Road deactivation for hillslope restoration: lessons learned on the Escalante Watershed Restoration Project

Mike Wise
GeoWise Engineering Ltd., North Vancouver, B.C.

Mike Leslie
Mike Leslie Consulting Ltd., Duncan, B.C.

Glynnis Horel
Ostapowich Engineering Services Ltd., Saltspring Island, B.C.

Denis Collins
Ministry of Forests, Vancouver Forest Region, Nanaimo, B.C.

Warren Warttig
International Forest Products Ltd., Campbell River, B.C.

Abstract

Permanent deactivation is often carried out using hillslope restoration for roads on moderate to steep hillslopes. In the Escalante River area, many potentially unstable roads were deactivated in the late 1990's with roadfill pullback due to stability concerns, and the remainder of the roads were crossditched with some light pullback. In January 1996, intense rainfall caused numerous landslides on these deactivated roads. Funded by Forest Renewal British Columbia, the Escalante Watershed Restoration Project was initiated to assess the roads in the watershed and carry out deactivation work where needed for long term road stability. Assessment of the existing deactivation work storm provided valuable information on its effectiveness in preventing landslides. Due to the existing roadfill pullback and landslide sites, it was necessary to assess the roads in terms of the expected difficulties and cost to re-establish access, and whether it was feasible to improve the existing deactivation. During the deactivation work, several techniques were developed to improve the standard of deactivation.

Road deactivation is the stabilization of abandoned forest roads by either preventative maintenance or hillslope restoration. The retrieval of potentially unstable roadfill, termed "roadfill pullback", is the primary technique for hillslope restoration and is the most effective means of reducing the potential adverse environmental impacts of resource roads.

Resource roads were constructed using a cut and fill method where material was excavated or bladed from the upslope side of the road to form the roadfill on the downslope side. Often termed "sidecast construction" in the forest sector, this method was carried out in coastal areas using grade shovels until the mid-1970's, and then bulldozers until the early 1990's. Currently, coastal road construction is almost exclusively done with hydraulic excavators, with sidecast construction typically carried out at selected, relatively stable locations.

Permanent deactivation on moderate to steep hillslopes involves roadfill pullback to "deconstruct" the roadfill and re-establish the slope profile and contour. The common objectives for this work are:

(i) to establish the pre-existing hillslope drainage paths;
(ii) to retrieve potentially unstable roadfills and place the materials on the road bench; and
(iii) where practical, to enhance the site productivity (tree and grass growth) along the road corridor.

In the summer of 1994, road deactivation became a key component within the Watershed Restoration Program of Forest Renewal B.C. Previously, many old forest roads were abandoned or poorly maintained following harvesting. Over time, landslides were caused by the deterioration of large woody debris in the roadfill and stumps supporting the road, plugging of culverts, and diversion of water along the roads. Many of these landslides adversely impacted streams and lakes.

Deactivation carried out before 1994 was somewhat experimental, with differing approaches used to "put roads to bed". Systematic assessment by engineering or geoscience specialists was virtually non-existent. The result was a large variation in the standard of the work carried out.

This paper describes the road deactivation work carried out from 1996 to 1998 as part of the Escalante Watershed Restoration Project (W.R.P.). While other deactivation projects were carried out at this time were of similar scale, the Escalante W.R.P. is unique in that many of the roads were "permanently" deactivated to the standard of the day following harvesting in the early 1990's.

The lessons learned during the work on the Escalante roads provided valuable information on the performance of the previous deactivation work, and the development of improved techniques for hillslope restoration to permanently deactivate roads.

Background

The Escalante Watershed (Fig. 1) is located on the west coast of Vancouver Island, some 40km southwest of Gold River and about 60km northeast of Tofino. Geographically, the watershed is roughly located between Nootka Sound and Hesquiat Lake, immediately north of the Clayoquot Sound Land Use Decision boundary.

The Escalante River has two branches, with a total length of about 32km. The watershed has an approximate drainage area of 3120ha. The climate in the area is very wet; the precipitation at nearby Estevan Point on Nootka Sound is about 3000mm annually.

The topography consists of a gently sloping marine terrace/peninsula and moderately steep to very steep mountains. From Muller (1977), the soft sedimentary rocks of the Carmanah and Escalante Formations (sandstone, siltstone, conglomerates) exist at depth in the terrace / peninsula areas. The Westcoast Complex (gneiss, quartz diorite, amphibolite) is present in the hillslope areas.

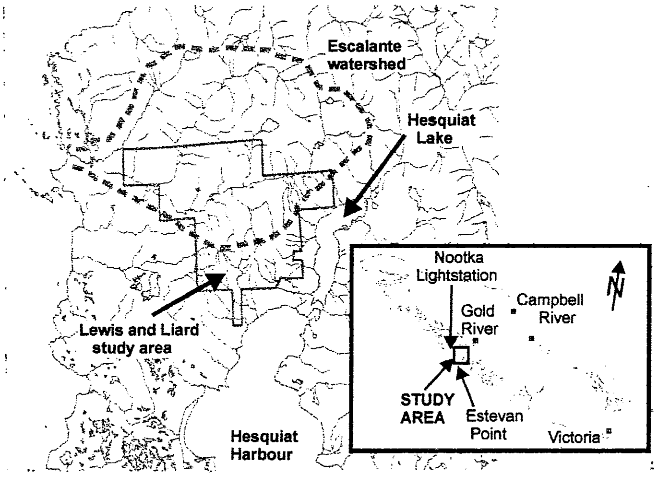


Fig. 1: Location of Escalante River, Vancouver Island

Surficial materials on the marine terrace consist of deep, unconsolidated fluvial soils that are poorly drained. This area is generally stable, except for the stream escarpments of the Escalante River where slumps and earthflows occur both naturally and following harvesting (Lewis and Liard, 1983). Roads in this terrain are generally stable, except for some cases where roadcuts intersect problematic soils (such as loose sands) and an increased maintenance is necessary.

