ABSTRACTS

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Planning for Watershed Restoration

Notes from Introduction to Coastal Forest Site Rehabilitation Workshop

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The Watershed Restoration Program 1998/99 Annual Compendium celebrates the excellent work taking place in the WRP. The Auditor General's Report of Forest Renewal BC consists of 39 recommendations, of which 30 are underway. The remaining nine would transfer costs to the licensees.

Following the shock of last year's dramatic budget cuts, we have a commitment this year to focus on fish and water, performance, transition, and funding. Meetings with organizations, individuals and community members have helped to prioritize these commitments.

Funding of $50 million for the current year and the next five years is expected to hold. These funds will be directed to the high priority key watersheds. WRP will continue to focus on whole watersheds, and the approach will be based on impact assessments. The aim is to have Resource Management Plans developed for 2001. Regional workshops are continuing. Tracking Performance and Effectiveness Evaluation are most important in achieving the objectives for the targeted resource values. ▲

WRP Planning and Priority Setting for the Next Five Years

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The Watershed Restoration Program has recently established goals of enhancing environmental values by restoring fisheries and aquatic resources in key watersheds throughout the province. The focus over the next five years will be to:

- Emphasize water quality and fish and fish habitat.
- Identify key watersheds in each region.
- Ensure an integrated, whole watershed approach.
- Increase monitoring and evaluation component of the program.

In order to implement Forest Renewal BC's new focus, an interagency team developed Resource Management Plan (RMP) guidelines that will lead to a single RMP for each Forest Renewal BC region. This paper explains how the objectives for the RMPs and investment plans are expected to be achieved.

Step 1: *Identification of High Priority Key Watersheds*

High Priority Key Watersheds are regionally significant watersheds that contain high values for targeted fish species or domestic water supply, and have a high likelihood of restoration success.

Regional planning teams have largely completed the identification process. For example, Pacific Region delineated 895 watersheds and targeted 177 key watersheds (20% of the total). The identification process includes the following tasks:

1) prioritize fish species by region
2) create a base map of watershed planning units
3) select watersheds that are important producers or conservation streams for the identified target species
4) select important domestic water supply watersheds
5) create a ranked list of watersheds (L-VH priority) The H and VH watersheds are the Key Watersheds
6) categorize the restoration potential for watersheds ranked High and Very High:

Category 1 – known impacts from pre-Code forestry and high potential for restoration
Category 2 – significant impacts from other land uses
Category 3 – minimal impact from forestry related activities
Category 4 – impacted so severely that restoration is unlikely to be successful
Category 5 – insufficient data to make a determination

High Priority Key watersheds are all category 1 and 2 watersheds with an inter-agency, coordinated plan in place. The characteristics of these watersheds are:

- ranked H or VH for target fish species or community water supply
- known impacts from pre-Code forest development
- high potential for restoration success

Step 2: *Selecting Target Watersheds*

This phase is part of the Forest Renewal Investment Planning Process. It involves the selection of Target Watersheds: the High Priority Key Watersheds that will be targeted for restoration activity over the next 5 years. The goal is to restore 20% of the High Priority Key Watersheds over the next 5 years.

Step 3: *Identifying Sub-Basins and Preparing Restoration Plans*

The next step is the identification of targeted sub-basins within the Target Watersheds, and preparing restoration plans for those sub-basins. The tasks are as follows:

- Within each Target Watershed, identify all of the sub-basins.
- Estimate the impact on fish habitat or water quality by component (hillslopes, riparian, channel) using overview assessment information.
- Estimate the likelihood for restoration success on each component within each sub-basin.

A Restoration Plan for each targeted sub-basin consists of the following:

- Use Level 1 assessments to identify the critical limiting habitat factors for the target fish species and to confirm the priority components for restoration success.
- Prioritize the works within these components based on risk, effectiveness, and cost.

- Schedule the work and the access management.
- The RP sets the benchmark for monitoring and for determining restoration completion.

The goal is that by 2001/02, over 90% of regional WRP investments will be targeted to fisheries and aquatic resource values in priority key watersheds. Some components of the model have already been implemented. A working draft of the guidelines for regional priority setting was incorporated into the 2000/01 Resource Management Plan. Work is now underway to complete the first two phases. A working draft of the watershed level planning guidelines (preparing the Restoration Plan) will be completed by April, 2000. ▲

Landslide and Roadway Stability Analyses in Timber Industry Watersheds in Northern California

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This paper was presented in Nanaimo by Terry Rollerson, on behalf of Tom Koler.

Pacific Lumber Company (PALCO) signed a benchmark document on March 1, 1999 with Federal and State wildlife agencies to preserve and protect critical habitat for threatened and endangered species found on the company's timberland. In this Habitat Conservation Plan and Sustainable Yield Plan (HCP/SYP), PALCO management agreed to complete watershed analyses for each of the twenty-two PALCO watersheds by the year 2003.

