MAPPING EXPOSURE TO AVALANCHE TERRAIN

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ABSTRACT: During the winter of 2009-10, several signs were created in collaboration with British Columbia government agencies for winter trailheads. The centerpiece of these signs is a regional-scale map of surrounding terrain with slope- to basin-scale polygons shaded according to the Avalanche Terrain Exposure Scale (ATES). The use of ATES for slope- to basin-scale terrain classification is a departure from its intended use as a descriptor of the overall seriousness of a particular route. The ATES technical model is designed at basin- to regional- scales and needed to be supplemented for use at different scales.

Adequate accuracy was maintained on the low precision and large scale trailhead maps solely through supplementary subjective terrain assessments using expert judgement. But there is a demand for similar Google Earth based maps with limitless scale requiring much higher precision. So there is a need for a more deterministic method to apply ATES at slope- to basin-scales, instead of relying solely on judgement. This paper presents work done to-date, and discusses experiences and ideas for future non-commercial backcountry recreation avalanche terrain exposure maps.

1. AVALANCHE TERRAIN EXPOSURE SCALE

The Avalanche Terrain Exposure Scale (ATES) was developed by Parks Canada to help backcountry users assess the severity of the terrain encountered in a given trip (table 1). The scale is designed to rate the overall seriousness of a route (line feature) with three terrain classes that describe the exposure of terrain to potential avalanche hazard. ATES ratings are applied by avalanche professionals who subjectively consider eleven weighted terrain parameters in ranking a route as one of the three exposure ratings.

2. TRAILHEAD SIGNS

2.1 _Background_

During the winter of 2009, several snowmobile areas throughout British Columbia were assessed and classified according to ATES. When work started for these areas, it was quickly realized that point-to-point trip ratings are not particularly useful to most snowmobilers. Riders tend to use trails or roads to access the open alpine where most of the riding takes place. An effective ATES rating should incorporate an entire "play area" where possible. For most of these areas, "trail ratings" were provided for point-to-point trips, and "play area" ratings were provided as polygons on a map.

Figure 1: Example of a trailhead sign with a 3-dimensional image of surrounding terrain classified with the ATES scale. The North American Avalanche Danger Scale and the Avaluator are also on the sign.

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Table 1: The Avalanche Terrain Exposure Scale technical model v1.04 (Statham et al., 2006). Parameters listed in italics default the assessed route into that class.

	Class 1 "Simple"	Class 2 "Challenging"	Class 3 "Complex"
Slope angle	Angles generally < 30º	*Mostly low angle, isolated slopes >35º*	*Variable with large % >35º*
Slope shape	Uniform	Some convexities	Convoluted
Forest density	Primarily treed with some forest openings	Mixed trees and open terrain	Large expanses of open terrain. Isolated tree bands
Terrain traps	Minimal, some creek slopes or cutbanks	Some depressions, gullies and/or overhead avalanche terrain	*Many depressions, gullies, cliffs, hidden slopes above gullies, cornices*
Avalanche frequency (events:years)	1:30 ≥ size 2	1:1 for < size 2	1:1 < size 3
Start zone density	Limited open terrain	Some open terrain. Isolated avalanche paths leading to valley bottom	Large expanses of open terrain. Multiple avalanche paths leading to valley bottom
Runout zone characteristics	Solitary, well defined areas, smooth transitions, spread deposits	Abrupt transitions or depressions with deep deposits	Multiple converging runout zones, confined deposition area, steep tracks overhead
Interaction with avalanche paths	Runout zones only	Single path or paths with separation	*Numerous and overlapping paths*
Route options	Numerous, terrain allows multiple choices	A selection of choices of varying exposure, options to avoid avalanche paths	*Limited chances to reduce exposure, avoidance not possible*
Exposure time	None, or limited exposure crossing runouts only	*Isolated exposure to start zones and tracks*	*Frequent exposure to start zones and tracks*
Glaciation	None	*Generally smooth with isolated bands of crevasses*	*Broken or steep sections of crevasses, icefalls or serac exposure*

British Columbia Parks approached the Canadian Avalanche Center (CAC) in the spring of 2009 to assist with producing new trailhead signs for popular backcountry areas in the South Coast region. The centerpiece of these signs (figure 1) is an area map with slope- to mountain-scale polygons shaded according to ATES. This allows backcountry users to assess terrain beyond the typical trip route (point A to point B), and provides a more engaging and visual approach to communicating avalanche hazards within the park. Several signs were created for high traffic backcountry areas in Mount Seymour, Cypress, Joffre Lakes and Garibaldi Provincial Parks (figure 2). Public response to these trailhead signs has been very positive. In addition, local avalanche course instructors found the signs to be a very useful educational tool.

