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Editor's Note

As an editor, I am always pleased when someone advises me of an error in Streamline because it means that it is being read carefully. Thank you to more than one alert reader for noticing that there were references missing in the feature article of Vol.5 No.1 about the Tsuk-si-tay Groundwater Side Channel. The references are included below. The article also omitted some important acknowledgements and at this time the author would like to recognize the following individuals that participated in making this side channel a reality: Seaton Taylor, Joe Thorne, Dale Ostapowich, Alan Chapman, Mel Sheng, Russ Doucet, Bill Pollard, Henry Sirkia, Brian Retzer, Eva Hollingshead, Mike Feduk, Deb Epps, Graham Hill, Rob Brouwer, and Luigi Sposato.

Additional References for Nitinat River WRP: Tsuk-si-tay Groundwater Side Channel and Uplsope Management:

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The Application of Decision Analysis to Forest Road Deactivation Problems – an Example in Coastal British Columbia

Clay Allison and David Tait

Professional resource managers constantly face an almost impossible job: they must choose between alternative levels of investment in road deactivation. Such decisions require that managers simultaneously juggle a very large mix of uncertain factors. Limited resources in a given budget require the manager to make tradeoffs in terms of when, where, and how much to invest in road deactivation. Decision analysis provides a tool that can aid in systematically organizing decision-making problems. Such analysis provides an organizational structure that both clarifies and documents the factors that managers must consider. Sensitivity analysis can then rate the relative importance of alternative restoration decisions. The results of this type of analysis are useful in revealing the range in potential values of various alternative investment decisions. Finally, with decision analysis, the supporting documentation provides managers with a clear rationalization for the difficult choices they are required to make.

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Feature

Such factors as the nature of the relationship between roads and landslides, the variety of damage that can result from road related slides, and the random nature of weather events that are thought to trigger road related slides, all contribute to the complexity of the manager's problem. In the past, most forest road construction used heavy equipment (e.g., bulldozers or line shovels) that offered little control of fill material. During construction, the natural surface and sub-surface drainage system was modified and the excess excavated material was pushed down the hillside. In some areas the road fill material was held in place by the root strength of old-growth stumps, other vegetation, debris that remained after logging, and retaining walls built of logs anchored by large stumps (Moore, 1994). A number of serious problems tend to arise as a result of these past practices. Over time, the logging debris and root networks of stumps decompose, increasing the probability of a road-related landslide (Sidle et al. 1985; Doyle et al. 1998). In turn, potential landslides can displace a wide range of volumes of soil, rock, and debris. The amount of slide damage to both timber resources and such watershed attributes as water quality and fish stocks, then depends on the frequency and magnitude of the event and the site-specific factors downslope of the event. The chance of a significant storm event further complicates the problem.

The manager needs to assess both the costs and the expected consequences associated with each alternative deactivation prescription, including the 'no treatment' option. The manager must subjectively integrate his or her understanding of the range of chance outcomes together with the uncertain nature of weather-related events. He or she must also assess the relative cost of the potential impact. In some situations there is not a high degree of certainty that the expected cost savings associated with a reduction in damage would exceed the cost of preventative measures.

Decision analysis provides the manager with a 'prioritization' tool. When applied to road deactivation decisions, decision analysis represents a framework that focuses attention on a sequence of independent sub-problems. The framework allows the manager to work systematically through the range of possible alternative outcomes. This method incorporates the expert's best assessments of the probabilities that specific outcomes will occur. The expert could be a single manager or, as in our case, a team of experts. Decision analysis also allows the expert to evaluate the relative impact of alternative potential slide events. These alternative decisions, or choices of road restoration prescriptions, can all be evaluated in terms of their average long-term benefits. The separation of the larger problem into a series of independent sub-problems reduces each individual problem's scope. The resulting focus can be used to establish a consensus amongst a group of experts. Alternatively, this can aid an individual to develop systematically his or her understanding of the value of alternative prescriptions.