A natural event in northern California, landslides cause concern for management of industry timber companies an many areas. They affect timber stand health, water quality, and aquatic habitat. Natural occurrences of landslides result from a combination of low shear strength soils, steep hillslopes, high rainfall, and seismic activity. The timber harvesting that has been occurring on PALCO lands for the past 130 years has also been a mechanism for initiating slope movement in many watersheds.

The wildlife agencies stipulated in the HCP/SYP that a modification of the State of Washington Forest Practices Board's Watershed Analysis Methodology be applied in the analyses because the climate and vegetation in northern California is similar to western Washington's. An inter-disciplinary team of watershed scientists was formed in June 1999 to initiate modifications for the various modules. The purpose of this modification was to "fit" the methodology to northern California conditions.

In the modification, the first step is to build a landform map based on topographic expression and geomorphic features. Second, a stratified random sampling of potential landform sites is located on nodes of a 1,000-ft. by 1,000-ft. mesh overlying the landform map. Typically, the number of total samples for a 16,000-acre watershed is 150 to 175. Spatial data are then collected at each site by cross sections, and soil data are collected by soil drive probe, auger, or Standard Penetration Tests. Slope stability is modeled stochastically and a mass-wasting hazard map for each landform type is produced. An overlay of the landslide inventory (completed by time-series aerial photography analysis) is placed for confirmation of observed with predicted data. This landslide inventory is the first step in the Washington State method. It is followed by field verification of the inventory, usually 10 to 20 percent of the inventory, and succeeded by the construction of a hazard potential map. Finally, the road stability is quantified by each landform. For example, self-balanced roadways found on mid-slopes within landform "X" have "Y" risk of delivering sediment to streams from debris landslides, debris flows, or deep-seated landslides.

The mass-wasting module in watershed analysis for the PALCO timberlands is a means for assessing the influence of timber harvest and road activities on resource protection over time. The watershed analysis is a planning tool that is then used for transportation planning and site-specific project analyses. ▲

Deactivation Lessons Learned

This session was presented by three separate individuals, all of whom have worked on road deactivation projects on Vancouver Island.

How Dry is the "Dry Season" on Vancouver Island

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As a result of a rainstorm and landslide that occurred in August near Tranquil Creek in Clayoquot Sound, the question was asked, "How dry is the dry season?" Consensus it seemed to indicate that these storms are pretty rare, but it turns out, upon investigation, that they aren't. Three questions were addressed:

- How common is a 100 mm rainfall in one day in the summer?
- Are there differences in the patterns of summer rainfall across Vancouver Island?
- Are any summer months (May through September) wetter or drier than others?

Data was purchased for the analysis from Environment Canada for a number of climate stations on Vancouver Island. There were 5 sites on the west side of the island and 2 sites on the east side. The sites with one exception were chosen for their long periods of records.

An analysis of the one-day storm rainfall suggests the following:
- short-duration large-magnitude summer rainstorms are common on Vancouver Island;
- the rain magnitudes are large enough to have geomorphic and engineering significance;
- the west side of Vancouver Island appears to substantially wetter than the east side, with respect to storm rainfall; and
- May, June and July have the lowest frequency of large rainstorms, while August and September have substantially higher frequency. ▲

Deactivation Lessons Learned on the Wet Side of the Island

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As you have just read in the above abstract, there is a large variation in rainfall intensity as you move into the watersheds from the outer coast and there are 100 mm plus events in summer, especially during August. This causes landslides to occur. In addition, both "minor sediment redistributions" in new deactivation and debris flows form open slopes, gullies and old roads. These facts imply the following:
- Access planning is required, particularly drainage management.
- There is increased risk until the deactivation is completed.
- Worker safety requires that rainfall shutdown criteria be implemented.
- Silvicultural work should be coordinated with deactivation work.
- Time is of the essence, even fairly early in the season.

Try to plan for speed in deactivation methodology by:
- Advance planning of project logistics
- Selection of equipment type and size
- Ensuring operator experience
- Planning extra shifts during long daylight and weekends in favourable weather
- Using excavators working in tandem where feasible

Working in Tandem has the following advantages:
- It is an advantage on wide roads, deep fills and gullies
- Can provide training opportunities – radio communication between machines
- Safety
- Speed
- Travel time minimized

Inspections are the single most significant factor in achieving expected standard of work. Forest Renewal BC projects do require sign-off of completed work and we have learned that it is important to have on-site review prior to start up, and frequent inspections at the early stages of work to establish the expectations of performance. The person that is expected to sign off on the work must be involved especially at the early stages. In addition, this individual must have adequate opportunity to inspect work in progress. This person may work with an experienced senior inspector who thoroughly understands the prescription and prescriber's intent.

