THE ASSOCIATION OF GEOHAZARD PROFESSIONALS

A non-profit organization
focused on bringing together
Contractors, Engineers, Geologists,
Manufacturers and Public Agencies in the
pursuit of excellence

www.GeohazardAssociation.org – Est. 2013

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Snow avalanche risk assessment and mitigation

Bruce Jamieson and Chris Wilbur

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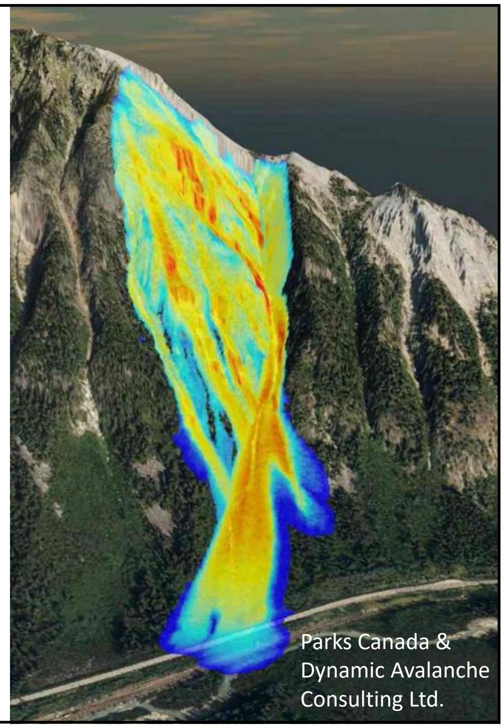
Characterizing, assessing and mitigating snow avalanche risk

- Differences from other slope hazards
- Methods not guidelines/thresholds
- Qualitative and quantitative methods



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Some physical differences: re other slope hazards

Failures occur in bonds < 5 C from melting.
Samples too fragile to be transported to lab.

UCalgary/ASARC photo

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Explosive triggering works. But timing critical!

B. Jamieson photo

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The Frank Slide deposit won't melt
…
but snow avalanche deposits do so no subsurface sampling of old deposits

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Snow avalanches vs other slope hazards:

Physical differences

- Many occurrences in same path / track
- Vegetation damage useful up to ~100 y (in some paths)
- Deposits melt, limiting estimation of return periods
- Subsurface sampling ineffective
- Failures occur in bonds < 5 C from melting
- Explosive triggering works! But timing is critical.

Comments or questions?

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Overview of methods

1. Characterization
2. Assessment
3. Mapping
4. Mitigation

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1. Characterization

- Terrain identification
- Avalanche characteristics
- Occurrence records
- Vegetation damage
- Snow climate
- Dynamic models
- Statistical runout estimation

LiDAR data courtesy Parks Canada. Processing by C. Argue

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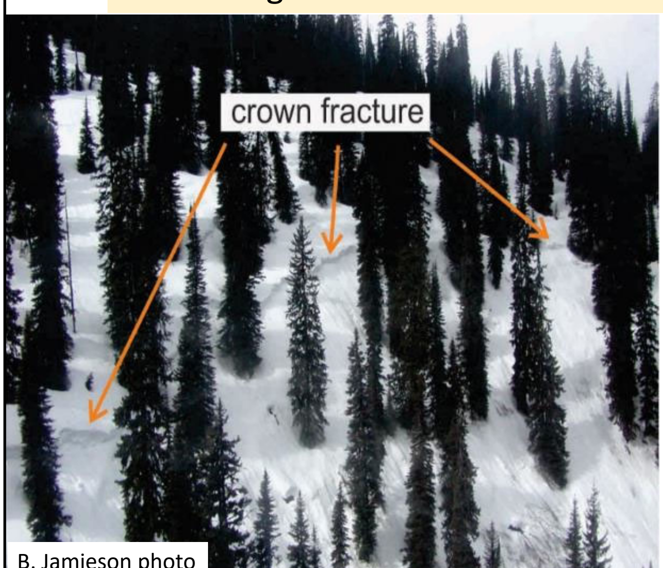
Characterization: Terrain

Two strong factors for start zones: slope angle & forest cover



B. Jamieson photo

Ucalgary/ASARC photo

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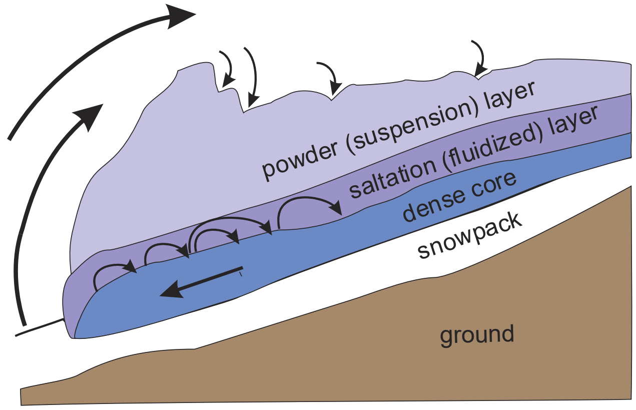
W. Geary photo



