiles and hydraulic variables such as water depths and average velocities displayed in both tabular and graphical formats.

FishXing used the survey elevation and culvert specifications to evaluate passage for each species and lifestages of salmonids known to currently or historically reside in the Del Norte County streams of interest. The swimming abilities and passage criteria used for each species and lifestage are listed Table 2. Although many individual fish will have swimming abilities surpassing those listed below, swim speeds were selected to ensure stream crossings accommodate passage of weaker individuals within each age class.

FishXing and other hydraulic models report the average cross-sectional water velocity, not accounting for spatial variations. Stream crossings with natural substrate or corrugations will have regions of reduced velocities that can be utilized by migrating fish. These areas are often too small for larger fish to use, but can enhance juvenile passage success. The software allows the use of reduction factors that decrease the calculated water velocities proportionally. As shown in Table 2, velocity reduction factors were used in the passage analysis of cutthroat trout, resident fish, and juveniles with specific types of stream crossing structures.

Using the FishXing program, the range of flows that meet the depth, velocity, and leaping criteria for each lifestage were identified. The range of flows meeting the passage requirements was then compared to the lower and upper fish passage flows to determine "percent passable".

Table 2. Fish species and lifestages used in the fish passage along with associated swimming abilities and passage criteria. Passage flows are based on current adult salmonid criteria combined with observational data from northern California coastal streams.

Fish Species/Age Class	**Adult Steelhead, Chinook, and Coho**	**2+ Rainbow/ Cutthroat Trout**	**1+ Rainbow/ Cutthroat Trout**	**Young of the Year (YoY)**
Fish Length	500 mm	200 mm	130 mm	80 mm
Prolonged Mode				
Swim Speed	6.0 ft/s	2.8 ft/s	2.4 ft/s	2.0 ft/s
Time to Exhaustion	30 min	30 min	30 min	30 min
Burst Mode				
Swim Speed	10.0 ft/s	6.4 ft/s	4.5 ft/s	3.0 ft/s
Time to Exhaustion	5 s	5 s	5 s	5 s
Velocity Reduction Factors**	Inlet = 1.0 Barrel = 1.0 Outlet = 1.0	Inlet = 0.8 Barrel = 0.6 Outlet = 0.8	Inlet = 0.8 Barrel = 0.6 Outlet = 0.8	Inlet = 0.8 Barrel = 0.6 Outlet = 0.8
Maximum Leaping Speed	12.0 ft/s	6.4 ft/s	4.5 ft/s	3.0 ft/s
Minimum Required Water Depth	0.8 ft	0.5 ft	0.3 ft	0.2 ft
Minimum Passage Flow	95% flow (Nov-April)	95% flow (Nov-April)	95% flow (Nov-April)	95% flow (Nov-April)

** Velocity reduction factors only apply to culverts with corrugated walls, baffles, or natural substrate. All other culverts had reduction factors of 1.0 for all fish.

Hydrology and Design Flow

When examining stream crossings that require fish passage, three specific flows were considered: peak flow capacity of the stream crossing and the upper and lower fish passage flows. Because flow is not gauged on most small streams, it was estimated using different techniques that required hydrologic information about the stream crossing's contributing watershed, such as:

- Drainage area;
- Mean annual precipitation; and
- Average basin elevation.

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

Peak Flow Capacity

Peak flows are typically defined in terms of a recurrence interval, but reported as a quantity; often as cubic feet per second (cfs). Current guidelines recommend all stream crossings pass the flow associated with the 100-year flood without damage to stream crossing (NMFS, 2000). Additionally, infrequently maintained culverted crossings should accommodate the 100-year flood without overtopping the culvert's inlet.

Determination of a crossing's flood capacity assisted in ranking sites for remediation. Undersized crossings have a higher risk of catastrophic failure, which often results in the immediate delivery of the road fill's sediment to the downstream channel. Undersized crossings can also adversely effect sediment transport and downstream channel stability, creating conditions that hinder fish passage, degrade habitat, and may cause damage to other stream crossings and/or private property.

The first step was to estimate hydraulic capacity of each inventoried stream crossing. Capacity is generally a function of the shape and cross-sectional area of the inlet. When assessing the flow capacity of an existing culvert, a headwater-to-diameter ratio equal to one (HW/D = 1) was used.

The culvert's hydraulic capacity was determined with both the FishXing program and from inlet control nomographs published by the Federal Highways Administration (Normann, 1985).

The second step was to estimate peak flows at each crossing. This required estimating the 10-year, 25-year, 50-year, and 100-year peak flows. Two methods were employed: regional flood estimation equations for various recurrence intervals and estimates using local stream gauging data. Values generated by each method were compared, and outliers were excluded from the reported figures.

Flood estimators have been developed for regions within and adjacent to Del Norte County by the USGS (Waananen and Crippen, 1977), the US Forest Service (Ott Water Engineers, 1979), and the Oregon Department of Fish and Wildlife (Klein, per. comm.). These equations require general hydrologic information pertaining to the watershed, such as drainage area and mean annual precipitation. To identify the best flood estimation equations, the predicted 10-year, 25-year, 50-year, and 100-year peak flows were compared to estimates from local gaged streams. The USGS equations were found to best describe peak flow conditions within the region and were used to assess stream crossing capacity.

The third step was to compare the stream crossing capacity to peak flow estimates. Risk of failure was assessed by comparing a stream crossing's hydraulic capacity with the estimated peak flow for each recurrence interval. Each crossing was placed into one of five "sizing" categories:

1. equal to or greater than the 100-year flow,
2. between the 50-year and 100-year flows,
3. between the 25-year and 50-year flows,
4. between the 10-year and 25-year flows,
5. or less than the 10-year flow.

These categories were utilized in the ranking matrix.

Fish Passage Flows

It is widely agreed that designing stream crossings to pass fish at all flows is impractical (NMFS 2000; Robison et al. 2000; SSHEAR 1998). Although anadromous salmonids typically migrate upstream during higher flows triggered by hydrologic events, it is presumed that migration is naturally delayed during larger flood events. Conversely, during low flow periods on many smaller streams, water depths within the channel can become impassable for both adult and juvenile salmonids. 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 (NMFS, 2000).

Upper fish passage flow for adult salmonids (Q_{hp}) is defined as the 2% exceedence flow (the flow equaled or exceeded 2% of the time) during the period of migration (Nov.-April), and the **lower fish passage flow (Q_{lp})** is the 95% exceedence flow for the migration period. Between the lower and upper passage flows stream crossings should allow unimpeded passage of all adult salmonids. Additionally, at the lower passage flow stream crossings should accommodate upstream juvenile passage. Because the upper passage flow for juveniles is not well defined, all fish were assessed using the 2% exceedence flow with the understanding that crossings may not need to pass juvenile fish at such high flows.

To evaluate the extent to which a crossing is a barrier, passage was assessed between the lower and upper passage flows for each fish species and lifestage of concern. Identifying the 2% and 95% exceedence flows required obtaining average daily stream flow data from nearby gauged basins. Most of the stream gages within the region are operated by the USGS and the California Department of Water Resources. In addition, flow data was obtained from Redwood National Park.

The following steps were followed to estimate upper and lower passage flows:

1. Obtained flow records from local stream gages that meet the following requirements:
   - At least 5-years of recorded daily average flows (did not need to be consecutive years);
   - A drainage area less than 50 square miles, and preferably less than 10 square miles; and,
   - Unregulated flows (no upstream impoundments or water diversions) during the migration season.

2. Used a spreadsheet to separate and discard flows outside the adult migration period, which was determined to be from October 1 through April 30.

3. Sorted and ranked flows from highest to lowest (a rank of $i = 1$ given to the highest flow). The lowest flow had a rank of n, which also equaled the total number of flows sorted.

