THE OREGON PLAN for Salmon and Watersheds

1998 - 2000 Habitat Restoration Effectiveness Monitoring for the Western Oregon Stream Project

Report Number: OPSW-ODFW-2001-07

1998-2000 HABITAT RESTORATION EFFECTIVENESS MONITORING FOR THE WESTERN OREGON STREAM PROJECT

Oregon Plan for Salmon and Watersheds

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Paul Jacobsen
Barry Thom

Aquatic Inventories Project

Oregon Department of Fish and Wildlife
28655 Highway 34
Corvallis, OR 97333

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This report characterizes change in habitat conditions resulting from activities that were conducted from 1998-2000 as part of the "Restoration Effectiveness Monitoring Plan for the Western Oregon Stream Project v. 2.0", and reports on the analysis of the collected data. The stream restoration monitoring plan was developed to monitor a subset of restoration projects for the period of January 2000 to June 2008, and is a continuation of monitoring activities that began on the North Coast in 1995.

The four main questions developed as part of the plan were:

- How much stream restoration work has been completed?
- Is the work leading to improved habitat conditions for salmonids?
- What fish are using the treated habitats?
- What are the trends in juvenile salmonid abundance in the treated reaches?

This report will focus on the first two questions, and examines the changes in physical habitat at the restoration sites following the restoration work. We compare the sites before and after restoration treatment, and in relation to overall habitat conditions coast-wide. Comparisons were made under summer low-flow conditions and during winter high base-flow conditions. Long-term plans are to conduct similar comparisons for each project after 4 – 6 years to look at change over a longer period.

PROJECT HISTORY

Stream restoration activities funded through the Oregon Wildlife Heritage Foundation (OWHF), Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Forestry (ODF), Oregon Watershed Enhancement Board (OWEB), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and private landowners have been carried out in coastal Oregon streams since 1995. These projects originally targeted coho salmon (*Oncorhynchus kisutch*) habitat in the North Coast and have since expanded throughout anadromous salmonid habitat in western Oregon. Restoration in the Willamette River basin (upstream of Willamette Falls) and coastal streams south of the Rogue River has focused primarily on steelhead (*O. mykiss*) and chinook salmon (*O. tshawytscha*) habitats. The following types of activities have been conducted:

- In-stream wood placements
- In-stream boulder placements

- Construction of off channel ponds
- Culvert replacement and bridge placement
- Conifer and hardwood riparian plantings
- Fencing and livestock management
- Artificial barrier removals
- Road decommissioning

Completed stream habitat restoration projects typically had two major goals. They were designed to increase the quantity and quality of aquatic habitat for juvenile salmonids over the short term (2-30 years), and restore the physical biological processes that create and maintain high quality habitat for the long term (10-100 years). As the project has progressed since 1995, both short-term and long-term goals have focused on increasing habitat for all ages of anadromous salmonids.

Increases in winter rearing areas have been shown to increase the survival of coho smolts (Solazzi et al. 2000). Stream enhancement and restoration in the form of large wood placement, increased slow water area, and off-channel habitat such as alcoves provides the refuge needed to increase the abundance of coho salmon juveniles (Solazzi et al. 2000). Streams with little large woody debris and a low potential for large wood recruitment, plus limited summer habitat complexity and limited winter off-channel habitat can benefit through a sequential process of large wood introduction (short term), improved road and culvert condition (short term to long term), and modified riparian and upslope management (long term) (Moore. 1997).

From 1995-2000 over $5,500,000 has been spent on coastal stream restoration activities, including project planning, materials, structure placement and monitoring (Rod Brobeck, Oregon Wildlife Heritage Foundation, pers. comm.). This work has also involved the time of eight full time habitat biologists and numerous individuals from the timber industry, the OWHF, ODFW, ODF and private landowners.

METHODS

STUDY DESIGN

The stream restoration monitoring plan was designed to monitor a subset of restoration projects in Western Oregon (Lacy et al. 2000). This plan compares stream habitat conditions in the year before and after restoration. Beginning in the summer of 2001 and winter of 2002, as well as every three years thereafter, post-treatment monitoring will be completed 4 to 6 years following enhancement to better look at change over time. All of the monitoring within this plan relies heavily on current coast-wide monitoring efforts that are part of the Oregon Plan for Salmon and Watersheds (OPSW). Habitat surveys that are conducted as part of the OPSW monitoring activities will serve as a baseline from which to evaluate treated stream reaches.

PROJECTS COMPLETED

Stream restoration projects completed were summarized by project location, type, length of stream treated, and type of monitoring conducted at the site. For the period 1998 – 2000, 238 in-stream restoration projects were completed (Table 1). The majority of these projects involved large wood and boulder placement, with some off-channel enhancement such as the creation of alcoves, riparian fencing, riparian plantings, and culvert replacement. Initially this project was restricted to the North and Mid-Coast areas, but by 1998, it was expanded to include all of Western Oregon (Figure 1).

PHYSICAL HABITAT MONITORING

A subset of restoration projects was surveyed to look for changes in habitat conditions. Monitoring took place before and after completion of restoration projects, in both winter and summer. The projects that received more detailed evaluation were selected based on a minimum amount of work completed (two in-stream structure sites within a 500 m segment) and the type of work completed. Physical habitat surveys consisted of a 300-800 m treatment segment in each site selected for monitoring. The methods used for physical habitat surveys were modified from the ODFW Aquatic Inventories protocols (Moore et al. 1997). Modifications to the survey methods included:

- Measuring all unit lengths and widths to avoid bias in estimations over short segment lengths.
- Riparian transects were taken at 125, 250 and 375 m through the surveyed reach during summer.
- Conducting winter surveys to quantify habitat area, depth, wood quantity and substrate.

Physical habitat surveys that were conducted as part of the OPSW monitoring activities were used as a baseline condition from which to compare changes in the treated areas (Thom, et al. 2000). The sites selected for the baseline surveys were randomly selected from the salmonid bearing tributaries of the study areas. Any segments used as comparison sites were of a similar channel width, gradient, and reach morphology as the treated stream reaches. The streams used in the comparison did not contain habitat structures. These baseline surveys represented the range of stream conditions in potentially treatable reaches that have been left untreated.

Pre-treatment conditions were available from ODFW Aquatic Inventory Project information gathered in 1997 and 1998. The methods used for the 1997 and 1998 pre-treatment surveys were slightly different than those used in 1999 and did not follow the changes mentioned above. After 1999, all pre- and post-treatment data was collected under similar methods. The winter and summer habitat surveys used in the analysis represent potentially different sites. Some overlap does occur between sites that are monitored in summer and winter.