On the hillslopes, two types of terrain occur (Lewis and Liard, 1983). The first, common in the Escalante area, consists of steep slopes mantled by glacial till and glaciofluvial materials of highly variable depth, with little bedrock outcrop. The glacial till is generally very dense, and has very low permeability. The surficial zone of weathered soil is typically about 1 metre thick. On the lower hillslopes, colluvial materials are present from debris flows. Gully systems are also present on the hillslopes, the result of fluvial erosion and repeated colluvial events. The second type of terrain on the hillslopes consists of steep, predominantly bedrock slopes with minor discontinuous veneers of colluvium or possibly glacial till. This type of terrain is relatively rare.

Resources in the Escalante River area consist of fish habitat, mainline forest roads, and site productivity. Resident fish species, including steelhead, are present in the upper reaches of the North and South Escalante Rivers, and four species of salmonids are present in the lower reaches. Forestry mainlines cross the lower hillslopes and valley areas, and are used for access by forest operations as well as nearby landowners. The hillslope areas are relatively productive forest site as they are better drained than the gently sloping terrace areas.

Forest Roads prior to January 1996

Lewis and Liard (1983), studied landslides in the Escalante / Hesquiat area and examined landslide characteristics both prior to roads and clearcutting during stages in the forest development. The study area overlaps with much of the Escalante watershed (Fig. 1). Table 1 summarizes their observations regarding landslides associated with forest roads, as well as those in clearcut and natural (forested) areas.

Lewis and Liard observed an increased rate of landslide disturbance due to "activities that create new unstable conditions", generally involving the road system. These rates increased from 0.17 ha/year (pre-1968) to 4.7 ha/year (Fall 1978 to Summer 1982), an increase of over 25 times.

The high rate of landslide disturbance, along with consideration of windthrow and wildfire as well as the potential impacts to the non-timber resources in the Hesquiat area (wildlife, recreation, and fisheries,) led to a review of the forest development strategy for the area.

Table 1: Landslide observations in the Escalante / Hesquiat area (after Lewis and Liard, 1983).

Time period	Road-related	Clearcut-related	Natural	Additional information
Pre-1968	0	0	33 (100%)	Landslides visible on historic air photographs. Estimated to extend back 150 – 200 years; older slides are likely completely re-vegetated. Most (21) landslides related to gully sidewalls and headwalls; 10 related to open hillslopes and 2 on escarpments of Escalante River.
1968 – Summer 1978	6% (85%)	1 (15%)	Not given	Road slides: 2 from blasting; 3 from sidecast material; 1 from removal of toe support.
Fall 1978 – Summer 1982	10 (62%)	4 (25%)	2 (13%)	Contributing factors for road-related landslides included removal of toe support for upslope materials, overloading slopes by sidecast construction, and concentration of drainage water by roads and ditches. Two road-related landslides initiated in unlogged areas below roads.
Fall 1982 to 1983	10 (59%)	7 (41%)	0	One clearcut landslide was reportedly related to windthrow; the remainder to root decay. Only 4 landslides intitiated in gully areas, indicating that these landforms are less affected by harvesting and road construction than open slopes.

The final consensus by a committee of land managers was to use accelerated clearcutting rather than the prevalent 50% cut – 50% leave approach and "promptly put roads to bed", or in today's terms, deactivated immediately following harvesting.

Lewis and Liard also discussed specific criteria relating to water management for roads crossing upper hillslope and ridge areas, uniform open slopes, and gully terrain. It is important to note that at that time, few geoscience or engineering specialists were involved with forest road construction and recommendations to deactivate roads were rare.

From 1982 to 1994, much of the Escalante and Hesquiat areas were clearcut and the road systems were deactivated following harvesting. At the time of the January 1996 storm, many roads in the Escalante had medium to heavy pullback, and the remainder of the roads were crossditched with some light pullback (Fig. 2). Examples of medium to heavy pullback, and light pullback with crossditches, are shown in Fig. 3.

January 1996 Storm Impacts

Approximately 400 landslides occurred during the storms of early January 1996 (Collins, 1996). These landslides were spread along the western coast of Vancouver Island, from the south end of Clayoquot Sound to the north side of Nootka Island. Slides occurred in unlogged terrain, on open slopes within cutblocks, and from roads. This storm event initiated the greatest number of landslides since the winter months of 1990-1991, when about 380 landslides occurred across most parts of the British Columbia Coast south of Terrace.

An analysis of the storm events revealed the return periods were not uncommon (Chapman, 1996). The sparse network of stations used for the analysis ranged from Cape Beale near Bamfield to Cape Scott on the northwest tip of Vancouver Island. The longest return period for any of the stations was Quatisino on northern Vancouver Island where the measured 24-hour rainfall 165mm exceeded the 100-year return period. However, most of the other stations used for in analysis of the measured 24-hour rainfall indicated a 2-year return period. Near the Escalante, the Nootka lightstation recorded a 24 hour rainfall of 133mm, corresponding to a 5-year return period. Preliminary analyses suggest that prolonged excessive antecedent rainfall may have contributed to the high incidence of landslides, but the link requires further analysis (Chapman, 1996). At Estevan Point, the measured rainfall corresponded to a 1-year return period for the 24 hour rainfall event.