Figure 2: Trailhead sign in Mount Seymour Provincial Park. (Photo: Mark Grist)

2.2 *Methodology*

All of these projects involved a similar method for determining appropriate ATES ratings. First, we relied on local expertise to draw the initial polygons. This would typically be a senior BC Parks Ranger. Then we would verify the boundaries of the polygons using topographic maps, Google Earth, and judgment based on our own experience in the area.

If possible, we would then verify our ratings by traveling in park. We would highlight any areas of uncertainty and try to view these areas on the ground. If the size of the area in question was too large and there were sufficient resources, we would do an aerial survey. After field verification (figure 3) we would adjust the ATES polygons as needed and provide a map or Google Earth image for the parks representative to take to their GIS department and printer.

The use of ATES for slope- to mountain-scale terrain classification is a departure from its intended use as a descriptor of the overall seriousness of a particular route. However, we found that a combination of the ATES technical model, public communication model, as well as the Avaluator (Haegeli and McCammon, 2006) Trip Planner (i.e. would this terrain be not recommended during considerable danger) worked well to subjectively classify slope- to mountain-scale areas, as long as low precision and large scale maps ensured adequate accuracy. That is, it worked well as long as the maps weren't too detailed and the polygons were broad-strokes applied to general areas.

Figure 3: Field surveys for terrain assessments. (Photo: Peter Marshall)

2.3 *Limitations*

The quality and accuracy of these maps are primarily dependent on the scale of the map being produced, and the size of the area being mapped. The map scale should be decreased as the area being mapped increases. For example, Joffre Lakes Provincial Park, which is approximately 1460 ha, can be mapped at a small scale far more accurately than Garibaldi Provincial Park, which is 194 650 ha. Several signs were produced for Garibaldi Park and the signs were placed in key high-traffic areas. This allowed for the extent of the map to be reduced to primarily include popular day trip areas within the park. Reducing the overall size and scale of each map will ultimately increase the overall accuracy of the terrain ratings, but they should still be viewed as being very broad and general.

Another issue we encountered was with determining the extent of the rated area. In some instances we would simply draw polygons to the park boundary (figure 4), but in other cases we would draw a boundary at the extent of where we believed the majority of park users would venture (figure 1). In general we would try and use natural terrain breaks like ridge tops or valley bottoms, but in some cases an ATES rating could end mid-slope.

This tool is designed to give general guidance to backcountry users. It is important that users do not make decisions based solely on the information provided on these signs. The terrain classifications are at a very broad scale and there may be significant variations in terrain within each class. For example, complex slopes may exist in areas that are highlighted as being challenging. The classification boundaries should also be treated as soft boundaries. Ideally the colors used to differentiate the classes should fade at the boundaries to indicate a rough transition zone. Park users should be made aware of the limitations of information presented by adding a clear and concise statement of uncertainty to each sign.

