Watershed Restoration Technical Bulletin
Streamline
Vol. 4 No. 3

SPECIAL EDITION FIVE YEARS OF WATERSHED RESTORATION

A Message from the Editor:

This special anniversary issue of Streamline reflects upon accomplishments and lessons learned in watershed restoration. It is now five years since the Watershed Restoration Program was established in British Columbia. Five years is not a long time to evaluate processes, and there remain some pockets of skepticism about the success of rehabilitation projects and their contribution to resource recovery. To extend the time frame for evaluation it is important also to examine other jurisdictions that have been monitoring for longer periods of time. Therefore, we include some examples from integrated, hillslope, and instream projects that have been evaluated for substantially longer than five years. We also have provided updates on some of the projects that were covered in earlier issues of Streamline.

This issue is based on the *Annotated Bibliography of Watershed Restoration Responses and Lessons Learned*, being compiled by Megan Sterling for Forest Renewal BC. This document provides details of approximately 100 projects that have undergone research on effectiveness evaluation. Streamline thanks Ms. Sterling and Forest Renewal BC for assisting with the preparation of this special anniversary issue, which follows the format used in the bibliography. Each evaluation process begins with a brief project description, the criteria that were applied to justify restoration, the restoration responses (results) and the lessons learned throughout the process. When Ms. Sterling's bibliography is completed, we will advise readers about accessing the document. Note that this issue of Streamline will not have the usual Features and Technical Tips sections. We will return to our usual format in the next issue.

This Quarter
Fall/Winter 1999

BRITISH COLUMBIA

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Integrated Watershed Restoration Projects

Watershed Restoration in Deer Creek, Washington – A Ten Year Review

J.E. Doyle, G. Movassaghi, M.Fisher, and R. Nichols.

Project Description

Deer Creek is a major tributary of the North Fork Stillaguamish River located in the western Cascade Mountains of Washington State. According to historical records, the steelhead run in Deer Creek was once one of the largest native runs of summer-run steelhead in Puget Sound, perhaps in the whole State of Washington. Deer Creek is 38 km in length with 26 km accessible to steelhead and coho salmon. Average channel width (bankfull) is 11 meters, with a substrate dominated by boulder- and rubble-sized materials. Average channel gradient is 2.5%. Although logging began in the watershed in the early 1920's, the scale of this activity was small during the next 3 decades: before 1950, most of the watershed was well vegetated by a mature conifer forest. In the 1940's to early 1960's, erosion, flooding, riparian logging, and channel widening and aggradation diminished the quality and quantity of salmonid habitat. The riparian area along the main channel in the lower watershed was, for the most part, entirely logged off by the mid-1970's. After harvesting, the landowner aerial-sprayed these riparian corridors for alder and willow control through the 1970's and early 1980's. Accelerated erosion accompanied and followed the logging, and in 1984 a large landslide of glacial sediments (known as the DeForest Creek slide) entered Deer Creek. By 1992, the landslide had contributed more than 1.5 million tons of silt, sand and gravel to Deer Creek. In the late 1980's, the summer steelhead run declined to very low levels.

From 1920 to 1990, the three landowners in Deer Creek had harvested a total of 25,730 acres of forest. Over this 70-year period, 48% of the mature forest in this watershed had been harvested: on Washington State land 91% had been cut, on private land 88% was cut, and on National Forest land 37% had been harvested.

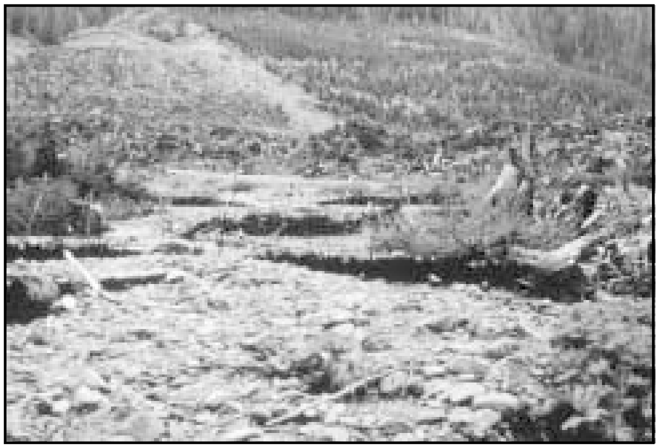

Figure 2. Looking upstream at this tributary, showing the initial upslope treatment which included sediment storage.

Figure 1. As shown in this pre-project photo, a Deer Creek tributary was chosen for large woody debris placement, sediment storage and bank stabilization.

Figure 3. Deer Creek four years after the photo in figure 1. This stream has benefitted from LWD placement and bank stabilization.

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The U.S. Forest Service began to conduct stream and fish habitat surveys in Deer Creek in 1979 and early in the 1980's. Beginning in 1984, the Mt. Baker Snoqualmie National Forest took the lead in conducting watershed-wide resource inventories and assessments. Figure 1 demonstrates upslope and stream conditions prior to the restoration projects. Based on the findings from these early inventories and assessments, the restoration strategy in the Deer Creek Watershed focused on modifying or altering the sedimentation process. The strategy was to reduce the coarse sediment delivery to the stream channel network and to mechanically stabilize the riparian sideslopes and streambanks. This was intended to lead eventually to riparian revegetation, stream channel recovery, and fish habitat improvement.

Figures 2 and 3 show the conditions following the restoration projects. This strategy employed two tactical operations: 1) restoration efforts that involved road, upland, and in-channel projects; and 2) restoration efforts that would be carried out over a multi-year period and would cover the entire watershed.

The specific restoration objectives for each treatment were:

Road and upslope

A. Reduce coarse sediment transport from roads and gullies into the larger, lower gradient stream channels through the use of sediment fences; and
B. Reduce the risk of major landslide failure at as many sites as possible.

Instream

C. Reduce the erosion of channel banks and thereby reduce sediment delivery to the channel; and
D. Promote stream channel downcutting to encourage formation of deeper and greater numbers of pools for fish habitat.

Prioritization for restoration treatment for each project site was based on factors of accessibility, achievability, cost, and risk of failure.

From 1984 to 1994, integrated watershed restoration in Deer Creek on National Forest lands involved:

I. 24 km of road decommissioning;
II. 93 km of road upgrading/ storm proofing;
III. 12.1 ha of hillslope and gully stabilization; and
IV large woody debris placement in channels.

Criteria for Restoration Evaluation: Fish population and migration.

The treatment results are general in nature because the Deer Creek restoration program did not have sufficient funding to implement monitoring for long enough to obtain quantitative results. This program restricted monitoring to the identification of observable trends including changes in watershed condition. The following table summarizes the monitoring accomplished in Deer Creek basin:

Type of Monitoring	Year(s)
Aerial Photos, low elevation	1982, 83, 84, 87, 88, 93
Aerial Photos, 1:12 000 (*=1:24 000)	1942, 56, 64, 72, 79*, 83, 89, 92
Channel Morphology	1984
Cross Sections	1984, 86-87, 88, 89, 91, 92
Fish Habitat Surveys/ Channel Stability Ratings	1979, 82, 84, 87, 91, 92
Fish Population Census	1955-61, 1970-73, 1981, 1983-94
Helicopter Video	1987, 89, 90, 91, 95
Landslide Inventory	1984-85
Stream Discharge	1917-30
Sediment Budget	1990
Temperature Study	1979, 84
Temperature Record	1984-89

Juvenile Fish

Since 1984, the Washington Department of Fish and Wildlife has been independently conducting juvenile salmonid population estimates at seven sites in the watershed. With the use of a 3-pass electrofishing method at each site, juvenile fish of all species were captured. The population of each species and age class were estimated and rearing densities were calculated for each species and age class.

Adult Steelhead

Monitoring has included adult summer-run steelhead abundance spawning surveys and estimating the number of adult fish returning to spawn. Helicopter survey is the preferred method.

Restoration Responses

Juvenile Fish

From 1984 to 1992, steelhead parr densities declined at the rate of 30-50% per generation. For the first time since the annual juvenile population estimates have been monitored, the juvenile densities for 1993 and 1994 had increased over those estimated in their parent year (Figure 4).

Adult Steelhead

An increase in the number of steelhead summer-run adults, from less than 100 in 1989 to more than 460 in 1994, represented a significant increase in the population.

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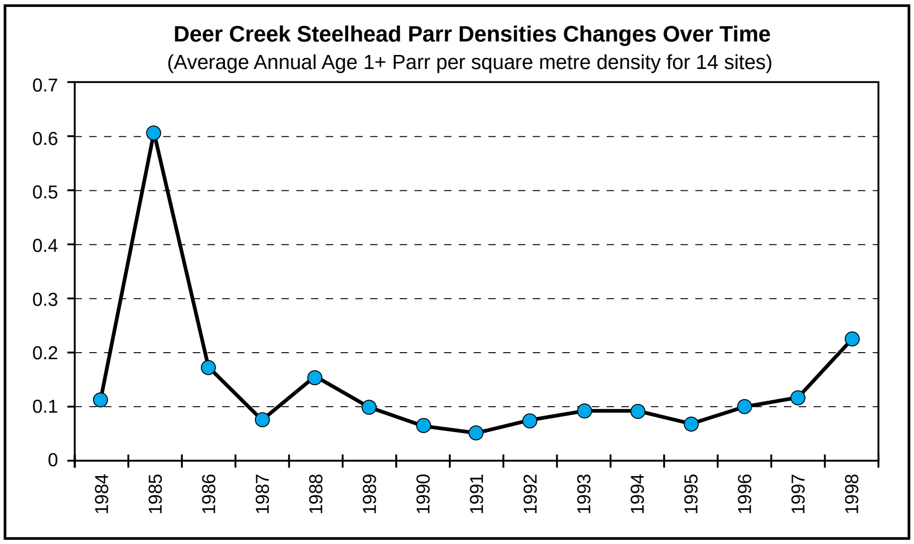

Figure 4. Deer Creek steelhead parr densities.

This increase was mainly due to the increase in freshwater survival of 1-year-old steelhead juveniles (parr). By the late 1990s it was estimated that stocks had recovered to 50 – 70% of historical abundance (J.Doyle, Jan. 2000).

Lessons Learned

The increase in steelhead production from essentially the same parr densities can only be explained by the combination of two factors: increased overwintering survival from parr to smolt and increased survival from smolt to adult. In view of the general poor smolt-to-adult survival of steelhead in the Puget Sound area for the past few years, and the apparent improvement in the freshwater habitat, it seems likely that the improved capability of the habitat in Deer Creek to produce juveniles accounts for most of the increase in adult production.

Fish populations in Deer Creek have increased significantly in the last two years. The observed increase in juvenile fish densities is a reversal of a decade-long decline. In part, this is attributable to the improvement of habitat during the past five years.

Stabilization efforts on the hillslopes, together with the large floods in 1990, were effective in removing sediment deposits from coarse boulder substrates, thus restoring the fish habitat. The reductions in sediment inputs from roads, gullies, and channels are inferred as the primary causes of coho and steelhead stock recoveries. ▲

Based on two documents: 1) Doyle, J.E., G. Movassaghi, M.Fisher, and R. Nichols. 1999. Watershed Restoration in Deer Creek – A Ten Year Review. *Sustainable Fisheries Management – Pacific Salmon.* 1999. E.E. Knudson, C.R. Steward, D.D. MacDonald, J.E. Williams, and D.W. Reiser (eds.). Lewis Publishers, New York and on: 2) Kraemer, C. 1999. Management Brief: 1999 Update on the Status of the Deer Creek Summer Steelhead. Draft. Washington Dept. of Fish and Wildlife.

Upper Willow Watershed Effectiveness Evaluation Strategy

Shannon Sterling

Project Description

The upper portion of the Willow River Watershed covers approximately 880 km^2 in the Quesnel Forest District (Cariboo Forest Region) and is located 55 km northeast of Quesnel, B.C. An Effectiveness Monitoring Strategy (EMS) – also referred to as an Effectiveness Evaluation Strategy – was designed and implemented to allow evaluation of rehabilitative works that were, or will be, prescribed and constructed. An EMS is designed to detect changes in the early stages following rehabilitation activities, as well as longer-term changes as a result of periodic events (e.g., large rainstorm). Monitoring continues until an apparent state of equilibrium has been reached.

The EMS was designed to monitor the large area economically (for less than 5% of the construction

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budget). A hierarchical chain of restoration objectives was developed so that site-level monitoring results obtained through a randomized sampling design could be extrapolated to the watershed scale.

An Integrated Watershed Restoration Plan (IWRP) was completed and a high value of fish habitat in the watershed was established. Restoration was necessary because of the many potential sediment sources caused by a high density of roads, and a peak flow risk resulting from a large clear-cut area (Figure 1).