As both the Nootka lightstation and the Estevan monitoring station is located at sea level, orographic uplift likely increased the amount and intensity of rainfall on the hillslopes. Orographic uplift is common, intensifying rainstorms as they pass over abrupt, mountainous topography. Experience with orographic uplift in nearby areas of Clayoquot Sound suggests that the annual precipitation on the hillslopes in the Escalante River may be at least 40% greater than measured at Estevan Point.

Of the 380 landslides recorded in the January 1996 storm, about 80 occurred in the Escalante watershed. Table 2 summarizes the types of landslides and their initiation sites. For the landslides in the Escalante, about 24% directly impacted watercourses, and 22% deposited material on forest roads. The landslides affected at least 30ha of productive forest site.

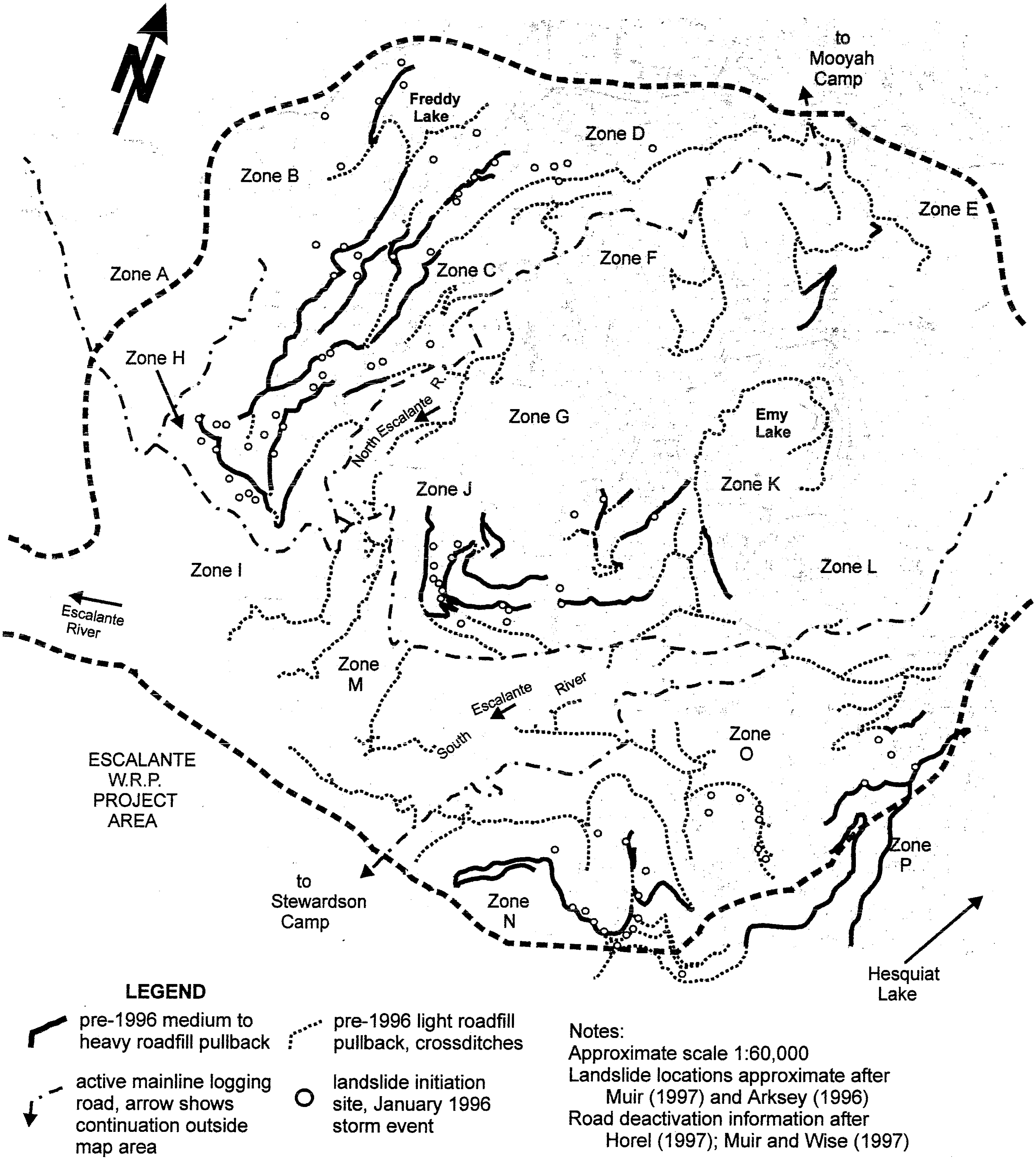


Fig 2: Pre-1996 road deactivation in the Escalante study area and approximate landslide locations from January 1996 storms.

Table 2: Landslides initiated or reactivated by January 1996 Storm (from Muir, 1997)

	Type of Landslide[1]		Landslide Impact[2]	
Initiation location within the Escalante Watershed	Debris Flow	Channelized Debris Flow	Mainline Road	Stream or Lake
Within road corridor				
semi-permanent deactivation[3]	5	0	1	1
permanent deactivation[4]	15	8	6	8
Outside road corridor (clearcuts)	40	10	10	10
Natural (unlogged terrain)	unknown	5	unknown	unknown

Notes:

1. At initiation site and down landslide track; channelized debris flows and tributary debris flows into the channel were counted as two separate landslide events. Counts may also include some pre-existing landslides that were reactivated.
2. Some landslides impacted both mainline roads and streams.
3. Semi-permanent deactivation consists of crossditches and light roadfill pullback.
4. Permanent deactivation consists of medium to heavy pullback.