In our use of decision analysis for road restoration, we decomposed the decision problem into a set of linked questions or sub-problems (Figure 1). A team of resource managers developed answers to questions such as: "If a particular deactivation action had been implemented, what do you think are the chances of a small- to medium-sized, road-related slide occurring at this location following a storm event?" Terms such as 'a small- to medium-sized road-related slide', 'a storm event', and the specifics of the deactivation action are all defined for the expert panel. The answers reflect a consensus of a group of experts. These experts still subjectively integrate their 'expert experience' together with documentation, maps, and road assessments. However, they now articulate their pooled expertise in terms of a testable expectation or probability. These articulated probabilities are combined with storm event frequencies and estimates of slide costs. The decision analysis framework leads to an expected average cost resulting from a road-related slide. This average value takes into consideration both the magnitude of the resulting damage as well as the probability of a slide actually occurring. The average value is calculated for each road restoration action (including the 'no treatment' action). The calculations are repeated for a sample of road sections and restoration actions. As a

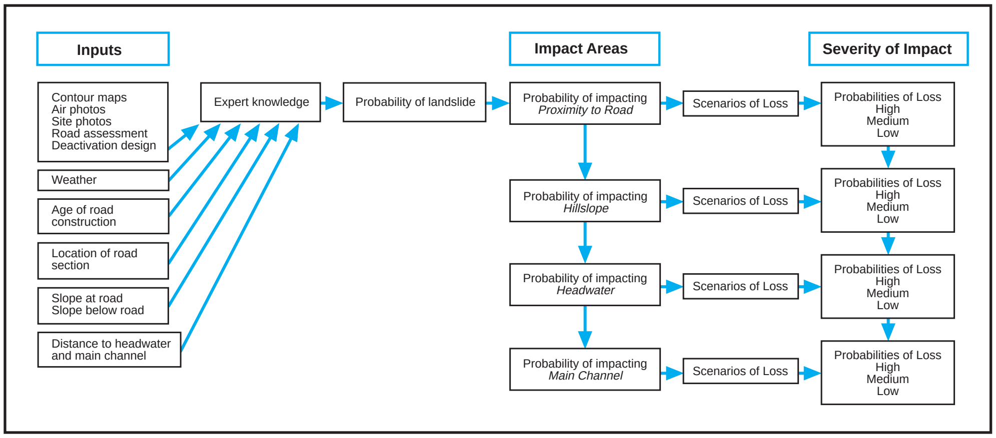

Figure 1. Probability Estimation Logic Chart.

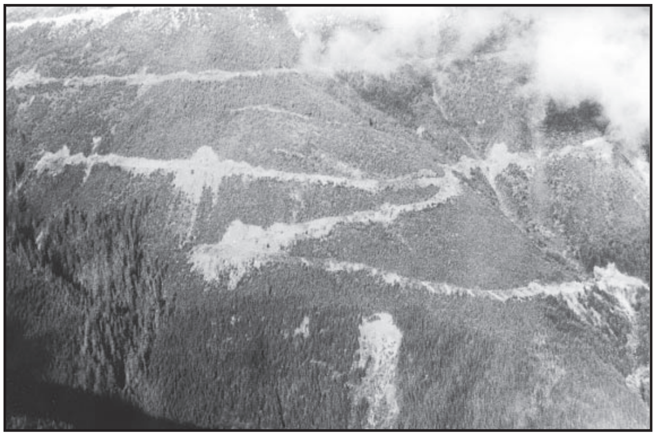

Figure 2. View of Misery Creek Watershed after road deactivation. Roads numbered 400 and 430.

result, the framework provides a transparent assessment of alternative road deactivation projects.

The following is an example of a sequence of road deactivation sub-problems used to construct a decision analysis framework. The problem sequence begins at the road section and poses the question: "Provided that a rainstorm has taken place with a recurrence interval of twenty years, what is the probability of a landslide taking place?" Follow-up sub-problems include: "Given that a landslide has occurred from the road section, what is the probability that the landslide will have an impact on a first or second order stream channel?" and "Calculate the probabilities that the stream channel impact will be severe, moderate, and minimal." Ranges of landslide impact (i.e. severe, moderate and minimal) were characterized using impact scenarios to assist professionals in establishing consensus. Later, these same scenarios were converted into a common metric (dollars in this particular example) that measured the relative impact between areas or read sections. Deactivation costs were also valued in dollar terms.