Restoration activities included:

- reduction of peak flow through installation of cross-ditches to restore the groundwater flows;
- reduction of mass wasting through soil bioengineering, water dispersion (cross-ditches, culvert removal) for return to original water pathways, and pullback of oversteepened eroding slopes for hillslope and gully stabilization;
- reduction of surface erosion through hydroseeding, installation of cross-ditches or water bars, insloping or outsloping of road, establishment of armour cover, removal of structures which are non-functioning or pose a risk of non-functioning in the future, and removal of road fill from channels to control surface erosion;
- reduction of sediment delivery through installation of cross-ditches to deliver sediment away from channels, and installation of live silt fences and sumps to control sediment generation;
- reduction of the potential for debris flows through removal of road fill from channels and gullies for debris flow control; and
- improvement of trout habitat through instream installation of LWD, riffles, and pool excavation.

Figure 1. This photograph shows the Rebman Creek watershed, one of the areas with peak flow concerns.

One other area of the Willow Watershed, the 150 m long Demonstration Site BVS50, was used as an operational test site for soil bioengineering to determine the most effective restoration technique for the local soil conditions. Construction of a Forest Service Road (24A) had accelerated three erosion processes at this site: surficial erosion (overland flow, rainsplash and rilling), mass movement, and sediment delivery. Restoration was needed to stop the cutslope from eroding and delivering fine sands and silts to a fish-bearing stream (Big Valley Creek). Treatments, completed in 1998, included willow staking, wattle fences, live silt fences, live pole drains, modified brush layers and hydroseeding. Planting materials included willow, cottonwood and pine trees. Treated and untreated sections, treatment types, and tree species were compared.

The same site (BVS50) was used to test the root growth rate and zone of influence of willow trees over time in the local soil conditions. Root growth test stakes were planted and areal and depth zone of influence is being measured against time. This study will provide information on how long it takes soil bioengineering sites to be effective, and what the spacing of the soil bioengineering structures should be.

Restoration work completed during 1998-1999 involved 76.3 km of road deactivation and rehabilitation, bioengineering of 5 landslides, and 2 km of stream restoration. A semi-annual (late June and October) monitoring frequency will be used for the first 2-3 years, followed by yearly monitoring.

Criteria for Restoration Evaluation: Pool/riffle composition, peak flows, vegetative cover, length of road surface erosion, and plantings survival.

The following monitoring variables are measured for each objective:
Peak Flow Control: effective watershed drainage density (the post-deactivation reduction in channel length is determined by measuring the length of cutslope with groundwater seepage that has been re-introduced to groundwater through the installation of frequent cross-drainages).

Instream Restoration: frequency of pools with functional depth and cover, length of channel with bank erosion, and presence/absence of fish in pools.

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Hillslope Stabilization: percent vegetative cover, number of new slope failures, volume of material beyond its angle of repose, and percent of bio-engineering structures with growth.

Surface Erosion Control: length of road with water running down it, presence of erosion in cross-ditches and road ditches, percent vegetative cover, and length of road with surface erosion.

At the demonstration site, the variables monitored include: percent vegetative cover, percent conifer cover, percent deciduous cover, number of new slumps, area of new slumps, whether sediment is reaching a stream below a culvert (connectivity), trapping of material behind live silt fences, percent survival of the bioengineering structures, and functionality of the culvert.

Restoration Responses

Success is characterized by a significant change or trend (defined for each monitoring variable) from initial conditions towards the desired watershed objectives, or by comparison with established levels (e.g. a bio-standard).

While the construction phase of the Willow Watershed Restoration began in November 1998, most work done so far was completed in 1999. Therefore, most sites have only two monitoring variable measurements (pre- and immediately post-work). Sites with work done in 1998 have three or four measurements. At this stage, the small number of measurements are only the beginning of monitoring, and these "results" are expected to change with time.

Peak Flow Control: The cross-ditch spacing for one part of the watershed was not frequent enough to achieve the peak flow objective in areas with fine soils (new channels were created below the cross-ditches, as opposed to the water returning back into groundwater). As a result, more cross-ditches will be added in 2000. Other areas show a reduction in effective channel length in the watershed, and therefore a reduction in the peak flow of the watershed is presumed (immediately post-work data only).

Instream Restoration: The frequency of pools greater than 0.3, 0.5 and 0.6 m residual depth increased to the bio-standard (the prescribed) frequency for rainbow trout (1 year of data).

Hillslope Stabilization: The soil bioengineering was very successful so far (Figure 2). At the Demonstration Site there have been no new slope failures in the treated area, while there was one in the untreated control, and the percent of structures in place and growing is near 100% (1 year of data). Areas with pullback have not had any new failures (immediately post-work data only).

Figure 2. Hillslope stabilization along this roadway involved wattle fencing, brush layers, live silt fences, willow staking, and hydroseeding. Willow and cottonwood were the species used.

Surface Erosion Control: The length of road with water running down it had mixed results; some areas will be reconstructed in 2000. Erosion was present in many cross-ditches; armouring will be increased in 2000. Percent vegetative cover results are awaiting analysis. In fine soils, cross-ditches constructed to ATV templates all survived the fall rains; many of the 4WD cross-ditches had already failed after the fall rains (Figure 3). The length of road with surface erosion (including ditch) has been reduced, but some results are still forthcoming (immediately post-work data only).

Figure 3. Post-work photo of 4WD Template cross-ditch breached since repairs.

Lessons Learned

Initial results revealed:

- Live Pole Drains collect water when properly located; however, some drains showed no evidence of water flow, suggesting that placement of drains is sensitive (1 year data).

- Cross-ditches should be closely spaced to return the cutslope seepage water to groundwater: spacing depends on site characteristics, and is particular to the conditions encountered in the Willow Watershed.
- Cross-ditches constructed in fine soils to ATV template had no breaches after the fall rains and hunting traffic; several constructed to 4WD template had been breached in the same conditions.
- The effective channel length was reduced to 44% of its pre-deactivation state in one watershed. This should reduce the peak flow in the streams and reduce destabilizing forces on landslides below.
- Riffles constructed by hand using compressed air withstood the large flood of spring 1999 (estimated to be greater than the average flood). ▲

S. Sterling, 2000. Upper Willow Watershed Effectiveness Evaluation Strategy, Northwest Hydraulics Consultants, North Vancouver, B.C. Progress Report.

The Keogh and Waukwaas Rivers Paired Watershed Study for British Columbia's Watershed Restoration Program: Juvenile Salmonid Abundance and Growth

D.J.F. McCubbing and B.R.Ward.

Project Description

The study assesses the effectiveness of WRP stream habitat rehabilitation techniques through in-stream sampling (electrofishing and seine netting) in representative treated and untreated reaches, and through comparison of results with population dynamics data gathered from 25 years of salmonid juvenile abundance in-stream, smolt enumeration, and adult steelhead run size estimates. In-river treatments include stream habitat structures and slow-release nutrient applications, in the Keogh watershed. These have been incrementally increased over the five-year period (Figure 1), along with earlier road deactivation and on-going construction of off-channel ponds and channels. Juvenile salmonid density, growth, smolt yield, and adult escapement data will be collated and analyzed for change, in a staircase-type experimental design. To strengthen the analysis, a neighbouring watershed (Waukwaas River) is being monitored, but without WRP stream rehabilitation treatments. Data on the escapement enumeration of pink and coho salmon in the Keogh River will be added to the adult steelhead data. This will assist in evaluating the effectiveness of WRP techniques, and in calibrating coho and steelhead smolt yield to adult escapement (i.e., smolts per spawner as a function of spawners pre- and post-treatment).

The Keogh and Waukwaas Rivers, two fourth-order streams, are situated at the northern end of Vancouver Island, B.C., in the coastal western hemlock bio-geoclimatic zone. The logging histories of both watersheds are similar. A summary of Keogh water-shed logging history indicates that approx. 53% of the basin had been logged since 1940, including 55% of the floodplain and up to 70% of the sub-basins. Past

Unit	1994 - 96	1997	1998	1999	2000	Reach
1		S	S	Fs	Fs	**Zt**
2		S	Fs	Fs	Fs	**Yt**
3		F	F	Fs	Fs	**X**
4		F	F	F	Fs	**W**
5			F	NS	NS	**Yu**
6				NS	NS	**Zu**
7						**Waukwaas**

Figure 1. Treatment plan and reaches used for fish density, growth, survival, and smolt yield assessment in the Keogh and Waukwaas Rivers for evaluation of WRP stream habitat rehabilitation techniques. See Figure 1 for definition of reaches; t= treated, u=untreated, blank = no treatment, F = fertilizer, S = structures, and Fs = fertilizer and structures, NS = not sampled.

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forest practices harvested 23 km of the river's mainstem riparian zone, and 26 km along the riparian zones of its tributaries. Habitat rehabilitation has been focused on these mainstem sections that lacked complex habitat structure.

In 1997, 121 WRP structures, such as LWD complexes and boulder clusters (Figure 2), were placed in the Keogh River over 5.4 km, and nutrient addition included the lowermost 19 km of the Keogh River mainstem and approximately 10 km of tributary stream length to compensate for depressed salmon escapements. In 1998, an additional 67 WRP structures were placed, for a total treated length of 6.8 km with fertilizer added to over 27.5 km of mainstem river and 11 km of tributaries. A further 121 WRP structures were placed over a length of 1.0 km in 1999. Inorganic nutrients, as an annual application of slow-release briquettes (total application rates on file = 1110 kg) were added over a total length of 36.5 km of the Keogh River mainstem, from the river mouth to 4 km upstream of Keogh Lake, as well as fertilizer addition to 11 km of key tributaries entering the mainstem from Muir Lake to the river mouth.

Figure 2. This boulder cluster in the Keogh River is one of the 121 structures constructed as habitat restoration in 1997.

Criteria for Restoration and Evaluation

Evaluation of success of watershed rehabilitation techniques can be measured by a positive response across several criteria: juvenile salmonid abundance, distribution, growth, survival, smolt yield, and adult escapement. Analyses here compared juvenile salmonid abundance within and among reaches, and within and between watersheds, along with assessment of the utilization of individual structure type and the benefits of nutrient addition to offset depressed salmon runs.

Restoration Responses 1997-1999: Juvenile Fish Abundance, Standing Crop and Smolt Yield.

A wide variance in salmonid abundance was found, both within watersheds and between watersheds in the three study years. These differences, where apparent, may have been the result of a combination of factors, including: habitat availability, adult escapement, juvenile mortality, and reach location within the watershed, along with environmental conditions in the year of sampling (e.g., drought low flows, winter floods, etc.).

Steelhead fry abundance in the Keogh River has been limited by low adult escapement (<100 adults) in recent years, due to poor rates of survival from smolt to adult (<4%). Despite low adult returns, a statistically significant ten-fold increase (to a mean of ~140 fry per 100m^2) in overall steelhead fry abundance was apparent between 1997 and 1999.

Densities of steelhead parr were significantly higher in 1999 on the Keogh River (mean of 55 parr per 100m^2), compared to 1998 and 1997 data (mean of 22.5 and 17 parr per 100m^2 respectively). In 1999, steelhead parr were in greatest abundance on the Keogh River in the reaches treated with structures and fertilizer (45 to 126 parr per 100m^2) compared to fertilizer-only reaches in the same river locations (40 parr per 100m^2). These densities from treated reaches in the Keogh River were greater than steelhead parr densities throughout the untreated Waukwaas River (4 to 38 parr per 100m^2).

Coho fry abundance was, on average (all reaches), higher in the Keogh River in 1999 than in either of the previous sample years, increasing by an average of 53% over 1998 results to 500 fry per 100m^2. Coho fry abundance on the Waukwaas River also increased over 1998 data by an average 42% to 173 fry per 100m^2, but was lower than that recorded in 1997.