Immediately following the January 1996 storms, the Ministry of Forests conducted aerial reconnaissance to assess the impacts of the landslides throughout Clayoquot Sound and nearby areas. In the Escalante, ground reconnaissance of the roads deactivated with medium to heavy roadfill pullback revealed that about 15% to 25% of these areas had significant tension cracks, signifying imminent failure. Many areas with crossditches and limited roadfill pullback also showed significant tension cracks.

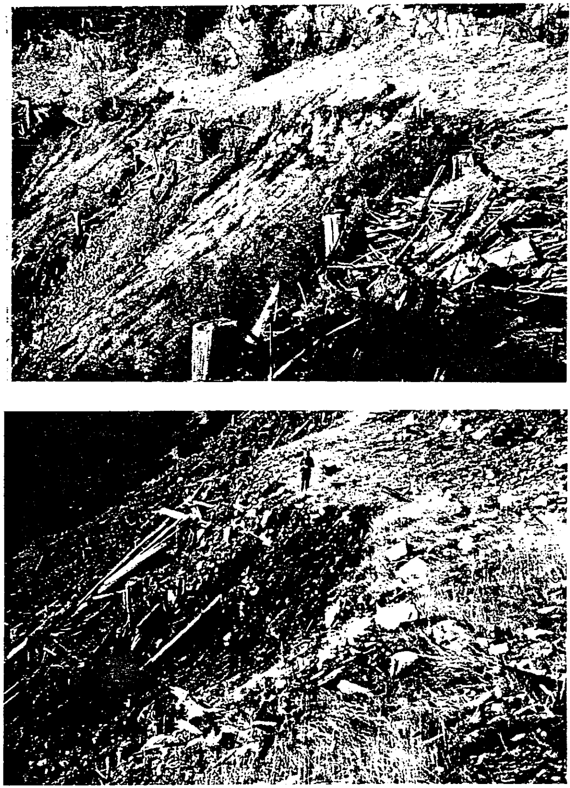


Fig. 3. Example of a landslide along an area with heavy roadfill pullback (upper photo) and light pullback (lower photo), Escalante watershed

Assessment Techniques

Assessments were carried out to systematically evaluate and rank the risk to downslope resources, develop site specific plans reactivating roads for access, and improve the standard of the deactivation work.

The common technique for road deactivation assessments is to carry out a foot traverses along the road corridors and measure distances using a hipchain (Baumann et al, 1995). Visual observations of physical slope characteristics are used to develop deactivation prescriptions, or recommendations for specific techniques at specific locations. Typical observations include: the geometry of the roadfill and cutslopes; the nature of the surficial materials; the likely road construction method; the concentration of hillslope drainage by the road; and stability history along nearby, similar roads. Subsurface investigation and analyses are not carried out for deactivation assessments; it is more cost-effective to provide field inspections and changes during the work to accommodate unexpected subsurface conditions.

In the Escalante, the common technique of assessing the roads for deactivation was not suitable for three reasons. First, it did not adequately assess the consequences of potential landslides to downslope resources along different roads, a key factor in rank the roads in terms of risk. Second, the existing pullback often obscured features such as seepage zones in the cutslope or large woody debris in the roadfill. Finally, the cost of safely reactivating the road through pullback and carrying out deactivation work to a higher standard had to be weighed against the expected increase to the standard of deactivation.

To address these concerns, and implement the project in a timely manner, a project team was formed with individuals having specific experience in road deactivation assessment, road construction, and risk assessment. The experience and expertise were complementary among the team members, and essential for the successful planning and implementation of the work.

Due to the outdated and inaccurate map base in the watershed, all the roads were located using a GPS receiver with a base station for local corrections. Data were plotted on a TRIM DTM contours forming the project base maps. The road systems were then divided into zones for assessment, planning, and deactivation work (Fig. 2).

Evaluating and Ranking Risk

Risk is the combination of hazard and consequence of a potential landslide to downslope and downstream resources. To assess consequence, the roads were ranked on a preliminary basis using the presence of resources (streams and roads) downslope. The numerous landslides in the area provided empirical information on potential runout distances and the potential impacts of future landslides. Subjective numerical scores for hazard and consequence were estimated and then multiplied together to determine the preliminary risk rankings for the zones. The potential for landslide initiation was re-evaluated once site-specific information was available from the detailed assessments along a road. Priority was given to roads where, if a landslide were to initiate, it would have a direct impact on either fish habitat or a significant impact on a mainline forestry road.

Developing Reactivation Plans

A significant problem was the type and amount of work necessary to reactivate, or re-establish access, along roads with existing roadfill pullback work or large landslides. Access was necessary for excavators and 4 x 4 fuel trucks to carry out the deactivation work. In many cases, the Escalante roads presented significant reactivation concerns due to:

- sites with tension cracks in the roadfill downslope of the old road grade, indicating probable failure if these areas were overloaded with sidecast during reactivation;
- existing landslide sites, where the road prism no longer existed and reconstruction was necessary;
- potential delays and high costs associated with reactivation through the pullback material on the old road grade, particularly in areas where end-hauling of the material was necessary due to the marginal stability of the slopes below the road or steep slopes on the pullback;
- potential landsides or sedimentation caused by misdirected or concentrated water along the reactivated road;
- logistical problems associated with completing the reactivation and deactivation work within the expected dry season, when increased stability would place the operators at less risk.