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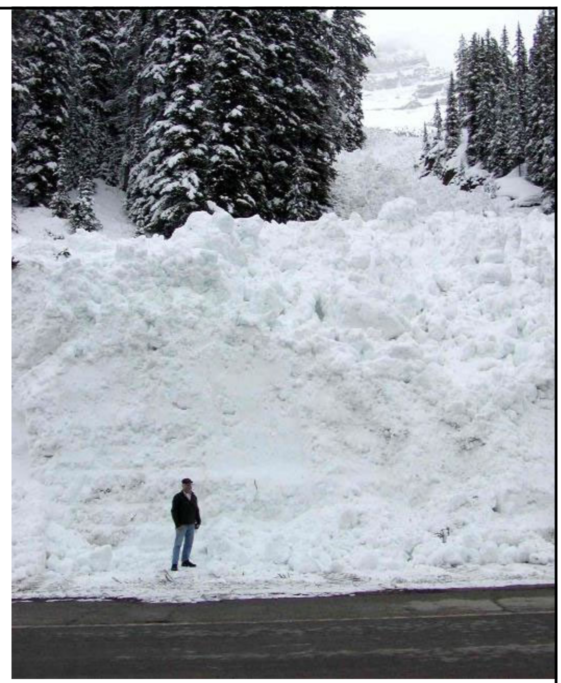
B. Jamieson photo

Snow avalanche deposits



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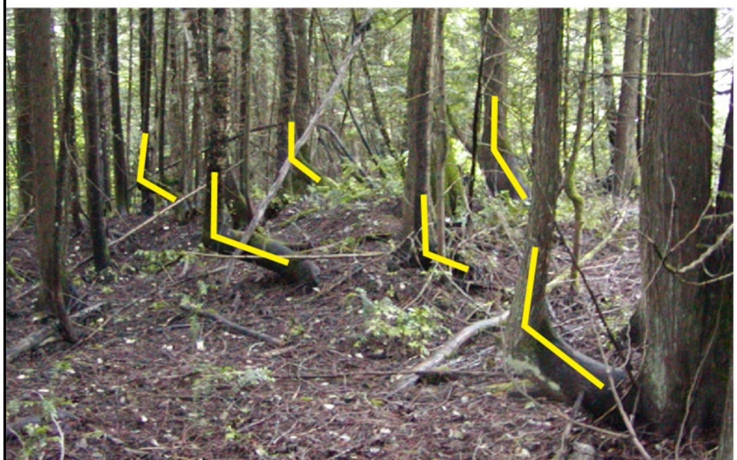
Characterization: vegetation damage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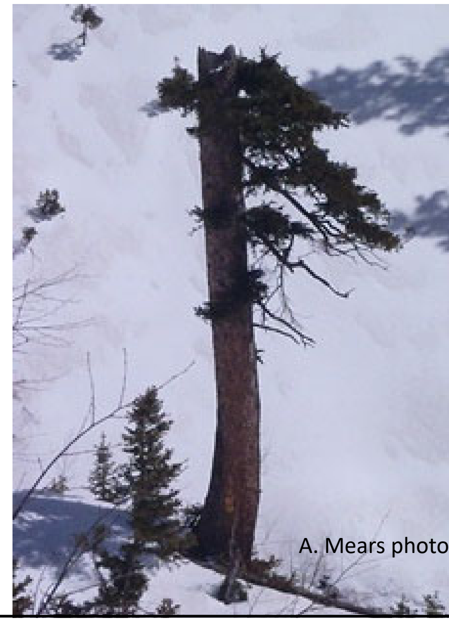
A. Mears photo

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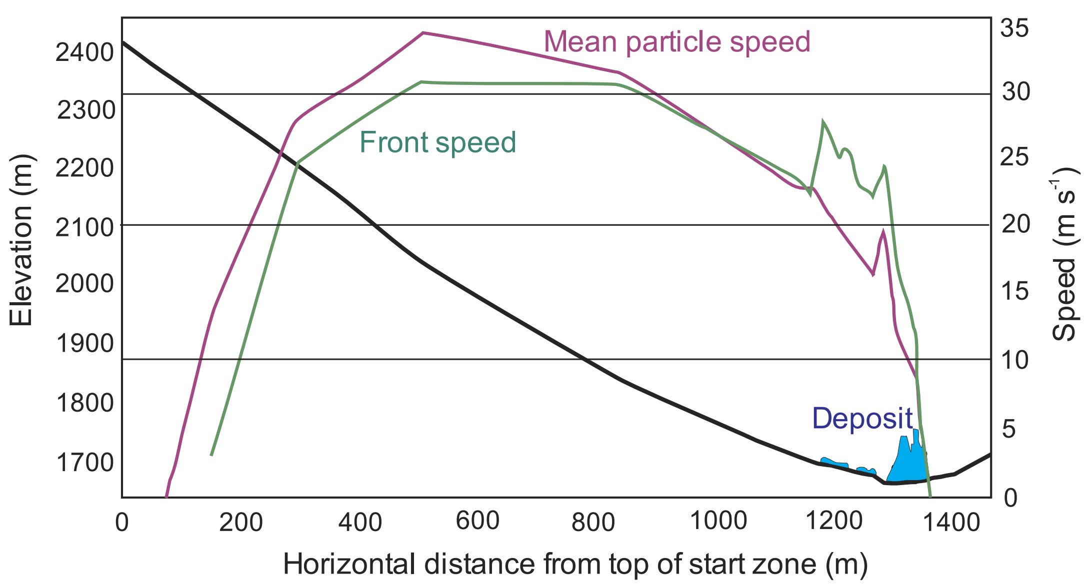
Characterization: Avalanche dynamic models