Smolt yield from the two watersheds has been assessed for five years, including two years pre-treatment and three years partial post-treatment of the Keogh River (Figure 3). Coho smolt numbers rose steadily for both watersheds through the first three years of investigation, but fell sharply in the Keogh River in 1998. A marked recovery of coho smolt yield was observed in 1999, to 53,000 fish (72% of 25-year average). In the Waukwaas River, the dramatic increase in coho smolt yield measured in 1998 was not sustained; yield dropped to levels that were similar to those of Keogh River in 1999. Steelhead smolt numbers had remained low and were increasingly reduced over the four-year study period to 1998 at the Keogh River. However, in 1999 smolt yield increased two-fold over 1998 to the highest on record since 1993. Substantial increases in estimated

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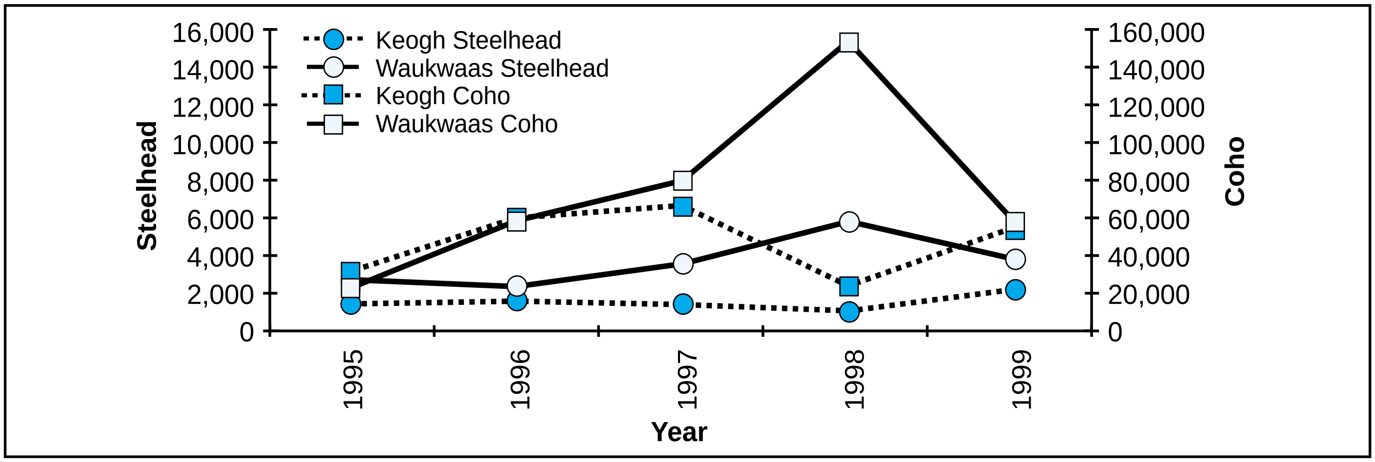

Figure 2. Smolt yield from the Keogh and Waukwaas Rivers 1995 to 1999. Keogh River, dashed lines and dark blue points: Waukwaas, solid lines and light blue points; steelhead, circles; coho, squares. The full response is not expected until 2001.

steelhead smolt yield on the Waukwaas River in 1998 were not sustained; levels fell to 1997 levels. Increases in Dolly Varden and cutthroat trout smolts were also recorded at the Keogh in the spring of 1999, for the first time in several years.

Habitat Structure Utilization

The average density of fish (no. per 100m^2) from 1997 to 1999 for all structure sites and for each structure type were compared, including results for steelhead fry, steelhead parr, and coho fry. The range in mean density was broad among common structure types in 1999 (coho fry, 41 to 95 fry per 100m^2; steelhead parr, 0 to 11 parr per 100m^2, e.g. Figure 4). This was in agreement with the overall range in values observed in 1998, which were an improvement over 1997 although fish response within each structure type was markedly different. For example, the greatest steelhead parr densities in 1999 were recorded in lateral debris jams (LDJ), versus root wads complexes (RW) in 1998 and A-Log structures (AL) in 1997. In 1999, steelhead fry, coho fry and steelhead parr densities in lateral debris jams (LDJ, n=9), boulder clusters (BC, n=7), single log deflectors (SDL, n =6), double deflector logs (DDL, n=2), root wads (RW, n=4), and A-logs (n=3) were not significantly different (anova) in these five structure types., Possibly this was due to high variance among sites and low sample size. Examining results from all structures across all sample years, trends emerged. Steelhead fry were most abundant in double deflector logs, and boulder clusters, whilst steelhead parr favoured double deflector logs and lateral debris jams. Coho fry were most abundant in double deflector logs and lateral debris jams, although there was much variance within this data. In all cases, yearly and within reach (same year) variations in juvenile salmonid abundance suggested that no common structure type significantly outperformed any other.

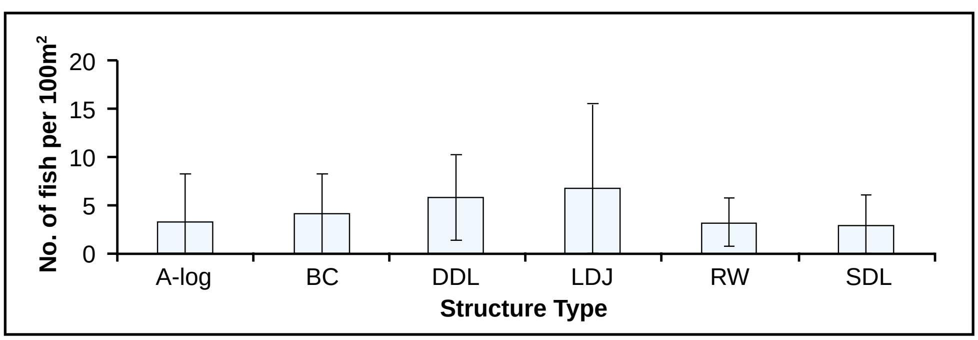

Figure 4. Average densities (+/- IS.D.) of steelhead parr in the Keogh River (1997 to 1999) in common habitat structure types: A-logs, boulder clusters (BC), double deflector logs (DDL), lateral debris jams (LDJ), root wads (RW) and single deflector logs (SDL).

Growth and Fertilization

Summer steelhead fry weights and lengths were significantly greater in the nutrient-enriched Keogh River than in the Waukwaas River (untreated) in 1999 ($p<0.001$, t-test for both weight and length). Similar results were observed in fertilizer-treated sections of the Keogh River in 1997 and 1998. Average weight of steelhead fry by autumn in the Keogh also exceeded that in the Waukwaas River, by over 50% (Figure 5).

Coho fry mean weights were on average 16% greater in the Keogh River in 1999 than in the untreated Waukwaas River. Despite this evidence

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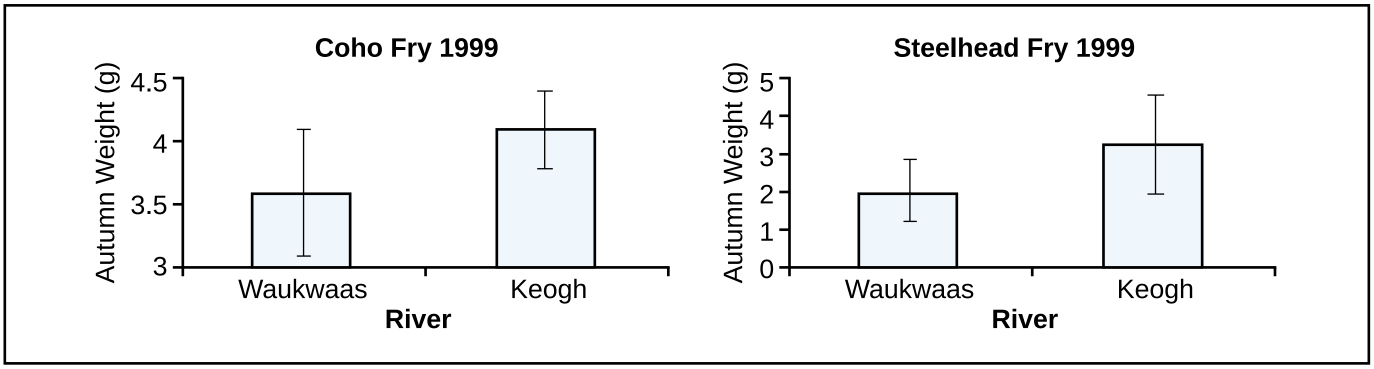

Figure 5. Weight (g) of coho salmon and steelhead trout fry (mean and standard deviation) by autumn in the Keogh and Waukwaas Rivers in 1999.

these data were not significantly different between rivers for either length or weight (p>0.05, anova), due in part to large variance between the mean weights of fry in different reaches on both rivers. A pattern of decreasing size and weight was observed in autumn coho fry on the Keogh River with increasing distance up the river. This was likely a density dependent response (high density, lower mean weight).

Growth differences in steelhead parr were more difficult to interpret as several age classes comprised the population within any reach. The age class structure also varied by reach on the Keogh River in any sample year. This was a function of recruitment and the progressive treatment of nutrient addition through the watershed as well as the number of years in which resident parr may or may not have been exposed to improved nutrient conditions. Abundance, size and scale age data from Keogh River smolts in 1999 (first year of a response in age 2 smolts from nutrient addition which began in 1997 over the lower half of the watershed) was used to examine the response to nutrient addition. These promising preliminary results indicated a numerical increase in smolt yield, an increased length-at-age (Figure 5), and decreased age at smolting. Initial results from whole-river nutrient addition on smolt yield are not expected until 2001.

Summary

Positive effects of treatments with nutrient addition, habitat structure introduction, off-channel habitat creation, and slope stabilization, all part of watershed restoration, were increasingly apparent from studies of juvenile salmonids in the Keogh River from 1997 to 1999. Results further indicated this positive response when compared to reference data collected in the untreated Waukwaas River. Results are summarized, for each key species:

steelhead response

- increased abundance and geographically wider distribution of steelhead fry within the watershed despite a continued low escapement of adults

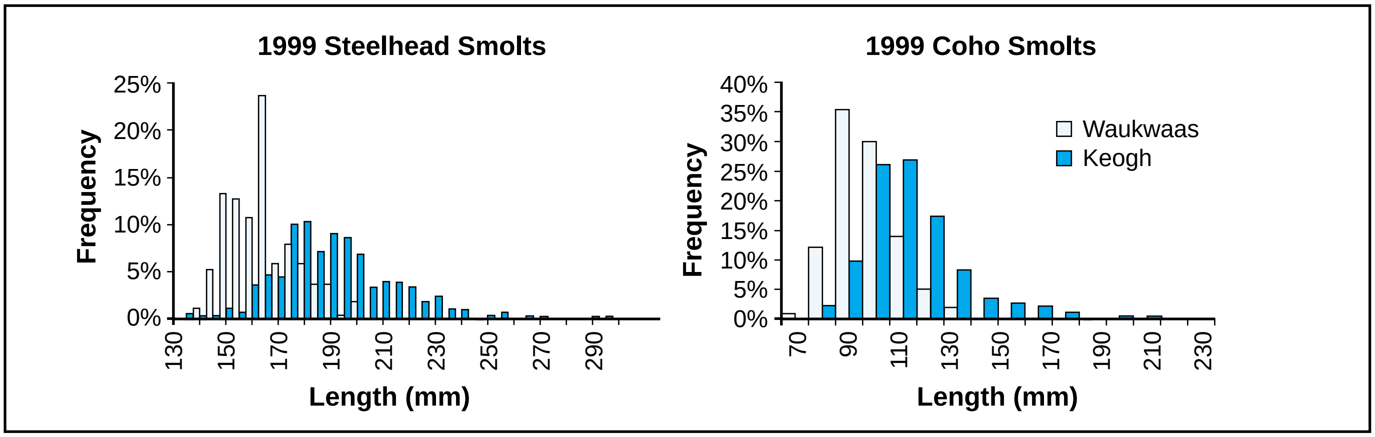

Figure 6. Steelhead trout and coho salmon smolt length frequency distribution in the Keogh (dark blue bars) and Waukwaas (light blue bars) rivers in 1999.

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- enhanced fry abundance within reaches in relation to nutrient addition
- fry growth rates improved by 50% compared to the untreated neighbouring watershed
- substantially increased parr abundance (260% since treatment began)
- improved smolt yield (highest count since 1993)
- larger size-at-age of smolts, indicating improved growth rates of parr during their in-stream residence
- evidence of a positive relationship between the complexity of the habitat structure and an increased abundance of steelhead parr.

coho response

- since treatments started, highest fry abundance was in 1999
- improved smolt yield in 1999, to 70% of long-term average (despite low fry densities in 1998)
- increased growth of fry despite high densities (approx. 1 fry per m^2)
- improved utilization of habitat by progeny of high adult escapement in 1998
- increased size-at-age of coho smolts
- evidence of a strong association of in-stream fry distribution with structure placement (particularly LWD)
- significant use of off-channel habitat developments, and in-stream structures during winter and summer.

other anecdotal observations

- increased size and abundance of (resident) cutthroat trout
- increased counts of cutthroat trout smolts
- increased Dolly Varden parr and smolt yield
- increased crayfish population size and distribution within the watershed.

Lessons Learned

Preliminary results to smolt yield indicate that habitat rehabilitation for juvenile salmonids in streams may partly counteract recent dramatic and persistent declines in survival observed in freshwater and marine life stages. Despite dangerously low levels of spawning escapement, fry and parr were found at high levels of abundance in treated areas, and at rates of growth and survival that surpassed that in the untreated stream.

Variations in structure performance indicated that a complex variety of habitat is required by all species of salmonids through the variety of environmental conditions they may experience in freshwater ecosystems. There may be danger of incorrect choice of habitat structure preference when the assessment of structure effectiveness has been over too short a term of evaluation, and without investigation of the effects of flow, adult escapement, habitat change, and overwinter survival. Evaluation must take place over the longer term, and preferably be based on treatment and control results from the diversity of B.C. watersheds.