4. Identified the rank associated with the 95% and 2% exceedence flows ($i_{95\%}$ and $i_{2\%}$ respectively), with the following equations:

   $$i_{95\%} = 0.95 \times n \qquad\qquad i_{2\%} = 0.02 \times n$$

   When rounded to the nearest whole number, the flows corresponding to those ranks are the 95% and 2% exceedence flows for the gauged stream.

5. To transfer these flows from the gauged basin to the ungauged basin above a stream crossing, the gaged flows were divided by drainage area and plotted against the mean annual precipitation (MAP) for the basin. A relationship was developed between the MAP within a watershed and the lower and upper passage flows (Appendix C).

6. Finally, the lower and upper fish passage flows for each the stream crossing were calculated using the graphs in Appendix C, the drainage area of the stream crossing, and an estimate of the MAP within the watershed.

   When analyzing fish passage with FishXing, these flows were used to determine the extent to which the crossing is a barrier. The stream crossing must meet water velocity, water depth, and culvert outlet criteria between Q_{lp} and Q_{hp} to be considered 100% passable (NMFS 2000). For the ranking matrix, at each road crossing, the extent of the migration barrier was determined for each salmonid species and lifestage presumed present.

Site Visits for Fish Migration Observations

During late-fall and winter storms, some sites were visited in order to observe salmonids attempting to migrate through culverts. These visits were limited to culverts with perched outlets because turbid conditions of most streams during winter migration flows allowed only observation of jump attempts.

The purpose of these visits was to:
1. confirm upstream migration of adult and/or juvenile salmonids;
2. record numbers of successful and failed attempts at specific culverts;
3. observe behavior of jump attempts;
4. identify locations with high levels of migration;
5. better understand the timing of fish migration as related to storm hydrographs; and
6. measure velocities through culverts and jump heights during migration flows.

The migration observation data was not intended for use in the ranking matrix for several reasons:
1. observations were made at a subset of culvert locations;
2. observations were conducted sporadically at various locations and flow levels; and
3. total observation time (in minutes) accounted for a small fraction of total migration period.

However, this information provided valuable insight of fish behavior at culverts and served as an important component of professional judgement in the final ranking of priority locations. The following protocol was used for conducting observations at perched culverts.

Fish Observation Protocol at Perched Culverts

1. First, measure present water depth inside the culvert at a location where the flow is relatively uniform (such as inlet invert or a specific location within the culvert). Record the location where the depth was measured. Also, if you're at a site with a stage plate record stage level.

2. Observe for jump attempts at culvert outlet for 20 minutes. Station yourself so that the entire outlet area is in view. If using a video camera, position it on a tripod so that the entire outlet is in view (record during the entire observation period). Stay focused on the outlet – jumps often occur quickly (best to have preliminary information entered and a tally table sketched in your field book prior to starting the first 20 minute observation period).

3. If no jump attempts are observed, re-measure the water depth (to determine if flow is rising, steady, or dropping), and then proceed to the next culvert location. Also record location, date, time, and weather conditions.

4. If jump attempts are observed within the first 20 minutes, stay for an additional 20 minute increment. If jump attempts are observed within the second 20 minute increment, stay for a third 20 minute period. Observe and record the following information outlined in steps 5-14. Also record location, date, time, and weather conditions.

5. Count jump attempts, tally as either "successful" or "failed" by juvenile and adult. For adults, note if they enter pipe, but are unable to swim through (see #7 below). Observe and note location of jump attempts.

6. When fish successfully enter the culvert, time how long they are in the pipe. Watch the outlet to see if fish is swept back. If there are two observers, one person should move to the upstream end of the culvert to watch for the fish exiting the culvert inlet.

7. For adult fish, if possible, identify to species. Often the jump (or swim-up) will occur too quickly. However, look for large, irregular-shaped spots on the back to ID chinook (also any fish greater than 20lbs is most likely a chinook). Coho will have small, round spots and may have a drab, olive-colored head and a red body. Steelhead will be more likely seen later in the spawning season (December – March); however look for distinctive red slash along sides and on gill plates. For adults, also break-out jacks (< 50 cm or 22") from larger fish. For adults, also estimate the condition of the fish (bright, dark, fungus on body, cuts or open wounds, "sore tails"). For juveniles, estimate size class as either 3"-5" or 5"-8" or > 8".

8. If possible, examine fish and determine if you can identify individual fish. If so, note time of each jump attempt, and the quality of the attempt (just rolled, ½ way to inlet, almost into inlet, etc.).

9. For failed attempts, what is the probable cause? Too high a jump (fish never enter outlet invert)? Confused outlet flow (baffles or low flow notches may create turbulence at outlet)? Too much velocity (fish enter pipe, but are swept out)? Are fish swept out immediately, or after a period of time (at Sullivan Gulch we noticed some adults would get in pipe, but could not swim to inlet and after several minutes were swept out).

10. A rough velocity estimate can be made by floating an object (stick, orange peel, fern frond, etc.) through culvert and timing with a stopwatch. Repeat at least three times and average all trials.

11. Always measure water depth at the start and end of all observation periods (to determine if flow is rising, steady, or dropping). This is especially important if you're on a re-visit to a location where no jumps were initially observed. If a stage plate is present (at NMFS study sites), record the water level at time of arrival and when you leave.

12. Measure the height of the jump into the culvert from the water surface to the culvert outlet invert. Make this measurement as soon as you see jump attempts and re-measure at the time you leave the culvert site. Also measure depth(s) of jump pool from location(s) of observed jumps.

13. Also visually note the flow and turbidity of the tributary at the culvert site versus the main stream/river channel. Are there differences that may induce juveniles to seek tributary habitat?

14. Note any sign of predation (avian or other) at outlet pools below culverts. This can include observing birds, raccoons, or otters; but also look for and record any sign of fresh tracks or scat on the banks or adjacent riparian vegetation.

15. Sites with high numbers of failed juvenile attempts are often prime candidates for sampling with nets to determine species and numbers of juveniles. Although "high" is subjective, use your best professional judgement and make recommendations for sampling at areas you think are important.

16. Note and record any other observations of interest – are fish being injured at culvert or jumping to exhaustion and moving back downstream? For example, at Sullivan Gulch adult salmon were observed ramming directly into culvert edges and receiving visible gashes (some then swept out of jump pool). Several other adults have missed the culvert inlet and landed on the rip-rap; one dead chinook was found head-first in the mud to the right of the culvert outlet.

17. Note any signs of poaching at pools below culverts, record what you observe and contact Fish and Game Cal-Tip ASAP (1-888-334-2258).

18. Sample Tally Sheet to sketch into field notebook:

ADULTS			JUVENILES		
Species	Success	Fail	Size Class	Success	Fail
Chinook Salmon			3”–5”		
Coho Salmon					
Steelhead Trout			5”-8”		
Cutthroat Trout					
Unknown			>8”		

Habitat Information

Because this project addressed fish passage in many tributaries of several watersheds, plan development was based both on prior assessment and evaluation; and on conducting habitat assessment and evaluation as part of the project. Habitat conditions upstream and downstream of culvert locations relied on previously conducted habitat typing or fisheries surveys. These surveys also provided information on past, present, and future land uses within watersheds that flow through culverts on the Del Norte County road system.

Communication with agency and private-sector biologists, watershed groups, coordinators, restorationists, and large landowners assisted in acquiring additional information on watershed assessment and evaluation (Burgess; Gale; McLeod; Perry; Schlotter; Waldvogel, per. comm.). Habitat information and fish distribution data were used from reports on file at CDFG offices in Eureka, Yurok Tribal Office, and reports located at Humboldt State University library. Personnel from several county, state and federal entities assisted in ranking the biological importance of tributaries crossed by Del Norte County culverts (Burgess; Gale; McLeod; Perry; Schlotter; Waldvogel, per. comm.).

Professional judgment from on-site inspection of culverts and stream habitat also aided habitat assessment and evaluation. In some cases, with landowner permission, longer reaches of stream were walked to better assess quality of habitat above and below county culverts. These surveys also aided in the examination of road crossings on private roads.

