A Spatial Evaluation of Habitat Access Conditions and Oregon Plan Fish Passage Improvement Projects in the Coastal Coho ESU

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Acknowledgements

We would like to thank all the landowners and landowner representatives who provided us with the data for this analysis including Bobbi Riggors, Ken Bierly, Elli Larson, Blake Lettenmaier; Dave Plawman, Gary Baker, David Stone, Vanessa Stone, Carl Walter, Tony Klosterman, Russell Langshaw, Maryanne Reiter, Jim Doyal, Jennifer Noonan, Blake Rowe, Rod Shepard, Mike Hicks, Jon Bowers, Russell Nance, and Scott Peets. The flow and accuracy of this draft was dramatically improved with the valuable reviews from Kelly Burnett, Marvin Pyles, and Tom Stahl. We also thank Kelly Burnett for providing the stream and intrinsic potential habitat data layers. Finally, we thank Jeff Rodgers, Jay Nicholas, Ken Bierly, and Ted Lorensen for their vision and leadership at critical junctures during the project.

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INTRODUCTION

One of the goals of the Oregon Plan is to improve access to fish habitat. State measures and guidelines describe methods to install and upgrade stream crossings to accommodate all life history stages of native fish. The purpose of the project is to quantify fish passage restoration projects, miles of stream with improved access, and current status of habitat access throughout the Coastal Coho Evolutionary Significant Unit (ESU). We provide some background on fish passage issues and summarize the regulatory and volunteer activities of the Oregon Plan for Salmon and Watersheds (Oregon Plan) that are designed to pass fish. We also provide a brief review of the science on implementation and effectiveness of fish passage strategies.

Background

The image that comes to mind when considering fish passage is usually that of adult salmon migrating upstream to native spawning grounds. Less thought of, but perhaps equally important, is the upstream movement of *juvenile* anadromous fish as well as *resident* fish. These younger and/or smaller fish have been observed to move both up and downstream and are thought to do so for a number of reasons including avoidance of predation or seeking better habitat (e.g. cooler temperatures or lower velocities) for given life stages. They may also move to seek less populated areas with better opportunity for food and cover (Bustard and Narver, 1975; Cederholm and Scarlett, 1981; Everest, 1973; Fausch and Young, 1995; Gowan et al., 1994; Hartman and Brown,1987; Reiser and Bjornn, 1979; Shrivell, 1994).

A fish's ability to move upstream depends in part on its size, swimming abilities, and streamflow characteristics. Therefore, while a structure may not be a barrier to adult fish, it might create a barrier to younger fish. Clearly, the "barrier" status is dynamic and will change as young fish grow or flows change to provide conditions that accommodate the swimming abilities of young and resident fish. These are often referred to as "partial" barriers. Unlike their older counterparts, young anadromous and small resident fish are more limited in their ability to jump and then swim upstream against fast flowing water for any extended period of time (Bell, 1986). Fish seem to conserve energy when navigating through culverts rather than utilizing their full athletic potential (Behlke et al., 1989). Therefore younger fish require very low gradient culverts ($\leq$ 0.5%), resulting in low velocity water (less-than two feet per second) that can be accessed without jumping into the culvert.

Barriers to fish passage can result from both natural features such as waterfalls, steep channels, or artificial structures such as stream crossings, tide gates, hatchery facilities, and impoundments. Culverts at stream crossings have historically been the most common artificial barriers to fish passage because they were installed to pass water as quickly as possible. However, to accommodate juvenile fish passage culverts are now designed and built so that velocities through the pipe are less than or equal to the velocity in the natural channel. This can be achieved with a number of strategies that provide areas where the young fish can retreat from fast flowing water and rest before moving upstream again. Such areas are referred to as a “velocity refuges”. Sometimes this involves placing or retaining gravel, cobbles or small boulders in the culvert to simulate a natural streambed and requires placing the inlet of the culvert below the streambed to be successful. Oregon Department of Fish and Wildlife (ODF&W) prefers and will likely soon require that small and large rock be placed in such culverts (personal communication Tom Stahl). These stream simulation strategies reduce culvert capacity for stream flow and thus culverts must be oversized to compensate for the loss in cross-sectional area. Another strategy is to place the culvert at a low gradient relative to the stream gradient to cause back watering through the culvert. This strategy requires burying one or both ends of the pipe relative to the streambed elevation and sometimes requires other back-watering techniques.

Velocity refuges can also be created within a culvert with structures such as baffles. Such designs allow for slightly higher gradient culvert installations and therefore can be used in some of the higher gradient forested streams. Anecdotal information from ODF&W suggests this strategy should is most effective in streams with 5% gradient or less (personal communication Tom Stahl). Juvenile fish passage can also be achieved with installations that keep the native streambed intact with structures such as open bottom arches, bridges, or fords. Another alternative is to place weirs at the downstream end of the culvert to create a step-ladder effect that eliminates the jump into the culvert and backs water through the culvert.

Barriers that result from tide gates, while thought to be less numerous than culverts present unique problems due to their position in the watershed and the type of habitat that has restricted access. Tide gates are structures that control flow to prevent tidal waters from inundating uplands but allow fresh upland water to flow out into the receiving waters. These structures have been used for centuries to drain estuaries and the lower sections of rivers so that adjacent lands can be managed for agriculture or development (Giannico and Souder 2004). Tide gates impact estuaries, wetlands, and streams, physically, chemically, and biologically in addition to altering access to fish habitat. Tide gates represent a significant barrier to estuarine habitats which provide juvenile salmon with a productive feeding ground, refuge from marine predators, and a transitional zone for gradual acclimation to salt water (Thorpe 1994). Any tide gate represents a total barrier to fish passage during the time it remains completely closed (Giannico and Souder 2004). In recent years there has been a movement to design, install, or retrofit existing tide gates to improve fish passage (Charland 1998). Unfortunately, few studies have been implemented to determine the effectiveness of such designs (Giannico and Souder 2004).