The inspection reports will contain details on "as-built" against the prescription. Inspectors will note where work is satisfactory, as well as noting any deficiencies. There should be notes as to any additional work that is to be done and re-inspected, whether erosion/stability hazards remain as a result of the deficiency, and what is the consequence. If "monitor" sites are identified, clearly indicate what type of monitoring is to be done, and what, if any subsequent action would be expected from outcomes of the monitoring. A clear conclusion should be stated as to whether or not the work meets the intent of the pre-scription. In general, if there were inadequate inspection opportunities for the person signing off, you are more likely to get a deficiency report without clear acceptance of the work. ▲

Lessons Learned in Coastal Road Deactivation

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Road deactivation has evolved significantly over the last eight years. With the advent of Forest Renewal BC, the amount of deactivation occurring throughout BC increased dramatically. In many cases, to meet this increased demand, a "cookie cutter" approach was used for deactivation. This approach resulted in the over-prescribing of some roads, and the under-prescribing of others. As well, it often failed to incorporate changing techniques for effective hill-slope stabilization, or increased emphasis on risk management (rather than hazard management).

Over-prescribing low-risk roads resulted in unnecessary loss of access, while the under-prescribing of high-risk roads failed to meet stability concerns. In some cases, the reactivation of previously deactivated roads is required, in order to re-deactivate to the required standard. To meet specific objectives, each road must be assessed separately, with prescriptions developed based on risk and future access. Effectiveness monitoring is also recommended to ensure that prescriptions and road deactivation techniques are meeting site-specific and project objectives. ▲

Rehabilitation of Upslope Disturbed Sites

Long Term Vegetation Development on Bioengineered Sites

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Soil bioengineering is the use of living plant materials to construct an engineered structure or to perform an engineering function. Bioengineering is used to treat steep and/or unstable slopes. Wattle fences are short retaining walls built of living cuttings that have been widely used to treat steep slopes. Wet seepage areas can be treated with live pole drains, and modified brush layers can be used on raveling slopes to control the movement of surface materials. In all of these cases, the soil bioengineering structures are used to address some form of instability that is preventing natural plant establishment and growth. Once the initial instability is overcome, subsequent plant establishment can proceed.

This paper explores the processes of site stabilization and plant establishment on sites where soil bio-engineering was used for initial stabilization. Key elements encouraging natural successional processes are presented in the context of these sites. Projections are made about the future of sites where new soil bioengineering techniques have been applied. Examples are drawn from the author's experience. ▲

The Use of Draglines in Road Rehabilitation/Deactivation: A Case Example from West-Central British Columbia

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In August and September 1998, Skeena Cellulose Inc. (SCI) undertook a major project to stabilize sections of three active logging road corridors in the West Kitsuns area south of Hazelton, B.C. Slide activity along or below these roads had damaged fish habitat in Kitsuns Creek and its tributaries, and also presented a safety hazard along some sections of the roads. Cutslope instability was also a problem in some areas. Because the roads were still required for future timber harvesting, permanent deactivation and re-contouring of unstable areas was not a suitable option.

Several different slope stabilization measures were used on this project, including:

- pullback of excess sidecast fill immediately below the roads using excavators working from the roads;
- construction of temporary tote roads to enable removal of excess sidecast material beyond the reach of excavators on the roads; construction of rock buttresses and toe berms to support the road or the toe of the road cut;
- installation of subsurface seepage collection/ interception measures, surface water diversions, and hydroseeding and/or planting exposed slopes with cottonwood (live staking).

We used one measure which, to our knowledge, has not been widely employed in this application in British Columbia. This was the use of draglines to remove excess fill well below the road, in areas where the construction of tote roads was considered impractical or unsafe. This enabled significantly more material to be recovered at some of the sites than would have otherwise been possible. Problems included the greater width of road required for the machine to swing, and difficulties with stumps and logs embedded in the fill.

Jacques Whitford and Associates (JWA) and SCI completed site investigation and engineering design for this project, with input from the Ministry of Forests, Prince Rupert Region. JWA provided field supervision and ongoing consultation during construction, assisted by Skeena Project Services Ltd. (SPS). Funding was provided by Forest Renewal B.C.

The author thanks Tim Dunne, P.Eng. of Chiltech

Forestry Ltd. (formerly with SCI), Howard DeBeck, P.Eng., of the Ministry of Forests, Lorne Sexton of SPS, and Armando Abello Jr. of JWA for their input and assistance with this presentation. ▲

Mineral Tenures and Road Deactivation

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The purpose of the talk was to explain in simple terms the need for road access for mineral exploration and to demonstrate how to obtain mineral tenure information for any watershed in the province. These are very broad subjects, therefore two key aspects of mineral tenures and road deactivations were covered:

1. Mineral exploration impacts in coastal watersheds
2. Identifying active mineral tenures in a specific watershed.

A requirement of all watershed deactivation proposals is to obtain information on active mineral tenures within the watershed. Most of this information can be readily obtained from the Ministry of Energy and Mines web site. This, and the mapping process, was also described in detail.