Length of potential salmonid habitat upstream of each county culvert was estimated off of digitized USGS 7.5 Minute Series topographic maps (Terrain Navigator, Version 3.01 by MapTech). The upper limit of anadromous habitat was considered when the channel exceeded an eight degree slope.

The presence of additional road crossings, above and below each county-maintained site, was also considered when evaluating potential habitat gains. In many cases, additional road crossings existed, either private-maintained or state (CALTRANS). These crossings were not evaluated in detail (with FishXing), but were examined for length, slope, and presence of perched outlets.

Initial Ranking of Stream Crossings for Treatment

Methods for ranking stream crossings were developed after carefully reviewing criteria used in Oregon (Robison et at. 2000) and Washington (SSHEAR 1998). The two protocols are fairly similar except for how stream habitat information was utilized. Robison et al. (2000) relied mostly on potential species diversity of the fish-bearing channel above a culvert site and did not factor in a "score" for habitat quality.

The Oregon method segregated culverts into five priority types, based on:

- Degree of barrier – partial or complete.
- Risk of failure – flow capacity.
- Species diversity of upstream habitat (in descending order) – coho salmon and others, steelhead and cutthroat, any gamefish, non-fish-bearing but flows into fish-bearing reach.

Once a cursory ranking of culverts was completed, the Oregon method used the input of fisheries professionals with knowledge of the stream's biological significance. The Oregon method also acknowledged numerous social, economic, and technical aspects often influences the ultimate order of treatment locations (and treatment options – replacement versus modification of existing crossing).

Washington used a complex equation which calculates the quadratic root of numerous factors, including discrete values assigned to habitat parameters (both physically measured and visually estimated) (SSHEAR 1998). The equation analyzed passage for each species and lifestage of salmonid which may be present and sums the results for a "score". Thus for each culvert a specific number (and rank) was generated. Initially, the method appears quite objective in nature, yet many of the habitat parameters assigned a discrete value were actually generated from subjective (unrepeatable) estimates. The method also attempted to quantify (and rank) gains in spawning and rearing habitat by assuming all pooltails and riffles are viable spawning habitat. The Washington method has merit, but seemed too complex for the task of determining a first-cut of high, medium, and low priority culvert locations.

The need for extensive habitat information collected in a consistent manner is also time consuming and expensive to generate. Detailed information was not available for many Del Norte County watersheds and conducting surveys was beyond the scope (and budget) of this project. The ranking objective was to arrange the sites in an order from high to low priority using a suite of site-specific information. However, the "scores" generated were not intended to be absolute in deciding the exact order of scheduling treatments. Once the first-cut ranking was completed, professional judgement played an important part in deciding the order of treatment. As noted by Robison et al. (2000), numerous social and economic factors influenced the exact order of treated sites.

Because Del Norte County intends on treating culvert sites identified as "high-priority" by submitting proposals to various fisheries restoration funding sources, additional opportunities for re-evaluating the biological merit of potential projects will occur through proposal review committees composed of biologists from CDFG and other agencies. The methods for ranking culvert locations is a developing process and will undoubtedly require refinement as additional information is obtained. This report also acknowledges (but makes no attempt to quantify or prioritize) that other potentially high-priority restoration projects exist throughout California, and these must all be considered when deciding where and how to best spend limited restoration funds.

Ranking Criteria

The method developed and utilized, assigned a score or value for the following parameters at each culvert location. The total score is the sum of five criteria: species diversity, extent of barrier, sizing, current condition, and habitat score.

1. **Species diversity:** number of salmonid species known to occur (or historically occurred) within the stream reach at the culvert location. **Score:** Because of ESA listing status as threatened, coho salmon = **2** points. Chinook salmon, steelhead and coastal cutthroat trout = **1** point each.

2. **Extent of barrier:** for each species and lifestage known to occur, over the range of estimated migration flows, assign one of the following values. **Score: 0** = 80-100% passable; **1** = 60-80% passable; **2** = 40-60% passable; **3** = 20-40% passable; **4** = less than 20% passable. For total, sum scores given to each species and lifestage.

3. **Sizing (risk of failure):** for each culvert, assign one of the following values as related to flow capacity. **Score: 0 =** sized to NMFS standards of passing 100-year flow at less than inlet height. **1** = sized for at least a 50-year flow, low risk. **2** = sized for at least a 25-year flow, moderate risk.. **3** = sized for less than a 25-year flow, moderate to high risk of failure. **4** = sized for less than a 10-year event, high risk of failure.

4. **Current condition:** for each culvert, assign one of the following values. **Score: 1** = good condition. **2** = fair, showing signs of wear. **3** = poor, floor rusting through, crushed by roadbase, etc. **4** = extremely poor, floor rotted-out, severely crushed, damaged inlets, collapsing wingwalls, slumping roadbase, etc.

5. **Habitat quantity:** above each crossing, length in feet to sustained 8% gradient. **Score:** Starting at a 500’ minimum; 0.5 points for each 500’ size class (**example**: **0** points for <500’; **1** point for 1,000’; **2** points for 2,000’; **3.5** points for 3,500’; and so on).

6. **Habitat quality:** for each stream, assign a “multiplier” of quality (relative to other streams in inventory) after reviewing available information.

- **Score: 1.0 = Excellent-** Relatively undeveloped, “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 inchannel habitat, channel floodplain relatively intact. High likelihood of no future human development. Presence of migration barrier(s) is obviously the watershed’s limiting factor.

- **0.75 = Good-** Habitat is fairly intact, but human activities have altered the watershed with likelihood of continued activities. Habitat still includes dense riparian zones of native species, frequent pools, spawning gravels, cool summer water temperatures, complex inchannel habitat, channel floodplain relatively intact. Presence of migration barrier(s) is most likely one of the watershed’s primary limiting factor.

- **0.5 = Fair-** Human activities have altered the watershed with likelihood of continued (or increased) activities, with apparent effects to watershed processes and features. Habitat impacts include: riparian zone present but lack of mature conifers and/or presence of non-native species, infrequent pools, sedimentation evident in spawning areas (pool tails and riffle crests), summer water temperatures periodically exceed stressful levels for salmonids, sparse inchannel complex habitat, floodplain intact or slightly modified). Presence of migration barrier(s) is probably one of the watershed’s limiting factor (out of several factors).

- **0.25 = Poor-** Human activities have drastically altered the watershed with high likelihood of continued (or increased) activities, with apparent effects to watershed processes. Habitat impacts include: riparian zones absent or severely degraded, little or no pool formations, excessive sedimentation evident in spawning areas (pool tails and riffle crests), stressful to lethal summer water temperatures common, lack of inchannel habitat, floodplain severely modified with levees, riprap, and/or residential or commercial development. Other limiting factors within watershed are most likely of a higher priority for restoration than remediation of migration barriers.

7. **Total habitat score:** Multiply #5 by #6 for habitat “score”. A multiplier assigned for habitat quality, weighs the final score more on quality than sheer quantity of upstream habitat.

For each culvert location, the five ranking criteria were entered into a spreadsheet and total scores computed. Then the list was sorted by "Total score" in a descending order to determine an initial ranking. On closer review of the rank, some professional judgement was used to slightly adjust the rank of several sites. The list was then divided subjectively into groups defined as "high", "medium", or "low" priority.

The high-priority sites were characterized as complete migration barriers with significant amounts of upstream habitat for several species of anadromous salmonids. Medium-priority sites were characterized as limited in upstream habitat gains, limited species diversity, and/or were only barriers to juvenile migration. Low-priority sites were either limited in habitat, habitat condition was poor, and/or the site allowed passage of adults and most juveniles.

Remediation of culvert sites identified as "high-priority" should be accomplished by submitting proposals to various fisheries restoration funding sources. The information provided in this report should be used to document the logical process employed to identify, evaluate, and rank these migration barriers.

Del Norte county should consicer ranking "medium and low-priority" sites a second time, focusing mainly on culvert condition, sizing, and amount of fill material within the road prism. Most medium and low-priority sites should not be considered candidates for treatment via restoration funding sources, unless an imminent site failure would deliver a significant amount of sediment to downstream salmonid habitat.