Fish hatcheries often present limited or complete blockages to fish passage. Some hatcheries are intentionally operated to block fish passage to upstream areas as a means of controlling disease. Others are operated to allow passage of wild fish only, and others may restrict movement only during certain times of the year, generally during low flow conditions, and only juvenile fish.

Regulatory, Non-regulatory, and Restoration Programs

There are regulatory, non-regulatory, and restoration programs and practices described under the Oregon Plan that are designed to improve access to fish habitat by removing or mitigating barriers to fish passage.

Fish passage laws in Oregon pre-date statehood (1850's) but the most current statute was passed in 2001. This statute re-wrote everything on passage (except screening and bypass) and applies to everyone in the state. Under this current fish passage statute (ORS 509.580-910), ODF&W has authority for fish passage and has subsequently adopted procedural rules (OAR 635 division 412). ODF&W establishes guidelines to accommodate juvenile fish passage based on physical abilities of fish. The intent is to accommodate the basic requirements for reproduction, habitat and refuge of the "weakest fish," usually juvenile fish as small as two inches in length (OWEB 1999). Fish swimming abilities vary by age and species, as do timings of upstream migration. ODF&W is expected to adopt additional rules in summer 2005, including new criteria for stream simulation culverts as noted above (personal communication Tom Stahl). See ODFW criteria for a summary discussion and legal references (ODF&W 2005).

In 1994, the Oregon Department of Forestry revised stream crossing rules to specifically require both adult and juvenile fish passage (OAR 629-625-0320 2a and 2b and OAE 629-625-600 8) (ODF 1995). The first detailed guidance on how to design stream crossings to pass juvenile fish was available from ODF in June 1995 (Robison, 1995) and has continued to evolve as a result of monitoring data.

As part of the Oregon Plan private, state and federal land owners made a commitment to install new crossings to meet the regulatory guidelines, as well as repair existing crossings to bring them up to the same standards. A memorandum of understanding (MOU) was signed in 1997 and the goal was to achieve these upgrades by 2012. The parties to the agreement included: Oregon Department of Transportation (ODOT), Oregon Department of Fish and Wildlife (ODF&W), Oregon Department of Agriculture (ODA), Division of State Lands (DSL), Federal Highway Administration (FHA), and the Oregon Department of Forestry (ODF) (ODOT, 1997). The MOU demonstrates agreement between these agencies to use the same criteria and guidelines when designing or consulting on projects that may affect juvenile and adult fish passage. Private and state forest landowners intended to complete upgrades on 100% of their known crossings with the understanding that it is an ongoing process.

Road-related restoration activities, including fish passage improvement projects, are the most common restoration practice reported to OWEB. From 1997 – 2004 the total monetary investment in fish passage and road improvement was 59 million dollars. Roughly half was invested by private industrial forest landowners and the remainder was from state resources. There has been considerable investment on the part of the state and private landowners to improve access to streams. For example, in 1998, 81% of all fish passage improvement projects reported to OWEB occurred on private industrial and state forestland (Maleki and Riggors, 1999). This trend has been consistent throughout the period of record evaluated in this study, 1997-2003.

A number of watershed councils have embarked on projects to identify and prioritize fish passage restoration projects. One example in the ESU is the Siuslaw Watershed Council (personal communication Todd Miller). Their project objective is to enhance fish passage to habitat throughout the watershed, with immediate concentration on highest priority areas. Their approach includes compiling all stream crossing data in the watershed and then evaluating priorities by sub-basin. Prioritization is based on a combination of ecological conditions and social factors (willing landowner base). Their goal is to work through all the high priority basins first. The Siuslaw project has faced similar challenges as this one including gaining a complete dataset for the watershed and precise placement on a common stream layer that is useful for GIS analyses.

Scientific Findings: Implementation and Effectiveness of Fish Passage Strategies
While, currently, there is not a systematic program for evaluating Oregon Plan fish passage projects, agencies and researchers have been evaluating stream crossings to determine the likelihood or ability to pass fish. Two studies done by the Oregon Department of Forestry evaluated compliance with fish passage guidelines on state and private forestland (Dent and Allen 2000; Paul et al. 2002). ODF randomly selected stream crossings installed from 1996 to 1998. Results suggest that 72-77% of stream crossings were successfully implemented to meet state guidelines in 2000 and 2001 (Paul et al. 2002). The most common reason for sites not meeting the guidelines during both reporting years were installing culverts at too steep a gradient for the chosen strategy, selecting strategy that was inappropriate for the channel gradient, and high outlet drops.

Based on the conditions assumed to provide fish passage (OWEB 1999), 71-74% of crossings installed on forest roads from 1996 to 1998 had a high likelihood to pass juvenile fish. Likelihood depended on whether all design flows or all flows except low design flows were considered (Paul et al. 2002, and Dent and Allen 2000). Bridges and open arches had the highest success rate (100%), followed by those that created a simulated streambed within the culvert (76-93%). The use of bare culverts at very low gradients (<0.5%) and baffled culverts had the lowest success rate for fish passage, at 55% and 25% respectively. The most common reason for the lack of success was not achieving the low gradients needed to reduce velocities (when this was the intended strategy), lack of sediment retention in planned stream simulation strategies, and/or creating outlet jumps.

A 1998 literature review by the Washington State Transportation Center (TRAC) indicated that the role of turbulence and velocity profiles in limiting the ability of fish to pass through culverts was under-studied and poorly understood. TRAC (Kahler and Quinn 1998) reported that fish were able to exceed both the theoretical limitations and laboratory performances and pointed to a need for field studies. Based on the results of a small number of studies they concluded that crossings that simulated natural streambeds should not create a barrier to fish passage. They reported that countersunk culverts (embedded) have proved to be better for fish passage than culverts with or without other modifications for fish passage. They tempered this conclusion with the concern that the steepest culverts had not experienced high flow events (> 10-year flood event) and thus long-term effectiveness is uncertain (Kahler and Quinn 1998). Baffled culverts were found to improve passage of coho and resident trout.