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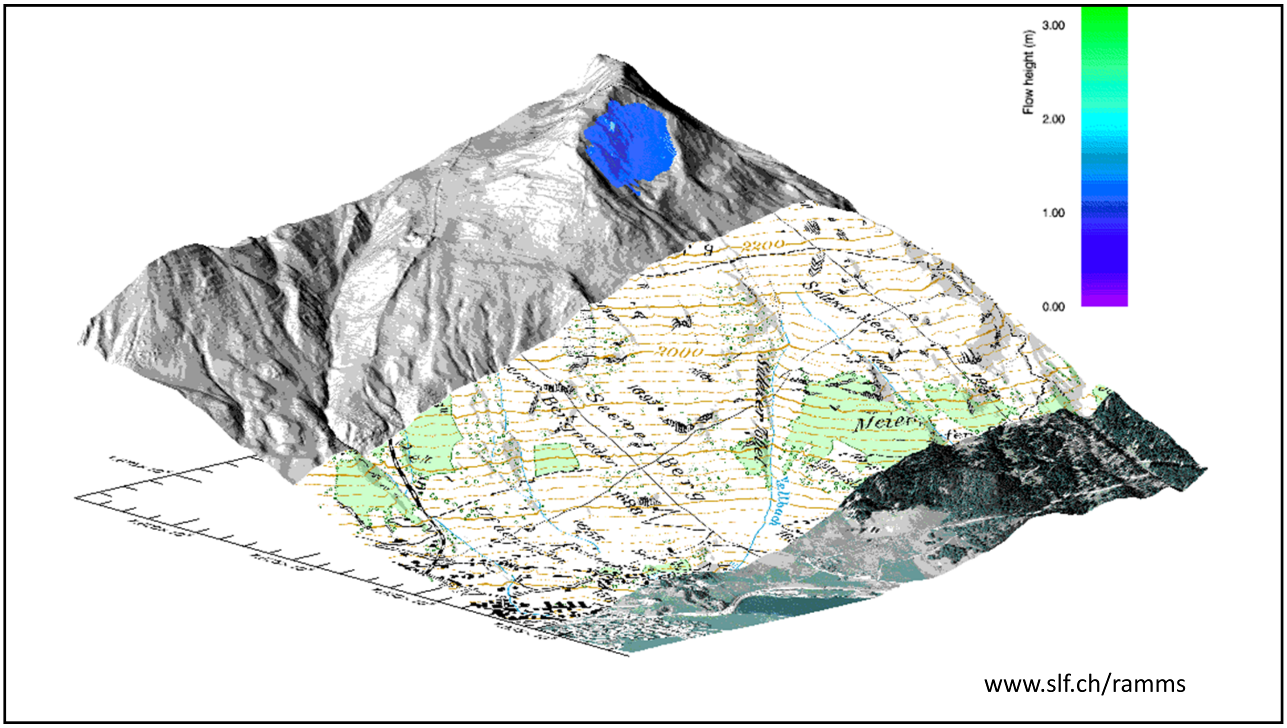

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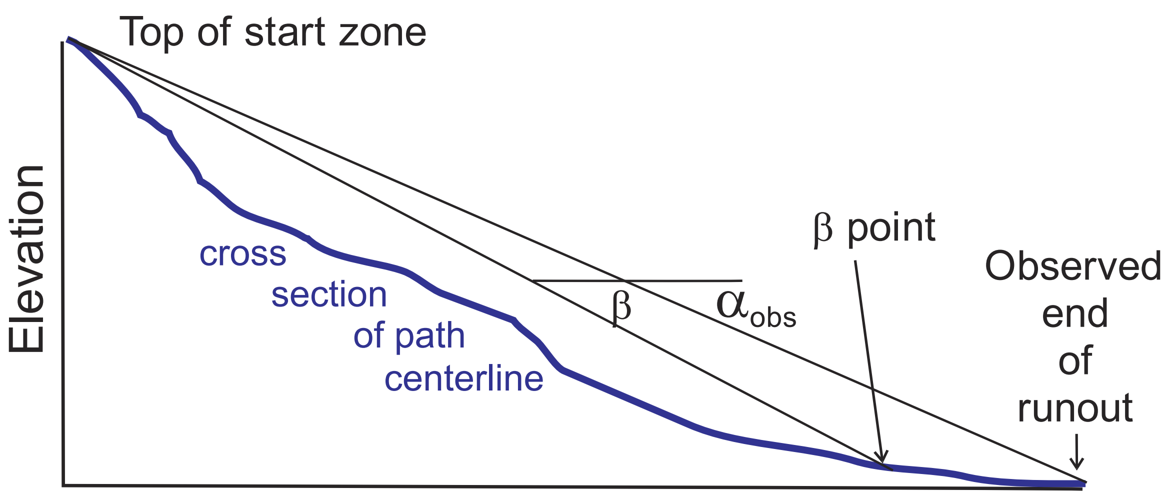
Statistical runout estimation