However, this information will provide Del Norte County Community Development Department a list of sites in need of future replacement with county road maintenance funds. When these replacements are implemented, this report should provide guidance on treatments with properly-sized crossings conducive to adequate flow conveyance and unimpeded fish passage.

RESULTS

Initial Site Visits

Initial site visits were conducted at a total of 39 stream crossings on roads in Del Norte County (Table 3). However, only 28 of 39 culverts were surveyed and included in the fish passage evaluation and prioritization. The reasons for excluding 11 sites in the evaluation varied and are listed in the right-hand column of Table 3. Most site visits and surveys were conducted during fall or spring low flows, which provided safer wading conditions in streams and through culverts. A table of the 28 culvert sites inventoried and their location information is provided in Appendix A.

Site-specific characteristics, site photographs, maps, and habitat descriptions are provided in a *Catalog of Del Norte County Culverts* (Appendix B). The following list is an overview of the culvert inventory:

1. A wide variety of culvert configurations and materials were discovered.

2. Several culverts were in poor condition (six sites or 21.4%) and are due for replacement. Another nine culverts (32.0%) were described as in “fair” condition, and were starting to show signs of deterioration.

3. All culverts were undersized, when compared to recently released NMFS guidelines that recommend stream crossings pass the 100-year storm flow at less than 100% of inlet height. This is mostly likely because most county crossings were constructed prior to the development of these conservative guidelines. However, only six culverts convey greater than a 15-year discharge at less than 100% inlet height:

   - Jordan Creek tributary #6 (50.2 years);
   - Jordan Creek tributary #8 (26.6 years);
   - Yonkers Creek #2/Wonderstump Road (16.9 years);
   - Ritmer Creek/Oceanview Drive (16.4 years);
   - Mynot Creek/Mynot Creek Road (15.4 years); and
   - Yonkers Creek #1/Lake Earl Drive (15.4 years).

   Many of the remaining culverts were extremely undersized, overtopping on less than a five-year storm flow (Table 4).

4. Jordan Creek, the largest stream flowing into Lake Earl, had the greatest number of road crossings (13 of 28 sites). Two sites were ranked as significant barriers due to severity of the barrier, high levels of fish observations, poaching, and extensive reaches of upstream habitat (Jordan Creek at Parkway Drive and at Elk Valley Road).

5. Many of the fish-bearing streams flowing into Lake Earl are excluded from USGS topographic maps and made collecting watershed information (such as drainage area and length of fish habitat) difficult. For future planning needs, the county should consider a comprehensive mapping project of Lake Earl's tributary system.

Table 3. List of stream-crossing locations visited in Del Norte County. Sites are listed by major watershed in a north-to-south direction.

BASIN NAME	STREAM NAME	ROAD NAME	COUNTY MAP #	STATUS OF 1ST SURVEY
Smith River	Tryon Creek	Moseley Road	1A34	Ditch
	Morrison Creek	Fred Haight Drive	1A34	Ditch
	Ritmer Creek	Oceanview Road	1A24	**Surveyed**
	West Branch Mill Creek	Hamilton Road	1A54	Private road
	West Branch Mill Creek	Hamilton Road	1A54	Private road
	Clark's Creek	Walker Road	1A54	**Surveyed**
	Peacock Creek	Tan Oak Drive	1A44	**Surveyed**
	Shelly Creek	Patrick's Creek Drive	2A	**Surveyed**
	Camp Six Creek	South Bank Road	1A44	Steep drop below road crossing
	Tenmile Creek	Gasquet Toll Road	2A	Too high gradient
	Twelvemile Creek	Gasquet Toll Road	2A	Too high gradient
Coastal	Lopez Creek	Ocean View Drive	1A24	**Surveyed**
	Nickle Creek	Enderts Beach Road	1A54	Hiking trail in park
Lake Earl	Huffman Creek	Lower Lake Earl Drive	1A34	**Surveyed**
	Jordan Creek	Lake Earl Road	1A44	Bridge
	Jordan Creek #1	Parkway Drive	1A44	**Surveyed**
	Jordan Creek #2	Elk Valley Road	1A44	**Surveyed**
	Jordan Creek tributary #1	Railroad Avenue	1A44	**Surveyed**
	Jordan Creek tributary #2	Cunningham Lane	1A44	**Surveyed**
	Jordan Creek tributary #3	Loop in Keller Park	1A44	**Surveyed**
	Jordan Creek tributary #4	Loop in Keller Park	1A44	Limited upstream habitat (<500').
	Jordan Creek tributary #5	Elk Valley X Road	1A44	**Surveyed.** Upstream habitat (<500').
	Jordan Creek tributary #6	English Lane	1A44	**Surveyed.** Upstream habitat (<500').
	Jordan Creek tributary #7	Parkway Drive	1A44	**Surveyed**
	Jordan Creek tributary #8	Sand Man Lane	1A44	**Surveyed**
	Yonkers Creek #1	Lake Earl Drive	1A44	**Surveyed**

Table 3 (continued). List of stream-crossing locations visited in Del Norte County.

Lake Earl	Yonkers Creek #2	Wonder Stump Road	1A44	**Surveyed**
	Brush Creek #1	Lake Earl Drive	1A44	**Surveyed**
	Brush Creek #2	Wonder Stump Road	1A44	**Surveyed**
	Brush Creek #3	South Kroft Lane	1A44	Limited upstream habitat (<500')
Elk Creek	Elk Creek tributary #1	Elk Valley Road	1A44	**Surveyed**
	Elk Creek tributary #2	Elk View Road	1A44	**Surveyed**
	Nune's Creek #1	Elk Valley Road	1A44	**Surveyed**
	Nune's Creek #2	Elk Valley Road	1A44	**Surveyed**
Klamath River				
	Richardson Creek	Klamath Beach Road	1B25	**Surveyed**
	Saugep Creek	Klamath Beach Road	1B25	**Surveyed**
	Waukell Creek	Klamath Beach Road	1B25	**Surveyed**
	Hoppaw Creek	Klamath Mill Road	1B25	Private road
	Mynot Creek	Mynot Creek Road	1B25	**Surveyed**

Table 4. Sizing for flood capacity of Del Norte County road crossings within fish-bearing stream reaches.

				Sizing For Flood Capacity (HW/D=1)			Return Interval
Stream Name	**Road Name**	**Drainage**	**DA (mi.^{2})**	**Capacity (cfs)**	**MAP (in/yr)**	**Ave Elev (1000-ft)**	**(Waananen& Crippen) (yrs)**
Lopez Creek	Oceanview Drive	Coastal	0.92	154	80	0.4	**2.1**
Ritmer Creek	Oceanview Drive	Smith River	0.85	369	80	0.3	**16.4**
Shelly Creek	Patrick's Creek Road	Smith River	0.83	189	90	2.5	**6.3**
Peacock Creek	Tan Oak Drive	Smith River	2.1	433	80	0.6	**3.3**
Clark's Creek	Walker Road	Smith River	1.9	530	80	0.3	**6.1**
Nune's Creek #1	Elk Valley Road	Elk Creek	0.31	56	70	0.2	**2.3**
Elk Creek Tributary #1	Elk Valley Road	Elk Creek	0.36	59	70	0.2	**2.1**
Elk Creek Tributary #2	Elk View Road	Elk Creek	0.27	95	70	0.2	**8.3**
Nune's Creek #2	Elk Valley Road	Elk Creek	0.35	56	70	0.2	**2.0**
Mynot Creek	Mynot Creek Road	Klamath River	3.49	1100	70	0.3	**15.4**
Richardson's Creek	Klamath Beach Road	Klamath River	1.61	135	70	0.15	**1.2**
Saugep Creek	Klamath Beach Road	Klamath River	1.04	56	70	0.3	**0.9**
Waukell Creek	Klamath Beach Road	Klamath River	3.18	640	70	0.2	**4.4**
Brush Creek #1	Lake Earl Drive	Lake Earl	1.6	120	70	0.05	**1.1**
Brush Creek #2	Wonderstump Road	Lake Earl	1.1	130	70	0.05	**1.6**
Huffman Creek	Lower Lake Earl Drive	Lake Earl	1.9	56	70	0.05	**0.7**
Jordan Creek #1	Parkway Drive	Lake Earl	2.17	220	70	0.05	**1.4**
Jordan Creek #2	Elk Valley Road	Lake Earl	1.23	160	70	0.05	**1.8**
Tributary to Jordan Creek #1	Railroad Avenue	Lake Earl	0.85	50	70	0.05	**0.9**
Tributary to Jordan Creek #2	Cunningham Lane	Lake Earl	0.64	100	70	0.05	**2.1**
Tributary to Jordan Creek #3	Loop in Keller County Park	Lake Earl	0.46	40	70	0.05	**1.2**

Table 4. (continued). Sizing for flood capacity of Del Norte County road crossings within fish-bearing stream reaches.