The completed decision framework transparently reflects a comparison of expected benefit with deactivation cost. The term benefit in this context is the reduction in the magnitude of loss that is associated with the implementation of a deactivation action when compared to the 'no action' alternative. The 'cost' in this context is the cost of implementing a deactivation action only. The 'no action' alternative has no cost. The ratio of expected benefit to cost, known as the benefit/cost ratio, can be used to develop a relative ranking of road deactivation decisions. The highest ranking benefit/cost ratio reflects the deactivation decision that is expected to have the highest benefit per dollar invested. The ranking can be used to develop a simple summary graph. The x-axis reflects the cumulative cost of projects if the projects are sorted in order of each project's benefit/cost ratio. The road sections are plotted with the highest benefit to cost ranked first and lowest ranked last. Successively summing the deactivation cost as road sections are plotted produces the cumulative expected cost total. Similarly, successively summing the expected benefit produces the cumulative expected net benefit, displayed on the y-axis. The slope of the graph at any point represents the benefit/cost ratio for the next best restoration decision.

The shape of the relationship between cumulative road deactivation cost and cumulative expected benefit is of particular interest to the resource manager. For example, if all restoration decisions had the same benefit/cost ratio, the cumulative curve would be a straight line originating from the origin. However, if some road sections offered relatively higher levels of expected benefit than others, the relationship would be represented by a curve the value of whose slope initially rose rapidly, then flattened off.

The pattern of the relationship between cumulative expected benefit and cumulative cost provides the resource manager with valuable insights that can assist decision-making in the road deactivation project. When the expected benefit is measured in dollar values, the point on the graph at which the curve flattens indicates the point at which the expected benefit is approximately equal to the cost of the road deactivation. Operationally, resource managers may want to identify whether there is a geographical pattern or location to the road sections that offer moderate or low return. The resource manager may also want to know if the relationship between the cumulative expected benefit and cumulative cost changes significantly when the cost of road deactivation is reduced on some road segments. Once the decision analysis framework is constructed, managers can examine many possible resource allocation scenarios.

A 25 km^2 area along the south-west coast of British Columbia in the Southern Pacific Range of the Coast Mountains was selected as a case study for forest road deactivation; this study would demonstrate decision analysis applied to road deactivation in British Columbia (Allison, 2000). About 17 km of forest roads were deactivated in the test area. The road deactivation was completed under Forest Renewal BC's Watershed Restoration Program in 1998. The project was located in two sub-drainages about 4 km apart: Misery Creek at an elevation of 400 m to 1200 m (49° 48' lat., 123° 45' long.) and Chickwat Creek at an elevation of 300 m to 1200 m (49° 50' lat., 123° long.).

To simplify the analysis, the 17 km of road was divided into 100 m segments. For each segment a choice could be made whether or not to deactivate the segment. Each choice was subject to the same set of uncertain events, for example: a rainstorm might occur, or not, possibly causing a landslide, or not. If a landslide did occur, it might affect all or some of the hillslope and the watershed. Another means of simplifying the analysis was to define four impact areas. In any of these areas, losses were a function of the severity of impact (i.e. from no impact to significant impact). To further simplify the analysis, severity of impact was characterized by three levels of impact. The decision frame, once developed, provided sufficient structure to allow an expert group to consider the probability that uncertain events might occur and to then calculate the expected loss.

The probability estimates were consensus estimates of the expert group. These experts were asked to imagine that a rainstorm with a return interval of twenty years had just occurred. They were first given the task of estimating the probability of a road related landslide, then of to estimating the probability of loss. The expert group examined each of a sample of seventeen road segments, both with deactivation and with no deactivation. They were to assume that the road would be re-exposed to a risk of future storms and that the potential for future slides would be the same as the current year. Future events were discounted to the present. Once the decision frame was completed, it was possible to average back the decision tree and determine the present value of each road deactivation decision for each segment.

Examination of the results for the sample of seventeen road segments showed that for road segments in Terrain Class IV and V there was a relationship between expected benefit and deactivation cost. No relationship was found for roads in Terrain Class III. Using the average expected benefit for Terrain Class III together with the relationship between cost and expected benefit in Terrain Classes IV and V, an estimated benefit for all road segments was calculated.