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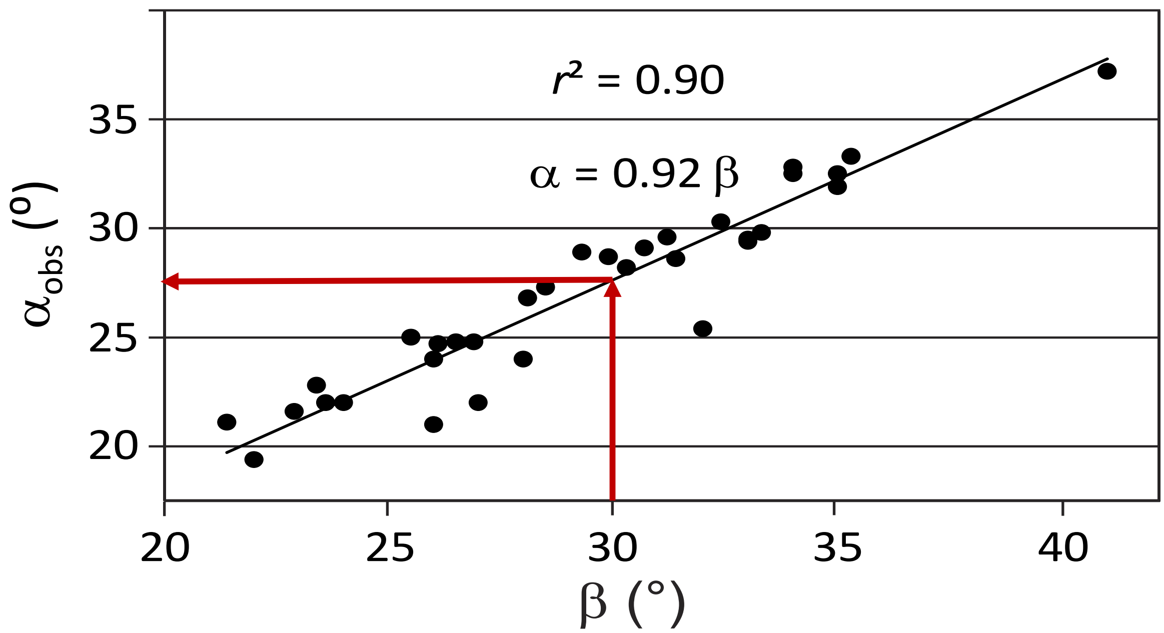
Regress α_{obs} on β



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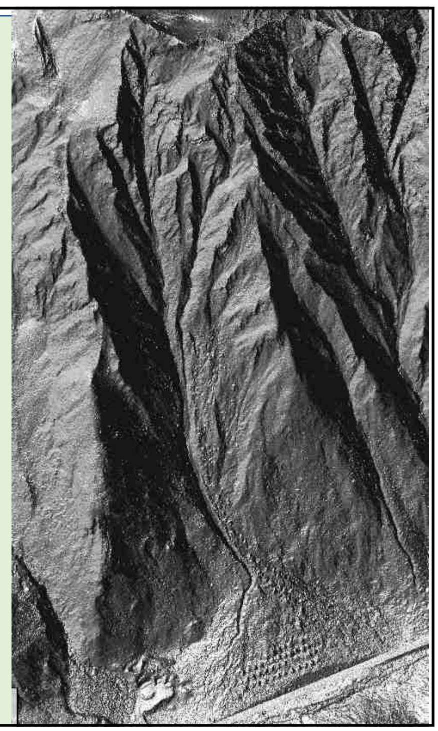
1. Characterization

- Terrain identification
- Avalanche characteristics
- Occurrence records
- Vegetation damage
- Snow climate
- Avalanche dynamic models
- Statistical runout estimation

Comments or questions?



LiDAR data courtesy Parks Canada. Processing by C. Argue

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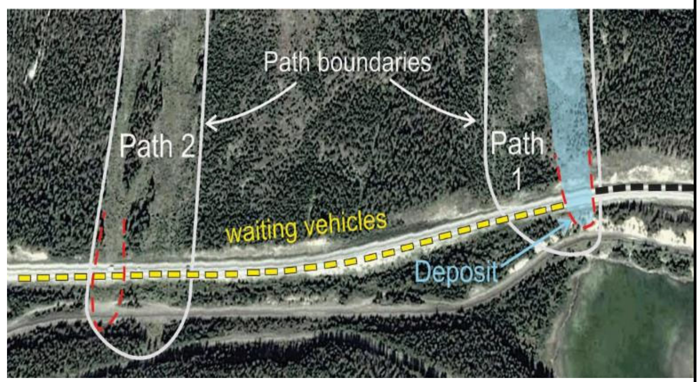
2. Assessment

- Combining the runout estimates
- Qualitative and quantitative assessment: Avalanche hazard and risk
- Avalanche hazard to roads from clear cuts
- Risk for transportation corridors



Google Earth image© 2017 Digital Globe.