In summary, providing juvenile fish passage requires innovative engineering approaches that bridge the gap between biological needs and infrastructure needs. While the science is fairly clear that juvenile fish do indeed move up and downstream, less clear is how successful the stream crossing solutions are at providing juvenile fish passage and on how the fish-friendly crossings will endure over time. More monitoring and research is needed to determine the effectiveness of stream crossing strategies both in the short and long term.

Project Goals and Questions
To date fish passage improvement projects have been reported in terms of numbers of projects completed and studies have had a narrow spatial scale or land base. The goal of this analysis is to

begin to frame fish passage improvement projects in the context of coho habitat and stream miles opened to fish as a result of those projects at a broad spatial scale (ESU).

Specifically, the questions we want to answer with the available data are:

1. How many passage improvement projects have taken place in coho habitat and non-coho habitat in the Coastal coho ESU?
2. What percent of all crossings in the ESU pass fish, limit fish passage, or have an unknown fish passage status?
3. How many coho and non-coho stream miles have improved access because of projects implemented under the Oregon Plan in the ESU?
4. How many coho and non-coho stream miles still have limited access in the ESU?

ANALYSIS METHODS

Spatial and Temporal Scale

This project is part of an Oregon Plan Assessment of the North Coast Coho (ESU) (Figure 1). This ESU is bound on the north by the Columbia River and includes all coastal draining watersheds southward to and including the Umpqua and Rogue River Watersheds.

Our analysis provides a single snapshot in time for an estimated 60-70% of stream crossings as of Spring 2004. We evaluated all crossings reported to Oregon Watershed Enhancement Board (OWEB) representing the time period from 1997 to 2003. We also gathered existing data on all crossings from multiple private landowners, state, and federal agencies. The data were current as of spring 2004. Detailed descriptions of these data and their limitations are described below.

Data Sources

Digital data have been compiled from ten different sources including Coastal Landscape Analysis and Modeling System (CLAMS) at Oregon State University, OWEB, Federal Agencies, four Industrial Forest Landowners, two Oregon Department of Forestry (ODF) districts, and ODF&W. Fish passage status (e.g. pass, limited, unknown) was provided by each source. Data used in this analysis include:

Modeled stream layer and habitat types: Described below. The stream layer approximates a “densified” 1:24,000 stream layer (Clarke et al. in review). Source: CLAMS

Fish passage improvement projects (1997 – 2003): Voluntarily implemented and reported by landowners and agencies under the Oregon Plan. Assumed all crossings passed fish. Source: OWEB

Location of all road-stream crossings with passage status (Current as of Spring 2004). Sources:

- Federal landowners: All fish-bearing stream crossings on US Forest Service in the ESU
- Private industrial forests landowners: Four landowners. Note- if pressed for time, private industrial landowners were asked to prioritize data and so reported on crossings only in coho habitat.
- State forests: All stream crossings within Western Oregon and crossings in coho habitat on

the Tillamook Districts.

- State and county roads. Source: Oregon Department of Fish and Wildlife (ODF&W)

Other Barriers. Natural barriers, fish hatcheries, dams, etc. Source: ODF&W.

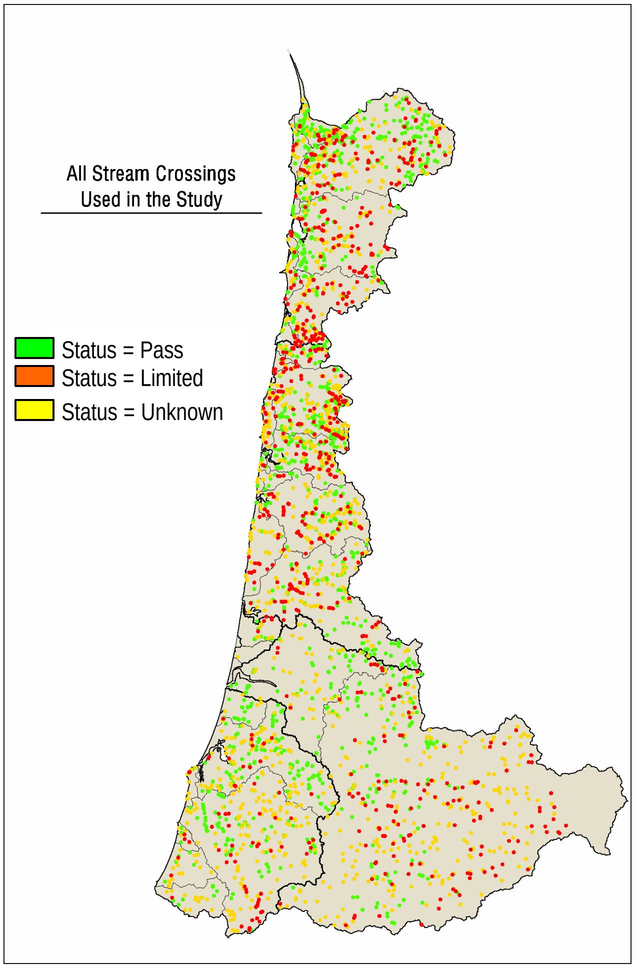

Figure 1. North Coast Coho ESU and locations of stream crossings used in the analysis. Their associated passage status indicated by color of the dot: pass = passes fish at all life stages (green), limited = partial or complete blockage (red), unknown = passage status is not known (yellow). Sample size = 3,392.