The addition of nutrients to the stream enhanced growth and survival of coho and steelhead juveniles, and resulted in increased smolt abundance, greater mean size and larger size-at-age. The results of whole-river nutrient addition are expected to be greater still.

Long-term monitoring is required to fully determine the restoration benefits. Further increases in juvenile abundance, smolt yield, and eventually, adult escapement are likely as the benefits of this WRP project unfold.

This positive recovery response is timely given the severe conditions for survival in the ocean that are now documented for steelhead and coho. A similar intensive effort at WRP in streams of the east coast of Vancouver Island and the Georgia Basin with stocks at risk should proceed immediately, while the work at Keogh continues to measure variation in response and the full benefits of treatments. ▲

The details included above are based on a compilation of three reports. The first (titled as above) was published in 1997 (BCWRP Technical Report Number 6), the second in 1998 (BCWRP Technical Report Number 12), and the third, based on 1999 results, is in preparation for publication. Thanks to Bruce Ward and Don McCubbing for updating this article with the most recent data in January 2000.

Please see the back page of Streamline for information on ordering Watershed Restoration Technical Reports from the Queen's Printers.

Hillslope Watershed Restoration Projects

Road Deactivation Effectiveness Monitoring

M. Leslie, W. Warttig and M. Wise

Project Description

The Lost Shoe – Thunderous Creek/Toquart Bay study areas are located on the west coast of Vancouver Island, ~30 km southeast of Tofino and 55 km southwest of Port Alberni, B.C. The study areas were logged primarily between 1975 and 1985. The Lost Shoe – Thunderous roads were deactivated in 1994, and the roads in Toquart Bay were deactivated in 1995. Objectives of road deactivation were to enhance forest site productivity along the road corridor and to decrease slope instability, thereby minimizing landslides from roads, soil erosion, and sedimentation along the road corridor.

Techniques for road deactivation for the Lost Shoe – Thunderous Creek Watershed and the Toquart Bay Watershed differed slightly. At Toquart Bay, trench drains and French drains, and therefore fewer cross-ditches, were used. At Lost Shoe – Thunderous Creek, more cross-ditches were used for hillslope drainage, and there was less soil sorting. In both projects, the road subgrade was decompacted prior to roadfill pullback. In addition, roadfill pullback material was sorted to establish improved subsurface water flow (also known as 'flow-through water management'), and all roads were hand-seeded and fertilized. These road deactivation variations, along with the storms that have affected the area since deactivation, provide a means to evaluate the effectiveness of the road deactivation activities.

The study sites were chosen to reflect the representative types of terrain, deactivation work, and revegetation work carried out. Most of the sites were located on open (unconfined) slopes. Only three of eleven sites were located on gully sidewall, gully headwall, or gully channel sites.

Criteria for Restoration Evaluation: Vegetative cover, road erosion, tree species, height, health, damage, and % ground cover.

Eleven sites were evaluated with respect to common visual field indicators of potential instability and erosion. Each study site consists of two vegetation-only circular plots within a 50 m road section (instability indicator). All existing road deactivations were recorded, along with any visual indicators of apparent and/or potential slope instability and soil erosion. At each study site, two revegetation plots were established, and data were measured/recorded in the plot area, typically 3.94 m radius.

Data for both road deactivation and site productivity were collected. For site productivity, the sites were evaluated for tree species, height, apparent health and damage, as well as ground coverage (understory) from grass or native plants.

For road deactivation, the sites were assessed for field indicators that are commonly associated with slope instability and erosion. Sites were also evaluated for overall effectiveness. The residual risk at the sites was also assessed with respect to safety, fish habitat and water quality, forest resources/property, and visual quality. For site productivity, the sites were evaluated for tree species, height, apparent health, and damage, as well as ground coverage (understory) from grass or native plants.

Restoration Responses

For the eleven sites, the road deactivation work was successful in decreasing slope instability and minimizing erosion due to the absence of field indicators at all but three sites. Statistical analysis of the plot data revealed most sites had a good cover of grass with abundant alder growth. Conifer regeneration was more sporadic, due to damage by deer, and perhaps inadequate soil sorting during pullback. Figure 1 summarizes variations in tree species and density for the three areas.

Examining the sites in terms of the degree of pullback also produced some interesting results (Figure 2). The

Site	Alder (sph*)	Cedar (sph)	Hemlock (sph)	Fir (sph)	Grass Cover
Toquart	872	179	26	0	Good (>67%)
Lost Shoe	4004	96	0	473	Fair (34 - 66%)
Thunderous	3076	0	0	649	Good to Fair
Average	2650	92	9	374	Good

* sph = stems per hectare

Figure 1. Tree species, density, and grass cover for Toquart, Lost Shoe, and Thunderous sites.

Hillslope Watershed Restoration Projects

Degree of Pullback	Alder (sph*)	Cedar (sph)	Hemlock (sph)	Fir (sph)	Grass Cover	Deer Browse (sph)
Light	0	0	0	615	Poor (<33%)	615
Medium	5229	0	0	718	Fair (34 - 66%)	461
Heavy	2840	183	0	298	Good (>67%)	205
* sph = stems per hectare						

Figure 2. Degree of pullback with tree density, grass cover, and deer browse.

reduced damage from deer browse in the heavy pullback areas may be because it is more difficult for the deer to access the seedlings. It is significant to note that both Lost Shoe and Thunderous sites had almost four times as many trees as Toquart; this may have been a result of the different types of grass seed mixtures used. The mixture was primarily sod forming in Toquart but a mixture of bunch and sod forming in Lost Shoe and Thunderous areas. Bunch grasses leave some exposed soil, allowing natural seed to get in.

Lessons Learned

I. Roadfill pullback appears to be an effective means of decreasing instability on slopes greater than 20 degrees.

II. Cross-ditches, trench drains and French drains are effective means of restoring hillslope drainage paths. Consider using trench drains and French drains in areas of heavy pullback to maximize the use of the stable road bench for pullback.

III. Field indicators, associated with potential landslides and erosion events for different terrain and climatic conditions, can be used to determine the effectiveness of the road deactivation.

IV. Use local and project-specific experience to select the study sites, in conjunction with senior personnel familiar with road deactivation techniques and monitoring studies.

V. Where possible, the site evaluation procedure should be made as straightforward as possible, using simple visual indicators where appropriate. A photographic record should be kept for the study sites, to provide a visual record of the site over time.

VI. Roadfill pullback, in addition to stabilizing the road prism, in many cases also provides an improved growth medium for revegetation.

VII. Consider alder a benefit in cases where the roadfill pullback material is likely to be deficient in soil nutrients. In these cases, alder can significantly increase the amount of nitrogen in the soil; these trees are often the first stage in pioneering by successional species.

VIII. Deer browse is a major problem when trying to re-establish conifers on deactivated roads, especially where deer have easy access. Sites where access is more difficult, such as heavy pullback with randomly scattered debris, appear to have far less deer browse.

IX. Grass seed deactivated roads with a balanced mixture of sod forming grasses, bunch grasses and nitrogen fixers that encourage the invasion by later successional species. As opposed to sod forming grasses, the bunch grasses allowed for small areas of soil under their leaf structure to remain exposed. These exposed areas are good sites for seed from later successional species to germinate.

X. Randomly distribute large woody debris and slash over deactivated road surface to make deer access as difficult as possible; this activity should reduce deer browse.

XI. Plant conifers among obstacles to make deer access as difficult as possible. ▲

Based on: Leslie, M., W. Warttig and M. Wise. 1999. Road Deactivation Effectiveness Monitoring: Lost Shoe – Thunderous Creek Watersheds and Toquart Bay Area, South Island Forest District. Prepared for Ministry of Forests, Nanaimo, B.C. 24 pp.

Hillslope Watershed Restoration Projects

A Strategy for Implementation, Effectiveness, and Validation Monitoring of Habitat Restoration Projects

E. Beamer, T. Beechie and J. Klochak. 1998

Project Description

These two examples are from the Skagit River Basin in Washington. The Illabot Creek sediment reduction project, located in Washington's Skagit River Basin, addressed road erosion and sedimentation using storm-proofing and decommissioning treatments. This project was considered a 'protection' project because there appeared to have been little road-related increase in sediment supply to Illabot Creek over the past few decades. Road storm-proofing was expected to reduce the existing risk of catastrophic failures into Illabot Creek and its tributaries. Road decommissioning was expected to have the same effect as road storm-proofing, but since the road fills in the drainages were removed, the risk of failure was expected to be lower.

Storm-proofing on Forest Road 16 included sidecast pullback, installing additional and larger culverts, adding road dips, lowering and reconstructing fills and rip-rap protection. Road decommissioning on Roads 1600012 and 1600012a spur included removing fills and culverts in stream channels, removing cross culverts and installing dips, pulling back sidecast material, and outsloping the road. All disturbed areas were seeded and mulched with a minimum of 4 inches of straw. Approximately 24 miles of road were treated.

Criteria for Restoration Evaluation: Aerial photographs, channel cross sections, width to depth ratio, LWD and pool/riffle composition.

Two active USGS stream flow stations were used to estimate the magnitude of peak flows experienced by Illabot Creek in 1995 and 1996. Historical sediment supply to Illabot Creek was assessed from 1950-1991. Changes in channel widths over time were measured by canopy opening width on aerial photos.

In-channel habitat conditions were monitored prior to the completion of the sediment reduction project (summer 1994) and one year following the project (summer 1996). Monitoring parameters included: changes in channel type, reach length, average channel width, average residual pool depth, number of pools, and amount of key-sized or larger LWD per 100 m of stream length.

Using habitat-based models to identify the spatial relationship between juvenile fish rearing potential and position in the Illabot Creek watershed, it was possible to estimate end-of-summer parr production of coho salmon and steelhead trout.

Lessons Learned

- Mass wasting has significantly increased due to roads in the last decade, but land use overall has caused relatively little mass wasting compared to that from mature forests and naturally unvegetated areas in the Illabot watershed.
- For pools formed by LWD, about half of the variation in residual pool depth is explained by the height of a log or LWD jam. In general, larger obstructions tend to create deeper pools, indicating that a change in the size of LWD over time should lead to a change in residual pool depths. This relationship is important for demonstrating that changes in residual pool depth that may be measured in the future are (or are not) a function of change in LWD size, rather than a change in sediment supply.
- Without an external control or reference watershed it may not be possible to discriminate the effects of treatment from natural variation.

Based on: Beamer, E., T. Beechie and J. Klochak. 1998. A Strategy for Implementation, Effectiveness, and Validation Monitoring of Habitat Restoration Projects. Mount Baker – Snoqualmie National Forest, Mount Baker Ranger District, Woolley, Washington.

Instream and Channel Restoration Projects

Response of Juvenile Coho Salmon and Steelhead to Placement of Large Woody Debris in a Coastal Washington Stream

C.J. Cederholm, R.E. Bilby, P.A. Bisson, T.W. Bumstead, B.R. Fransen, W.J. Scarlett and J.W. Ward.

Project Description

Large woody debris (LWD) was added to North Fork Porter Creek, a small tributary of the Chehalis River, located west of Olympia, Washington. This project was part of an effectiveness and cost comparison study between two techniques. Additions began in late summer 1990 and ended in late summer 1991. More than half the wood and all the cover structures were added in autumn 1991 so habitat restoration from LWD addition was not expressed fully until winter of 1991-1992. Three 500-metre study sections contained one Reference site, one Engineered site, and one Logger's Choice site. The Engineered method involved placing conifer logs in the channel using heavy equipment and securing the wood in place. Five different configurations were used: full crossing structures, partially crossing, parallel, pyramid, and logjam structures. The inexpensive Logger's Choice method involved cutting and felling red alder trees from the stream bank into the channel and cabling the logs to their stumps (Figure 1). Structures included full crossing, partial crossing, and parallel logs.

Figure 1. An example of felled and cabled red alder trees at the Logger's Choice site. This less-expensive restoration has now approached the pre-treatment condition, only five years after treatment.

Criteria for Restoration Evaluation: Pool/riffle composition, fish population, and LWD.

Changes in habitat and response of juvenile coho salmon *Oncorhynchus kisutch* and steelhead *O. mykiss* were monitored to determine effectiveness of the two LWD restoration techniques. The three stream sections were evaluated seasonally beginning in June 1988 through spring 1994, for three years before and three years after LWD additions in 1991. Salmonid populations from representative habitat types were surveyed by electrofishing. Fishes collected were identified to species, and fork length was measured for each individual. Fish population estimates and habitat surveys were conducted in March, June and late September, allowing for low-flow and high discharge information. Habitat units consisted of 4 types of pools (scour, plunge, dam and backwaters), and 3 types of fast water (riffles, cascades and glides). Coho salmon smolts were collected in traps each year from early April through mid-June, identified, measured, transported below the lower study site, and released.