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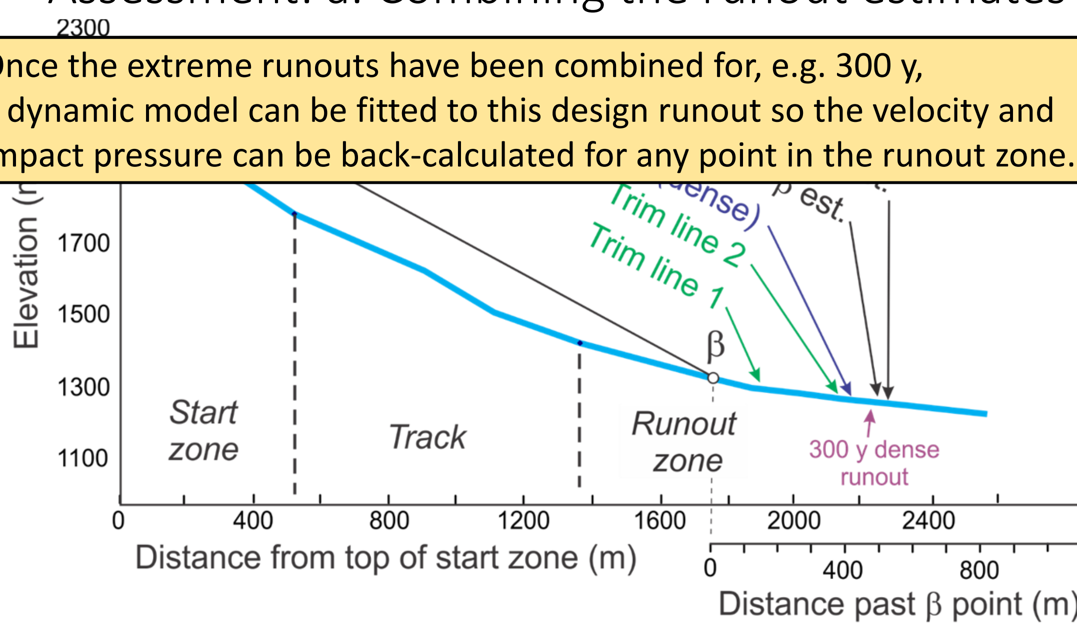
Assessment: a. Combining the runout estimates

Once the extreme runouts have been combined for, e.g. 300 y,
a dynamic model can be fitted to this design runout so the velocity and
impact pressure can be back-calculated for any point in the runout zone.



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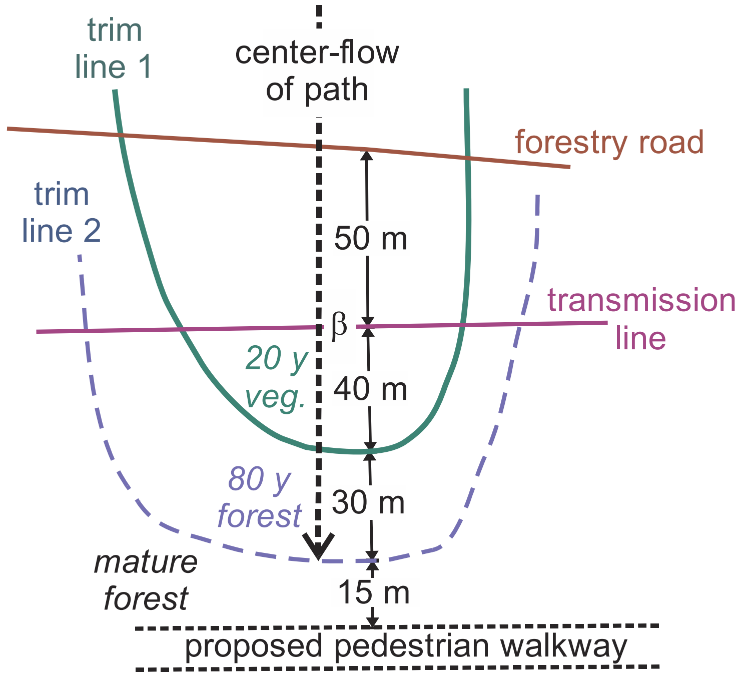

An example of
runout estimation using
occurrence records and
vegetation damage

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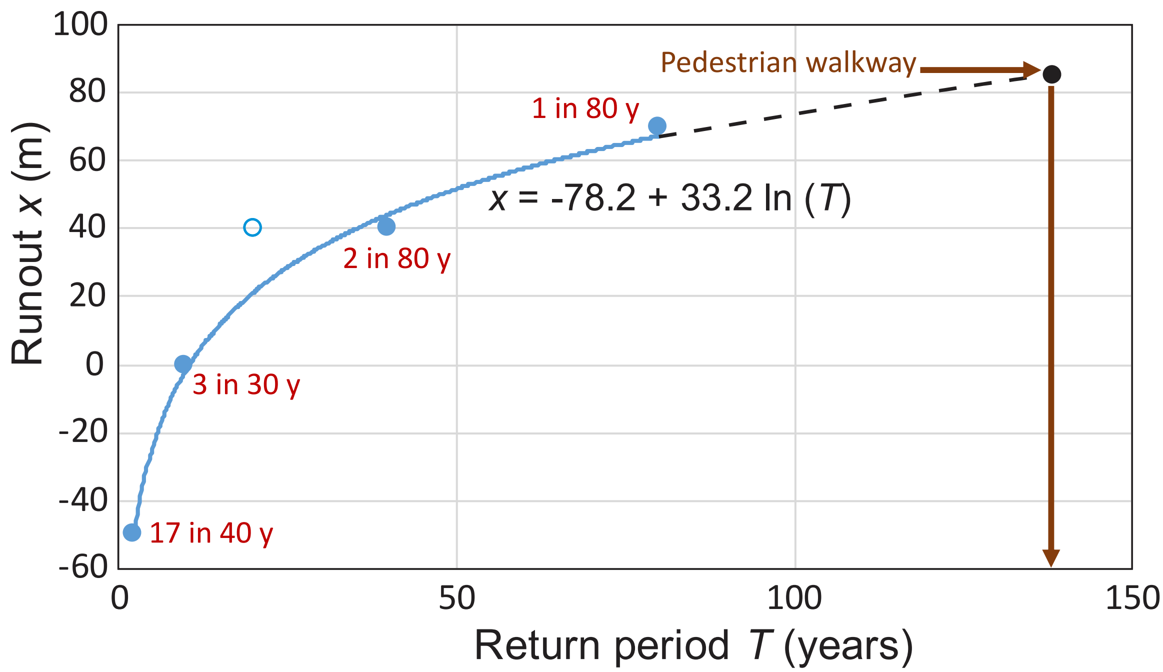