To evaluate these issues on site, the project team developed reactivation plans. These detailed the potential safety problems for operators (such as tension cracks and narrow roads), the existing deactivation along the road, and contained prescriptions for crossing streams and reconstruction through landslide sites. Common aspects included:

- recommendations to reduce the safety risk to operators. These ranged from simply noting the tension cracks in the prescriptions, to requiring the operator walk ahead of the excavator and assess the site in more serious cases. Where conditions were difficult or unusually hazardous, highly experienced operators were recommended. In critical areas, operators or site supervisors were brought on site during the assessment to develop safe reactivation plans, or conclude that safe work was not possible.
- noting the existing deactivation along the road. This was important to determine the difficulty of establishing access. Assessed qualitatively, this information was important to budget time for reactivation and avoid having previously pulled back roads open during the wet season. Changes to the existing drainage system were also prescribed to manage water to in the best manner possible.
- identifying areas of marginal stability below the road, where end-hauling of materials was necessary. This helped reduce the potential overloading of residual roadfills and/or hillslopes.
- providing site specific recommendations for reconstruction through landslide sites. At such sites, the goal is usually to move the road onto a stable bench of undisturbed material (termed a "full bench"). The options involve lowering the road grade to gain running width, excavating into the roadcut to gain the needed width, and/or occasionally constructing a stable roadfill of coarse, angular rock.
- designating all possible end-haul spoil sites to provide the greatest amount of flexibility for the crew to end-haul material as needed. During the project, specific types of end-haul sites were used, based on the site geometry and stability (Wise and Horel, 1998).
- identifying stream crossing sites where water may be flowing at the time of reactivation. At such locations, the need for sediment control was evaluated and general recommendations were provided relating to the type of structure needed (such as armoured swales, fords, or the installation of metal pipes).

No previous cost data were available for reactivation through existing pullback. However, our tracking of times and costs during the first field season provided the necessary information to make reasonable decisions about scheduling. Specific aspects of the reactivation plans, such as wet crossings and end-haul spoil sites, were also summarized as necessary for timely agency approval.

Detailed prescriptions were submitted to the regulatory agencies on a road system basis rather than for the entire watershed or zone. A total of 61 prescriptions or updates were submitted to the Ministry of Forests during the project, including reactivation, deactivation, specific wet crossing sites, and some special engineering structures.

Improving the Standard of Deactivation

Evaluating the amount and stability of any existing residual roadfills was a key to improving the standard of deactivation along the roads in the Escalante. For areas with no pullback and potentially unstable roadfill, improving the standard of deactivation was straightforward. However, on roads with existing medium to heavy roadfill pullback, improving the existing deactivation was less certain. Along these sections, the assessment included a careful examination for residual roadfill and its stability as well as the stability of the slopes immediately below the road.

At some locations, existing crossditches and the "room problem" (FCSN, 1998) contributed to the amount of residual roadfill on steep slopes in the Escalante. The room problem relates to bulking of soil and rock during excavation; for sidecast construction the volume excavated usually exceeds the available room on the exposed bench. This problem is more acute in areas with numerous crossditches, since the crossditches take up room on the bench that may be needed for holding pullback.

In terms of water management within pullback areas, improvement was also possible at most locations. In many cases, there were insufficient crossditches to maintain a dispersed drainage on the hillslope. At isolated locations, culverts remained that could plug allowing the road to divert drainage. In areas prescribed for roadfill pullback, using the "flow-through" technique for pullback placement and prescribing trench drains and blanket drains helped accommodate hillslope drainage. Trench drains (Fig. 4) are essentially crossditches filled with coarse rock, and are useful at locations where small overland streams cross the road or where heavy seepage is coming out of the roadcut. At locations with moderate to light seepage, a blanket drain was prescribed to allow water to flow through the coarse rock at the roadcut and the base of the pullback. These drains allowed for the maximum amount of material to be placed on the road bench.

Outside areas prescribed for pullback, prescriptions were made to maintain the dispersed hillslope drainage by increasing the number of crossditches where necessary.

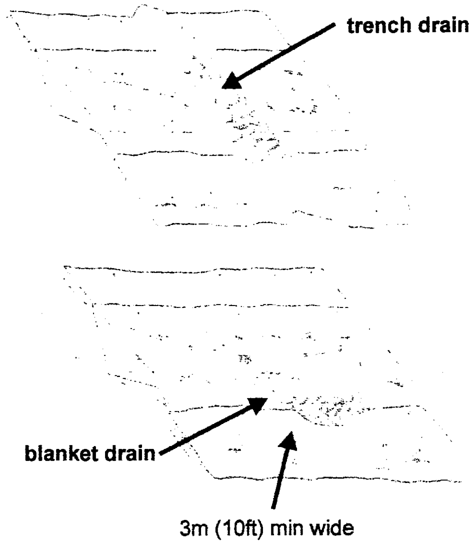


Fig. 4: Trench drains and blanket drains in pullback.

With deactivation work starting in 1996 on selected roads in the Escalante, there was an opportunity to discuss the cost effectiveness of the prescribed work with the operators and site supervisors. This feedback helped develop practical alternatives that were then incorporated into ongoing assessments. Developing a common framework for presenting the reactivation and deactivation prescriptions as tables and maps also helped the overall project communication.