Restoration Responses

Physical Habitat

LWD

Winter storms brought additional LWD from the red-alder dominated riparian stand to all 3 study sites, however, LWD pieces added were much smaller than those placed at the treated sites. In 1994, the number of pieces/total wood volume of LWD in the Engineered site was 8.9/11.5 times the pretreatment level, 3.6/3.0 times in the Logger's Choice site, and 2.3/1.3 times in the Reference site. Average length of each piece at the Engineered and Logger's Choice sites increased significantly following restoration.

Pools

Pool surface area increased significantly in both modified sites and decreased slightly in the reference site. The Engineered site displayed the most dramatic increases in pools, with the proportion of the water surface composed of pools increasing from 33%, 38%

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and 38% in spring, autumn and winter, respectively, to 59%, 74% and 56%. Most of the increase was due to the creation of dam and plunge pools associated with the full-crossing LWD structures placed in the stream. The Logger's Choice site exhibited increases of 7% to 12% in proportion of pool areas, due almost entirely to creation of additional scour pools.

Fast-waters
Fast-water habitats decreased at both rehabilitated sites. In the Engineered site, riffles decreased and cascades were eliminated after completion of restoration. In the Logger's Choice site, riffles increased during spring and winter, but stayed relatively constant during autumn before and after restoration. The proportion of cascades decreased by more than 10% during all three seasons in the treated sites. Fast-water habitats increased at the reference site.

Substrate
Large amounts of gravel accumulated at the structures added to the two treated sites.

Spawning activity
Coho salmon and steelhead were frequently observed spawning in the treated sites after restoration. Prior to restoration, few coho salmon and steelhead were observed spawning throughout the entire study area.

Coho salmon and steelhead populations

After restoration, winter juvenile coho salmon abundance increased twenty-fold in the Engineered site and six-fold at the Logger's Choice site; the reference or control site exhibited no change. There were no significant differences in the coho salmon populations during spring and autumn at any of the sites. The coho smolt yield tripled after the rehabilitation project in the engineered site, and nearly tripled in the Logger's Choice site, but decreased slightly in the reference site. Age-0 steelhead abundance declined significantly at the Logger's Choice site in spring, and remained the same in fall and winter for all sites. However, the populations at the reference and engineered sites both increased in winter. There was no difference in age-1 steelhead abundance among sites, nor pre- and post-restoration during any season. Winter populations of juvenile coho salmon and age-0 steelhead were inversely related to maximum and mean winter discharges; however, both species declined at extremely high winter discharges.

Lessons Learned

- It was estimated that the habitat in the Logger's Choice site would approach the pre-treatment condition within 5 years of treatment as a result of wood decay, breakage and displacement during high flow periods.
- The Engineered site was designed to persist for 25 years or more; no evidence of decay was observed in the coniferous LWD and very little damage to structures was experienced by repeated exposures to elevated flows.
- The greater longevity of structures added to the Engineered site offsets the higher initial cost relative to the Logger's Choice method, when considered in terms of cost per additional coho salmon smolt produced.
- The Logger's Choice approach for adding LWD may be most appropriate where conifer trees can be felled into the channel.
- Habitat restoration efforts were most effective during winters of low or moderate flow (< 1.5 m^3/s), but were of little benefit during winters with extremely high flows. The pools created by LWD placement in the two treated sections did not offer sufficient protection from periods of extremely high discharge.
- The availability of suitable winter habitat was likely a major factor limiting coho salmon production in the study area.

Six Year Retrospective

Jeff Cederholm shared the following observations in January 2000, about recent happenings:

- Alders within the Logger's Choice site have decayed as predicted and the habitat has responded by declining to its previous state. Therefore the lesson learned is that alder provides a relatively short-term benefit.
- The Engineered site continues to provide highly desirable habitat because most large woody debris remain relatively intact except for some logs that have been scoured and been degraded in their effectiveness.
- Logs continue to be contributed from the streamside area due to blowdown in all three sites, Reference, Logger's Choice and Engineered.
- Adult steelhead and coho are using the experimental area for spawning. ▲

Based on: Cederholm, C.J., R.E. Bilby, P.A. Bisson, T.W. Bumstead, B.R. Fransen, W.J. Scarlett and J.W. Ward. 1997. Response of Juvenile Coho Salmon and Steelhead to Placement of Large Woody Debris in a Coastal Washington Stream. North American Journal of Fisheries Management 17: 947-963. Updated by Jeff Cederholm, January 2000.

Instream and Channel Restoration Projects

Durability of Pacific Northwest Instream Structures Following Floods

Brett B. Roper, D. Konnof, D. Heller and K. Wieman

Project Description

Instream structures are an important component of stream restorations and have been used throughout the world to alter stream characteristics and improve stream conditions for fish populations. They are particularly prevalent in the Pacific Northwest, and have been demonstrated to increase specific stream biota. This is the first study that specifically evaluates the physical durability of structures. Although a structure may increase fish production in the short term, if it has a short life span (<5 years), its overall benefit may be minimal.

The evaluation described here is part of a broad, multi-phased assessment of the effects of the 1995 and 1996 floods on U.S. Forest Service lands in the Pacific Northwest. This study focused on the instream structure durability, and had three objectives :

- to determine the overall durability of instream structures following floods with 5 to 150 year return intervals,
- to relate durability to geomorphic and stream conditions, and
- to provide recommendations to improve future performance of structural instream restoration treatments.

Criteria for Evaluation

The study examined flooded streams with return intervals exceeding 5 years, and that contained restoration structures. Initial surveys included about 4,000 structures in more than 100 streams. However, because of incomplete records, the data set used for analysis consisted of 3,946 in 94 streams. Overall durability was high; less than 20% of the 3,946 instream structures were removed from the site following floods exceeding a 5-year return interval.

Lessons Learned

- Magnitude of flood events had a significant effect on structure durability with higher magnitude floods reducing durability (see Figure 1).
- Stream order also affected structure durability; structures in large streams were 20 times more likely to have been removed from the site of original placement than structures in small streams (see Figure 2).

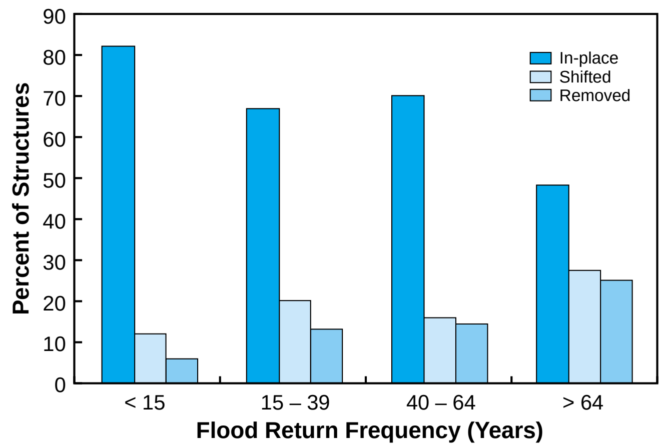

Figure 1. The relationship between flood magnitude and structure durability.

- Other conditions that affected structure durability included location of the structure within the stream channel, whether the structure was anchored or not, structure material and upslope landslide frequency. Structures designed with connections to the stream bank had greater durability. In addition, structures could be less durable in unconstrained stream channels. Consequently, durability is probably greatest for instream structures

			Structure Movement Category		
Stream order	Sample size	Flood frequency (years)	**In place (%)**	**Shifted on site (%)**	**Removed (%)**
2	176	<40	83	8	9
2	157	≥40	70	20	10
3	794	<40	70	21	9
3	702	≥40	64	19	17
4	711	<40	76	15	9
4	847	≥40	51	31	18
5	118	<40	60	20	20
5	334	≥40	41	17	42

Figure 2. The percentage of structures in each movement category stratified by stream order and flood frequency.

used in constrained reaches of small- to moderate-sized streams (fourth order and smaller) and placed with a connection or connections to the stream bank.

- Instream structures are most appropriate when used as short-term tools to improve degraded stream conditions while activities that caused the habitat degradation are simultaneously modified.
- When instream structures are part of a properly sequenced watershed restoration strategy, they can improve habitat conditions through a range of flow conditions, including large floods. The relationship between instream structure durability and upslope variables indicates the importance of a watershed perspective when implementing stream restoration. ▲

Based on: Brett B. Roper, D. Konnof, D. Heller and K. Wieman, 1998. Durability of Pacific Northwest Instream Structures Following Floods. American Journal of Fisheries Management, 8:686-693. American Fisheries Society.

Brett Roper works for U.S. Forest Service in Idaho, Deborah Konnoff and Dave Heller are in the Pacific Northwest Region Office of U.S. Forest Service in Oregon, and Ken Wieman is with the Wind River Ranger District Office of U.S. Forest Service in Washington.

Intensive Monitoring of Instream Works: Methodology and Year 1 Results

S. Babakaiff and R.Harelt

Project Description

The prime objective for the intensive monitoring of restoration sites on Vancouver Island was to determine the "effectiveness" of instream structures based on site-specific biological and geomorphological targets, or "effectiveness standards." A secondary objective was the collection of several biological and physical variables at both reach and site scales, to allow detailed inspection of relations between physical parameters (e.g., cover) and responses (e.g., fish abundance). The four geomorphic and two biological objectives associated with the restoration techniques are to:

- improve gravel accumulation or reduce percent fine sediment in bed,
- increase LWD cover,
- increase depth/reduce width (bank protection, bar stabilization),
- improve pool characteristics,
- increase fish production, and
- improve fish access to habitat.

Seven streams in five Vancouver Island watersheds underwent intensive monitoring in 1998. The *San Juan River watershed* contains Halliday, Five Mile and Renfrew Creeks, and is located 10-15 km east of Port Renfrew.The *Kootowis Creek watershed* contains Indian Bay tributary (test) and Staghorn Creek (control), and is located 15 km south of Tofino. The *Nimpkish River watershed* contains Lukwa Creek, the *Eve River watershed* contains Montague Creek, and the *Salmon River watershed* contains Big Tree Creek.

In the *San Juan watershed*, a culvert washout on a forestry road crossing adversely affected Halliday Creek. The road failure caused a large amount of sediment to enter the channel and fill pool habitat. The objective of the restoration work was to increase fish production and accessibility by excavating excess bedload and reconstructing riffle-pool sequences. Most of the LWD was removed from the reach at Five Mile Creek during stream cleaning practices during the 1980's. This resulted in a limited cover for fish during high flows and a lack of residual pool depth. The biological objective was to increase fish production by restoring cover and habitat complexity with the re-introduction of LWD. The lower reaches of Renfrew Creek have been affected by the loss of LWD cover and associated habitat complexity. Increased sediment inputs have resulted in infilling of pools. In 1997, restoration objectives were to increase LWD cover and habitat complexity by stabilizing LWD and introducing more LWD. Scouring during high flows will help to maintain residual pool depths.

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Logging in the *Kootowis Creek watershed* began in 1960; within 20 years, 42% of the watershed had been logged. Cross-stream yarding and wood waste left in the floodplain left a high density of wood debris in the streams. This degraded fish habitat affected adult fish accessibility and stranded adult and juvenile fish in flooded areas. Habitat restoration work involved extensive removal of woody debris from the stream channel. Stable wood was left in the channel and cabled in place to promote scour and provide cover for fish. The objective was to increase fish production by restoring stream channel to pre-logging conditions.

At Lukwa Creek, in the *Nimpkish River watershed*, sediment and debris inputs from the headwater reach, torrented tributaries, and two slides from the north valley wall have contributed to channel instability, bank erosion and infilling of fish habitat. The 1997 restoration work objectives were to re-establish the main channel through LWD re-alignment, removal of accumulated coarse sediment, and protection of eroding banks. Improvements to the channel stability would also benefit fish through reducing sediment input and scoured pool habitat.

Most of the lower reach of Montague Creek, in the *Eve River watershed*, was harvested with a minimal leave strip. It now has minimal instream cover and limited hydraulic diversity in the form of deep pools. The 1997 restoration work was conducted on the lowest section of Montague Creek. The biological objective was to increase fish production through increased habitat complexity. LWD structures were constructed along the channel margin, and boulder clusters were placed in the middle of the channel.

Big Tree Creek, in the *Salmon River watershed*, flows through a wide, irregular, and laterally unstable channel. Restoration activities in 1997 were confined to the lower 1300 meters of the creek. The biological objective was to provide stable rearing habitat for both adult and juvenile salmonids. LWD structures were placed in a natural pattern of clusters and individual logs to provide increased thalweg depth, increased habitat complexity and cover.