Tributary to Jordan Creek #4	Loop in Keller County Park	Lake Earl	0.19	40	70	0.05	**2.5**
Tributary to Jordan Creek #5	Elk Valley Cross Road	Lake Earl	0.12	30	70	0.05	**2.1**
Tributary to Jordan Creek #6	Parkway Drive	Lake Earl	0.26	154	70	0.05	**50.2**
Tributary to Jordan Creek #7	Sandman Lane	Lake Earl	0.21	62	70	0.05	**5.1**
Tributary to Jordan Creek #8	English Lane	Lake Earl	0.14	77	70	0.05	**26.2**
Yonker's Creek #2	Wonderstump Road	Lake Earl	0.51	210	70	0.05	**16.9**
Yonker's Creek #1	Lake Earl Drive	Lake Earl	1.1	400	70	0.05	**15.4**

Passage Analyses

Of the 28 culverts included in the inventory, 25 were evaluated for passage with FishXing. Two sites were not evaluated with FishXing due to the lack of upstream habitat:

1. Jordan Creek tributary #4 on Keller Park Campground Loop road.

2. Jordan Creek Tributary #5 on Elk Valley Cross Road.

One site, Richardson's Creek on Klamath Beach Road was not evaluated with FishXing due to lack of access to perform the longitudinal survey. However, this crossing probably provides fish passage on most flows due to the apparent gradual slope and the backwatering effect of the lower Klamath River during both high tides and elevated storm flows.

FishXing proved a useful tool in identifying where passage problems occurred and probable causes. However, like most models which attempt to predict complex physical and biological processes with mathematics, there were limitations and assumptions that must be acknowledged.

Field surveys to numerous culverts during migration flows (in Del Norte, humboldt and Mendocino counties) have revealed confounding results generated by FishXing, such as:

1. Adult salmonids having great difficulties entering culverts which FishXing suggested were easily within the species' leaping and swimming capabilities.

2. Adult salmonids successfully moving through water depths considered "too shallow".

3. The behavior and abilities of fish are too varied and complex to be summed up with an equation or number taken from a published article. Even a single fishes' jumping and swimming abilities at a culvert may change as numerous attempts are made. We observed individual fish become fatigued over repetitive attempts, and conversely documented other fish gaining access to culverts after numerous failed attempts (Taylor 2000; Love pers. com.).

Passage results generated by FishXing are displayed as "percent passable" within the range of migration flows (Q_{lp} – Q_{hp}) calculated for each stream crossing locations in four watershed categories (Lake Earl, Elk Creek, Smith River, and Klamath River) (Figures 2-5). For each site, by species and lifestage, FishXing evaluation results are provided in Appendix C. The "Comments" column in Appendix C lists any site-specific assumptions made while running FishXing.

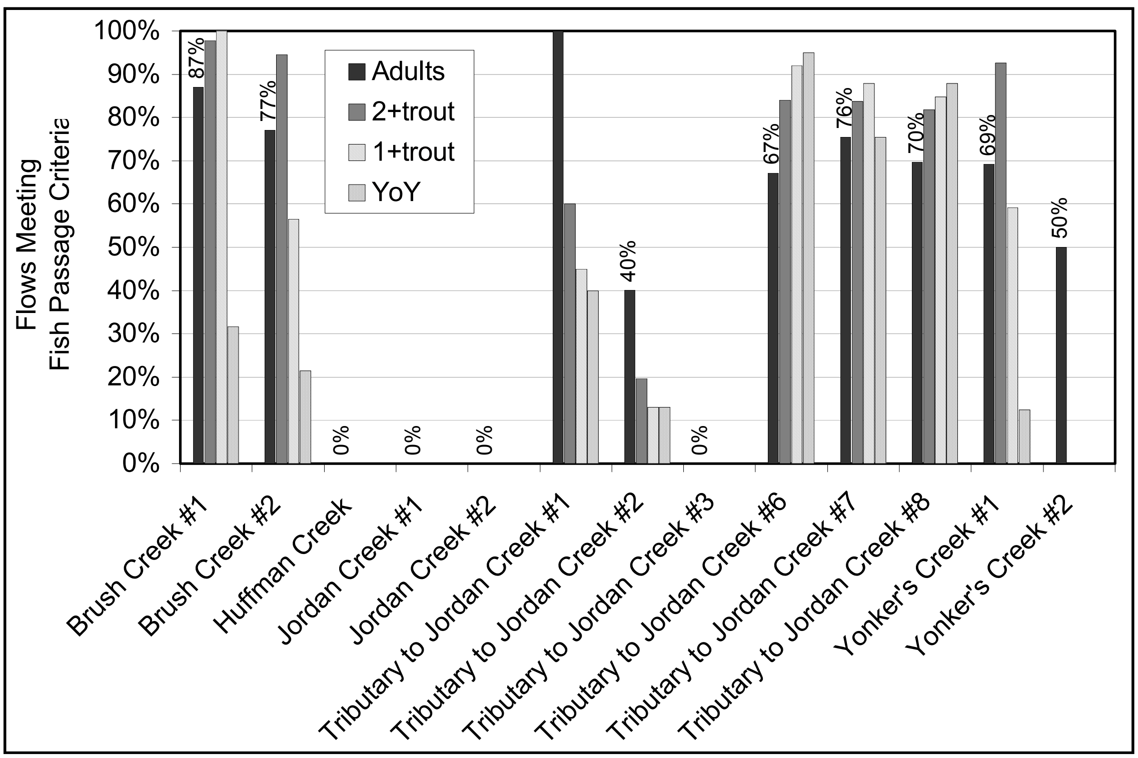

Figure 2. Percent passable as estimated by FishXing for 13 Del Norte County road crossings within the Lake Earl watershed, by salmonid species and lifestage.