Stream Layer Model

We used a modeled stream layer provided by CLAMS that approximates a densified stream network represented at a 1:24,000 scale. Streams were modeled from 10 meter DEMs to calculate gradient and valley morphology. The model is limited by the accuracy of the raw data used, in this case, the 10 meter DEMs. It is known that 10 meter DEMs reflect differences in contour line crenulations on the maps from which they were derived. This difference is then expressed in the final digital line network as stream density differences that follow the map quadrangle boundaries of the base data. That is, some quadrangles have a much greater stream density than an adjacent quadrangle. This difference is due only to the contour line crenulations and not to precipitation, soil, or elevation differences. This denser stream network probably has limited influence in depicting anadromous fish streams, particularly coho streams, but likely depicts more resident fish streams.

Coho Over-Winter Habitat: Intrinsic Potential Model

To evaluate the influence on coho habitat we utilized a modeled habitat stream layer from CLAMS. The model predicts the *potential* for streams to provide high quality *winter* habitat for coho. The prediction is based on stream gradient, stream flow, and channel constraint. Gradient and constraint are calculated with a 10-meter digital elevation model and flow is estimated using ODF's average annual stream flow equation (Lorensen et al. 1994).

Intrinsic winter habitat potential is calculated for coho salmon (Burnett et al. personal communication) at a reach scale. The reaches are defined as areas with homogenous channel constraint, flow, and gradient. Reach length is proportional to stream width. The smallest stream reach is approximately 50 meters long.

Using approaches discussed by Van Horne and Wiens (1991), gradient, channel constraint, and average annual stream flow were related to intrinsic potential through habitat suitability index curves specific to over-winter coho habitat. Reach-scale estimates for the three stream attributes were modeled in conjunction with the digital stream network (Clarke et al. personal communication). The strength of association between a stream attribute and fish-use is based on published literature. Intrinsic potential in each reach is then expressed as the geometric mean of the valley constraint, mean annual stream flow, and gradient. Calculated intrinsic potential ranges from zero to one (or zero – 100%) with higher values indicating a greater potential to provide high quality rearing habitat.

Simply put, high quality winter habitat is provided by streams with low channel gradients, high interaction with flood plains (low constraint), and moderate to high average annual stream flows. While it clearly does not account for other habitat factors that relate to complexity such as large wood and cover, intrinsic potential provides an index by which to evaluate the potential for a stream reach to have winter habitat. We categorized streams and report our findings by three habitat types with this model:

1. *Non-coho streams*: These are defined as streams with a maximum gradient greater than 7% and or streams above known natural barriers. Coho streams are defined as streams with a maximum gradient less than 7%.
2. *High Intrinsic Potential (High IP)*: Rating greater than or equal to 80% and maximum gradient less than 7%.
3. *Medium/Low Intrinsic Potential (Low IP)*: Rating less than 80% and maximum gradient less than 7%.

The 80% threshold for High IP was selected as a conservative estimate of the stream's potential to provide high-quality winter coho habitat. As described below, under *Sensitivity Analysis*, we evaluated the effect that this selection had on our results.

Stream Crossings
We gathered data (as listed above) from industrial landowners, federal and state agencies and data sets thought to include a complete census of state and county roads. This was an attempt to get the best available data, providing the greatest spatial coverage in a short amount of time. However, not all landowners have contributed to the data set and we do not have a precise measure of data completeness for those who have. We estimated the level of completeness as shown in Table 1. Our estimate, based on ownership acres, suggests that we have captured approximately 66% of the data (Table 1).

While this is not a complete census we estimate that the majority of stream crossings are represented for low elevation, high intrinsic potential stream reaches. This is based on the fact that the State and County crossing data are considered a complete census. These roads tend to be the most commonly occurring roads that cross lower gradient coho streams. Finally, if they could not provide a complete data set, we asked landowners to focus on roads that cross coho streams.

Number of Crossings
We used 3,392 stream crossings in our analysis (Figure 1 and Table 2). We started with a total of 4,412 crossings in our database. We only used 3,392 crossings for the analysis to control potential errors that occur when attempting to precisely locate stream crossings on a common stream layer. This error control is discussed below. Sample size by data source is shown in Table 2.

Table 1. Estimate of how complete this data set is for stream crossings in the ESU.

	Column 1	**Column 2**	**Column 3**
Ownership Category	**Percent of ESU in Ownership Category (based on total acres)**	**Percent of Data Captured from Ownership Category For this Study (Estimate of % completeness of data captured)**	**Estimate of Completeness for ESU (column 1 x column 2)**
Forest Service	38%	100%	38%
State	9%	90%	8%
Private Industrial	32%	60%	19%
Private Non-Industrial	20%	0%	0%
State and County Roads	0.3%	100%	0.3%
Total for ESU	100%	0 – 100%	**66%**

Fish Passage Status
Fish passage status was provided by landowners and we assumed all OWEB stream crossings passed fish. For the purposes of this study we did not verify if crossings passed or blocked fish access. This would be an important element of future studies of this nature.

A determination of fish passage status is typically based on the physical properties of the crossing and stream rather than an observation that fish are moving or have moved through a crossing. Properties include but are not limited to culvert gradient, inlet and outlet jumps, sediment retention in the culvert, water depth through the culvert, and velocity within the culvert. In Oregon, these physical properties are based on the best available science, the needs of juvenile fish, and are described in guidance (OWEB 1999). The fish passage status was determined by the data source and we performed no additional monitoring or field verifications.