Fifteen test reaches were selected for the study, three from each of the five watersheds. All but one watershed had at least a single reference reach: a very short alluvial channel length at Montague Creek did not allow identification of a reference reach, and no surrogate reference reaches in adjacent watersheds were identified.

There were 56 test sites within this study. They contained only three general types of rehabilitative techniques: boulder clusters (4), constructed rock riffles (3), and LWD placements (49). To allow for a more discrete inspection of LWD placements, the techniques were further differentiated:

- single LWD piece, cabled to an anchor boulder or stump (2);
- multiple pieces of LWD, oriented dominantly perpendicular to flow (13);
- multiple pieces of LWD, oriented dominantly parallel to flow (21); and
- multiple pieces of LWD left *in situ*, with SWD removed from the channel (7).

Criteria for Restoration Evaluation

The intensive monitoring methodology focuses primarily on effectiveness monitoring: "have desired conditions and restoration objectives been met?" The monitoring variables included:

- Reach-based Fish Habitat Assessment Procedures (FHAP) variables: habitat unit length, gradient, bankfull depth, bankfull and wetted width, pool area, pool residual depth maximum pool depth, total and functional number of LWD pieces, total and functional LWD lengths, substrate type, and percent cover by type.
- Biological data (using Gee traps): fish abundance, life stage, species and length.
- Survey data: cross-sections, longitudinal profile, scaled plan view, structure descriptions.
- Supplemental data: bed surface sampling, stream discharge.

Both biological and geomorphic parameters were monitored and results were given a 1 to 4 class ranking. Class 4 fully meets or exceeds effectiveness standards, Class 3 adequately meets effectiveness standards, Class 2 poorly meets standards, and Class 1 is defined as not meeting effectiveness standards.

Impacts of Restoration

The mean biological and geomorphic effectiveness ratings for the structures are listed in Figure 1.

Restoration Technique	Mean Effectiveness Rating	
	Biological	Geomorphic
Boulder Cluster	3.0	3.0
Riffle-pool construction	1.7	4.0
LWD: single piece	3.0	2.0
LWD: multiple pieces, dominantly ⊥ to flow	3.2	2.2
LWD: multiple pieces, dominantly parallel to flow	2.7	2.0
LWD: multiple pieces, both ⊥ and parallel to flow	3.2	1.7
LWD: multiple pieces left *in situ*, but SWD removed	2.7	2.4

Figure 1. Comparision of watershed restoration structures based on geomorphic and biological effectiveness scales.

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The riffle-pool sites have low biological effectiveness ratings, but the mean biological effectiveness ratings of the other six structures are all 3.0 ± 0.3, that is, the six structure types have equal biological effectiveness ratings. Examination of site-specific case studies also did not yield evidence to suggest that particular variations of LWD placements induce greater biological effectiveness. All treated reaches with LWD structures are going through only the second or third year of high flow conditions. Scouring at these structures has the potential to further increase residual pool depth and improve fish habitat.

Geomorphic effectiveness ratings are high in the rock-based structures (boulder clusters and riffle-pool sites) but low at the LWD structures. It is likely that the LWD structures require flood events of a greater return period to induce bed scour compared to the rock structures. It is also possible that residual pool depths measured at rock structures have not been formed naturally, but were anthropogenically excavated during rock placement.

- As with the biological effectiveness ratings, there was little difference in geomorphic effectiveness rating between the six LWD structures; all are 2.0 ± 0.4. The geomorphic effectiveness ratings were generally lower than the biological effectiveness ratings because of an apparent lack of a significant post-construction flood event to induce bed scour.
- Time dependency is required for high effectiveness class ratings of some geomorphic parameters. For example, when an alteration in the hydraulic geometry or a reduced width:depth ratio is targeted, it may take several years for the bank erosion rates or width:depth ratios to reflect the impact of the instream prescriptions.

Geomorphic effectiveness ratings will probably show a general increase in the next few years, assuming that the prescriptions perform adequately.

Lessons Learned

- Site selection should be based on the presence of pre-restoration data.
- Summer fish sampling may give the structures a higher class ranking.
- Particular configurations of LWD placements did not induce greater biological effectiveness ratings.
- Location of structures in the channel together with site-specific conditions were responsible for effectiveness, regardless of the structure type, its orientation to thalweg, or channel confinement.
- Selection of class boundaries has a significant effect on ratings.
- This methodology is a useful technique for evaluating projects that may not have a reference site pre-established. ▲

Based on: Aquaterra Environmental Services and Babakaiff and Associates Geoscience Inc. 1999. Intensive Monitoring of Instream Works: Methodology and Year 1 Results. Prepared for Ministry of Environment, Lands, and Parks.

Development of Techniques to Rehabilitate Oregon's Wild Salmonids

M.F. Solazzi., T.E.Nickelson, S.L.Johnson, and J.D.Rodgers

Project Descriptions

Various types of habitat restoration techniques aimed at increasing rearing density of salmonids have been tried in Oregon coastal streams. These techniques have included placing structures made of wood, boulder, or concrete across the stream channel, excavating off-channel alcoves, and placing wood and boulders in various configurations into coastal streams. Most of the instances where habitat improvements were evaluated relied on data collected only during summer months.

During the first phase of the research an extensive sampling program was established on many Oregon coastal streams to evaluate the effectiveness of existing instream restoration projects. The purposes of this sampling were to:

- examine the types of rearing habitat created by habitat improvement techniques
- compare the relative effectiveness of the habitat created by these techniques to support juvenile coho salmon during the summer and winter, and
- compare the density of juvenile coho salmon in

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constructed habitats with that of juvenile coho salmon in natural habitats of the same type. This work was published in Nickelson et al. (1992), see above.

In this research a number of studies are summarized and it is shown that juvenile salmon use different types of habitat at different times of the year. The availability of winter habitat may limit coho salmon smolt production in many Oregon coastal streams. Habitat restoration projects that do not create good winter habitat will fail to increase the production of coho salmon smolts. The work summarized in this paper involved two treatment streams and two reference streams (Alsea/Nestucca Winter Habitat Study). The habitat modification project increased the amount of dammed pool and alcove surface area and decreased the amount of rapid, riffle and glide surface area in both treatment streams during winter. The addition of large amounts of woody debris to the main channel dammed pools helped to reduce velocities in those habitats. It was designed to examine the effects of increasing winter habitat on the production of downstream migrant salmonids, particularly coho salmon. Another study (Tenmile Watershed Restoration Study) was initiated in 1991 on Tenmile Creek and Cummins Creek, both ocean tributary streams on the central coast of Oregon. This study examined the effects of watershed restoration on the production of downstream migrant salmonids, particularly steelhead and cutthroat trout. The post-restoration sampling is ongoing.

During the second phase of this research an intensive sampling effort concentrated on a few streams before and after restoration work to determine if the habitat modification resulted in significant changes in total smolt production. A portion of this work has been submitted for publication.

Criteria for Restoration Evaluation: pools created by construction of structures placed across the full width of stream channel, constructed alcoves, and pools created by log deflectors.

Population sizes of juvenile coho were measured by blocking of the pool with seines and conducting a mark-recapture estimate using electrofishing equipment and seines.

Restoration Responses

In the first phase of the research, it was clearly demonstrated that instream restoration involving full-width log structures resulted in an increase of summer juvenile coho three times greater than the reference streams (Figure 1).

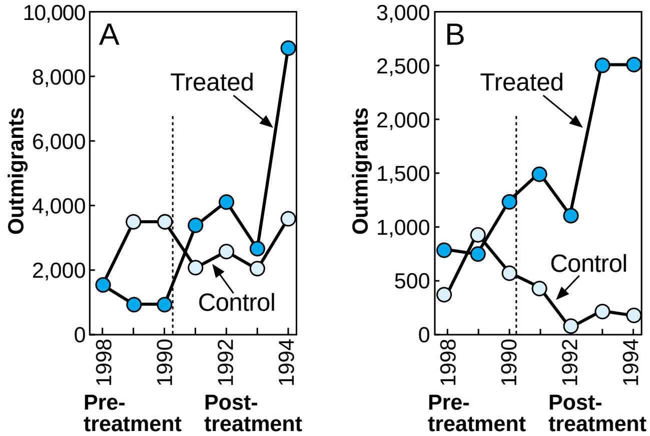

Figure 1: Increases in numbers of out-migrant coho salmon smolt after experimental addition of large woody debris to debris-poor streams in the Alsea/Nestucca streams in western Oregon (after Fig.8-1a, Tech Circ.9)

During the second phase of research, Nickelson, et al. (1992) found that adding bundles of small trees to dammed pools resulted in significant (ANOVA) increases in coho densities during winter. Habitat modification was designed to improve winter habitat for coho salmon, but the increased slow-water habitat and stream complexity also benefitted juvenile steelhead and cutthroat trout. Upper age class steelhead and cutthroat trout migrant populations did increase. This suggests that winter habitat was limiting their abundance and that the habitat modifications increased the capacity of the streams to produce steelhead and cutthroat trout.

Lessons Learned

- Construction of full-width log structures in small streams increases summer juvenile coho survival.
- Habitat modification was designed to improve winter habitat for coho salmon, but the increased slow-water habitat and stream complexity also benefitted juvenile steelhead and cutthroat trout.
- The results suggest that constructed dam pools should contain scour logs or boulders to maintain depth in a portion of the pool if it is to be used for winter rearing.
- By adding bundles of small trees to constructed dammed pools the density of coho salmon increased in the pools during the winter. ▲

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Based on two phases of research carried out between October 1, 1985 to September 30, 1998. The earlier phase of work is summarized in : Nickelson, T.E., M.F. Solazzi. S.L. Johnson and J.D. Rodgers. 1992. *Effectiveness of selected stream improvement techniques to create suitable summer and winter rearing habitat for juvenile coho salmon (Oncorhynchus kisutch) in Oregon coastal streams*. Canadian Journal of Fisheries and Aquatic Science. 49: 790-794. The second phase of research is summarized in*: Final Report: Fish Research Project, Development of Techniques to Rehabilitate Oregon's Wild Salmonids*, 1998. Oregon Department of Fish and Wildlife, P.O. Box 59, Portland Oregon. 41 pp.

The Contribution of Restored Off-Channel Habitat to Smolt Production in the Coquitlam River

A.S. Decker and M. Foy

Project Description

The Coquitlam River is a 4th order tributary that joins the Fraser River 8 km east of New Westminster, B.C. Since the 1970's, a number of groups and agencies have voiced concerns about the decline of salmonid populations in the river. The decline is due, in part, to extensive development of the watershed beginning in the late 1900's. Development includes dam construction, logging, gravel mining and urban growth, which have all contributed to extensive loss and degradation of salmonid habitat. Remaining salmonid habitat occurs primarily in mainstem and tributary reaches of a 12 km long section of the river between the Coquitlam Reservoir and the city of Port Coquitlam.

From 1993 to 1997, an intensive off-channel habitat restoration program occurred in the Coquitlam River, providing ~43,000 m^2 of artificial pond and channel habitat at six sites. Prior to construction, off-channel habitat represented less than 1% of available habitat in the river. This increased to 14% following restoration. The sites range in size from 845 to 17,300 m^2. Each site consists of an inlet spawning channel which diverts flow from the Coquitlam River, an outlet channel and one or a series of rearing ponds. The ponds represent the majority of wetted area at each site. The ponds were created by the construction of earthen dikes in low-lying areas of the river's flood plain. Trees and root wads removed during dike construction were added to the ponds to provide cover.

Examined in isolation, groundwater-fed side channels and off-channel ponds have been shown to support relatively high densities of coho smolts, and in some cases, steelhead smolts, but relatively few studies have compared the proportional use of off-channel versus mainstem habitat at a watershed scale. Initial assessment of off-channel sites in the upper Coquitlam River in 1996 indicated that juvenile coho and steelhead densities in off-channel habitat were high, relative to densities in mainstem habitat. In 1997 and 1999, numbers of smolt outmigrants from off-channel sites were compared to estimated numbers from mainstem and tributary habitat in a 12 km section of the river in order to assess the relative contribution of constructed off-channel habitat to stream-wide smolt production.

Criteria for Restoration Evaluation: Smolt outmigrant populations.