Editor's Note: This information will be included as the Tech Tip in Vol.5, No.1 (June 2000). ▲

Restoration in Forested Karst Terrain: Planning and Operational Concepts.

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Past watershed restoration projects in British Columbia have in many cases overlooked the significance of karst terrain. This distinct landscape requires a specific approach to restoration. Approximately 5-10% of B.C.'s land mass is underlain by soluble bedrock types (e.g., limestone, dolomite, marble) that can potentially develop karst. Productive coastal and interior forests overlie a significant proportion of these potential karst areas. Karst terrain can be considered a three-dimensional system with its own geomorphology, hydrology and biological characteristics. The main distinguishing characteristics of karst terrain are: a lack of surface drainage, an irregular surface topography, and a subsurface network of conduits.

The primary objectives of karst management are to preserve karst ecosystem and to ensure that natural, dynamic karst processes are not unduly modified. A secondary objective is to provide opportunities for persons to engage in scientific research, appropriate recreation, and educational pursuits. While recognizing the non-renewable nature of many karst features, particularly in caves, good management demands that damaged features be restored insofar as this is practicable.

Karst rehabilitation must be based on sound principles of geology, hydrology, meteorology and biology. Geologically, natural rates of sedimentation, weathering, and erosion should be restored so that the natural quality of the karst resource is maintained, with protection of any vulnerable geological features (e.g., cave sediment or sub-fossil sites). For karst hydrology, catchments and flow regimes should be restored to a near-natural state, along with restoration of normal rates of surface run-off, infiltration, and subsurface flow. Where possible, introduced debris materials should be removed from water courses so as not to cause further damage. Air quality and movement in karst biospaces should be returned to as nearly natural a state as possible by removing any physical obstructions and polluting sources. Finally, biological resources of the karst site should be restored to their natural state as far as possible.

Karst restoration requires both careful assessment and planning prior to any field activities. In general, restoration of karst sites is probably more effective and worthwhile where evidence for past forestry activities is readily apparent. Restoration of very old sites, where some level of natural recovery has occurred, may be less beneficial and in some cases possibly detrimental. Karst restoration projects require accurate delineation of the site, careful assessment of hydrological, meteorological, geological and biological functions, and the identification of sensitive features. The project objectives should be well defined, and any practical constraints identified. All karst restoration methods should be carefully designed with scheduling, contingency and monitoring plans in place.

Restoration can be applied to both the surface and underground components of karst. Examples of surface restoration activities include the following:

- Restoration of natural soil-vegetation systems in sensitive epikarst zones (e.g., appropriately revegetating areas prone to soil piping and/or loss).
- Employing special tree planting techniques (e.g., planting seedlings in soil-filled solution openings).

- Replacing non-native plant species with perennial native species (depending on the nature, extent and impact of non-native species on the karst site).
- Restoration of karst sites formerly used for ballast quarrying, waste storage, or disposal.
- Restoration of karst sites modified by roads and landings (e.g., where infiltration is impeded by impervious road or landing surfaces).
- Controlling the erosion along sinking streams (in both carbonate and contributory non-carbonate uplands).
- Controlling erosion on destabilized sideslopes within linear and point karstic depression features.
- Removing unnatural accumulations of debris from sink points.
- Eliminating or designing drainage control structures that unnaturally divert surface water flows and recontouring sealed road surfaces to shed water laterally.
- Deconstructing roads to restore 'inaccessibility' to sensitive karst features.
- Installing sinking stream filters upstream of sink point (e.g., grizzly, screen, cloth) to reduce ongoing impact.
- Recovering windthrown trees from sensitive features.
- Reviewing the need for all existing roads within the karst catchment.
- Relocate access roads outside sensitive karst sites and their catchment, if possible.

Examples of subsurface restoration activities , following careful assessment, can include:
- declogging subsurface caves and conduits, and
- high-pressure washing of rock surfaces (e.g., silt films, stains, needles

Rehabilitation of a karst site should not be done without a sound and complete understanding of the surface and subsurface components of the karst system. This knowledge can be drawn from karst inventory and assessment information. Three levels of karst inventory have been proposed to better identify and evaluate the karst landscape. These inventories have been developed mainly with active forest development (e.g., harvesting and road construction) in mind, however they can also be applied to restoration projects.

The highest, or reconnaissance, level at 1:250,000 scale has been completed for BC with the development of a set of preliminary karst potential maps. This inventory is an office-based analysis of regional bedrock data and is intended only to identify and flag likely areas of karst development. For any restoration project, these maps can quickly be consulted to determine whether the area of interest or watershed occurs within a likely karst area.