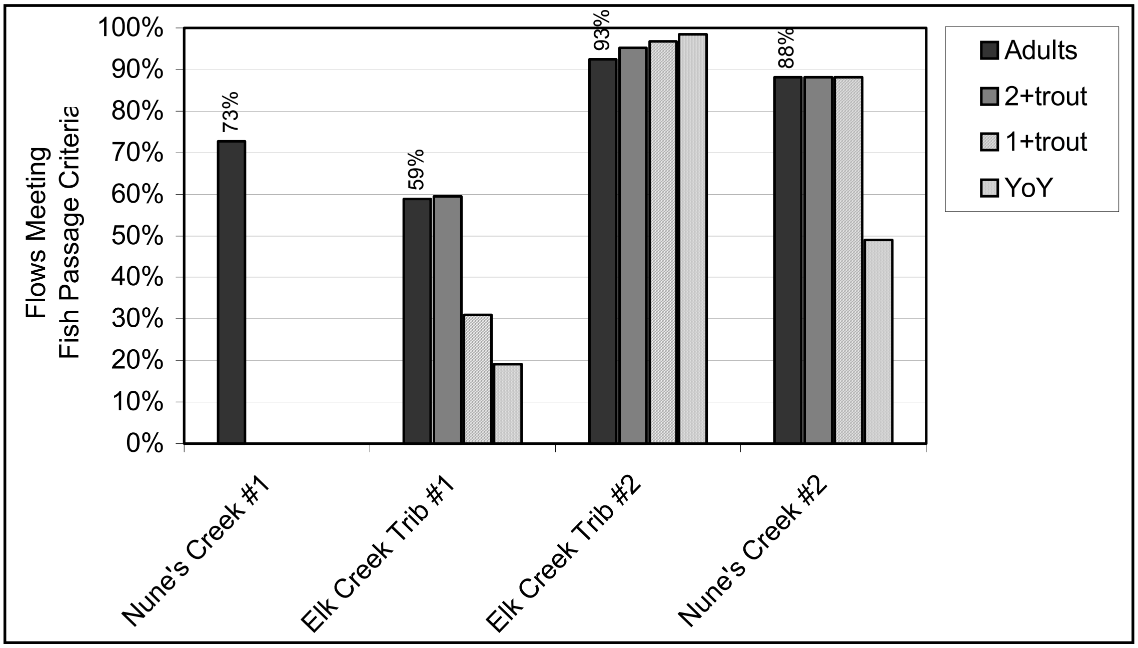

Figure 3. Percent passable as estimated by FishXing for four Del Norte County road crossings within the Elk Creek watershed, by species and lifestage.

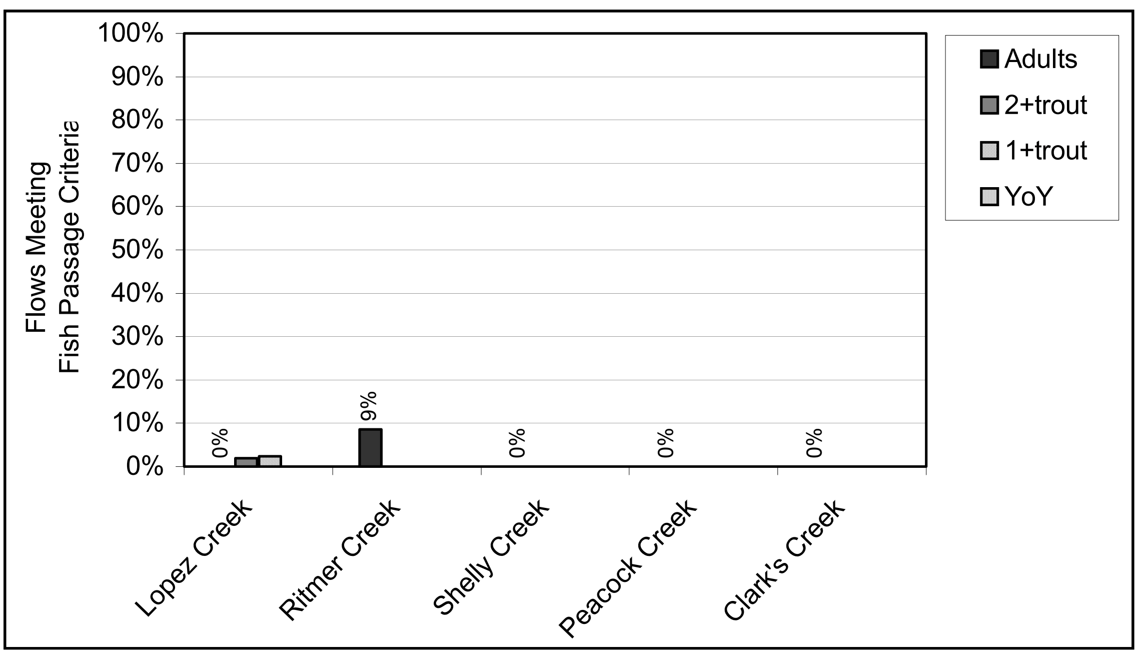

Figure 4. Percent passable as estimated by FishXing for five Del Norte County road crossings within the Smith River watershed, by species and lifestage.

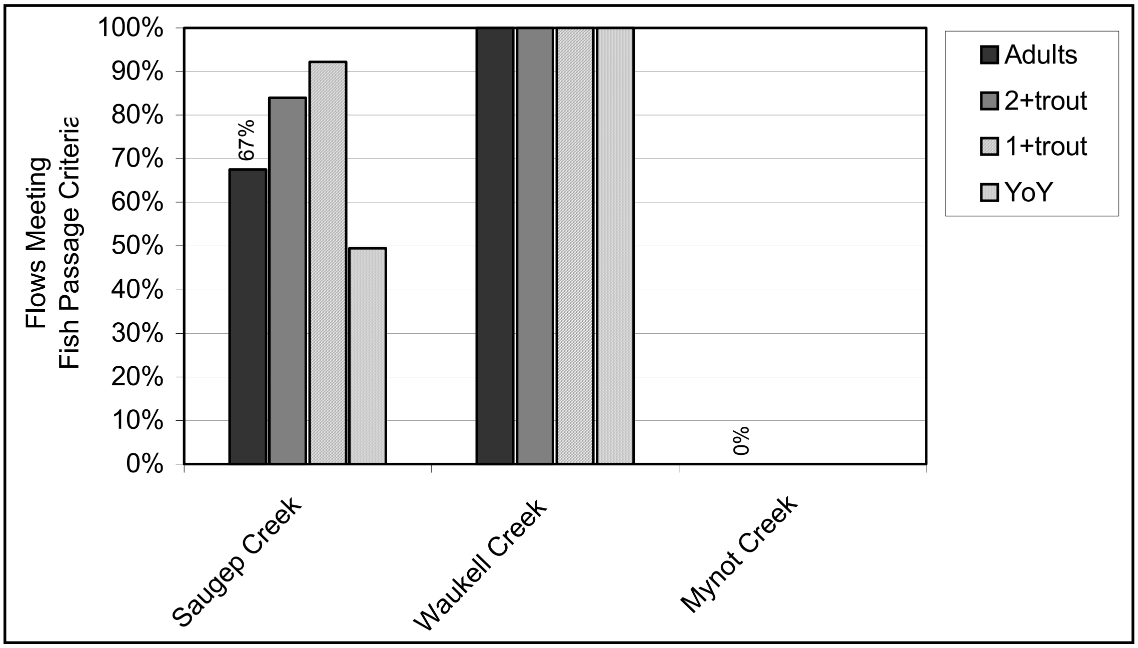

Figure 5. Percent passable as estimated by FishXing for four Del Norte County road crossings within the lower Klamath River watershed, by species and lifestage.

Due to these factors, passage evaluation results generated by FishXing were used conservatively in the ranking matrix by lumping "percent passable" into large (20%) categories. Only four sites were evaluated as allowing unimpeded access for all adults at the entire range of migration flows (Nune's Creek #2, Waukell Creek, Brush Creek #1 and #2).

Thirteen of 28 sites (46%), inventoried were temporary or partial barriers to adults salmonids, especially coastal cutthroat trout because of their smaller body size and limited jumping and swimming capabilities. Ten of the 28 culverts (36%) were considered total barriers to all adult and juvenile salmonids.

By species, the number of sites considered significant barriers (not passable on >60% of estimated migration flows) varied, as did the amount of upstream habitat blocked:

- Fifteen of 28 sites within stream reaches presumed to support coastal cutthroat trout were defined as significant adult barriers which blocked migration to 13.0 miles of upstream habitat.

- For steelhead, eight of 21 sites were defined as significant adult barriers which blocked migration to 8.9 miles of upstream habitat.

- For coho salmon, five of 12 sites were defined as significant adult barriers which blocked migration to 8.0 miles of upstream habitat.

- Chinook salmon were presumed present at only two sites (Peacock and Clark's Creeks); both were defined as 100% adult barriers which blocked habitat to 2.7 miles of upstream habitat.