ANALYSIS

Aquatic habitat information was analyzed to determine if the treated stream reaches increased in both habitat quality and quantity after addition of large wood. This analysis compared changes in treated reaches before and after treatment using a paired t-test. These changes were then compared to the OPSW random reaches using cumulative frequency distribution graphs of the monitored attributes. The random reaches were used as baseline reference conditions for comparison to the treated sites. As controls, the randomly selected OPSW reaches help to explain some of the changes or lack of significant changes detected in treated reaches using the paired t-test comparison.

When presenting the results, we looked at changes in several quantifiable attributes, including:

- large wood, defined as pieces of wood touching or within the active stream channel that are at least 3 m long and 15 cm in diameter.
- fine sediment defined as all substrate material less than 64 mm, including silt, sand, organics, and small diameter gravel.
- habitat area, the wetted area within the active stream channel.

RESULTS

PHYSICAL HABITAT COMPARISONS

The analysis of habitat change over time included only those sites with both post-treatment data in 1999 or 2000. For this report, pre/post-treatment pairs for winter conditions were collected at 11 sites in 1998/1999 and 10 sites in 1999/2000. Pre/Post-treatment pairs of summer conditions were collected at 10 sites in 1998/1999 and 12 sites in 1999/2000. Monitoring sites were only located in the North and Mid-Coast project areas for the 1998 and 1999 pre- and post-treatment data set. For the 1999/2000 pre- and post-treatment data set, sites were located in all six project areas (Figure 1).

Winter Surveys

Wood

Significant increases were observed in the quantity of woody debris in the treated stream reaches. These increases were observed for the 1998/1999 data set and the 1999/2000 data set. Significant increases were observed in the number of wood pieces, the number of key wood pieces, the volume of woody debris and the number of wood jams (See Table 2 for p-value comparisons). For the combined 1998-2000 data set, wood pieces increased by one-half, wood volume increased 2.7 times, key wood pieces increased three fold and wood jams increased 3.2 times. The average number of key wood pieces per 100 m of stream length was 1.8 for the treated stream areas after treatment.

Sediment

Changes in fine sediment and gravel levels were highly variable between survey years. Overall, fine sediments were high with an average of 38.5 percent fines in riffle units and 52 percent fines overall after treatment (Table 2). The 1998/1999 data set showed an increase in fine sediments, while the 1999/2000 data set showed a decrease in fine sediment levels. Significant change did not occur in the combined data set due to the highly variable nature of the sediment readings. Gravel levels showed an opposite pattern to fine sediments with gravel levels decreasing from 1998/1999 and increasing from 1999/2000. The net result for the combined data set was no net change in gravel levels over the period monitored. The fine sediment levels and gravel levels were both very high over the period monitored with 38.5 percent fine sediments in riffle units and 41.8 percent gravel in riffle units in the treated areas.

Habitat Area

Winter habitat area did not change significantly between the pre- and post-treatment surveys. The proportion of the habitat area in dammed pools was highly variable during the period of the study. Although dammed pool area doubled from 4.8 to 9.3 percent on average after treatment, this change was less than significant ($p = 0.16$, Table 2). The percent habitat area in pools was high both before and after treatment with over 45 percent pool area on average both before and after treatment. The density of deep pools actually decreased slightly over the period monitored.

Summer Surveys

Wood

Similar to the winter surveys, significant increases were observed in the quantity of in-stream wood in the treated stream reaches. Increases were observed in the number of wood pieces, the number of key wood pieces, the volume of wood and the number of wood jams (Table 3). The number of wood pieces increased 1.5 times, wood volume increased 2.4 times, key wood pieces increased over 5 times and wood jams increased 2 fold.

Sediment

Summer fine sediment and gravel levels appeared very similar in pattern to the winter data set. The high between-site variability led to non-significant changes in sediment levels. Post-treatment fine sediment and gravel levels were high, with 23.5 percent fine sediments and 44.5 percent gravel in riffle units and 36.2 percent fine sediments and 32.6 percent gravel overall (Table 3).

Habitat Area

There were no significant changes observed for channel area, secondary channel area, or pool areas in the summer habitat surveys. For the combined 1998/1999 and 1999/2000 data set, the proportion of stream habitat that comprises pools was high both before and after treatment. The average pool area was 46 percent before wood additions and 50 percent pool habitat after treatment (Table 3).

PHYSICAL HABITAT OVERALL HABITAT QUALITY

The interactions between habitat metrics were examined through a series of data queries relating to habitat quality. The number of sites that had high quality habitat, or the potential for high quality stream habitat, were summarized by channel type. The major channel type divisions were: wide valley floor (greater than 2.5 times the active channel width) and narrow valley floor (less than or equal to 2.5 times the active channel width). The wide valley floor channels were subdivided into: unconstrained reaches (flood prone width greater than 2.5 times the active channel width and terrace height less than flood prone height); potentially unconstrained reaches (terrace height less than 25% greater than flood prone height); and deeply incised reaches (terrace height more than 25% greater than flood prone height).

The criteria used to define high quality in-channel habitat were: pool area > 35% of channel area, the presence of slackwater pools or secondary channels, wood volume greater than 20 m^3 per 100 m of stream channel and at least 1 key piece of woody debris per 100 m of stream length. (Appendix B).

High-quality stream habitat for salmonids is measured in part by the combination of percent of pool area, secondary channel and off-channel habitat, wood volume, and key large wood pieces in the surveyed sites. Overall habitat quality for the selected areas increased by 27-40% from pre- to post-restoration. Of the twenty-two summer sites selected, one had high quality habitat prior to treatment while seven met the high quality standards after treatment. In the twenty-one winter sites, one had high quality habitat prior to treatment while nine met the high quality standards after treatment (Table 4). This is a very positive response as most of these sites were selected based on having lower quality habitat but having potential for improvement. Many sites have potential to improve further, but no major flow events have occurred since structure placement to help recruit more wood, scour pools, or develop additional channel complexity. In addition, some sites may require a longer time frame to fully restore because many of these sites offer little upslope wood recruitment opportunities due to past land management activities.

PHYSICAL HABITAT COMPARISONS TO OPSW RANDOM SITES

Frequency distributions of habitat variables were compared for the summer and winter habitat data gathered for the OPSW as well as the restoration monitoring sites. OPSW random surveys were available for the summers of 1998 and 1999 and the winter of 2000. There were no significant differences observed between habitat variables in the random surveys between 1998 and 1999 (Thom et al. 2000). The data set used to calculate the cumulative frequency distributions is larger (n = 149 for summer, n = 42 for winter) than the data set used for the paired t-test comparisons (n = 21 for summer, n = 22 for winter). All pre- and post-treatment data were used regardless of whether a matching pre- or post-treatment survey was conducted at the site.