We assumed all crossing projects reported to OWEB pass fish. For the other data, we asked the landowner to describe crossings as "passes" fish at all life stages, "limits" fish passage (blockage), or has an "unknown" passage status. The meaning of these terms is neither a precise nor a quantified term and may vary among landowners. This variability can obviously influence this study's results. For example, the term "blockage" is loosely used to encompass stream crossings that represent both partial and complete blockages. Complete barriers prevent movement of all fish during all life stages, during all times of the year. Partial blockages limit access for one or more life stage, for one or more species of fish, and for one or more times of the year. For the purposes of our analysis we made no distinction between crossings that provide partial access and those that are complete blockages. We therefore refer to both partial and complete blockages as "limiting access". This decision to lump partial and complete barriers was based in part on the availability of data on partial access as well as the potential for a lack of consistency in judging partial access. This lumping exercise provides a conservative estimate of fish passage. Undoubtedly, some barriers treated as total barriers provide some passage thus potentially overestimating our estimate of inaccessible stream miles. Therefore, for this analysis crossings have three status categories: Pass, Limited Access, and Unknown.

Table 2. Sample size by data source. Total sample size and number of crossings that located precisely on our common stream layer are provided.

Data Source	Total Number of Crossings	Number of Crossings Located "Precisely"	Percent of Crossings Located Precisely
OWEB	842	788	94%
Federal	436	164	38%
Private Industrial Forests	718	526	73%
State Forests	272	144	53%
ODF&W: State and County Roads and Barriers	2144	1770	83%
TOTAL	**4412**	**3392**	**77%**

Network Analysis Calculations

We used the Network module of Arcinfo to calculate the miles of stream above crossings. The software treated crossings attributed as "pass" or "limits" as open or closed switches, respectively. This provided results of accessible and inaccessible stream miles. Mileage upstream of unknown passage status was calculated separately.

We report the numbers of crossings and miles upstream of pass, limited, and unknown crossings for three habitat types: Non-coho, High IP coho, and Low IP coho habitat.

Controlling Error in Locating the Crossings on a Common Stream Layer
Stream crossing structures, barriers, and fish hatcheries were located, or “snapped” to the CLAMS stream layer. This involved moving crossing locations so they precisely overlay on the CLAMS stream layer. There are limitations with the “snapping” process. For example the crossing may be on a large mainstem stream, but might have snapped to a tributary (or visa versa), changing the outcome of the results.

We evaluated this error by randomly selecting 109 crossings and manually evaluating at what distance they snapped correctly. The error nearly doubled (from 11% to 22%) if the snap distance was set at 150 feet rather than 100 feet (22% versus 11% incorrectly located). Therefor we only used crossings that snapped within 100 feet of their original location and estimate an 11% error in the number of crossings located correctly. While this approach improves confidence in precision, sample size decreases and introduces potential errors associated with missing culverts.

Sensitivity Analysis
Selection of a single gradient to represent the upper extent of coho and the cutoff for high quality winter habitat places artificial thresholds on what is otherwise recognized as a dynamic continuum of habitat. We evaluated the sensitivity of our results to the selection of these gradient and High IP thresholds. We used modeled CLAMS stream layer data from 10 meter DEMs and tested the influence of maximum gradients in 1% increments, ranging from 1 – 12%. We tested the influence of the High IP threshold in 20% increments, ranging from 20 – 100%. The sensitivity analysis demonstrates the variability in results that one could expect if the thresholds are changed, and the implications of changing these thresholds if they are shifted “higher” or “lower” than what was selected for this analysis.

RESULTS
Fish Passage Improvement Projects
The first two objectives of this project were to determine:

1. *How many passage improvement projects have taken place in coho habitat and non-coho habitat in the Coastal coho ESU?*
2. *What percent of crossings pass fish, limit fish passage, or have an unknown fish passage status?*

A total of 759 fish passage improvement projects were reported to OWEB from 1997 to 2004 (Table 3). Projects reported to OWEB often include multiple crossings. Thus we had 842 OWEB crossings for this analysis of which 788 were precisely located. Of the 788 crossings, approximately 76% of Oregon Plan fish passage projects have taken place in coho habitat. Fifty-one percent were in Low IP coho habitat and 25% were in High IP coho habitat.

Using the data compiled for this project we estimate that currently 43% of all crossings pass fish, 20% limit fish passage, and 37% remain unknown in terms of their ability to pass fish. These results vary depending on habitat type (Table 4). In particular, a larger percentage of structures in High IP pass fish (60%) than in the other habitat types.

Miles of Stream With Improved Access
The third objective of this project was to determine:

3. *How many coho and non-coho stream miles have improved access because of projects implemented under the Oregon Plan?*

For the ESU, we calculated the percent of stream miles with improved access to coho habitat and non-coho habitat that resulted from projects implemented under the Oregon Plan. We estimate that Oregon Plan activities have improved access to coho streams by 6-10% (Table 5). We estimate there is 6% improved access to High IP streams and 10% on Low IP streams. Oregon Plan activities have improved access by 16% on non-coho streams and by 14% on all stream miles (coho and non-coho streams). The range depends on if unknown status is assumed open or closed.

Table 3. State and private forest landowner's fish passage improvement *projects reported to OWEB from 1997 –2004.

Landowner Type	**Year**							
	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**Total**
PI Forest	78	132	115	95	90	54	34	**598**
PNI Forest	7	5	10	5	3	6	8	**44**
State Forests	13	20	9	9	33	11	22	**117**
Total								***759**

* 759 projects were reported to OWEB. Projects often include multiple crossings thus we had 842 OWEB crossings for this analysis.

Table 4. Percent of stream crossings that pass, limit, or have unknown fish passage status.

Habitat Type	Pass (% of total number)	Limit (% of total number)	Unknown (% of total number)
All X-ings	43	20	37
Low IP	43	20	37
High IP	60	14	26
Non-Coho	29	26	44

Table 5. Estimated percent of stream miles with improved access (Data Source: OWEB 1997-2003 for the ESU). The range depends on if unknown status is assumed open or closed.

Habitat Type	**Percent of miles with Improved Access***	**Average percent improved access**
Non-Coho	12-19%	16%
Low IP Coho	9 – 11%	10%
High IP Coho	6 – 7%	6%
All Streams	11 – 17%	14%

* = Low end of range reflects assumption that unknown are closed. High end reflects that unknown is open.