Off-Channel Habitat Sites

During 1996-1999, smolt outmigrant populations from several of the off-channel sites were enumerated at converging downstream weir fish traps, or estimated using minnow traps and single census mark-recapture methodology. Downstream traps were operated from late March to mid-June each year. Minnow trapping was conducted during mid- to late March. *In cases where total captures were low (i.e., < 100) or marked proportions in recoveries were low (i.e., < 15%), mark-recapture estimates were not generated.*

Coquitlam River

Smolt output from a 1.7 km section of the upper Coquitlam River below Coquitlam Dam (reach 4) has been assessed periodically since 1986. As part of this study, we enumerated smolt outmigrants from reach 4 at a downstream fish trap from 1996 to 1999. In 1997,

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smolt abundance was also estimated for reach 3, the remaining downstream portion of the 12 km study section (13.7 km of mainstem and tributary habitat). This was done using stratified mark-recapture methodology: fish captured in reach 4 and the off-channel sites were batch-marked according to capture period, and then recovered along with unmarked fish from the mainstem and tributaries in a fyke net located at the downstream end of reach 3. In 1999, the study was repeated, but a rotary screw trap was used in place of the fyke net and reach 3 was shortened to 5.6 km of mainstem and tributary habitat. Smolt population estimates for the 12 km section were derived by extrapolating mean estimates for reaches 3 and 4.

Restoration Responses

Coho Salmon

Coho smolt densities in off-channel sites were considerably higher compared to those in the Coquitlam River. Between 1996 and 1999, coho smolt densities in the off-channel sites ranged from 5.3 to 84.6 smolts/100 m^2 and averaged 38.6 smolts/100 m^2, whereas densities in reaches 3 and 4 averaged just 4.2 and 10.0 smolts/100 m^2, respectively (see Figure 1).

In 1997, juvenile coho use of off-channel vs. mainstem and tributary habitat was highly disproportionate: four man-made off-channel sites, representing 12% of total rearing area of the 12 km section, were used by an estimated 47% of coho smolts (13,771 of 29,333). Results for 1999 were similar: six off-channel sites, representing 14% of wetted area, supported an estimated 48% (12,491 of 25,878) of overwintering smolts. This high degree of use suggests that off-channel habitat restoration has strongly influenced the distribution of coho smolt production in the watershed, and may have increased its carrying capacity.

A comparison of annual smolt abundance in reach 4 before and after habitat rehabilitation suggests that relatively high smolt output from off-channel sites has not affected fish production in the mainstem. Prior to construction of the Grant's Tomb and Or Creek off-channel sites in 1995, annual coho smolt production ranged from 81-3227 fish (n = 3) (Figure 1).

Results from experimental fry releases suggested that low recruitment, rather than winter carrying capacity, may have limited coho smolt production in some of the sites. For example, 4000 and 3000 hatchery fry were released in the Archery Pond site during the 1996 and 1997 smolt years, respectively, while 10,000 hatchery and 11,400 wild fry were released in Oxbow Lake site during the 1998 and 1999 smolt years, respectively. Mean smolt numbers from the Archery Pond and Oxbow Lake sites for years when fry stocking occurred (3220 and 2106 smolts, respectively) were greater than numbers for years when no stocking occurred (477 and 1187 smolts, respectively).

Steelhead

Steelhead smolt densities for constructed off-channel habitat were comparable to those for natural mainstem

		Off-channel Sites								Mainstem and Tributaries			
		Grant's Tomb		Or Creek		Archery		Oxbow		Reach 4		Reach 3[1]	
	Year	total	density	total	density	total	density	total	density	total	density	total	density
Coho	1996	1220	37.0	2864	73.6	1457	52.0	-	-	290	1.4	-	-
Coho	1997	679	46.3	11281	84.6	623	10.7	1187	6.9	2773	13.6	15562	5.9
Coho	1998	1390	42.1	-	-	-	-	917	5.3	3813	18.6	-	-
Coho	1999	1822	57.0	1138	8.5	3423	59.0	3924	19.0	1331	6.5	2405	3.6
Steelhead	1996	57	2.7	55	1.5	-	-	-	-	258	1.3	-	-
Steelhead	1997	11	0.8	411	3.5	115	2.0	121	0.7	207	1.0	-	-
Steelhead	1998	-	-	-	-	-	-	275	1.6	421	2.1	-	-
Steelhead	1999	42	1.3	91	1.2	-	-	292	4.3	560	2.7	1781	2.6

[1]Reach 3 consisted of 13.7 km of mainstem and tributary habitat in 1997 and a 5.6 km section in 1999.
[2]The Or Creek site was 3936 m^2 in wetted area in 1996 and was expanded to 13,336 m^2 in 1997.

Figure 1. Summary of coho and steelhead smolt numbers and densities (smolts 100/m^2) for off-channel sites and mainstem reaches of the Coquitlam River, 1996 - 1999.

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and tributary habitat. Between 1996 and 1999, steelhead smolt densities in the off-channel sites ranged from 0.7 to 4.35 smolts/100 m^2 and averaged 2.0 smolts/100 m^2, whereas densities in reaches 4 of the Coquitlam River ranged from 1.0 to 2.7 smolts/100 m^2 and averaged 1.8 smolts/100 m^2 (see Figure 1). In 1997, too few steelhead smolts were recovered in reach 3 to provide a population estimate. In 1999, estimated density in reach 3 was similar to that in reach 4 (2.6 smolts/100 m^2).

In 1999, an estimated 7% of steelhead smolts in the 12 km section overwintered in the off-channel sites (520 of 7,444 smolts). Given that off-channel areas represent 14% of available habitat, off-channel use by steelhead was low in proportion to availability. However, extrapolating smolt densities from the upper river mainstem to lower reaches likely resulted in an overestimate of smolt numbers; earlier studies found steelhead densities were lower in downstream reaches compared to reaches 3 and 4. As well, steelhead smolt output from reach 4 in 1999 was relatively high compared to six previous sample years. During 1996 and 1997, steelhead (smolts and parr) use of off-channel habitat in reach 4 was proportional to its availability. The Grant's Tomb and Or Creek sites, representing 45% of wetted area in reach 4, supported 34% of steelhead in 1996 and 67% in 1997.

Similar to results for coho, the construction of off-channel habitat did not appear to adversely affect steelhead smolt production in existing mainstem and tributary habitat. Mean smolt output from reach 4 averaged 362 for post-construction years (n = 4) compared to 207 for pre-construction years (n = 3). However, higher numbers in the mainstem in the post-construction period may have been influenced by increased flow releases from the dam.

Lessons Learned

The pond-channel design appears to be an effective approach to increasing coho smolt abundance through habitat restoration. The Coquitlam River pond-channel projects have been successful in part because they provide critical coho overwintering habitat in a system where natural overwintering habitat is scarce.

- Data for the combined pond-channel projects at Coquitlam River suggests that this type of off-channel habitat may also provide important over-wintering habitat for steelhead and cutthroat.
- The tendency for stable off-channel habitat to produce consistent smolt yields may be more important than its ability to augment production in any one year, particularly in a degraded watershed such as the Coquitlam.
- Fry recruitment may be an important factor, particularly in the case of larger off-channel sites with limited access to the stream's mainstem. During construction, effort should be made to enhance the attractiveness of outlet channels to migrating adults and juveniles through the addition of artificial log jams or other debris structures. If hatchery enhancement occurs in the watershed, consideration should also be given to releasing fry in off-channel sites. ▲

This information is compiled from reports (1996-1999) that were prepared for B.C. Hydro Power Facilities and the Department of Fisheries and Oceans' Resource Restoration Division, Vancouver, B.C. Funding for the restoration and assessment work was provided by B.C. Hydro, DFO, FRBC, and the Port Coquitlam Fish and Game Club.

Case Studies of Whole-stream Fertilization in British Columbia

P.A. Slaney, and K.I. Ashley.

Project Description

Whole-river fertilization experiments have been conducted in British Columbia on a series of oligotrophic coastal and interior streams that have been affected by past logging practices and/or hydroelectric development.. These experiments were designed to determine, under diverse conditions, the effects of inorganic nutrient addition on water chemistry, periphyton and invertebrate community composition and biomass, and fish growth and abundance. The treated systems include Keogh River, Salmon River, and Adam River, all located on the northern Vancouver Island; Big Silver Creek, located near Harrison Lake

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on the southern mainland; and the large Mesilinka River, located in northern British Columbia (280 km north of Prince George). The fertilization treatments and responses of these 5 streams represent a broad spectrum of stream types and fish communities in various regions of B.C.

Restoration Responses

Keogh River

Stream fertilization during the spring in 1984, 1985, and 1986 resulted in striking increases in the average weights of steelhead and coho salmon fry, in response to augmented periphyton and benthic insect communities. In 1981, inorganic fertilization increased geometric mean weights of salmon and trout fry respectively by 1.6-1.7 times and 1.9-2.1 times the control. During whole-river treatments from 1984 to 1986, larger sizes-at-age of steelhead parr were usually detected. In 1984, mean weight-at-age of parr did not differ statistically between the upper treated reach and the control. However, in the two other reaches in 1984, and within the three treated reaches in 1985 and 1986, age 1+ parr were 30-130% greater in geometric mean weight than parr in the upstream control section. The older age 2+ parr were 41-63 % larger in the treated reaches than in the control in 1985 and 1986. In 1981, mean salmonid biomass in the treated reach increased 1.8 times, from 35 kg/ha to 65 kg/ha, as compared to the control reach.

Steelhead smolts, as primary mainstem users, increased in production by 62% by brood year over pre-treatment years. Peak smolt output (1987) from the Keogh River was 2.5 times greater than the average for pre-fertilization years. Fertilization also shifted the age class structure of the smolts; age 3 smolts dominated pre-fertilization smolt yields, whereas age 2 smolts dominated the annual smolt production during fertilization, and age 1 smolts appeared for the first time in 1987 as a significant portion (12%) of the annual yield. However, fertilization had a minimal effect on average smolt size: mean smolt length in 1985, 1986, and 1987 was 175, 160, and 170 mm, respectively. Thus, smolt migrated at about the same size as pre-fertilization but one year earlier on average. Adult steelhead originating from smolt cohorts of fertilized years returned to the river from 1986 to 1990. Their numbers, and catch in the sport fishery, corresponded with the increased numbers and size-at-age of smolts, whereas the catch of wild steelhead at an untreated river nearby showed little change.

There was also a 21% increase in coho smolts, possibly as a result of fertilization. However, there are 16-19 untreated tributaries and 6 small lakes that produce an estimated 60% of coho outside the mainstem. Their presence confounded the analysis of treatment effects on mainstem coho production in the treated areas. Mean coho smolt length and age did not change significantly as a result of the treatment.

Fertilization of 30 km of the Keogh River resulted in about a 50% increase in adult steelhead, or an additional 15 adults per km.

Salmon River

Past logging-related instability made fertilization one of the few options in this bouldery stream. During 1990 and 1991, peak periphyton responses were similar to those recorded at the Keogh River during fertilization in 1984-86. In May to July of 1990 and 1991, chlorophyll *a* at the treated sites and downstream in the mainstem at the diversion, peaked at 5-10 times the level of the control section, 10 mg/m^2. By 1992, at the fertilized site in Grilse Creek and at the Salmon River diversion site (9 km downstream of the 4th nutrient dispenser), peak chlorophyll *a* was only moderately elevated to 42 and 37 mg/m^2 by late July, respectively. On the other hand, the peak in the control and 25 km downstream of the fertilizer dispenser in the Salmon River were low in July (6.4-9.0 and 6.3-7.5 mg/m^2). In 1993, more intensive sampling of chlorophyll *a* was conducted. Mean peak chlorophyll *a* biomass was moderate to low, except at the surcharged (10 mg P/L and 40 mg N/L) section at Norris Creek (80 mg/m^2). Peaks at the other seven sites ranged from 17-39 mg/m^2, somewhat higher than the two untreated sites, which ranged from 16-27 mg/m^2. Insect grazing apparently moderated initial algal responses to nutrient addition, which was confirmed elsewhere.

In 1992, the abundance and composition of insects within colonized baskets in Grilse Creek and the Salmon River (in which chlorophyll *a* levels were elevated by 3-4 times) was 2.5 times and 7 times higher than both the upstream control and the sampling site located 25 km downstream from the fourth fertilizer dispenser. The relative percentages of insects varied among the four sites. Mayflies dominated the control (52%) and the fertilized sites (50%) in the Salmon River, with slightly less at the lower Salmon site (40%) and still less in Grilse Creek (20%). Dipterans, which mainly consisted of chironomids, dominated the composition at the Grilse Creek site (75%) and were also evident at the other sites (29-36%). In the lower Salmon River 13-14% of the benthic insects were stoneflies and caddisflies; elsewhere these insects were generally sparse (<10%), although 14% of the insects at the Salmon diversion were caddisflies. In 1993, additional sampling sites facilitated a more rigorous comparison between the control (n=2) and treated (n=8) sites; the mean

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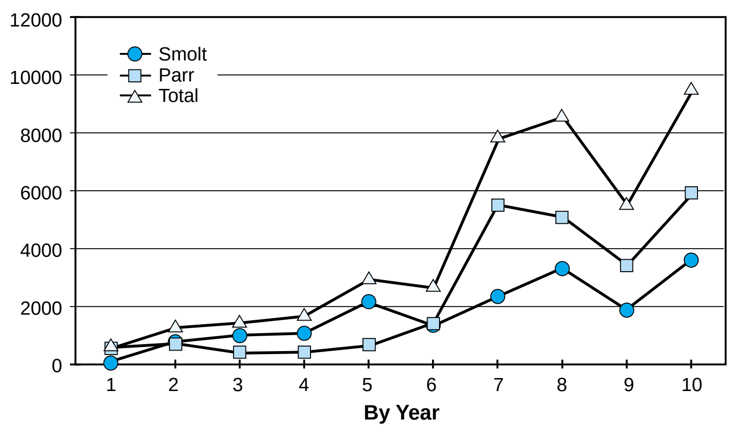
biomass of benthic insects from the fertilized sites was 3.7 times greater than the untreated control sites.