Winter Surveys

Wood

Wood levels observed in the pre-treatment winter surveys were either similar to or significantly lower than those observed in the 2000 random surveys (Figure 2). In all cases, the post-treatment wood levels were significantly higher than those observed in the random surveys, a result also seen in the paired comparisons. The distribution of wood piece, wood volume, and key wood piece densities fall within the range of expected high-quality stream habitat based on the ODFW benchmarks (Moore 1997). In the pre-treatment data set, 30 percent of the sites did not have key wood pieces. In the post-treatment data set, 50 percent of the sites had at least one key wood piece per 100 m of channel length. Wood jams were high when compared to ODFW benchmarks after treatment with a median wood jam density of 11 jams per km of stream length.

Sediment

The distribution of the percent fine sediments in riffle units agreed with the results of the paired t-tests. There was not a significant difference between the pre- and post-treatment data sets. However, the pre- and post-treatment sediment levels were both significantly higher than the conditions observed in the OPSW random winter surveys (Figure 2). The percent gravel in riffle units also did not show a significant difference between the pre- and post-treatment data sets. The pre- and post-treatment data sets and the OPSW random surveys all show moderate to high gravel levels, with a median gravel level of approximately 45 percent for the three data sets.

Habitat Area

The proportion of habitat in pools was significantly higher in both the pre- and post-treatment restoration surveys than the 2000 OPSW random winter surveys. The median value for pool area was over 40 percent in the reaches selected for wood additions and less than 30 percent in the randomly selected stream reaches. In the treated stream reaches there were no sites with less than 20 percent pool habitat, where as in the random surveys 25 percent of the sites had less than 20 percent pool habitat (Figure 2). The density of deep pools was significantly higher in the pre- and post-treatment data sets as compared to the OPSW random winter surveys and no significant differences existed between the pre- and post-treatment data sets.

Summer Surveys

Wood

The summer wood levels closely corresponded to those observed in the winter pre- and post-treatment surveys. In the post-treatment state, sites had significantly higher wood levels than the OPSW random summer surveys and the pre-treatment data set (Figure 3).

Sediment

Fine sediments in riffle units were not significantly different between the 1998/1999 OPSW random summer surveys and the pre- or post-treatment data sets. The median fine sediment levels for all three data sets were near 20 percent. The percent gravel in riffle units was higher in the pre- and post-treatment data sets than in the OPSW random summer surveys. The median percent gravel was near 45 percent for the pre- and post-treatment data but less than 30 percent in the random surveys (Figure 3).

Habitat Area

The proportion of habitat in pools was significantly higher in both the pre- and post-treatment restoration surveys than the 1998/1999 random surveys. The median value for pool area was over 50 percent in the treated stream reaches, and less than 40 percent in the randomly selected stream reaches. Deep pool density was very similar between the three data sets, and much lower than in the winter data set. The median deep pool density for the post-treatment summer surveys and the OPSW summer random surveys were approximately one deep pool per kilometer of stream. In the winter restoration surveys this density increased to upwards of six deep pools per kilometer of stream (Figure 3).

DISCUSSION

The pre-treatment condition of monitored streams had adequate levels of pools and gravel. Most areas lacking complexity improved with added wood. The amount of fine sediments in riffles was high. It is likely that the wood is trapping both fine and coarse-grained sediments. In the low gradient sections where work is being conducted, it is actually indicating a high level of fines in the system. High fines are observed everywhere, but become more apparent locally when they are trapped by added wood.

The frequency distributions help to better explain some of the patterns observed in the t-tests, both that an increase in gravel and pools would not be expected given the pre-treatment condition of having adequate levels of gravel and pools, as well as that significant increases have occurred in wood levels in the treated areas. In low-gradient reaches with high numbers of pools, it may be difficult to increase pool area, but may be possible to increase pool frequency.

The added wood may be creating an increase in winter habitat because of the damming action of the wood. Dammed pool habitat is more prevalent in winter. In the random surveys, dammed pool habitat is 9 percent in summer and 5.3 percent in winter. In the restoration areas, dammed pool habitat is 1.5 percent in summer and 9.3 percent in winter. The short-term response indicates that the structure work has significantly increased the proportion of sites with overall high quality habitat in winter and summer. This relationship will be better examined with increased sample size as well as winter random surveys conducted in 2000.

Restoration sites are currently surveyed the winter and summer before and the winter and summer after treatment is applied. Consequently, only minimal changes in the treated section will be illustrated unless there is a major winter flow event. These sites need to be revisited after a longer period, perhaps 4 – 6 years after structure placement, in order to determine if the applied treatments are effective.

MANAGEMENT RECOMMENDATIONS

Target restoration efforts toward areas that have lower amounts of fine sediments. Thus far, most work has been completed in areas with high fine sediments and it would be of interest to see the effects of restoration where pool enhancement is needed while the amount of available fines is reduced. It may be necessary to address road-related issues and the size of streamside buffers first to reduce sediment delivery into the stream system.

Increase key wood pieces and wood levels at all sites to create a high wood level (3 or more key wood pieces per 100 m), plus increase the amount of branches and small wood to better trap small material and sediments, and add complexity to pool habitat. This increased complexity will help provide needed winter refuge for juvenile salmonids.

Increase the size of the wood placed. Most large wood currently used is restricted to cull logs that are shorter in length and smaller in diameter than is desirable. Whole trees greater than 90 cm in diameter with attached rootwads will help more accurately represent naturally functioning conditions and increase structure stability. Larger pieces will better trap sediment and collect smaller pieces of wood.

Direct some of the restoration process to areas lacking pools and having moderate gradient. Thus far, work has been concentrated in low gradient, pool-rich areas. It would be valuable to increase pool area where it is currently deficient and to determine if fine sediments are trapped at the same levels as the low gradient areas.

Complete follow up surveys on the 4 – 6 yr post-restoration cycle, starting the summer of 2001 as outlined in the Restoration Monitoring Plan (Lacy et al. 2000). These surveys will provide the opportunity to review change over time at the sites completed in 1995 – 1997. It is important to determine if the habitat structures are affecting the stream channel in a positive manner or if a modification to structure placement methods is warranted.