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Avalanche risk assessment is consistent with international landslide guidelines

Avalanche hazard

Frequency/ likelihood/ probability

Magnitude

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Example of qualitative hazard assessment

Hazard ratings for expected a
downslope transportation co
affected. After CAA (2002a).

Frequency range (avalanches per year)
1:10 to > 1
1:10 to 1:100
< 1:100

Chris Stethem photo

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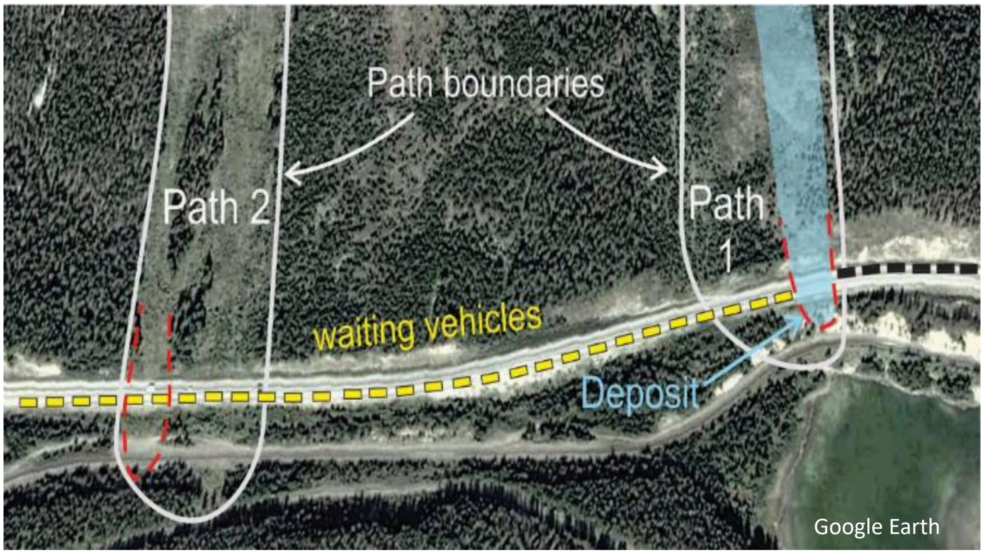
Quantitative assessment: Risk to transportation corridors: Moving and waiting traffic



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2. Assessment

- Combining the runout estimates (prior to back-calculating velocity & impact pressure)
- Qualitative and quantitative assessment: Avalanche hazard and risk
- Avalanche hazard from clear cuts. Risk for transportation corridors

Hazard ratings for expected avalanche size and frequency for forest harvest when downslope transportation corridors, facilities or essential resources may be affected. After CAA (2002a).

Frequency range (avalanches per year)	Average frequency (avalanches per year)	Avalanche destructive size		
		D2	D3	> D3
1:10 to > 1	1:3	Mod.	High	High
1:10 to 1:100	1:30	Low	**Mod.**	High
< 1:100	1:300	Low	Low	High

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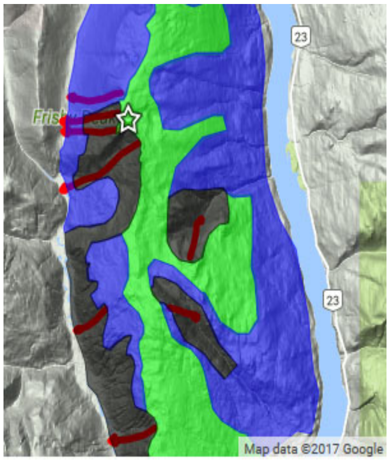
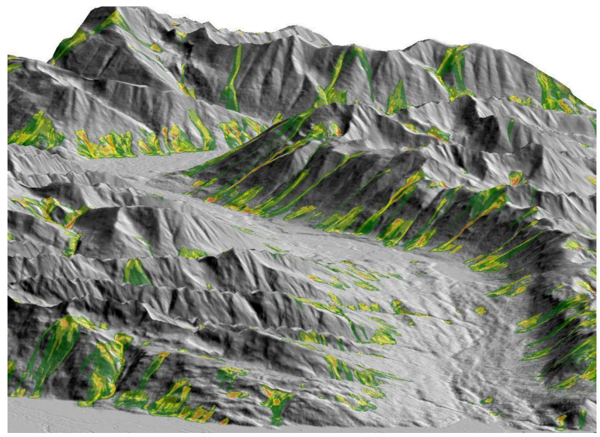
3. Mapping: Examples of avalanche maps