In 1990, the mean weights of trout fry were 3 times greater on average in sites associated with liquid fertilization than in the spatial control, in both Grilse Creek and the Salmon River. In 1992, without nitrate addition there was still a 2 times greater size of fry in fertilized reaches on average, and about 2 times larger than sites >35 km downstream where peak periphyton chlorophyll *a* was not elevated. In addition, mean weights of age 1+ parr were 2-3 times greater in 1990 and 1992 at the sites associated with fertilization.

A strong response to nutrient addition was evident in outputs of migrant steelhead parr and smolts, as enumerated each spring at a hydro-diversion bypass on the Salmon River (Figure 1).



Year	1988[1]	1989[2]	1990	1991	1992[1]	1993	1994	1995	1996	1998[2]
Smolts	150	902	1041	1128	2265	1379	2414	3446	1931	3718
Parr	500	763	447	490	718	1357	5593	5312	3403	6014
Total	650	1665	1488	1618	2983	2736	8023	8758	5334	9732

[1]Efficiency of smolt screen estimated at less than 50% .
[2] Trapping and enumeration later than usual.
**Fence not operated because hydro diversion canal was closed during 1997 and 1999.

Figure 1. Steelhead smolts and parr enumerated at the hydro-diversion bypass on the treated Salmon River.

Big Silver Creek

Big Silver Creek is a large coastal stream located 35 km north of Harrison Hot Springs, B.C. It originated from the Coast Mountains and flows for about 40 km in a southerly direction before emptying into the expansive and highly oligotrophic Harrison Lake. Pre-fertilization conditions were documented in 1992 and 1993 (Toth et al. 1993). It was fertilized in 1994 with 9.5 tonnes of 10-34-0 (ammonium polyphosphate) added in the Middle treatment zone (T1; 13 km upstream from Harrison Lake) and again in 1995 with 9.5 tonnes of 10-34-0. Nitrogen (i.e., 28-0-0) was not required because of the natural high background concentration of dissolved inorganic nitrogen in Big Silver. Approximately the same nutrient load (i.e., 9.5 tonnes of 10-34-0) was added in 1996 and 1997.

In 1995, peak periphyton biomass (measured as chlorophyll *a*) was 4-5 times greater in the Middle (T1, 6 to 13 km from Harrison Lake) but only slightly greater in the Lower treatment zones (T2, 1 to 6 km from Harrison Lake), compared to the control reach (13 to 15 km from Harrison Lake) and to pre-treatment years. Benthic invertebrate biomass increased 2-3 times in T1, and increased spectacularly in T2. Total number of rainbow trout >20 cm per ha was constant in the control. The number increased >3 times in the Middle reach, but only increased about 50% in the Lower reach. Electrofishing surveys indicated juvenile rainbow trout density was similar between the control and fertilized sections; however, the biomass of the juvenile rainbows in the fertilized reach was 20% greater than the biomass from the control reach of the mainstem. Mountain whitefish abundance (a species that only inhabits the lowest reach near the lake) increased > 2 times after fertilization. A P-induced nitrogen limitation probably limited the response of Big Silver to nutrient addition.

Adam River

The Adam River is an oligotrophic coastal trout stream located 80 km northwest of Campbell River on Vancouver Island. It was fertilized in 1994 with 2.3 tonnes of 10-34-0 (ammonium polyphosphate) and 1.03 tonnes of 28-0-0 (urea-ammonium nitrate), added in the lower treatment reach (T2; ~8 km). The river was fertilized again in 1995 with the same type and amount of fertilizer. About the same nutrient load (i.e., 2.3 tonnes of 10-34-0 and 1.03 tonnes of 28-0-0) was added in 1996 and 1997.

Peak periphyton chlorophyll *a* was almost 2 times higher in the post-fertilization period within the unfertilized control and T1, but T2 reach was >4 times higher than in pre-fertilization years. Confounding by forest fertilization may explain the elevated levels in untreated reaches C and T1. Benthic invertebrate biomass was sampled in both spring and summer; a strong increase was evident in summer but not in spring in the T2 fertilized reach. This indicates that it required several weeks to obtain an insect response to increased periphyton accrual. On average, underwater counts of total numbers per ha of rainbow, brown and cutthroat trout >20 cm did not increase in

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the fertilized reach compared to the other reaches until 1997. Also, electrofishing surveys indicated increased juvenile rainbow trout biomass in the fertilized reach compared to the untreated reaches. By 1996, there was evidence of straying of fish from T2 into T1, possibly in response to a food gradient and deep pool availability in low summer flows.

Mesilinka River

The Mesilinka River is a large cool river located in B.C.'s northern interior 280 km north of Prince George. The headwaters originate in the Omenica mountain range and flow for a distance of about 120 km prior to joining B.C.'s largest body of water, the Williston Reservoir. The external control in this project, the Nation River, is located about 100 km south of the Mesilinka River. Fertilization was selected as one of the few practical options for mitigating for loss of habitat in the lower Mesilinka and Omenica Rivers because large reaches of the Parship, Finlay and Peace rivers and their numerous tributaries, were flooded by impounding the Peace system as the expansive Williston Reservoir.

Peak periphyton biomass (measured as chlorophyll *a*) in 1994 was 10 times and 2 times higher in T1 and T2, respectively, than the control reach. By 1994, benthic invertebrate biomass increased 2 times in T1 but less so in T2. Adult fish densities were higher in T1 and T2 following the first year of nutrient treatment, mainly due to a response from mountain whitefish. By 1995-97, fish populations continued to increase in treatment reach T1, but less so in treatment reach T2. Increases in abundance ranged between 1.5 and 3 times, except for highly migrant bull trout in T2 which lagged until a marked increase in 1999. Large rainbow trout (> 30 cm) increased 3 times in both reaches. Given the cold climate and longevity of the target species in the Mesilinka (e.g., bull trout, Arctic grayling), several years of fertilization will likely be required before the overall response is confirmed.

Lessons Learned

- To date, the results of experimental stream fertilization inferred from the response of five streams strongly demonstrate that low-level seasonal addition of limiting nutrients can substantially increase the trophic productivity of oligotrophic streams. (methods including slow release are described in technical circular 9)
- The effective distance of fish growth resulting from nutrient additions was approximately 15 km on average (range 12-15 km) in the Salmon River.
- This technique is applicable to streams with depressed nutrient influxes (lacking salmon carcasses), as well as to increase fish survivals in disturbed watersheds, such as the Salmon River. ▲

Based on : Slaney, P.A. and K.I. Ashley. 1998. Case Studies of Whole-stream Fertilization in British Columbia. Restoration of Fisheries by Enrichment of Aquatic Ecosystems. 1999. pp. 83-98, In: J.G. Stockner and G. Milbrink (Eds.). Proceedings of the International Workshop at Uppsala University, March 30 to April 1, 1998, Uppsala, Sweden. 219 pp.

Update

Conferences

Technologies for New Millenium Forestry, Demo 2000 International. Sept. 11-16, Kelowna, B.C. For updated information, consult the following websites: www.cwfcof.org or www.forestindustry.com. This event is organized every four years, so don't miss it. Approximately 8,000 - 10,000 registrants are expected from over 30 countries.

International Conference on Ecology and Management of Wood in World Rivers. Oct. 23 – 27, 2000. Corvallis, Oregon. Call for papers: abstracts must be received by April 1, 2000. Further information on abstract formatting and registration are available at the conference website at http://riverwood.orst.edu.

Workshops

Watershed Assessment in the Southern Interior of B.C. March 9 and 10, 2000. Penticton Lakeside Resort. Penticton, B.C. The objectives of the workshop are to present recent hydrologic research to assist in watershed analysis in the interior of B.C., to present research on the four main topics included in watershed analysis to enable better watershed assessments, and to present research about topics related to watershed analysis. For registration information, contact April Anderson tel: 250-226-7641.

2000 Interior Forest Site Rehabilitation Workshop in Kamloops on April 12th & 13th, 2000 at the Best Western Towne Lodge. The IFSR will again be an interesting two-day event based around this year's theme "*Results and Accomplishments - toward better forests, stabilized channels and cleaner water*." The emphasis will be on lessons learned over the last 5 years and various projects of the WRP program – what techniques and measures have stood

Update

the test of time, which have not and which ones provided sound investments. Presentations will focus on experience gained from the accomplishments of successful projects. Consistent with this theme and the purpose of the workshop, expressions of interest for presentations, which relate to the topics listed below, will be considered for the workshop agenda, according to merit. The workshop will be preceded by a one-day seminar on April 11, which will focus on interior watershed processes (specific topics to be defined). For further information please contact Tom Rankin at tel:(250) 573-3092 fax: 250-573-2882 or e-mail at trankin@telus.net

Courses

INTRODUCTORY COURSES: Forest Worker Training. This five-day course is designed to introduce participants to the WRP and the field techniques used on WRP projects. Feb 28 - March 3, 2000, Campbell River, B.C. April 3 - 7, 2000, Vernon, B.C. May 1 - 5, 2000, Prince George, B.C. Registration Fee: $ 710.00 + $ 49.70 gst

Fish Habitat Assessment Procedure (FHAP). This 2.5-day workshop combines classroom and field components in assessing fish habitat for watershed restoration work. Available on demand.

Introduction to Fish Habitat Rehabilitation Procedures (FHRP). This 1.5-day workshop introduces participants to the various techniques used to rehabilitate fish habitat that has been impacted by past timber harvest practices. April 26 - 27, 2000, Vernon, B.C. Registration Fee: $ 225.00 + $ 15.75 gst

Riparian Assessment & Prescription Procedures (RAPP). This workshop will introduce participants to the WRP RAPP as described in the WRP Technical Circular No. 6 (1999). April 17 - 19, 2000, Chilliwack, B.C. May 8 - 10, 2000, Prince George, B.C. Registration Fee: $ 330.00 + $ 23.10 gst

ADVANCED COURSES:
Fish Habitat Rehabilitation: Off-Channel Habitat. This practical workshop will give an in-depth description of off-channel WRP projects; when off-channel habitat is appropriate, how to determine the type of off-channel habitat to use, prescribing rehabilitation projects and the design and implementation of prescribed projects. May 2 - 3, 2000, Chilliwack, B.C. Registration Fee: $ 315.00 + $ 22.05 gst

Fish Habitat Rehabilitation: In-Stream Structures, Large Woody Debris and Boulders This practical workshop will give an in-depth description of in-stream WRP projects, including large woody debris (LWD) and boulder structures; when in-stream structures are appropriate, how to determine the type of structure to use, prescribing rehabilitation projects, and the design and implementation of prescribed projects. April 26 - 28, 2000 Port Hardy, B.C. October 25 - 27, 2000 Kelowna area Registration Fee: $ 315.00 + $ 22.05 gst

Channel Condition Prescriptions and Assessments Procedure (CCPA) The CCAP is an objective and repeatable method of assessing changes in stream channel morphology brought about by timber harvest activities. April 13 - 14, 2000, Chilliwack, B.C. June 14 - 15, 2000, Prince George, B.C. Registration Fee: $ 290.00 + $ 20.30 gst, if applicable.

To express your interest in WRP courses and/or receive course delivery details, contact the FCSN office in Vancouver at tel: 604-222-9157, fax: 604-222-1730, email: pcb@interchange.ubc.ca, or leave a message on our toll-free registration line: 1-877-222-9993. For course information, contact Phil Blanchard at: 250-477-5560, email: prb.fcsn@home com. For information on the WRP program, contact Heather Deal, WRP Training Coordinator, Ministry of Environment 604-222-6768 or Heather.Deal@gems1.gov.bc.ca

Streamline

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Streamline's goals are to communicate information on practical approaches to watershed restoration including the rehabilitation of stream channels, riparian zones and hillslopes, and to act as a link between geographically separated WRP proponents and their contractors by facilitating the sharing of information and ideas between the regions of B.C. We rely on our readers' participation. **Please send articles and project descriptions (with relevant photos and drawings), as well as information for our "Update" section. We reserve the right to edit submissions for appropriate content, style, and relevance to the Technical Bulletin.**

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