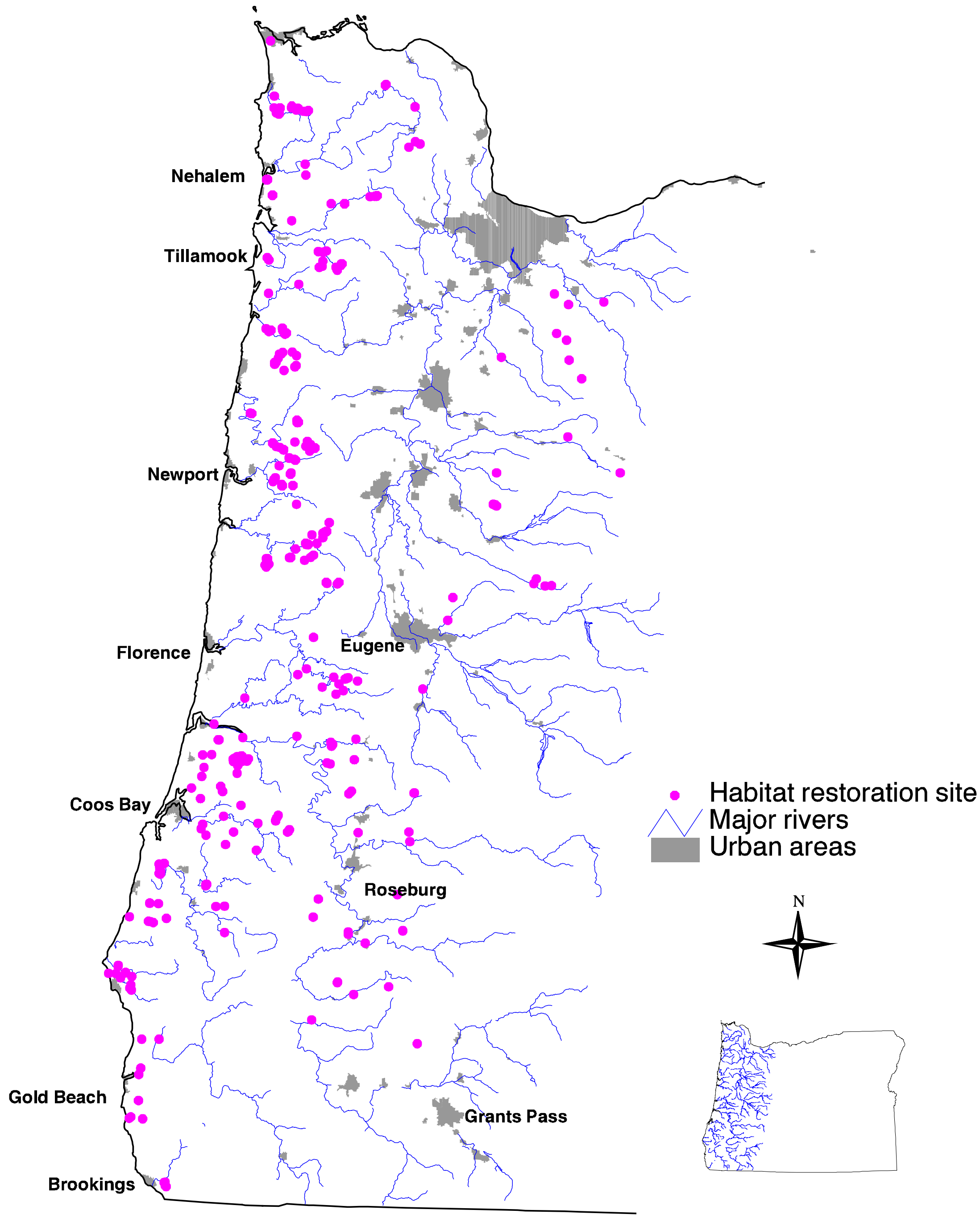

Figure 1: Western Oregon Salmon Habitat Restoration Projects. 1998 – 2000.