The planning level inventory, typically at the 1:20,000 scale, uses field work to delineate the boundaries and three-dimensional shape of the karst unit, determine the intensity and variability of karst development, and evaluate the regional hydrology. This information could be critical to a watershed restoration project in terms of prioritization, identifying sensitive areas (e.g., failing road fill slopes above a series of swallets or cave entrances) and its overall effectiveness (e.g., leaving roads with minimal surface runoff and identifying streams leading into swallets where debris cleaning is required).

The operational level inventory at the 1:5,000 or 1:10,000 scales evaluates in detail the karst system at a site, assessing the types and distribution of surface karst features, as well as their connection to the subsurface. At this inventory level, karst features can be identified and evaluated for their significance with specific prescriptions determined for restoration (e.g., removal of logging debris from an important sinkhole or sinking stream). Old roads and quarries can be also assessed for deactivation at this level, and prescriptions determined to minimize the impact on karst hydrology and its associated surface and subsurface features. ▲

Forest Site Rehabilitation in Jones Lake Watershed

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The slopes above the eastern shore of Jones Lake, a BC Hydro reservoir, (in the Skagit Range of the Cascade Mountains) have experienced significant disturbances by forestry road-related landslides. The area has significant socio-economic values with public interests including a BC Hydro reservoir (Jones/Wahleach Lake built in 1951-52), fisheries resources, two campgrounds, cabins, a drinking water supply for the cabins, and an active mainline logging road. The detailed investigation used an array of geological, geotechnical, geomorphological and bio-engineering techniques. With the exception of bio-engineering, the project was completed in four months. The final aspect of the project, the bio-engineering, was scheduled for completion in November 1999.

The roads were deactivated following prescriptions provided by a multidisciplinary team of professionals including geoscientists, geotechnical engineers and bio-engineering specialists. Deactivation prescriptions ranged from water management structures excavated by hand-held tools to a complete removal of road fill in the most critical areas and recontouring of the slope. Landslide rehabilitation concentrated on minimizing further instability in the headscarp areas and minimizing the erosion and sediment transport from landslide tracks. Gully rehabilitation was confined to areas with the highest likelihood of future instability. The objective of the site rehabilitation, with respect to the existing water supply system for the Jones Lake cabins, was two-fold: to prevent sedimentation of the water source and to improve the water supply system by constructing a subsurface intake. ▲

A Storm-based Sediment Budget for Russell Creek

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A sediment budget investigation was carried out in Russell Creek watershed to determine the relative contribution of different types of sediment sources to the sediment load of mainstem channel sites in Russell Creek and its main tributary, Stephanie Creek. The investigation was a success. Its findings were that the sediment yield measured in the creeks was very similar in volume to the total sediment production at those main sediment sources that are connected to the channel network . Overall, sediment contribution from sources affected by logging amounts to 20% of the total sediment yield. There is no evidence to suggest that logging has increased sediment yield from gullies or landslides. The biggest sediment producers are naturally occurring sediment sources. Sediment contributed by road-related sources amounts to 15% of the total sediment yield. The sediment yield at road crossings is directly proportional to the area of exposed sediment on cut-and-fill slopes that has not been stabilized by deactivation or rehabilitation. ▲

Rates of Revegetation of Gullies in Coastal British Columbia: Implications for Fine-sediment Production

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Large tracts of forested terrain in coastal British Columbia are dissected by gullies. Because of their steepness and instability, they are important sources of sediment and large woody debris. Much of this material is delivered by debris flows, triggered by relatively small debris slides on steep, unstable gully walls. Following a debris flow event, large quantities of fine sediment are produced as a result of the scouring of gully sidewalls. Scouring is usually deep enough to strip the gully sidewalls of most of the vegetation cover. This exposes large areas of bare soil to accelerated erosion by rainsplash, overland flow, dry ravel, and frost heave. This cycle of accelerated sediment production persists for several years after a debris flow, but relatively little is known about the time frame of gully sidewall destabilization and the associated decline in sediment production.

The main objectives of this study have been to compare the rates of recovery of gully revegetation between logged and unlogged areas, to estimate the fine sediment discharge from gully sidewalls at different stages of vegetation recovery, and to examine the role of abiotic factors such as slope angle, aspect, soil conditions, and moisture regime on plant succession and fine sediment production. A total of 92 vegetation quadrats in 15 gullies in Coquitlam basin were surveyed on gully sidewalls, and eighteen of the 92 plots were monitored for one year with sediment traps 1.2 m in width.