Exposure of workers



Model-based Large Scale Mapping



SLF Swiss Federal Institute for Snow and Avalanches

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Occupied Structures

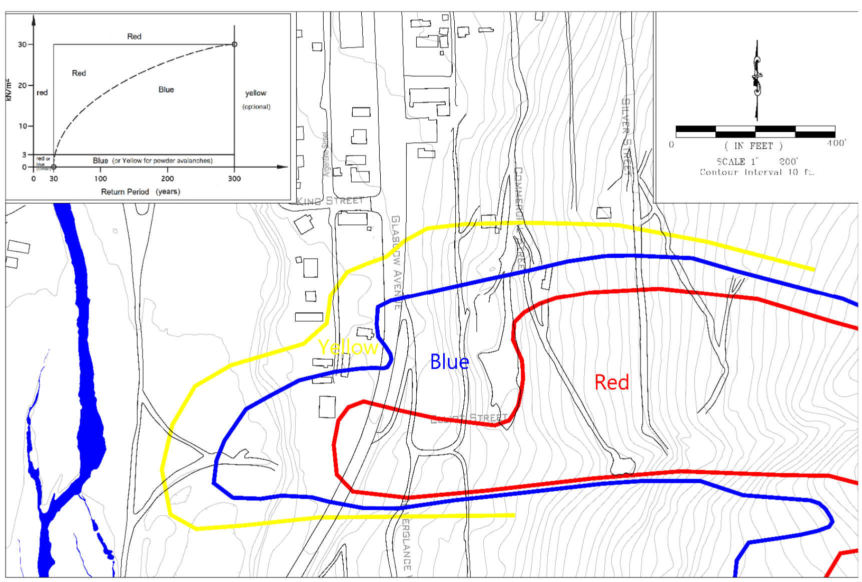
Avalanche Zones

Red (high) Hazard

Blue (moderate)

Yellow (low)

White (negligible)



Rico, Colorado

Wilbur Engineering, Inc.

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3. Mapping

- Hazard mapping for occupied structures
- Exposure mapping for backcountry workers

Comments or questions?

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4. Mitigation

- Avalanche impact
- Defense structures (start zone, runout zone)
- Structural design for avalanche impact
- Temporary measures:
  - Detection systems
    forecasting, closures, evacuations
  - explosive triggering including
    Remote Avalanche Control Systems

B. Jamieson photo

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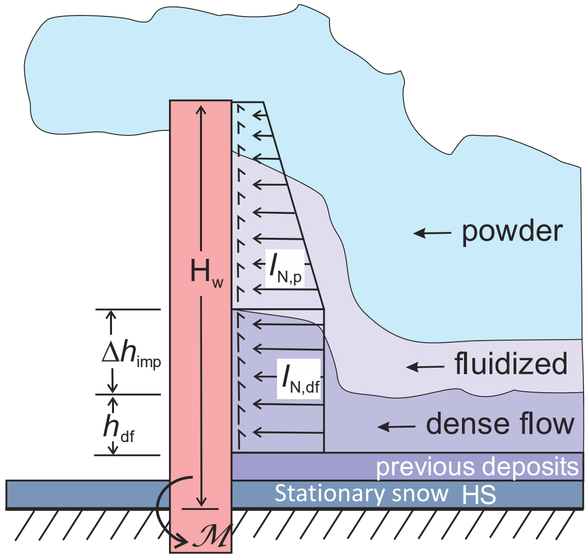
Mitigation: Avalanche impact

Sudavik, Iceland, 1995, 14 deaths
(also 1995: Flateryi, Iceland, 20 deaths)

B. Jamieson photo



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Mitigation: Defense structures

B. Jamieson photo

BC Ministry of Transportation and Infrastructure and S. Brushey.

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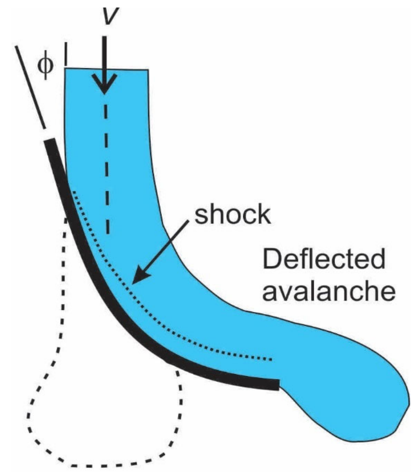
B. Jamieson photo



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B. Jamieson photo

Stopping Dam
Taconnaz, France


Splitting Wedge
Girdwood, Alaska

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C. Wilbur photo

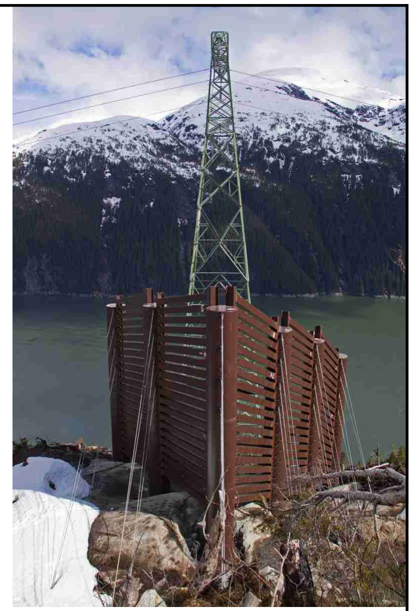

Photo courtesy B. Glude and Alaska Light & Power

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Ryan Buhler photo

Chris Wilbur photo

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Arni Jonsson photo

Towers designed for impact

If consequences of an outage are high
(e.g. aluminum smelter),
the transmission lines can be twinned.