Most surveyed culverts were some form of barrier to juvenile salmonids, more so young-of-year (y-o-y's) than one-year old (1+) juveniles.

- For 1+ fish, 12 of 28 (43%) culverts were total barriers and 15 of 28 (54%) sites were classified as barriers on greater than 60% of migration flows. Approximately 12.2 miles upstream habitat is located above these 15 sites.

- For y-o-y's, 16 of 28 (57%) sites were classified as total migration barriers, and 20 of 28 (71%) sites were classified as barriers on greater than 60% of migration flows. Approximately 12.2 miles upstream habitat is located above these 20 sites.

Only three sites allowed for unimpeded juvenile upstream migration on the entire range of estimated migration flows: Elk Creek tributary #1; Jordan Creek tributary #6; and Waukell Creek.

For both age classes of juveniles, their extremely small size renders them most vulnerable to culverts with perched outlets or those with velocities during migration flows exceeding two to four feet per second. Passage evaluation scores are provided in the Culvert Ranking Matrix (Appendix D).

Fish Observations

Fish observations were conducted at six culverts during the winter of 1999-2000, for a total of 800 minutes (13.3 hours) (Table 4). Data sheets with species and lifestage-specific information are located in Appendix E.

Observations provided insight into salmonid migration, including:

1. Most upstream migration occurred during the falling limb of storm hydrographs.

2. Regardless of jumping abilities cited in literature, most perched culverts were migration problems for adult salmonids. Site-specific hydraulics at culvert outlets appeared to create confusing flow patterns to migrating salmonids.

3. When individual fish made repeated jump attempts, these often occurred at regular intervals spaced about five to 12 minutes apart and often occurred at the same location. Individuals were rarely observed attempting leaps from a variety of locations at an outlet.

4. At Jordan Creek/Parkway Drive, extremely high levels of fish activity occurred and this migration barrier is extremely detrimental to salmonids. Twice during winter visits, people were disrupted attempting to poach salmonids amassed in the outlet pool. On one occasion the person had a large landing net and another was using a rod and reel.

5. Although most literature on fall/winter, upstream movement of juvenile salmonids concerned only coho salmon, we observed upstream movement of three year-classes of either juvenile coastal cutthroat trout or steelhead (young-of-year, 1+, and 2+) at several culverts.

Fish observations assisted in final ranking of culvert locations. Jordan Creek/Parkway was considered the top-priority site because of the level of migration activity and poaching observed. Potential poaching was also observed at Peacock Creek/Tan Oak Drive, where three chinook salmon were found dead and partially fileted in the outlet pool on 12/5/00 (Taylor and Schlotter, per. comm.).

Table 4. Observations of salmonid migration at six culverts on the Del Norte County road system, November 1999 – February 2000.

Stream Name	# of Visits	Total Obser-vation (minutes)	Adult Successful Attempts	Adult Failed Attempts	Juvenile Successful Attempts	Juvenile Failed Attempts	Comments
Jordan Creek #1 at Parkway Drive	5	180	1	37	0	23	On two visits, persons observed poaching fish in the outlet pool.
Jordan Creek #2 at Elk Valley Road	10	240	0	2	0	1	Few fish observed, probably due to severity of Parkway Drive barrier.
Jordan Ck tributary #3 in Keller Park	4	100	0	0	0	0	Cutthroat spawning above culvert. However, on high flow, vel. = 6.4 ft/s.
Mynot Creek at Mynot Creek Road	3	80	0	0	0	0	Measured velocities of 4.6 and 5.1 ft/sec. Shallow sheet flow shoots out into outlet pool.
Peacock Creek at Tan Oak Drive	3	100	0	0	0	0	Observed high velocity in culvert and turbulent flow out of concrete outlet pool.
Clark's Creek at Walker Road	3	100	0	0	0	0	Observed three large redds above culvert. Shallow, sheet flow during visits.

Ranking Matrix

The 28 Del Norte County culvert locations were sorted by "Total Scores", the sum of the five ranking criteria (Appendix D). The final ranked list of Del Norte County culverts reflects changes made due to professional judgement calls (Table 5).

Table 5. Ranking of 28 culvert locations on the Del Norte County road system.

Final Rank	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
1	Jordan Creek #1	Parkway Drive	**1**	Top-priority site due to: severity of barrier (100% for all species and lifestages), high degree of migration attempts, high levels of poaching at culvert outlet; and high probability of treating additional upstream road crossings (private crossing on Fergusun Dairy and at Elk Valley Road). Upper 1.1 miles contains high-quality stream habitat within Jed Smith State Park.
2	Clark's Creek	Walker Road	**2**	High-priority due to: severity of barrier (100% for all species and lifestages); species diversity of watershed; and quality of upstream habitat. Current box culvert is in poor condition. Caltran's box culvert on Highway 199 should be assessed for passage and proper sizing.
3	Peacock Creek	Tan Oak Drive	**3**	High-priority due to: severity of barrier (100% for all species and lifestages); species diversity of watershed; condition and sizing of current culvert; and quantity/quality of upstream habitat. CALTRANS crossing at Highway 197 provides passage. Summer water extraction by Golf Course needs to be addressed.
4	Jordan Creek #2	Elk Valley Road	**4**	High-priority due to: severity of barrier (100% for all species and lifestages); is uppermost road crossing before access to Jed Smith State Park, should be treated in conjunction or closely after Parkway Drive replacement. Crossing is undersized and high velocities have impacted downstream channel with excessive scour.
5	Mynot Creek	Mynot Creek	**5**	High priority due to: severity of barrier, quantity of upstream habitat, potential species diversity; and cost – modify current crossing, instead of replacement. Adult cutthroat and juvenile chinook, coho, and steelhead all observed or sampled below county culvert (Gale, pers. comm.)
6	Yonker's Creek #2	Wonderstump Road	**8**	High-priority due to: severity of barrier (100% for all species and lifestages); length of upstream habitat; and poor condition and sizing of current culvert.
7	Nune's Creek #1	Elk Valley Road	**7**	Moderate priority due to: limited spawning and rearing habitat upstream of crossing. Coho salmon adults are able to pass on most flows. Current culvert is extremely undersized.
8	Lopez Creek	Oceanview Drive	**9**	Moderate-priority due to: although a total barrier to all species and lifestages; there is limited upstream habitat (1,700'). Downstream habitat is of margin quality too. No current habitat or fisheries information available at CDFG.

Table 5 (continued).

Final Rank	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
9	Ritmer Creek	Oceanview Road	**10**	Moderate-priority due to: although a total barrier to all species and lifestages; there is limited upstream habitat. Downstream habitat is of margin quality too.
10	Shelly Creek	Shelly Creek Road	**12**	Moderate-priority due to: Size and condition of current crossing; remote location; and diversion potential at crossing. Crossing failure could have significant downstream impacts to high-quality salmon and steelhead spawning areas in Patrick's Creek.
11	Elk Creek tributary #1	Elk Valley Road	**10**	Moderate/low-priority due to: limited amount of upstream habitat and partial passage of adults and older juveniles.
12	Jordan Creek tributary #3	Campground Loop in Keller Park	**6**	Moderate/low- priority due to: limited upstream habitat (900') and presence of numerous spawning cutthroat upstream of crossing – even though FishXing predicted it as a total barrier to adult migration. Current culvert is extremely undersized
13	Jordan Creek tributary #2	Cunningham Lane	**13**	Moderate/low-priority due to: limited amount of upstream habitat, and partial passage of adults and juveniles through current crossing.
14	Huffman Creek	Lower Lake Earl Drive	**16**	Moderate/low-priority due to: current crossing allows adult migration on most flows and partial juvenile migration. Final rank increased because of length of habitat (9,000').
15	Brush Creek #2	Wonderstump Road	**17**	Moderate/low-priority due to: current crossing allows adult migration on most flows and partial juvenile migration. Crossing is extremely undersized and is known to flood over road surface.
16	Jordan Creek tributary #4	Campground Loop in Keller Park	**14**	Low-priority due to: Very limited amount of upstream habitat and presence of coastal cutthroat spawners above a crossing that FishXing deemed a total barrier.
17	Jordan Creek tributary #5	Elk Valley Cross Road	**15**	Low-priority due to: Very limited amount of upstream habitat in a tiny stream channel.
18	Yonker's Creek #1	Lake Earl Drive	**18**	Low-priority due to: current crossing allows adult migration on most flows and partial juvenile migration.
19	Jordan Creek tributary #1	Railroad Drive	**19**	Low-priority due to: current crossing allows adult migration on most flows and partial juvenile migration.
20	Brush Creek #1	Lake Earl Drive	**20**	Low-priority due to: current crossing allows adult migration on most flows and partial juvenile migration.
21	Richardson's Creek	Klamath Beach Road	**21**	Low-priority due to: current crossing allows for adult and juvenile passage; also, upstream habitat is degraded and of minor importance to lower Klamath fisheries.
22	Nune's Creek #2	Elk Valley Road	**22**	Low-priority due to: current crossing allows adult migration on most flows and partial juvenile migration. Upstream channel is quite small and of limited fisheries significance.