Explosives have also been used with success for road deactivation at inaccessible sites (Muir et al, 1999), particularly where potentially unstable sites are isolated and where limited woody debris exists in the roadfill. At some locations in the Escalante, explosives were considered as a means to stabilize the slope. However, in most cases it was not feasible to use explosives given the large amount of potentially unstable roadfill and the large amount of woody debris in the roadfill.

Developing Work Plans

Based on the detailed assessments, a work plan was developed for each field season. The goals of the work plan were to:

- maximize the amount of risk reduced by permanently deactivating the greatest amount of the high risk road;
- utilize the different sizes of excavators and support equipment to the fullest extent possible;
- avoid leaving roads in a reactivated (less stable) state over the wet winter months;
- schedule activities in logical work units on specific road systems to reduce mobilization costs. For example, it was often expedient to plan deactivation on moderate risk roads in an area where work on high risk roads was planned.

Reactivation and Deactivation Techniques

Road deactivation work on the Escalante Watershed Restoration Project was carried out from 1996 to 1998 by operators from Consider it Done Restoration, Alliford Bay Logging, and Walter Merrit Contracting. During the 1997 field season, eight excavators were on the project. A program of "mentoring" was developed to help teach less experienced, talented operators the deactivation techniques developed by the more experienced operators. This mentoring and the experienced site supervision on the project were instrumental in achieving the high quality of deactivation work.

Safety was a prime concern during the work, and it was a standard operating procedure for the site supervisor to review the road and discuss safe approaches for reactiation or deactivation with the operator. In some cases, on site changes were necessary due to unexpected subsurface conditions. Conservative wet weather shutdown criteria were also used, to suspend activities at times when landslides were relatively more likely to occur.

Reactivation Techniques

Re-establishing a bench for the excavator on the old road grade was the preferred method of reactivating roads with heavy to moderate roadfill pullback. As much material as possible was left on the inside of the road. Excess material was placed on the slopes immediately below the road. Where the stability of the slope below the re-established road grade was not certain, or too steep, end-hauling of the excavated material was carried out. The challenge was to safely remove, sort, and store this material during reactivation.

Progress rates for reactivation through the pullback areas ranged from 350 to 500 metres/day in areas with light to moderate pullback (and little excavation required) to as little as 50 metres/day in areas with steeply sloping pullback with end-hauling. Times for road reconstruction at landslide initiation sites varied significantly, depending on the amount (and difficulty) of excavation necessary. At landslide deposition sites, material was often moved to expose the original grade or, in suitably coarse materials, a ramp was constructed over the landslide material for short-term access.

Deactivation Techniques

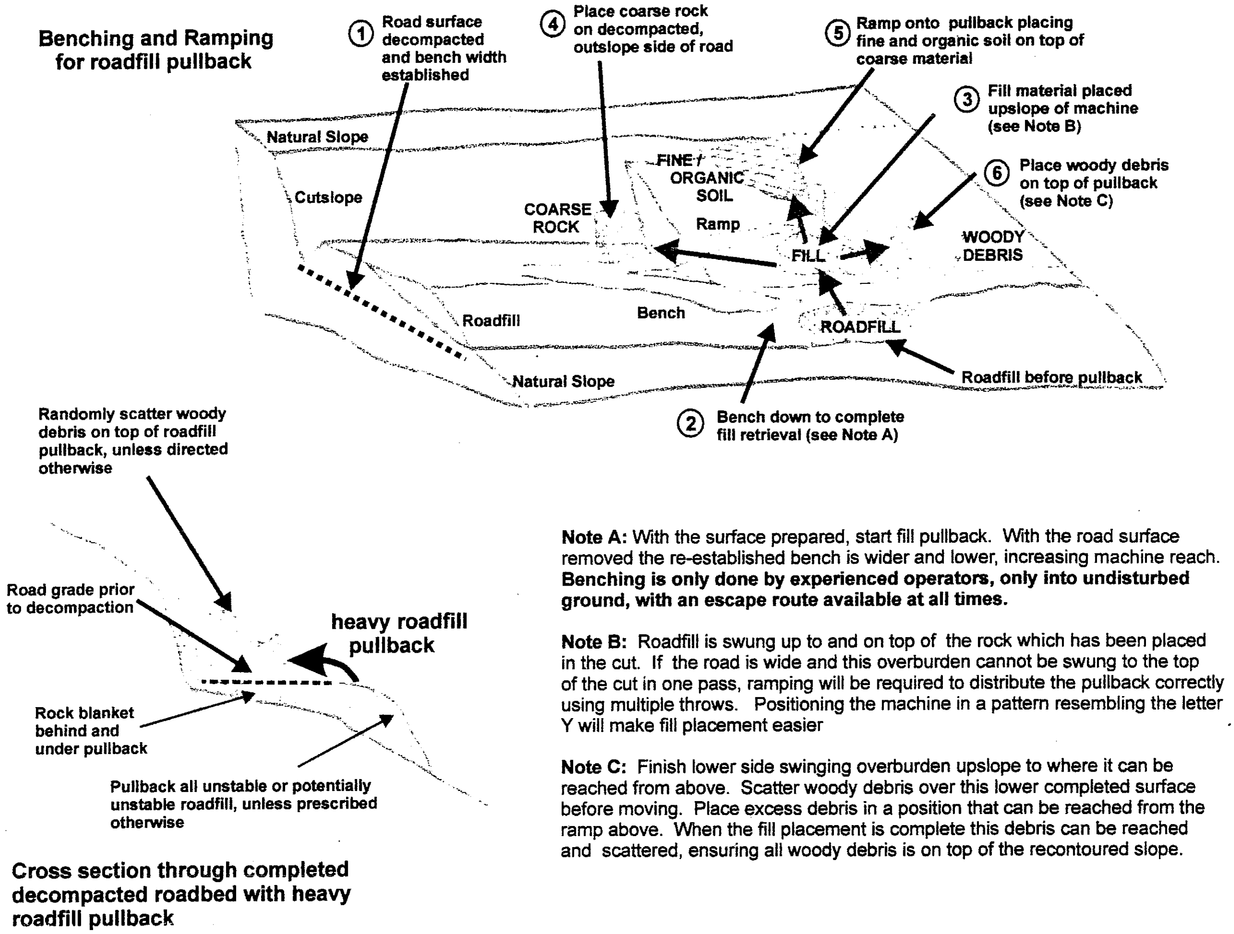
The deactivation prescriptions provide site-specific objectives along the road corridor. Standard operating procedures were developed for the work in the Escalante to complement the prescriptions and establish expectations and approaches for carrying out the deactivation work. Prescriptions will often not identify all potential work necessary at a site, and it is important that the site supervisor and operators clearly understand the intent of the prescriptions and the expectations for the completed work, and adjust their actions accordingly. Several techniques were developed to improve the safety and effectiveness of the hillslope restoration work during roadfill pullback and culvert removal.