Chris Wilbur photo

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Temporary measures

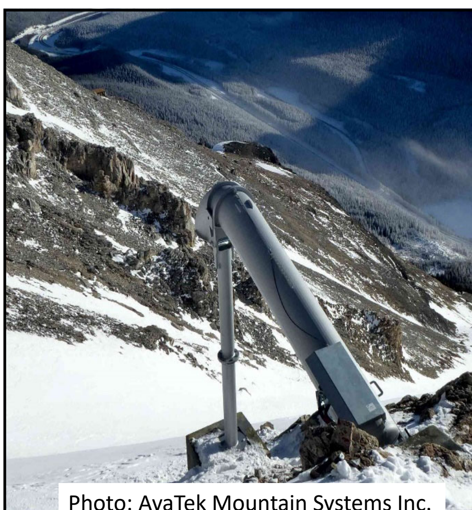

Photo: AvaTek Mountain Systems Inc.

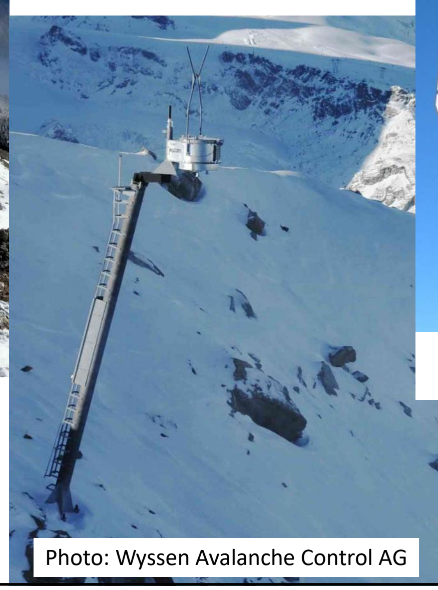

Photo: Wyssen Avalanche Control AG

Photo: BC Ministry of Transportation and Infrastructure

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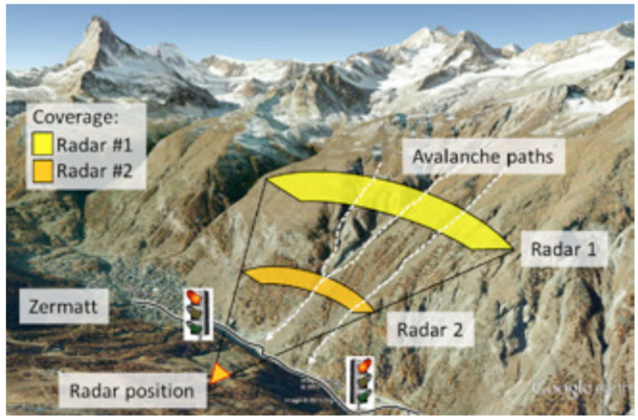
Detection

- ➢Infrasound
- ➢Radar
- ➢Seismic
- ➢Mechanical
- ➢Time lapse



Geopraevent image

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4. Mitigation

Comments or questions?

- Avalanche impact
- Defense structures (start zone, runout zone)
- Structural design for avalanche impact
- Temporary measures:
  - Detection systems
  - forecasting, closures, evacuations
  - Remote Avalanche Control Systems

B. Jamieson photo

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Case study: Kangiqsualujjuaq

B. Jamieson photos

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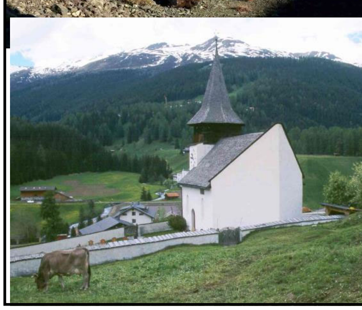
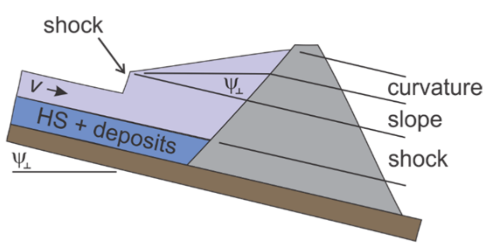
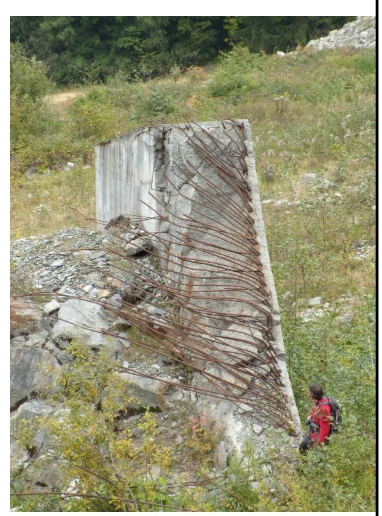
Snow avalanche risk assessment and mitigation



Questions and comments?





B. Jamieson photos

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