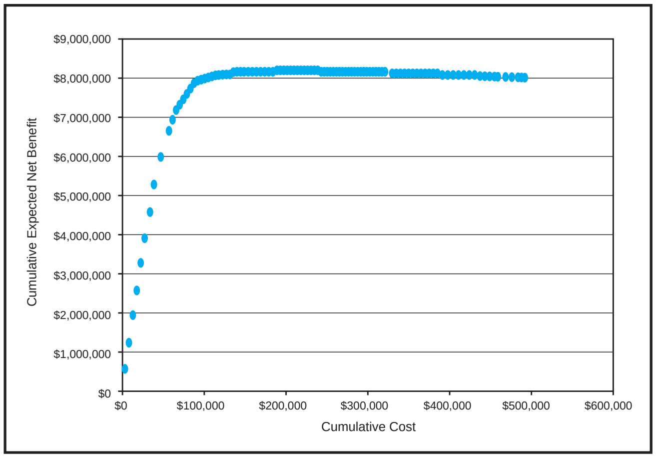

Figure 3. Cumulative expected benefit to cost produced by sorting the road segments in order of their expected benefit/cost ratios (discount rate set at 4.25%).

Figure 4. View of Misery Creek Watershed before road deactivation (Road number 400.)

To produce such a cost effectiveness curve (Figure 3), we plotted the expected benefit from each road segment, ranked by the benefit/cost ratios, in order, from high to low. We then plotted the cumulative cost and expected benefit. The resulting cost-effectiveness curve indicates that cumulative expected net benefits reach a maximum and remain constant as additional road segments are deactivated. **Moreover, the curve shows that seventeen road segments accounted for 18% of the cumulative cost and 98% of the cumulative expected benefits from road deactivation.** Sensitivity analysis indicated that these results were not sensitive to changes in key variables of the analysis such as the discount rate. Details of the study can be found in Allison (2000).

This case study demonstrated that decision analysis could be used to organize systematically the inherent complexity in road deactivation decisions. The application of decision analysis to the study area was not resource-intensive. The expert group used available road deactivation information, maps, and aerial photographs. In relation to project cost and potential savings, the additional professional time required by the decision analysis process was not significant. The distinct advantage provided by decision analysis is its systematic approach to uncertainty in multiple possible landslide impact areas and its accounting for uncertain outcomes in the future. By using this systematic approach, it is possible to make better use of available data both to target expenditures and better defend these decisions, to lower risk to an acceptable level, and to achieve cost-effective road deactivation.

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A Practical Approach to Risk Management of Roads Using GIS (ArcView™)

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A geographic information system, or GIS, has many uses for analyzing and managing land-based infrastructure. This article describes how the GIS program ArcView™ can help to optimize risk-based road deactivation or maintenance programs.

GIS programs link spatial (i.e., visual map) data with database (dbf) files that carry attributes for the theme (polygon, line, or point) that is displayed visually. ArcView™ displays lakes, forest cover, terrain mapping as polygons, streams and roads as lines, and bridges, culverts, and sign locations as points. Attributes are carried in the ArcView™ dbf table for the theme; additional attributes can also be compiled in separate dbf files and then joined to the ArcView™ dbf table. This allows for a virtually unlimited range of attributes and great deal of flexibility in viewing and analyzing data using ArcView™.

The following is a minimum GIS data set that will allow the ArcView™ user to optimize road deactivation, inspection and maintenance programs:

Themes:
- Unit boundaries (watershed, tenure, or operating area) - polygons
- Water bodies (lakes, ocean) - polygons
- Roads - lines
- Streams - lines
- Bridges - points

Attributes:
- Roads: permits, status (maintained mainline, level of deactivation, abandoned, etc.), hazard level
- Streams: fish habitat and non-fish habitat
- Bridges: type, span length

Analysts are determining road hazard levels as part of watershed restoration programs, watershed assessments for forest development plans (CWAPs), and other forest management functions. To capture this information in the GIS is immensely useful for a forest operation that is managing the forest land base for the long term. Where roads have not been previously assessed for hazard, a hazard rating by road segment