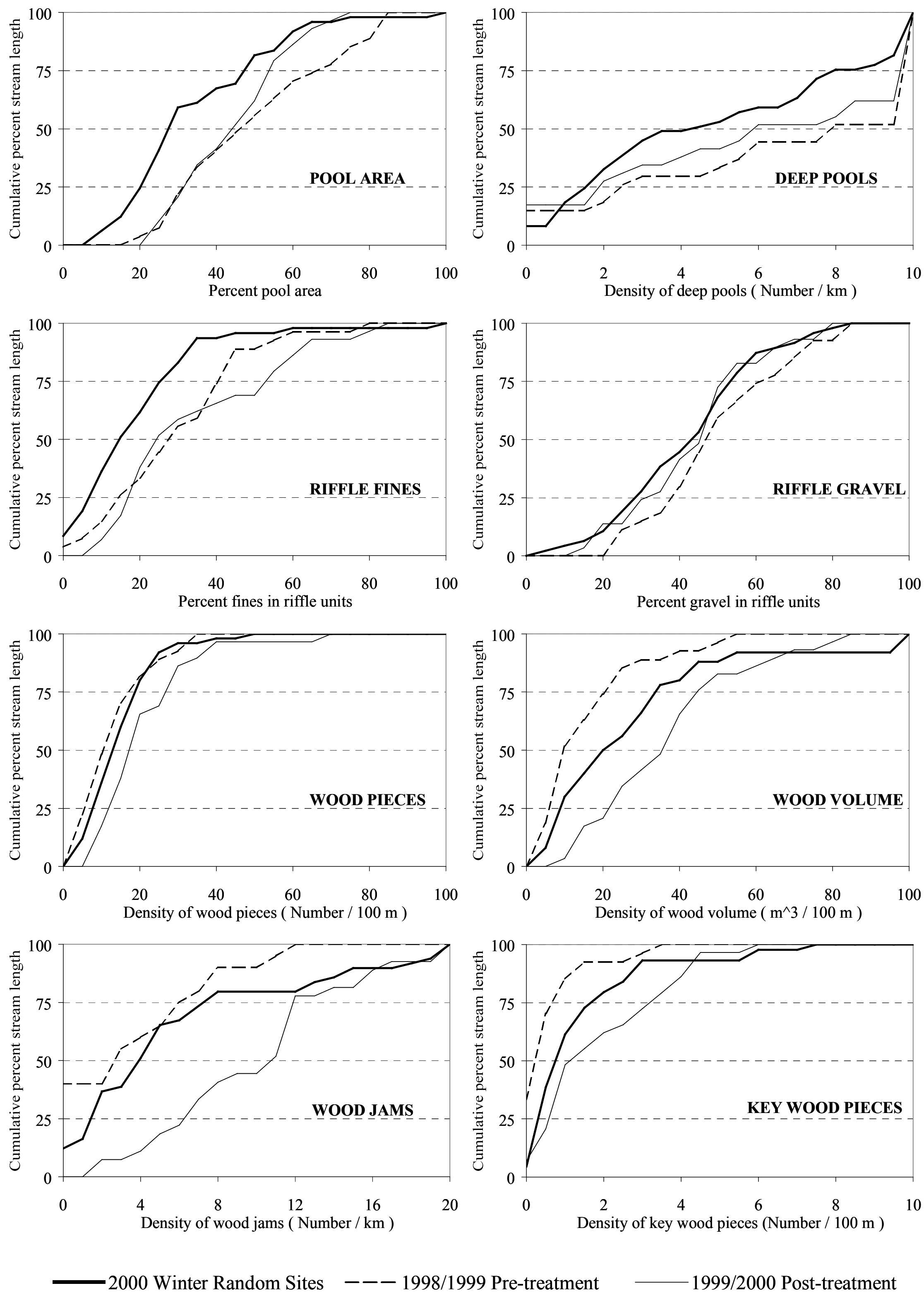

Figure 2: Winter Characterization of Pre-Treatment and Random Sites vs. Post-Treatment. 1998-2000.

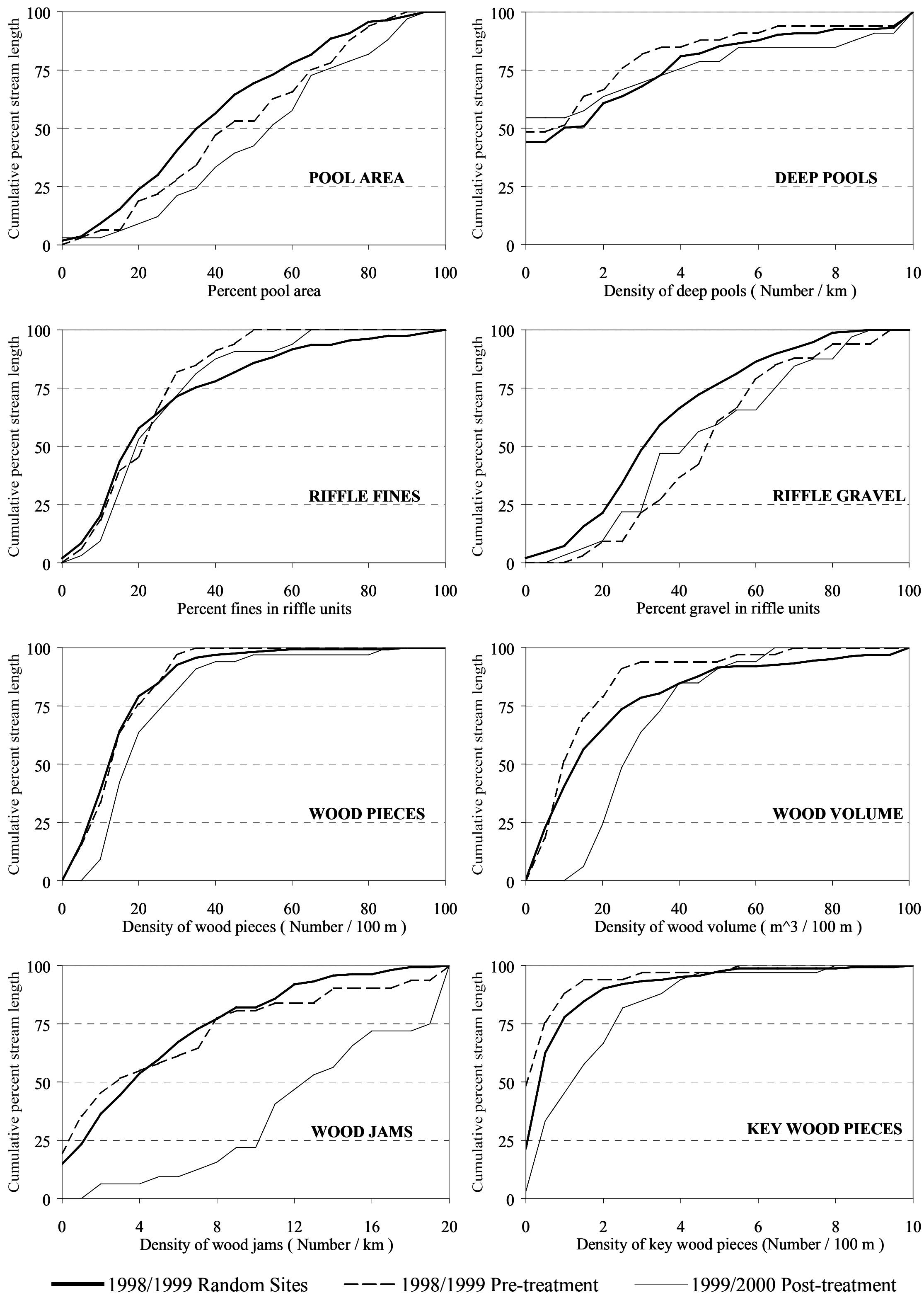

Figure 3: Summer Characterization of Pre-Treatment and Random Sites vs. Post-Treatment. 1998-2000.

Table 1. 1998 – 2000 Restoration Projects by Area and Project Type.

			large wood	boulders	culverts	fencing	riparian plantings	Misc.	# miles
North Coast									
	1998		9	1	9		1	2	21.4
	1999		11	1					7.1
	2000		12						8.87
Mid Coast									
	1998		17		11		3	4	12.45
	1999		10		2		9	3	10.4
	2000		10			1	2	3	4.45
Mid-South Coast									
	1998		7	3	4			3	6.25
	1999		5						3.25
	2000		5						3.3
Umpqua									
	1998		5			1		2	3.5
	1999		5						3.75
	2000		6		2	8	2		13.5
South Coast									
	1998		9					1	4.3
	1999		7						1.9
	2000		7						1.9
Willamette									
	1998		5						3.55
	1999		9		3		1	1	4.3
	2000		6		8	1	1		6.25
Totals		238 Projects	145	5	39	11	19	19	120.42

Table 2. Results of Two-Tailed T-Tests Comparing Change of Pre- and Post-Treatment Data. Winter 1998 – 2000.