Miles of Stream That Still Have Limited Access

A final objective was to quantify:

4. How many coho and non-coho stream miles still have limited access?

Throughout the ESU, we estimated that 10-11% of coho streams have limited access (Figure 2). Eleven percent of Low IP streams and 10 percent of High IP streams are estimated to have limited access. While 10-11% is a relatively low number, the access status of 28-31% of coho stream miles was estimated as unknown at the time of this analysis. The condition is similar for non-coho streams. Approximately 16% of stream miles are estimated to have limited access, while access is estimated as unknown for 41% of non-coho stream miles. The higher percentages for non-coho streams is likely to reflect greater numbers of non-coho streams and a greater number of crossings on these streams. We estimate that of all the stream miles with limited access approximately 18% are High IP streams.

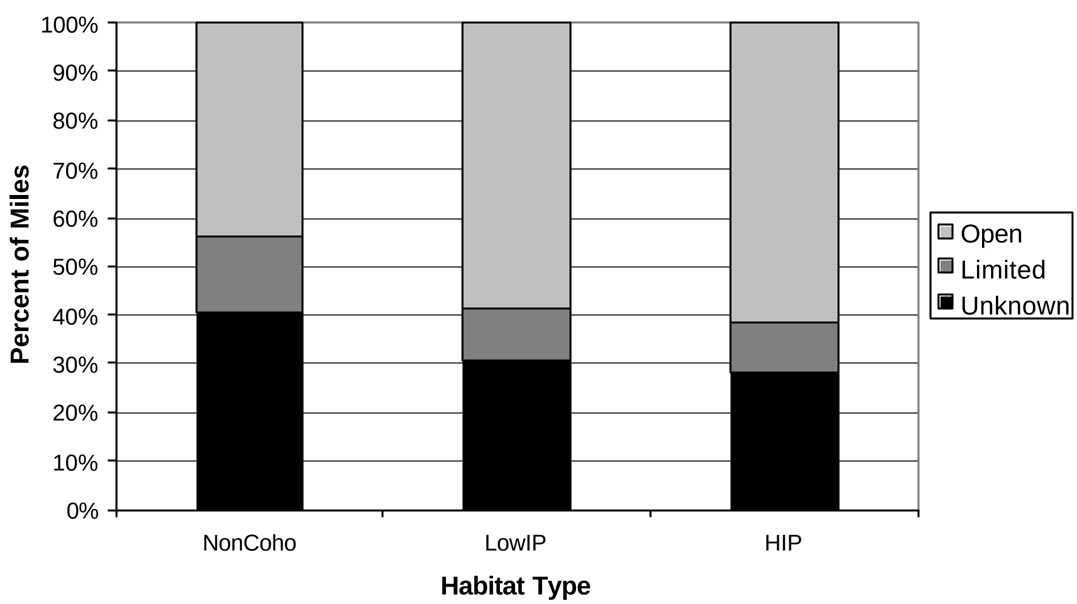

Figure 2. Estimated percent of stream miles within access status categories by habitat type for the ESU.

Sensitivity Of Results to Gradient and High IP Thresholds

We assessed the sensitivity of our results to changing the maximum gradient (e.g. 5% rather than 7%) that represents upper extent of coho and the percent at which we define High IP (e.g. 60% rather than 80%).

Changing the maximum gradient that represents the upper extent of coho. We tested a range of gradient thresholds ranging from 2 – 12% in 1% increments. The sensitivity analysis suggests that estimates of percent of coho habitat limited by stream crossings changes less than 3% with changes in maximum stream gradient thresholds used to define coho habitat (Figure 3). Estimates of percent of Low IP limited do not change substantially either (3% or more) until coho habitat is defined as being less than 2% or conversely as high as 11%. Estimates of percent High IP streams with limited access did not change substantially with threshold gradients ranging from 2 – 12%.

Estimates of percent *open* are more sensitive. Changes of >3% are encountered for percent of Low IP and High IP streams *open* when coho habitat is defined at maximum gradients less than 5% and 3%, respectively. An upper gradient sensitivity was found at 10% for Low IP streams but was not detected for High IP streams. The analyses suggest that unless the definition for coho habitat changes to <3-5% or <10 – 12%, our results will not change significantly.

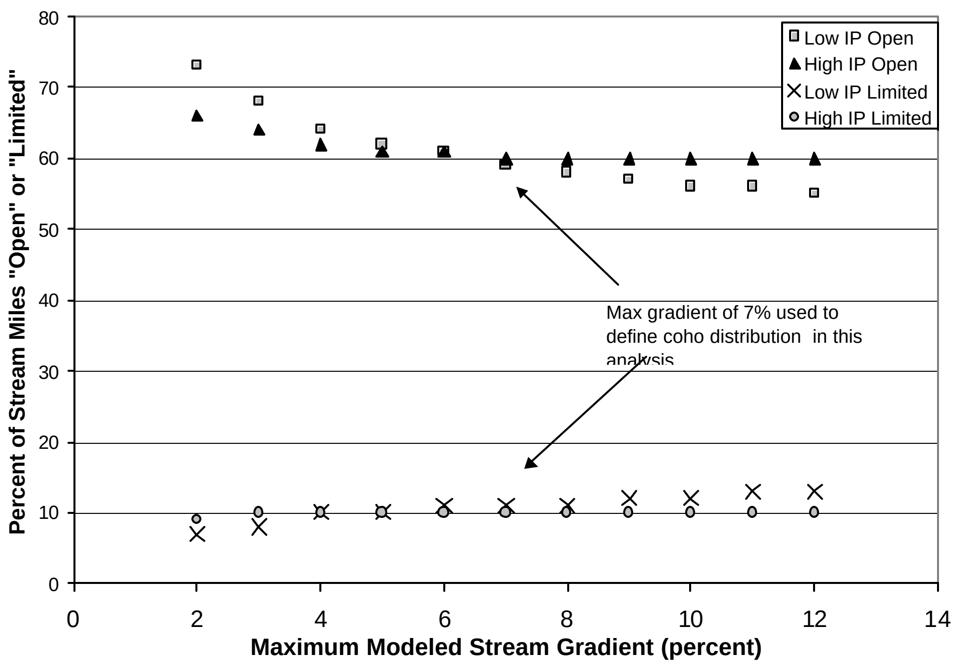

Figure 3. Change in results with incremental changes in maximum gradient threshold used to define upper extent of coho habitat.