Decompaction during roadfill pullback, along with benching and ramping, provided three distinct benefits (Fig. 5). Decompaction is the initial step in benching, where the operator excavates about the top one metre of the old roadbed to determine the stable bench width and the amount of roadfill present at the site. Firstly, if the roadfill is more than half the width of the road, and is located in wet or fine textured materials, then the site may present a safety hazard and the operator would adjust his machine positioning accordingly or postpone work. It was important for the operator always position his machine on undisturbed soil or very stable roadfill. Excess roadfill may also mean that end-hauling is needed to reduce the amount of potentially unstable roadfill left following deactivation.

Secondly, removing the road surface and decompacting the roadfill allowed the excavator to reach farther downslope from a stable position. This was important in the Escalante, since in many cases it was necessary to retrieve roadfill for some distance down the slope. At some locations, the distance from the top of the placed pullback material on the road to the downslope edge of the roadfill measured 45 metres.

Finally, the decompaction allows for outsloping of the undisturbed material on the road bench, which is important to maintain dispersed subsurface flow. In existing pullback areas, the ditchline sometimes flowed for days after it was intersected during reactivation. This indicated significant stored water in the buried ditch. The misdirected water may contribute to landslides at some road locations where the buried ditch exits the pullback, such as a switchback corner or a gully sidewall.

Benching and ramping were carried out to retrieve excessive roadfills and place materials in a specific order tightly against the roadcut. To create a bench, the operator excavated a short temporary "road" into undisturbed ground below the existing grade. The length of the bench varied depending on the site. The roadfill was retrieved and placed at an intermediate location (see Fig. 5). The operator then travelled back to the existing grade and up onto a ramp, sorted the material, and placed it on the bench. In cases where the bench was short, or the roadfill could be reached from the decompacted road surface, then the material was sorted during the initial pullback and a ramp was not needed. Large logs in the roadfill were a significant hazard to operators, especially



Note A: With the surface prepared, start fill pullback. With the road surface removed the re-established bench is wider and lower, increasing machine reach. **Benching is only done by experienced operators, only into undisturbed ground, with an escape route available at all times.**

Note B: Roadfill is swung up to and on top of the rock which has been placed in the cut. If the road is wide and this overburden cannot be swung to the top of the cut in one pass, ramping will be required to distribute the pullback correctly using multiple throws. Positioning the machine in a pattern resembling the letter Y will make fill placement easier

Note C: Finish lower side swinging overburden upslope to where it can be reached from above. Scatter woody debris over this lower completed surface before moving. Place excess debris in a position that can be reached from the ramp above. When the fill placement is complete this debris can be reached and scattered, ensuring all woody debris is on top of the recontoured slope.

Fig. 5: Benching and ramping for retrieval of roadfill during hillslope restoration. Numbers in top sketch indicate suggested sequence for placing material in roadcut.

if they were embedded in the road and supporting the excavator. These logs were carefully exposed and pulled up using steel cables and then placed on top of the pullback.

End-hauling was also carried out for pullback in gully areas where excessive roadfill accumulated during road construction (Fig. 6). This was important since gully systems usually represent a higher risk to downslope areas, due to increased debris flow runout distances and greater sediment transport rates in these areas.

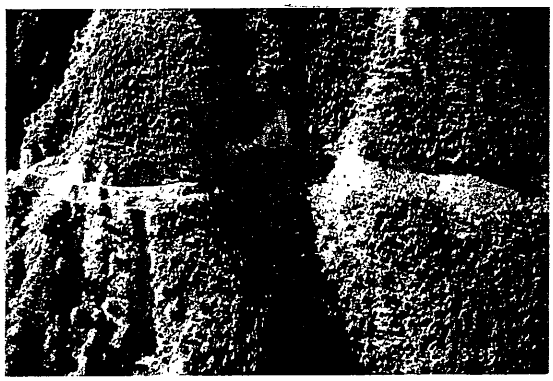


Fig. 6: Photo of roadfill pullback and end-hauling in gully area; note truck and excavator on left side of gully.

Re-establishing the natural drainage patterns along pullback sections was carried out with trench drains and blanket drains, as well as crossditches where appropriate. The amount of coarse rock near to the site was an important consideration in the cost effectiveness of trench drains and blanket drains.