	n = 11				n = 10				n = 21			
Variable	98 Pre	99 Post	Change*	P-Value	99 Pre	00 Post	Change*	P-Value	98-99 Pre	99-00 Post	Change*	P-Value
Active Channel Width	7.2	6.8	-0.4	0.470	7.7	7.6	-0.2	0.810	7.4	7.2	-0.3	0.690
Channel Area	1571.5	2352.5	**781.0**	0.002	2999.9	2532.7	-467.2	0.070	2251.7	2438.3	186.6	0.520
% Secondary Channel Are	2.2	4.7	**2.5**	0.040	5.6	6.1	0.5	0.830	3.8	5.4	1.5	0.230
% Pool Area	59.1	52.1	-7.0	0.260	38.4	43.0	4.6	0.220	49.2	47.8	-1.5	0.780
% Dammed Pool Area	5.0	11.4	6.4	0.160	4.6	6.9	2.3	0.450	4.8	9.3	4.5	0.100
Deep Pools / km	13.1	11.4	-1.7	0.360	6.2	5.5	-0.7	0.610	9.8	8.6	-1.2	0.590
% Riffle Fines	26.7	56.6	**29.9**	<0.001	30.5	18.6	**-11.9**	0.050	28.5	38.5	10.0	0.130
%Riffle Gravel	57.5	33.0	**-24.5**	<0.001	39.4	51.4	**12.0**	0.010	48.9	41.8	-7.1	0.190
% Total Fines	44.8	71.4	**26.5**	<0.001	39.0	30.6	-8.4	0.210	42.0	52.0	9.9	0.150
% Total Gravel	38.7	18.4	**-20.4**	<0.001	26.8	40.4	**13.6**	0.002	33.0	28.9	-4.2	0.330
Wood Piece / 100 m	11.0	17.9	**6.9**	0.005	10.3	14.5	**4.2**	0.020	10.7	16.3	**5.6**	0.020
Wood Volume / 100 m	13.3	32.3	**19.1**	0.002	11.2	34.8	**23.6**	0.001	12.3	33.5	**21.2**	<0.001
Key Wood Pieces / 100 m	0.6	2.0	**1.4**	0.018	0.5	1.7	**1.1**	0.010	0.6	1.8	**1.3**	0.001
Wood Jams / km	2.4	7.7	**5.2**	<0.001	2.8	13.2	**10.5**	0.003	3.2	10.3	**7.1**	<0.001

*Significant ($p < 0.05$) differences in value between pre- and post-treatment in bolded font.

Table 3. Results of Two-Tailed T-Tests Comparing Change of Pre- and Post-Treatment Data. Summer 1998 – 2000.

	n = 10				n = 12				n = 22			
Variable	98 Pre	99 Post	Change*	P-Value	99 Pre	00 Post	Change*	P-Value	98-99 Pre	99-00 Post	Change*	P-Value
Active Channel Width	5.7	6.2	0.5	0.450	8.3	7.8	-0.4	0.410	7.2	7.1	-0.1	0.920
Channel Area	1623.1	1641.6	18.5	0.920	2334.3	2362.6	28.3	0.860	2011.0	2034.9	23.9	0.920
% Secondary Channel Are	7.9	5.1	-2.7	0.230	6.4	10.1	**3.7**	0.010	7.1	7.8	0.8	0.770
% Pool Area	44.5	47.8	3.3	0.300	48.1	51.4	3.3	0.400	46.4	49.8	3.3	0.630
% Dammed Pool Area	3.5	1.0	-2.5	0.180	4.5	1.9	-2.7	0.200	4.1	1.5	-2.6	0.055
Deep Pools / km	2.5	1.8	-0.7	0.120	1.9	2.6	0.7	0.320	2.2	2.3	0.1	1.000
% Riffle Fines	20.9	33.0	**12.1**	0.010	21.1	15.6	-5.5	0.140	21.0	23.5	2.5	0.540
% Riffle Gravel	51.3	47.3	-4.0	0.340	41.5	42.2	0.7	0.920	46.0	44.5	-1.5	0.820
% Total Fines	36.8	44.2	7.4	0.210	34.9	29.5	-5.4	0.080	35.8	36.2	0.4	0.930
% Total Gravel	32.6	34.0	1.4	0.720	29.9	31.5	1.6	0.700	31.1	32.6	1.5	0.740
Wood Piece / 100 m	10.4	21.6	**11.2**	0.010	15.5	18.6	**3.1**	0.006	13.2	20.0	**6.8**	0.020
Wood Volume / 100 m	9.8	28.5	**18.7**	0.002	15.0	32.2	**17.2**	0.006	12.6	30.5	**17.8**	<0.001
Key Wood Pieces / 100 m	0.3	1.9	**1.6**	0.010	0.5	2.0	**1.6**	0.030	0.4	1.9	**1.6**	0.001
Wood Jams / km	----	----	----	----	7.9	13.6	**5.7**	0.020	5.9	13.3	**7.4**	0.001

*Significant ($p < 0.05$) differences in value between pre- and post-treatment in bolded font.

Table 4. Number of Restored Reaches With High Quality Habitat Based On Channel Type And Instream Habitat. All Reaches <5% Gradient.

Summer Pre-Treatment	Wide Valley Floor			Narrow Valley
	Unconstrained	Potentially Unconstrained[a]	Deeply Incised[b]	Constrained by Hillslopes
High Quality	0	1	0	0
Moderate-Low Quality	5	7	6	3
Total Number	5	8	6	3

Summer Post-Treatment	Wide Valley Floor			Narrow Valley
	Unconstrained	Potentially Unconstrained[a]	Deeply Incised[b]	Constrained by Hillslopes
High Quality	1	4	2	0
Moderate-Low Quality	4	4	4	3
Total Number	5	8	6	3

Winter Pre-Treatment	Wide Valley Floor			Narrow Valley
	Unconstrained	Potentially Unconstrained[a]	Deeply Incised[b]	Constrained by Hillslopes
High Quality	1	0	0	0
Moderate-Low Quality	4	8	7	1
Total Number	5	8	7	1

Winter Post-Treatment	Wide Valley Floor			Narrow Valley
	Unconstrained	Potentially Unconstrained[a]	Deeply Incised[b]	Constrained by Hillslopes
High Quality	4	3	2	0
Moderate-Low Quality	1	5	5	1
Total Number	5	8	7	1

a - Terrace height < 1.25*Floodprone height, b - Terrace height > 1.25*Floodprone height

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APPENDIX A: LIST OF MONITORED SITES AND OREGON PLAN (OPSW) STREAMS. 1998 – 2000.