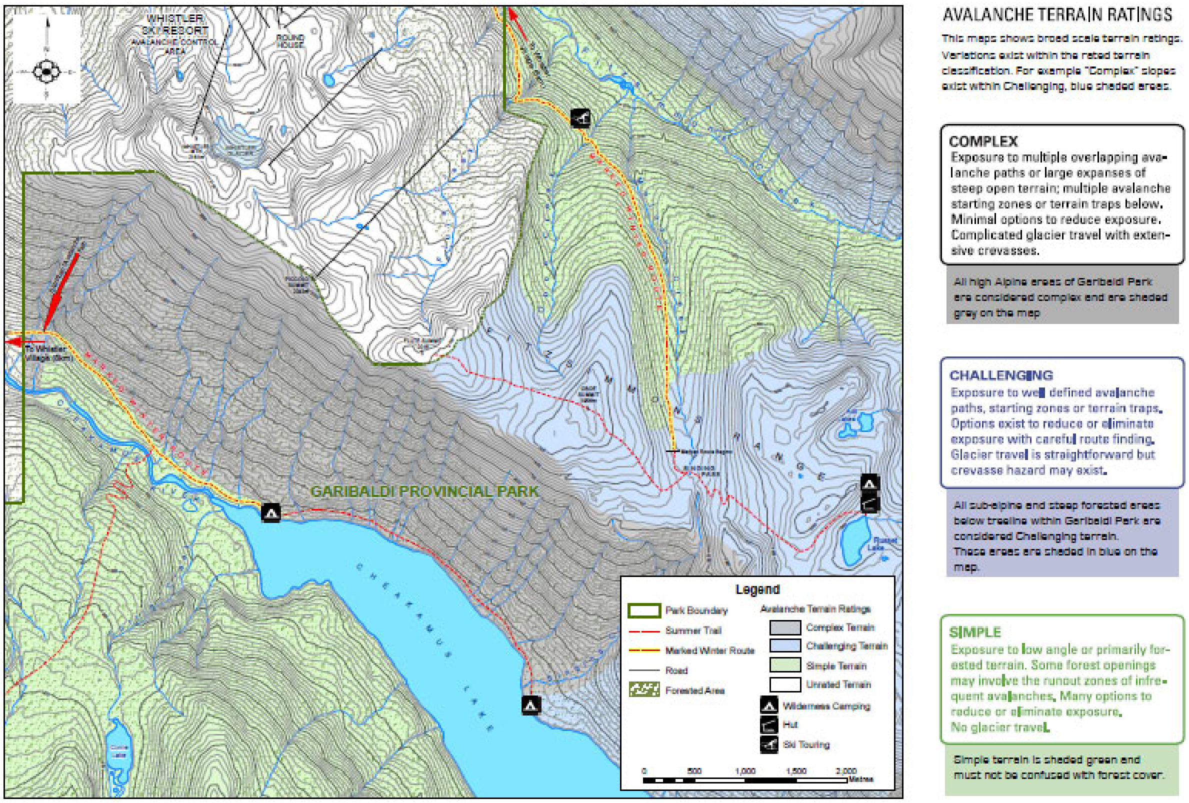

Figure 4: Topographic map of Cheakamus Lake area in Garibaldi Provincial Park with surrounding terrain classified according to the Avalanche Terrain Exposure Scale. Note that the classified terrain extends to the park boundaries.

3. SNOWMOBILE AREA MAPPING INITIATIVE

3.1 _Background_

There has recently been a demand for similar Google Earth based maps for snowmobile areas across British Columbia. One challenge with Google Earth representation is limitless and uncontrollable scale, so we need a more deterministic method of drawing polygons instead of relying so much on judgement. With the recent advances in Geographic Information Systems (GIS) and terrain data, a reasonable approach to create such maps is with the help of digital elevation models (DEMs) and orthophotos.

GIS visualization algorithms can be created for the more definitive and objective ATES parameters. For instance; cumulative slope angle and surface area give a good representation of convolution or slope shape, and upslope cumulative slope angle is a proxy for density of depression-type terrain traps (Richardson, M., 2010, pers. comm).

Delparte (2008) developed GIS algorithms to categorize forest density, slope angle, slope shape, and interaction with avalanche paths. Each attribute category is assigned a score that when totalled determined the ATES classification. These alone can produce a fairly accurate ATES maps as most of the other ATES parameters are a function of these variables.

3.2 _Methodology_

A local avalanche professional, who is familiar with the area, starts by drawing the extent of the riding area (area to be rated), including all the trails and play areas. This is done in collaboration with local stakeholders using Google Earth. The boundaries of the area to be rated should follow dense forest, drainages, ploughed roads and other natural snowmobile area boundaries, while honouring designated non-motorized use areas, wildlife closures, tenure areas, etc. The local avalanche professional then identifies crux areas, or decision points, with regards to safe backcountry travel in avalanche terrain. A description of the crux and tips for safe management are provided.

Next a Qualified Avalanche Professional draws the Class 2 and Class 3 ATES polygons based on GIS analysis as per Delparte (2008) and Richardson (2010, pers. comm.) and modelled runouts of major avalanche paths. This uses a concentric approach with special attention given to parking lots, staging areas, emergency shelters, common play areas and popular routes. A polygon resolution of 1-10km should be sufficient for trip planning purposes, while not exhausting resources. However, higher resolution is appropriate to extend continuous areas by connecting similar polygons. The local area expert assessor then adjusts the ATES polygon boundaries based on expert knowledge, and field surveys.

3.3 *Limitations*

This methodology for creating maps of ATES ratings has yet to be applied in practical applications. The extent of area to be rated may not encompass all terrain accessed from the trailhead.

4. DISCUSSION

It is important to note that these maps are strictly for trip planning purposes (i.e. choosing appropriate terrain for the conditions) and not navigation. This should be clearly stated on maps. Regardless, any considerable amount of noise on a map intended to guide the public in safe route selection is unacceptable since it might be easily be misinterpreted with potentially high consequences.

As mentioned previously, mapping ATES as slope-scale polygons is a departure from its intended use to describe the overall seriousness of a basin-scale route. Models are usually designed to be applied at a specific scale and for a specific feature, and to use them for different than intended purposes may require re-modelling.

5. NEXT STEPS

The methodology outlined in section 3.2 will be used to peer-review existing maps and produce new maps as a beta test. Reasonable performance metrics will then be developed to assess and revise the methodology. This includes determining optimum accuracy and resolution based on the application and the user, while considering available resources.

6. REFERENCES

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