In the first five years following debris flow scour, average sediment yields from logged gully sidewalls were greater than double those from unlogged sidewalls. Over a 15 - 20 year period following debris flow, sediment yields in both environments declined, but at a slightly higher rate on logged sidewalls. This is associated with more rapid growth of fast colonizer species, which cause sharp reductions in bare soil area over time. ▲

Effectiveness Monitoring in Road Deactivation

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Road deactivation is the "deconstruction" of forest roads to accomplish three typical project objectives: decrease slope instability, minimize erosion, and enhance site productivity. Deactivation is commonly carried out as part of Watershed Restoration Projects (WRP) sponsored by Forest Renewal B.C. (FRBC). Road deactivation is also carried out as part of regular operations in forest development, as required by the Forest Practices Code.

This report documents the effectiveness of road deactivation work to accomplish these typical project objectives. Field indicators of potential instability, potential erosion, and existing forest site productivity were used as a means of determining whether the work carried out to deactivate the road met the objectives. Due to the close link between the site level objectives (road deactivation prescriptions) and the project level objectives, more elaborate consideration of the component level (intermediate) objectives are not necessary to determine the effectiveness of road deactivation.

The effectiveness monitoring reported in this study is for the Lost Shoe-Thunderous Creek and Toquart Bay areas on western Vancouver Island. Eleven sites were evaluated with respect to common visual field indicators of potential instability and erosion. Observed revegetation at the sites within two circular plots was recorded, and the data compiled to qualitatively evaluate the revegetation at the sites. 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 that 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.

Recommendations are provided for continued monitoring of these study sites and future effectiveness monitoring projects. These involve using local and project-specific experience to select the study sites, in conjunction with senior personnel familiar with road deactivation techniques and monitoring studies. 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. ▲

Risk Management

Debris Flow Initiation in Coastal British Columbia Gullies

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This study investigates debris flow initiation hazard in Coastal British Columbia gullies. A total of 286 slope failures were analyzed, of which 75 were debris flows. Four geographic areas were field assessed: north of Nitinat Lake on Vancouver Island, south of Nitinat Lake, the Squamish River and Mamquam River drainages in the Coast Mountains, and the Deena Creek and Ghost Creek drainages in the Queen Charlotte Islands. The study involved collection of information on gully and slope failure characteristics, including slope failure location (headwall or sidewall), gully wall slope angle, gully wall slope distance, channel gradient, surficial material and surficial material depth, soil drainage, slope failure dimensions, the volume of slope failure debris delivered to the channel, the planimetric angle of entry of the slope mass into the channel, and whether the slope failure continued to transport as a debris flow down the gully channel.

Slope failures in gully headwalls were much more likely to initiate a debris flow than slope failures in gully sidewall locations. Headwall debris flows initiated on lower gradient slopes than sidewall debris flows. The minimum initial failure volume required to initiate a headwall debris flow was about half the volume required to initiate a sidewall debris flow (11 m^3 compared to 25 m^3). Angle of entry is closely associated with location. The median headwall slope failure angle of entry is 0°, compared to the median sidewall slope failure angle of entry of 74°.

In addition to gully location (headwall or sidewall), the initial failure volume and the volume of debris delivered to the channel were the most important factors in determining whether a slope failure would result in a debris flow. Larger initial failures, and larger amounts of debris delivered to the channel, were much more likely to initiate debris flows than small slope failure volumes. Larger volume slope failures are associated with deeper surficial materials on sidewalls, but not headwalls. Surficial material depth, or terrain type, divided into shallow and deeper classes, is significant in the prediction models. About 90% of debris flows had at least 80% of the initial failure volume delivered to the gully channel.

Although three of the geographic areas (South Nitinat, Squamish, and Queen Charlotte Islands) did not have significant differences in debris flow initiation, the fourth area, North Nitinat, showed a different pattern. The most likely explanation for this difference was the presence of highly sheared bedrock within gullied areas.

The results of this study showed that debris flow initiation is a complex process. As with most geomorphic processes, a significant degree of uncertainty exists. The results of this study better define the factors which are associated with debris flow initiation. However, there are limitations to this type of study, therefore caution must be used when applying these results. Terrain scientists should examine relationships between local slope failures and debris flows in gullies before applying these results to specific locations in Coastal British Columbia. ▲

Meager Creek Geohazards and Risk Management Study

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Meager Creek Hotsprings has been a popular wilderness destination for at least 75 years. However, since the documentation of a major landslide that occurred in 1931, it also has been recognized as one of the most geologically active areas in Canada.

Starting in the early 1970's, when logging roads allowed easy access to the valley, recreational use increased dramatically. This eventually led to overuse, and ultimately, to a temporary closure of the area in 1996 for health reasons. During this time, there were also a number of additional landslides that destroyed or damaged hundreds of thousands of dollars worth of equipment and structures, stranded numerous people and their cars, and, tragically, killed a number of BC Hydro workers who were exploring for geothermal energy. There have been hundreds of additional events, involving both large and small quantities of rock, debris, water, or snow.