Table 5 (continued).

Final Rank	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
23	Saugep Creek	Klamath Beach Road	**23**	Low-priority due to: current crossing allows for adult and juvenile passage; also, upstream habitat is degraded and of minor importance to lower Klamath fisheries.
24	Elk Creek tributary #2	Elk View Road	**24**	Low-priority due to: current crossing allows for adult and juvenile passage; also, there is minimal upstream habitat.
25	Waukell Creek	Klamath Beach Road	**25**	Low-priority due to: current crossing allows for adult and juvenile passage; also, upstream habitat is degraded and of minor importance to lower Klamath fisheries.
26	Jordan Creek tributary #7	Sandman Lane	**26**	Low-priority due to: current crossing allows for adult and juvenile passage; also, there is minimal upstream habitat.
27	Jordan Creek tributary #8	English Lane	**27**	Low-priority due to: current crossing allows for most adult and juvenile passage; also, there is minimal upstream habitat.
28	Jordan Creek tributary #6	Parkway Drive	**28**	Low-priority due to: current crossing allows for most adult and juvenile passage; also, there is minimal upstream habitat.

Site-Specific Treatments and Scheduling

High-priority Sites

During the past few years, several sources of restorations funds have been available for treating priority culverts – SB271, Pacific Coastal Salmon Recovery Program, and Proposition 13. As of January, 2001, Del Norte County has already submitted proposals to treat the top four ranked sites. Jordan Creek at Parkway Drive was successfully treated in September, 2000. The County received funding in 1997 to initially modify the existing concrete box culvert; however, after further review the crossing was replaced with a bottomless 15’9” wide x 8.0’ high aluminum arch set on concrete footings. The contractor also replaced the private-property culverts located 30’ upstream of Parkway Drive with a 70’long flatcar bridge.

Of the six “high-priority” sites, recommendations are for five replacements and one tentative modification at Mynot Creek/Mynot Creek Road (however, CDFG and NMFS hydraulic engineers should be consulted prior to any action at this road crossing). Because all sites in Del Norte were undersized, very few are candidates for modification of existing crossings due to the fact that baffles will further decrease flow conveyance capacities of already undersized structures.

The following general guidelines draw from design standards used in Oregon and Washington, and are consistent with NMFS draft guidelines for new culvert installations (NMFS 2000). However, site-specific characteristics of the 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 from removal of a perched culvert. Bates et al. (1999) is recommended as an excellent reference to use when considering fish-friendly culvert installation options. Robison et al. (2000) provides a comprehensive review of the advantages and disadvantages of the various treatment alternatives.

Order of Preferred Alternatives

1. Bridge.
2. Open bottom arch culverts.
3. Culvert set below stream grade (countersunk or embedded).
4. Culvert set at grade with baffles installed to allow low-flow passage and reduction of velocities during higher migration flows.
5. Culvert perched with outlet pool weirs and baffles throughout culvert. Entry jumps should never exceed 1.0 feet for adults or 0.5 feet for juveniles.

Design Criteria for Proper Sizing and Alignment

1. Pass a 100-year storm flow at less than 100% of the culvert's height. This allows for passage of woody debris and bedload during extremely high flows.
2. Culvert width sized at least equal to active channel width – base winter flow, about at line of vegetation growth. Should reduce constriction of flows at the inlet associated with fish migration. (NMFS may recommend sizing to a wider channel width).
3. Avoid projecting culvert inlets.
4. Align culvert with the general direction of channel – avoid sharp bends in channel at approach to inlet.
5. Avoid installing trash racks at culvert inlets.

Moderate-priority and Moderate/low-priority Sites

The "moderate-priority" and "moderate/low-priority" tiers of culvert locations requiring treatment to improve fish passage includes nine locations, ranks #7-15. The exact scheduling of these treatments is unknown at the time because:

1. Del Norte County Community Development Department has a large task of completing the scheduling, contracting, permitting, and implementation required to treat the top six locations. The county should focus on completing these higher priority projects with properly designed and constructed treatments before addressing the second tier of sites.

2. Del Norte County is a participant in the Five-Counties Salmon Group, which plans to acquire treatment funds for passage problems in all five counties (Del Norte, Trinity, Siskiyou, Mendocino, and Humboldt). Thus, the second tier of Del Norte county culverts should be ranked and evaluated with respect to priority culverts located in the other four counties. Culvert inventories are currently underway in coastal Mendocino and Siskiyou counties; and will be started in Trinity County in spring of 2001. Humboldt County's inventory was completed in April, 2000 and their planning department has already received funding to treat the top 15 priority road crossings.

3. When addressing the "moderate-priority" tier of culverts, the current biological condition and/or importance (such as quantity) of the streams starts to diminish. Thus, these sites may not rank well compared to other types of projects proposed to state and federal funding sources. However, other sources of funding, such as urban stream programs should be considered. Sites in poor condition and/or undersized should be eventually treated with county maintenance and repair funds.

4. The Shelly Creek site was raised from "moderate/low" to "moderate" priority because of a large diversion potential. If this undersized crossing was to fail, the stream flow will likely proceed down the unpaved road prism for an unknown distance before returning to the creek channel, potentially introducing thousands of cubic yards of sediment. This site is located about eight miles above anadromy, but eventually flows into Patrick's Creek, a Smith River tributary with high-quality spawning and rearing habitat utilized by coho salmon, chinook salmon, steelhead, and coastal cutthroat trout. The county should consider submiting a proposal to Proposition 13 to treat this site as a sediment-reduction/water quality project.

Low-priority Sites

The remaining sites, ranked #16-28, are of "low-priority". These sites either allow fish passage, or have minimal biological benefit if treated. However, these sites should be examined for "consequence-of-risk" as to current condition, sizing, and fill amount. All future replacements with county maintenance funds should include properly sized crossings that permit unimpeded passage of adult and juvenile salmonids.

The four most common activities impacting these Del Norte County streams are timber harvesting, agriculture, unfenced grazing, and residential development. Most of these low-priority creeks generally exhibited some or all of the following characteristics:

1. Lack of pools and habitat complexity;
2. Denuded or non-existent riparian zones;

3. Extensive straightening, berming, and diking of channels;
4. High volumes of fine sediment; and
5. Warm summer water temperatures.

Limited fisheries restoration dollars should probably not be spent on improving fish passage in these streams, unless significant improvements occur. However, the County should carefully examine this list and determine which locations may be treated with existing maintenance funds. For example, Del Norte County may have a general plan for improvements to specific traffic corridors or routes. Also, when low-priority culverts fail during winter storms, planners should examine the sizing of the failed structure and budget for properly-sized replacements. When applying for FEMA funds, Del Norte County Public Works should utilize this report to explain why the replacement should be a larger and higher-quality crossing (for both fisheries and future-flood benefits).

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