Changing the percent at which we define High IP (e.g. 60% rather than 80%). We tested a range of High IP thresholds ranging from 20 – 100% in 20% increments. Our existing estimates assume that high intrinsic potential occurs with a score of 80%. The sensitivity analysis suggests that estimates of high and low intrinsic potential with limited, unknown or open status does not change until we define High IP at the extreme ends of the range. Specifically, if High IP were defined as either

100% or 20% (Table 8 and Figure 4). Our results are relatively insensitive to shifting numeric definitions of High IP.

The sensitivity analysis suggests that our estimates of accessible stream miles are sensitive to a shift in the gradient used to define the upper extent of coho. The estimated percent of stream miles accessible would reduce by about 3% if the upper extent of coho habitat were defined as less than 5% rather than 7%. Estimates of percent of stream miles with limited access were relatively insensitive to shifting gradients to define the upper extent of coho as well as thresholds to define High IP.

Table 6. Change in estimated percent of stream miles with open, limited, or unknown access with shifting thresholds that define High IP. Results are provided by habitat types. The threshold used in this study was 80%.

HABITAT TYPE	High IP Threshold	Estimated percent of stream miles in Access Categories		
		Open	Limited	Unknown
Non-Coho	20%	44	16	41
Low IP	20%	62	12	35
High IP	20%	58	10	30
Non-Coho	40%	44	16	41
Low IP	40%	60	12	35
High IP	40%	58	10	30
Non-Coho	60%	44	16	41
Low IP	60%	59	12	34
High IP	60%	60	10	29
Non-Coho	80%	44	16	41
Low IP	80%	59	11	33
High IP	80%	60	10	28
Non-Coho	100%	44	16	41
Low IP	100%	59	11	32
High IP	100%	100	0	0

Discussion and Conclusions

As with any analysis and evaluation, results are highly dependent on the assumptions and the validity, precision, and accuracy of the data used in the analysis. The limitations of this spatial evaluation were described with regard to positional accuracy, data completeness, and data consistency across space. Additionally, the meaning of "passes" and "limited" passage status for each crossing is neither a precise nor quantified term and may vary among land owners. These limitations introduce uncertainty into our results. In aggregate, the limitations are likely to have little effect on our estimates of fish passage status and habitat access for coho streams. The error in our estimates is likely to increase as we move up the channel network, where potential missing data and imprecision in crossing locations is compounded.

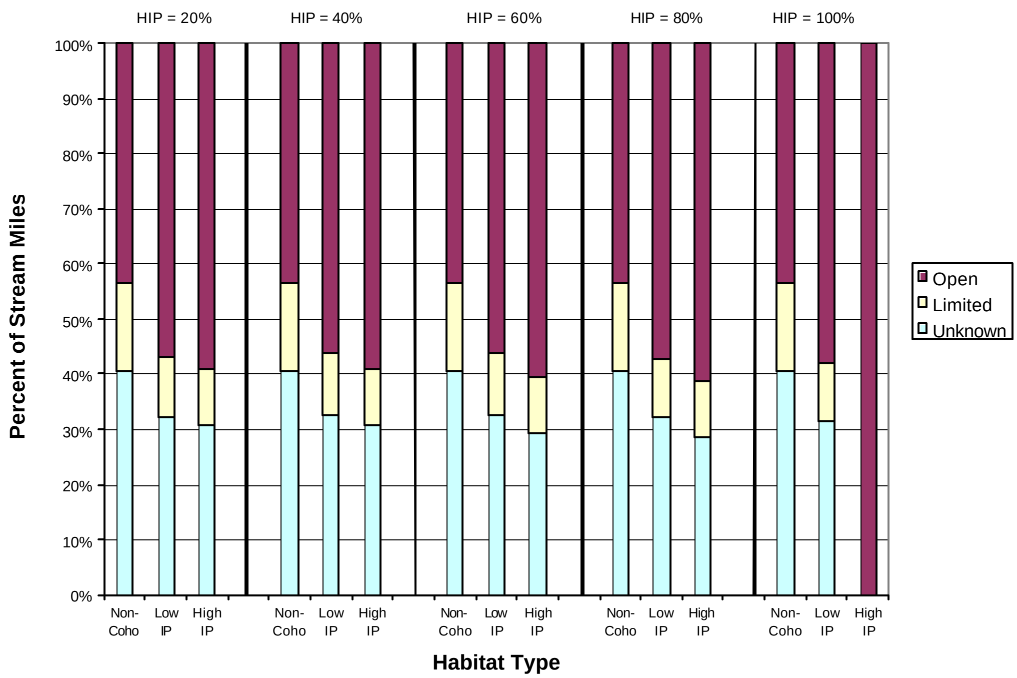

Figure 4. Changes in estimates of percent of stream in various access categories with incremental changes in definition of High Intrinsic Potential. The threshold used in this study was 80%.