Following the occurrence of a major debris flow in 1984, the Ministry of Forests, Squamish District became involved in attempting to define and manage the landslide hazard in the Hotsprings Creek Recreation Area. This work resulted in the delineation of specific camping and day-use only areas, increased signage, and re-alignment of the South Meager FSR to prevent the road from capturing Hotsprings Creek and directing it into the hotsprings area. Additional major debris flows in 1987 and 1990 illustrated the on-going nature of the activity and risk in this area.

In 1998, after resolution of the health problems, re-development of the site started, partially funded by Forest Renewal BC. However, in July 1998, a 150 m section of the access road to the hotsprings was destroyed by an estimated one million cubic metre debris flow which came down Capricorn Creek, and blocked Meager Creek. It then formed a new, one kilometre long lake behind the debris dam. This major event was followed in the spring and summer of 1999 by innumerable additional events that continually blocked the road and stranded visitors and forest workers in the valley. These events triggered a re-assessment of proposed development plans in the Meager Creek Hotsprings Recreation Area. It also led to the commissioning of a major geohazards study that is attempting to define all hazards in the area and establish their run-out areas and potential impacts. A second important objective of this study is to provide specific information on risk management and development options so that land managers can ultimately define levels of acceptable risk for various activities, and then decide where, and under what restrictions, those activities can take place in the Meager Creek area. ▲

Snow Avalanche Activity in Forested and Harvested Terrain

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Snow avalanches have affected at least 10,000 clear-cuts in British Columbia. An overview of the problem based on our research was presented. Our study sites include an area in the southern coast range and an area in the interior, each with about 500 examples. The summary is a progress of work to date toward risk-based decision methods and inclusion of guidelines in the Forest Practices Code. The goals of the project are to provide:

- modelling of magnitude and frequency of avalanches in clear cuts
- magnitude, frequency and dynamics of avalanches in forested terrain; and
- decision support for logging in steep alpine terrain. ▲

Fish Habitat Rehabilitation

Fish and People – Progress in Fisheries Renewal

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Most of us cannot believe that in the span of less than a decade, the economic and social character of fisheries in British Columbia have changed so drastically. While wild fish are still being caught, some stocks are facing extreme difficulty. With the advent of salmon farming, the market place for B.C. wild salmon has changed radically. Communities dependent upon fishing have gone through a tremendous upheaval. Despite all these changes, the message to British Columbians and the world is that fisheries in this hold a bright future.

Established by provincial legislation in 1997, Fisheries Renewal BC is one of the province's newest Crown corporations with a mandate to help restore habitat, protect fish, and encourage fish production. The corporation is also charged with assisting in diversification, opening up new fisheries, new product development, job creation, and assisting fish-dependent communities.

To date there has been a balance of inputs in restoration and enhancement. The focus of the Fisheries Renewal funding is directed to community-based models, local decision-making, and broad-based partnerships.

We need examples of new fisheries and numbers from habitat improvement. There is encouraging news from new fisheries such as neon squid, mackerel, tilapia and crayfish. ▲

Fish habitat Restoration in the Cypre River Watershed

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In 1996, with funding from FRBC, MacMillan Bloedel catalyzed the formation of a partnership for fish habitat restoration in the Cypre River. The participants are Weyerhaeuser Canada Ltd., Nuu-chah-nulth Tribal Counsel, Ahousaht First Nation, Tofino Enhancement Society, Provincial Forest Renewal BC and Fisheries Renewal BC, as well as the Federal Department of Fisheries and Oceans. This collective has contributed support, technical expertise, equipment, and most important, multi-source funding.

The Cypre River is located approximately 15 km northeast of Tofino in the coastal temperate rainforest of Clayoquot Sound, on the West Coast of Vancouver Island. The watershed drains an area of approximately 60 km^2. Historic logging practices in conjunction with poor slope stability have affected the channel morphology. Observable changes typically involve increased bedload and associated aggredation in low gradient sections of the river.

Overview and instream assessments indicate a lack of high water juvenile refuge habitat as being one of the primary limits to fish production. The lack of stable spawning substrate throughout the lower reach was also noted as a significant concern.

The highest instream restoration priority focused on the loss of protected winter refuge habitat. In 1998, the first restoration project was completed: a groundwater-fed coho rearing channel located 9 kilometers upstream. Monitoring has shown this new habitat to be highly utilized. During the summer of 1999, a second off-channel project was built primarily to provide stable chum salmon spawning habitat. The secondary objective was to create overwintering and refuge habitat for coho and other salmonids. A trial was also undertaken in 1999 to test the function of low-profile conifer brush bundles as mainstem cover structures. The effectiveness of this year's projects is not yet fully known.