At existing culverts, a standard technique was developed to decrease sedimentation and increase efficiency. The general approach was to: expose the corners or ends of the culvert; carefully create a non-erodible surface adjacent to the pipe culvert, or maintain the existing streambed under wood culverts; divert the water flow to the non-erodible channel; remove the remainder of the roadfill; and armour the outlet and sides of the crossditch as necessary.

Enhancing site productivity was also an important objective, to assist in tree and grass growth along the road corridor. Roadfill materials were sorted during pullback, as shown in Fig. 5, to maximize the amount of fine and organic soil on the surface. Grass seed and fertilizer were applied to provide short term protection from rainsplash erosion, and conifer seedlings were planted the following season. Coarse woody debris (logs and stumps) were placed on the surface to provide more favourable growing sites for conifer seedlings and reduce deer browse (Leslie et al, 1999).

Deactivation progress rates varied from 200 metres/day for pullback areas with easy decompaction and little excess roadfill, to as few as 30 metres/day for sites requiring multiple benching. We estimate the reactivation and deactivation in the Escalante cost as much as 15 times more than the original deactivation work.

The road deactivation work in the Escalante was also a product of good project organization and communication. During 1996 and 1997, site meetings were held on a weekly basis (or more often if necessary) to adjust the techniques and incorporate new ideas into prescriptions. In addition, bi-weekly reports were submitted to the Ministry of Forests and the data was entered into a Resource Management Database. All deactivation work was traversed shortly after completion to evaluate the work and provide feedback to the operators. Where the prescriptions were not met, the sites were either redone (if moderate or high risk) or identified for continued monitoring in less serious cases. At the end of each field season, a review meeting was held with forest company representatives, consultants, and regulatory agencies to reflect on the initial priorities and objectives, review accomplishments, discuss obstacles, and develop schedules for the next field season.

Present Conditions

The road deactivation work on the Escalante Watershed Restoration Program was stopped at the end of the 1998 field season. This was in response to Forest Renewal B.C. decision to focus more funding on watersheds with greater instream values than those in the Escalante River. By this time, the total deactivation expenditures (not including camp costs) for the Escalante Project exceeded \$3 million and approximately 35.2km of road were deactivated. To date, no landslides have initiated from the areas deactivated from 1996 to 1998, while about 15 landslides have occurred in other areas (Warttig, 2001).

Recent work in the Escalante involves continued monitoring of the roads and landslides using remote sensing (Collins et al, 2001) as well as visual inspections.

Concluding Remarks

Several lessons can be learned from the previous road deactivation work in the Escalante, as well as the assessments and later deactivation work carried out as part of the Forest Renewal BC Watershed Restoration Project.

- Forming a core working group that includes site supervisors, consultants, and all appropriate agency personnel is fundamental to making timely decisions for planning and project scheduling.
- Pullback that leaves significant roadfill on the slopes below the road can lead to landslides once the woody debris supporting the roadfill decays. This is important for sites where the slopes below the road are steep and marginally stable. End-hauling of material from gully systems is important to reduce the risk of debris flows.
- Technical specialists doing deactivation assessments should discuss objectives and approaches with the operators and site supervisors doing the work. At critical locations, it is important to review the sites together to determine effective and safe approaches.
- Detailed prescriptions must assess reactivation as well as deactivation where access is impaired or safety issues exist. For existing deactivated roads, it is important to weigh the expected benefit of improved deactivation against its cost.
- Work plans must maximize the amount of risk reduced for a given budget, given the access conditions, deactivation costs, and constraints such as timing windows and expected wet weather seasons.
- Site supervisors and operators need to understand the intent of the prescriptions, and have clear expectations for the completed work. Using standard operating procedures allows for a common or "default" approach to doing the work.
- Decompacting the road surface and benching where necessary can increase the amount of roadfill pulled back. Decompaction and benching also helps the operator to determine how much roadfill is present, as well as the type of material and the presence of seepage at the site. Decompacting the road surface also helps to restore the natural hillslope drainage paths since ditches, even when buried, can divert water along the road corridor.
- Sorting materials during pullback can enhance the site productivity. This is achieved by placing fine and organic soil on the upper surface of the roadfill pullback and scattering large woody debris (logs and stumps) on top.
- Reactivation of roads with medium to heavy pullback is expensive, as is improving the standard of deactivation. It is imperative that roadfill pullback work be carried out effectively the first time, particularly in areas that have high value resources downslope.

All of the roads in the Escalante were constructed before the Forest Practices Code (F.P.C.). The Forest Road Regulations within the F.P.C. contain legislated requirements for the assessment, design, construction, maintenance, and deactivation of forest roads. The effort needed to deactivate these F.P.C. roads will be significantly less than for older, abandoned roads. However, many of the lessons learned on the Escalante W.R.P. can be applied to new forest road construction (Horel, 1998). Building narrower, more stable roads that preserve the natural hillslope drainage paths, as well as reducing the amount of roadfill on steep slopes (using end-haul construction) can significantly reduce deactivation costs. Limiting the amount of roadfill on steep slopes can greatly decrease the amount of benching and ramping needed where permanent deactivation using hillslope restoration is planned. Hauling coarse rock during construction for armouring of crossditches and fords can also decrease costs.

Based on the techniques developed during the Escalante Watershed Restoration Project, suggested general approaches for completing deactivation work safely and efficiently were developed. Many of these approaches are still used today on road deactivation projects carried out by International Forest Products Ltd. Many of these techniques are now documented in a Best Practices Handbook regarding hillslope restoration (Wong et al, 2001).

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