Our lack of knowledge regarding passage status to 38% of stream miles represents a substantial limitation on our results. Stream miles with unknown access status are more than twice that of stream miles known to have limited accesses (15%) and nearly equals that of miles with known access (47%). Therefore the status of these crossings could substantially shift our conclusions about miles of accessible or inaccessible habitat. The ratio between unknown and known access was less substantial for coho streams, and particularly High IP streams. Therefore, the implications are not as significant regarding our findings for High IP streams. Furthermore, the implications are negligible for estimates of percent of miles with improved access, introducing a variability in results ranging from 1 –7% depending on the habitat type.

We tested the sensitivity of our results to thresholds for upper extent of coho distribution and High IP. The sensitivity analysis suggests that our estimates of accessible stream miles are somewhat sensitive to a shift in the gradient used to define the upper extent of coho. The estimated percent of stream miles accessible would reduce by about 3% if the upper extent of coho habitat were defined as less than 5% rather than 7%. Estimates of percent of stream miles with limited access were relatively insensitive to shifting gradient thresholds. None of the results were sensitive to shifting thresholds that define High IP.

While recognizing these limitations there are a number of strengths as well. First, while this is not a complete census we estimate that the majority of stream crossings are represented for low elevation, High IP stream reaches. This is based on the fact that the State and County crossing data are considered a complete census. These roads tend to be the most commonly occurring along lower gradient coho streams. In addition, if they could not provide a complete data set, we asked landowners to focus on coho stream crossings. Another strength of this study is that it is the first of its kind performed at a broad spatial scale (ESU). A unique contribution from this analysis is that it goes beyond simply counting the number of projects to include a spatial component that estimates how these projects have collectively affected access to coho and non-coho habitat. Finally, we have utilized a GIS tool that could be used to evaluate priorities for future projects if the target species is coho. The tool could also be adapted to accommodate other species, spatial scales, and time-trend analyses.

Given the combined strengths and weaknesses of this study we must emphasize that stream percentage results are estimates. These estimates are based on what we consider to be the best available data for this ESU.

Our analysis suggests that a relatively small percent of coho habitat remains inaccessible (10-11%) and that Oregon Plan fish passage restoration projects have improved access to 6-11% of coho habitat. However, our analysis also suggest that a significant proportion of the coho habitat has unknown access status (28-31%). With unknown access to approximately 1/3 of the habitat, fish passage cannot be eliminated as a risk to coho at this point in time.

Oregon has a strong regulatory program that requires passage of juvenile fish at stream crossings. The regulatory programs are supported by state of the art technical guidance on how to achieve this goal for juvenile fish passage. In addition, there has been a significant commitment through volunteer activities to improve access throughout the ESU. Of particular importance to this coho assessment, is that the bulk of non-regulatory fish passage improvement projects were placed in coho habitat (76%). These projects improved access to coho habitat by 6-11% over the past seven years. If only 10-11% of coho habitat remains inaccessible, and if restoration continues at the levels estimated by this analysis, it is feasible that fish passage could be eliminated as a risk to coho within the next 7-10 years. This suggests that the original goal of the Oregon Plan to address fish passage issues by 2012 will be achieved.

Many strategies can be used to provide for fish passage but only a few studies have evaluated the effectiveness of those strategies. Particularly lacking is information on fish-friendly tide gates. There is general agreement among studies that for culverts, stream simulation strategies are the most effective. However, it is important to recognize that this strategy is not appropriate for all stream types. For example this strategy is only appropriate for channels with deep valley fill, and mobile cobble and gravel streambeds. If fines dominate the natural streambed, this alternative may not work. Channel gradients must be less than 4% or 9% depending on how the culvert is installed.

There is a clear need for a systematic approach to study short-term and long-term effectiveness of fish passage projects as well as continued inventories of passage status. This study estimated that the passage status of 37% of all stream crossings is unknown, indicating a need to simply inventory culverts and other artificial barriers to determine if they pass fish or not. This type of survey should be done with a common methodology across all ownerships and barrier types. There is also a need for more complete information about partial barriers and the degree to which they represent an important biological truncation to resident and anadromous fish habitat utilization. This will require more research on fish movement, timing, and interactions with barriers.

Future analyses at this scale could incorporate data sets that were not used for this project. For example, at the time of this writing ODOT was working on an inventory of tide gates that could be incorporated. Including data from small landowners, remaining data on industrial ownership, and data outside of coho habitat that were not captured would increase the completeness of the data used for this analysis. Watershed Councils often prioritize fish passage and could help populate the database. Finally, Soil and Water Conservation Districts (SWCDs) have been instrumental in collecting and prioritizing fish passage projects and represent a wealth of information that was untapped for this project.

There is a need to establish priorities for further fish passage improvement projects. For example, if coho are the key species of concern, then access lower down in the stream network may be more important than higher up in the watershed where habitat is not as ideal for coho. The Network tool utilized for this project could be applied at any scale to aid in a prioritization process. It could be used as an analysis tool for watershed councils, private landowners, or state agencies to prioritize where resources are likely to provide the greatest benefit for the particular species of concern.

In summary, our analysis suggests that fish passage restoration activities have improved access to coho habitat as well as other fish-bearing streams. Existing studies suggest compliance with state standards and guidelines on forestland is moderately high and is likely to continue into the future given Oregon's statutory requirements and volunteer activities. Current regulations, guidelines, and strategies are evolving, as is the state of the science, which increases the likelihood that effectiveness of fish passage strategies will continue to improve. Therefore, it is highly unlikely that improvements in either implementation or effectiveness would come about by increasing regulatory requirements. Rather shifting our emphasis to monitoring and research is likely to improve our ability to successfully install fish-friendly crossings and shorten the time it takes to eliminate fish passage as risk to coho and other fish. This monitoring should be applied across all ownerships and habitats, capture the full range of artificial barriers, and provide data on effectiveness of strategies to eliminate barriers. As the state develops its effectiveness monitoring program it will be important to evaluate and prioritize the scale of interest. For example, for this study, we could only answer questions at the ESU scale. In the future it may be important to evaluate habitat access at the population unit.

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