The habitat restoration projects in the Cypre River watershed have had positive social impacts. So far, more than 25 individuals have been employed at a wide range of tasks to accomplish the work. Almost all of these have been local residents. This activity has nurtured community "ownership" for a previously remote and relatively under-monitored resource. The momentum of this partnership and its activity is planned to continue. ▲

Off-Channel Spawning Habitat

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Why do we do off-channel fish habitat restoration work? Off-channel habitat has been lost due to stream channelization, dyking, and forest road construction. These areas provide a stable, clean water supply and over-wintering rearing habitat for local populations of fish. They also function as refuge for immigrant fish moving out of main channels during high flows. Off-channel ponds and streams trap nutrients, most of which is in the form of returning salmon carcasses.

Once established, the returning salmon provide a food source for fish, birds and mammals. Upland or riparian vegetation also benefits. Constructing off-channel streams and ponds is a quick and cost-effective way to reestablish fish and wildlife abundance and to strengthen genetic variability of fish populations.

These sites also provide an effective forum for public education. Controlled flow off-channel ponds and streams, whether groundwater- or surface-fed, are designed to renew ecological links and to restore fish and wildlife abundance back to historical levels and/or to compensate for permanently lost habitat by using natural templates as guides.

The reasons we do off channel work are to:

- restore habitat for fish and wildlife, and
- control the flow and water quality (choosing the right site) to provide stability over time.

Target species for off channel work are:

- ground water channels/infiltration-Chums/Coho/ steelhead;
- surface water channels-Steelhead/Coho/Pink/ Sockeye/Chums/Chinook. ▲

Observations of the Success of the Willow Planting on the Sand, Gravel and Cobble Bars of the Lower San Juan River

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In the spring of 1998 and 1999, an extensive willow planting of the migrating sand, gravel, and cobble bars of the lower San Juan River was undertaken. The intent of the program, the underlying reclamation principles, the implementation logistics, and observations of the performance of the work, as well as a discussion of current success were presented in an interim report.

The project shows that planting techniques have a valuable role in stabilizing damaged channels. Observations suggest that willow plantings benefit from using larger, deeper placed stock that better survives the natural and anthropogenic rigors of this environment. Large diameter machine-planted willows showed superior growth. Survival rates following the summer drought showed that the deeply buried willows fared better than the ones that were not as well dug in; most survived the heavy browse and mechanical damage by 4X4s. The fall floods provided the most interesting results, with large quantities of sediment being deposited on the plantations. Sediment deposition and river scour combined to create a more defined riverbank and thalweg. The paper summarizes the specific techniques, performance and logistics issues associated with the success of the project.

It is apparent to the author that vegetative techniques are worthwhile. They can help produce stable river morphologies when applied to disturbed river sites, by improving channel performance and enhancing in-stream habitat.

The San Juan River Watershed Restoration Project is funded by Forest Renewal BC, involving TimberWest (now TFL Forests Ltd.), the Ministry of Forests South Island Forest District Duncan office, the Pacheedaht First Nations, local forest workers group, the local fish hatchery, various contract specialists, and with the co-operation of Ministry of Environment, Lands and Parks, DFO and the San Juan Steering Committee. ▲

Chinukundl Creek Restoration

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Chinukundl Creek is a high value fish stream located on the south-east side of Graham Island in the Queen Charlottes. In 1992, a 90 hectare block located on an escarpment above the lower end of Chinukundl Creek was harvested by Fletcher Challenge. Since then, a number of landslides have directly affected Chinukundl Creek. Numerous waterbars and X-ditches failed to reduce landslide frequency. Attempts to disperse water had met with limited success.

In 1997, an interagency committee consisting of members from the Ministry of Forests, the Department of Fisheries and Oceans, TimberWest Limited, and the Hecate Straight Stream Keepers, was formed with the objective of rehabilitating both the up-slope and the in-stream areas of Chinukundl Creek. Professional assistance was contracted to do the assessment. Funding was approved in July 1998, subject to money being spent prior to April 1999. Projects were divided into up-slope and back channel works. The committee decided to attempt to divert water away from the areas of instability. Upslope, trench upgrades were conducted under the direct supervision of a registered professional. Slide areas that could be accessed safely were hand-seeded and fertilized. Great care was exercised to preserve standing vegetation and, where necessary with the instream work, rip-rapping was completed by hand. Water is now controlled through a supply pond with a check dam. The purpose was to create sediment-free over-wintering habitat.

The actual costs were $129,954. The cost of the Level 1 Assessment was $26,065. The trench upgrade was $6115, professional design for new trench construction was $30,072 and the professional supervision of construction was $20,954. These costs do not include district and regional support costs. The initial estimate for surface water interception is approximately 65%.

Monitoring continues; however, funds are limited. Success or failure cannot be determined at this stage, and only time will tell what impact these trenches will have on landslide size and frequency. ▲