		OREGON PLAN STREAMS USED FOR BASELINE DATA AND FREQUENCY DISTRIBUTIONS		STREAMS USED AS RESTORATION SITES AND FOR T-TESTS	
BASIN	**STREAM**	**WINTER**	**SUMMER**	**WINTER**	**SUMMER**
NESTUCCA	BAXTER CREEK			X	X
NESTUCCA	BEAR CREEK				X
ALSEA	BURCH CREEK			X	X
YAQUINA	BUTTERMILK CREEK			X	
SIUSLAW	CONGDON CREEK				X
YAQUINA	DEER CREEK #2 UPPER			X	X
WILSON	DEVILS LAKE FORK WILSON RIVER			X	X
SIUSLAW	DOE CREEK			X	
SIUSLAW	DOGWOOD CREEK			X	X
TRASK	EF TRASK RIVER				X
NEHALEM	FALL CREEK				X
SILETZ	FOURTH OF JULY CREEK			X	
ALSEA	HEADRICK CREEK			X	X
NECANICUM	KLOOTCHIE CREEK				X
ALSEA	LITTLE LOBSTER CREEK - LOWER			X	X
SILETZ	LITTLE ROCK CREEK			X	X
SILETZ	LITTLE STEER CREEK				X
SILETZ	LONG PRAIRIE CREEK - UPPER			X	X
SILETZ	LONG TOM CREEK			X	
NECANICUM	MAIL CREEK			X	X
NECANICUM	NECANICUM RIVER - UPPER			X	X
NECANICUM	NF NECANICUM RIVER TRIB A				X
YAQUINA	SALMON CREEK			X	X
ALSEA	SEELEY CREEK #2 UPPER			X	X
YAQUINA	STEER CREEK			X	X
SILETZ	SUNSHINE CREEK			X	
SIUSLAW	SWARTZ CREEK			X	X
SILETZ	WHISKEY CREEK			X	
WILLAMETTE	ABERNETHY CREEK		X		
NEHALEM	ANDERSON CREEK		X		
ROGUE	BANNING CREEK		X		
YOUNGS	BAYNEY CREEK		X		
SALMON	BEAR CREEK		X		
SIUSLAW	BEAR CREEK	X	X		
NESTUCCA	BEAVER CREEK		X		
SIUSLAW	BEAVER CREEK		X		

BASIN	STREAM	WINTER	SUMMER	WINTER	SUMMER
COQUILLE	BEAVER DAM CREEK		X		
WILSON	BEN SMITH CREEK	X			
NEHALEM	BENEKE CREEK		X		
SILETZ	BENTILLA CREEK		X		
NESTUCCA	BIBLE CREEK		X		
COQUILLE	BIG CREEK		X		
UMPQUA	BIG TOM FOLLEY CREEK	X			
TRASK	BLUE BUS CREEK		X		
COOS	BOTTOM CREEK	X			
OCEAN	BOULDER CREEK		X		
SILETZ	BOULDER CREEK		X		
UMPQUA	BOULDER CREEK		X		
TRASK	BOUNDARY CREEK	X			
UMPQUA	BRUSH CREEK	X	X		
COQUILLE	BUCK CREEK		X		
APPLEGATE	BULL CREEK		X		
NEHALEM	BULL HEIFER CREEK		X		
ALSEA	BULL RUN CREEK		X		
NEHALEM	BUSTER CREEK	X			
NEHALEM	BUSTER CREEK		X		
NEHALEM	BUSTER CREEK TRIB B		X		
WILLAMETTE	BUTTE CREEK		X		
NEHALEM	CALVIN CREEK		X		
COQUILLE	CAMAS CREEK		X		
SANDY	CAMP CREEK #2		X		
CLATSKANIE	CARCUS CREEK		X		
SANDY	CAT CREEK		X		
WILSON	CEDAR CR, N FK	X	X		
NEHALEM	CEDAR CREEK #2		X		
CLATSKANIE	CLATSKANIE RIVER		X		
CLATSKANIE	CLATSKANIE RIVER		X		
NESTUCCA	CLEAR CREEK #4		X		
COQUILLE	COQUILLE R, E FK		X		
YAQUINA	COUGAR CREEK		X		
COOS	COX CANYON	X			
ROGUE	COYOTE CREEK		X		
NEHALEM	DEER CREEK		X		
YAQUINA	DEER CREEK #4		X		
NEHALEM	DELL CREEK	X	X		
CLACKAMAS	DELPH CREEK		X		
WILSON	DEYOE CREEK		X		
SIUSLAW	DOGWOOD CR	X	X		
SIUSLAW	DREW CREEK		X		
SILETZ	DRIFT CREEK TRIB.		X		
UMPQUA	DUMONT CREEK		X		
MILLICOMA	EAST FK MILLICOMA RIVER	X			
UMPQUA	EAST FORK POOLE CREEK		X		
UMPQUA	EAST FORK SHIVELY CREEK		X		
UMPQUA	EAST GULCH		X		
COLUMBIA	EIGHTMILE CREEK		X		
COOS	ELK CREEK		X		

BASIN	STREAM	WINTER	SUMMER	WINTER	SUMMER
UMPQUA	ELK CREEK	X			
WILSON	ELK CREEK		X		
OCEAN	ELKHORN CREEK	X	X		
TRASK	ELKHORN CREEK TRIB.		X		
ALSEA	FENDALL CREEK		X		
COQUILLE	FERRY CREEK		X		
COLUMBIA	FIFTEENMILE CREEK TRIB.		X		
CLACKAMAS	FISH CREEK		X		
SIUSLAW	FISH CREEK		X		
COLUMBIA	FIVEMILE CREEK		X		
OCEAN	FOURMILE CREEK		X		
ALSEA	GOLD CREEK	X			
NEHALEM	GRAVEL CREEK		X		
ALSEA	GREEN RIVER		X		
SIUSLAW	HAIGHT CREEK		X		
UMPQUA	HALFWAY CREEK TRIB		X		
ALSEA	HATCHERY CREEK	X			
SIUSLAW	HAWLEY CREEK		X		
UMPQUA	HORSE HEAVEN CREEK		X		
NEHALEM	HUMBUG CREEK	X			
UMPQUA	INDIAN CREEK		X		
COQUILLE	JOHNS CREEK	X			
WILSON	JORDAN CREEK	X	X		
WILSON	JORDAN CREEK		X		
ROGUE	JUMPOFF JOE CREEK		X		
COOS	KENTUCK CREEK		X		
NEHALEM	KENUSKY CREEK	X	X		
SIUSLAW	LAKE CREEK		X		
LEWIS AND CLARK	LEWIS AND CLARK RIVER TRIB.		X		
NEHALEM	LINDGREN CREEK TRIB.		X		
CLACKAMAS	LITTLE CEDAR CREEK		X		
ALSEA	LITTLE LOBSTER CREEK	X	X		
NEHALEM	LITTLE NORTH FK NEHALEM RIVER		X		
NEHALEM	LITTLE NORTH FK NEHALEM RIVER		X		
YOUNGS	LITTLE WALLOOSKEE TRIB.		X		
YOUNGS	LITTLE WALLOOSKEE TRIB.		X		
UMPQUA	LITTLE WOLF CREEK	X	X		
NEHALEM	LOST CREEK		X		
TRASK	M FK OF N FK TRASK RIVER		X		
COOS	MATSON CREEK		X		
UMPQUA	MIDDLE CREEK TRIB		X		
COQUILLE	MIDDLE CREEK		X		
COQUILLE	MIDDLE CREEK	X	X		
TENMILE	MILL CREEK #3	X			
MIAMI	MINICH CREEK	X	X		
UMPQUA	N. MYRTLE CREEK	X	X		
SMITH	N.F.SMITH RIVER TRIB		X		
WILLAMETTE	NEBO CREEK		X		
SILETZ	NORTH CREEK	X	X		
ALSEA	NORTH FORK CASCADE CREEK		X		
KLASKANINE	NORTH FORK KLASKANINE RIVER		X		

BASIN	STREAM	WINTER	SUMMER	WINTER	SUMMER
ROGUE	NORTH FORK SILVER CREEK		X		
ALSEA	NORTH FORK SULMON CREEK		X		
COLUMBIA	NORTH SCAPPOOSE CREEK		X		
NEHALEM	OAK RANCH CREEK		X		
SIXES	OTTER CREEK		X		
SIUSLAW	OXBOW CREEK TRIB.		X		
WILLAMETTE	PARSONS CREEK		X		
COLUMBIA	PINE CREEK		X		
SIUSLAW	PORTER CREEK		X		
SIUSLAW	RALEIGH CREEK		X		
COLUMBIA	RAMSEY CREEK		X		
COQUILLE	ROCK CREEK		X		
COQUILLE	ROCK CREEK TRIB 2		X		
COOS	ROGERS CREEK	X			
COQUILLE	S. FK. ELK CREEK	X	X		
SILETZ	SAM CREEK	X			
SILETZ	SAMPSON CREEK TRIB.		X		
SIUSLAW	SCHOOLHOUSE CREEK		X		
NEHALEM	SELDER CREEK		X		
NESKOWIN	SLOAN CREEK	X	X		
SMITH	SMITH RIVER, S FK	X	X		
NEHALEM	SOUTH FORK BATTLE CREEK		X		
CLACKAMAS	SOUTH FORK EAGLE CREEK		X		
WILSON	SOUTH FORK JORDAN CREEK		X		
SILETZ	SOUTH FORK SCHOONER CREEK		X		
SMITH	SOUTH SISTER CREEK	X	X		
SMITH	SOUTH SISTER CREEK		X		
UMPQUA	SPENCER CREEK TRIB.		X		
YAQUINA	SPOUT CREEK	X	X		
UMPQUA	STARVOUT CREEK		X		
YACHATS	STUMP CREEK		X		
SILETZ	SUNSHINE CREEK	X	X		
UMPQUA	SUTHERLIN CREEK		X		
TENMILE	TENMILE CREEK		X		
OCEAN	THIEL CREEK		X		
NESTUCCA	THREE RIVERS		X		
COLUMBIA	THREEMILE CREEK		X		
TILLAMOOK	TILLAMOOK RIVER		X		
COOS	TIOGA CREEK	X	X		
COQUILLE	TIOGA CREEK	X			
COQUILLE	TWO BY FOUR CREEK		X		
OCEAN	TWOMILE CREEK	X	X		
COQUILLE	UPPER LAND CREEK	X			
TILLAMOOK BAY	VAUGHN CREEK	X			
SIUSLAW	WAITE CREEK TRIB.		X		
UMPQUA	WEATHERLY CREEK		X		
UMPQUA	WEAVER CREEK TRIB.		X		
SMITH	WEST FORK SMITH RIVER TRIB.		X		
SIUSLAW	WHITTAKER CREEK TRIB.		X		
SIUSLAW	WILDCAT CREEK		X		
COOS	WILLANCH CREEK		X		

BASIN	STREAM	WINTER	SUMMER	WINTER	SUMMER
COOS	WILSON CREEK		X		
NESTUCCA	WOLFE CREEK		X		
UMPQUA	WOOD CREEK #2	X	X		
COQUILLE	WOODWARD CREEK		X		
COOS	WREN SMITH CREEK	X	X		
COQUILLE	YELLOW CREEK		X		

APPENDIX B: STREAM CHANNEL AND RIPARIAN HABITAT BENCHMARKS.

(Modified from Moore, K. 1997).

	UNDESIRABLE	DESIRABLE
POOLS		
POOL AREA (% Total Stream Area)	<10	>35
POOL FREQUENCY (Channel Widths Between Pools	>20	5-8
RESIDUAL POOL DEPTH		
SMALL STREAMS (<7m width)	<0.2	>0.5
MEDIUM STREAMS (≥7m and <15m width)		
LOW GRADIENT (slope <3%)	<0.3	>0.6
HIGH GRADIENT (slope >3%)	<0.5	>1.0
LARGE STREAMS (≥15m width)	<0.8	>1.5
RIFFLES		
WIDTH / DEPTH RATIO (Active Channel Based)		
EAST SIDE	>30	<10
WEST SIDE	>30	<15
GRAVEL (% AREA)	<15	≥35
SILT - SAND - ORGANICS (% AREA)		
VOLCANIC PARENT MATERIAL	>15	<8
SEDIMENTARY PARENT MATERIAL	>20	<10
CHANNEL GRADIENT <1.5%	>25	<12
SHADE (Reach Average, Percent)		
STREAM WIDTH <12 meters		
WEST SIDE	<60	>70
NORTHEAST	<50	>60
CENTRAL - SOUTHEAST	<40	>50
STREAM WIDTH >12 meters		
WEST SIDE	<50	>60
NORTHEAST	<40	>50
CENTRAL - SOUTHEAST	<30	>40
LARGE WOODY DEBRIS* (15cm x 3m minimum piece size)		
PIECES / 100 m STREAM LENGTH	<10	>20
VOLUME / 100 m STREAM LENGTH	<20	>30
"KEY" PIECES (>60cm dia. & ≥10m long)/100m	<1	>3
RIPARIAN CONIFERS (30m FROM BOTH SIDES OF CHANNEL)		
NUMBER >20in dbh / 1000ft STREAM LENGTH	<150	>300
NUMBER >35in dbh / 1000ft STREAM LENGTH	<75	>200

*Values for Streams in Forested Basins