LANDSLIDE SUSCEPTIBILITY MAPS OF THE SEA TO SKY CORRIDOR, BRITISH COLUMBIA - A QUALITATIVE APPROACH

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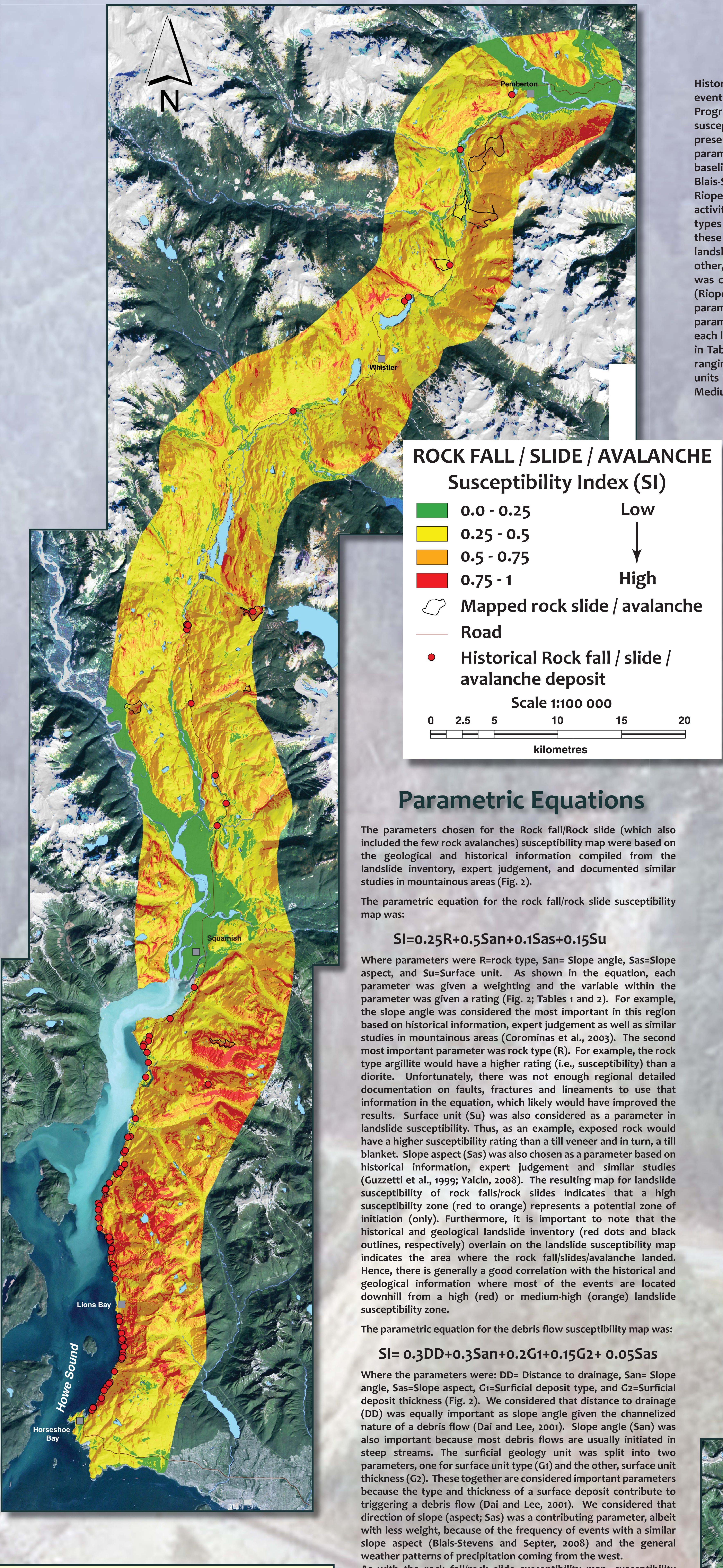
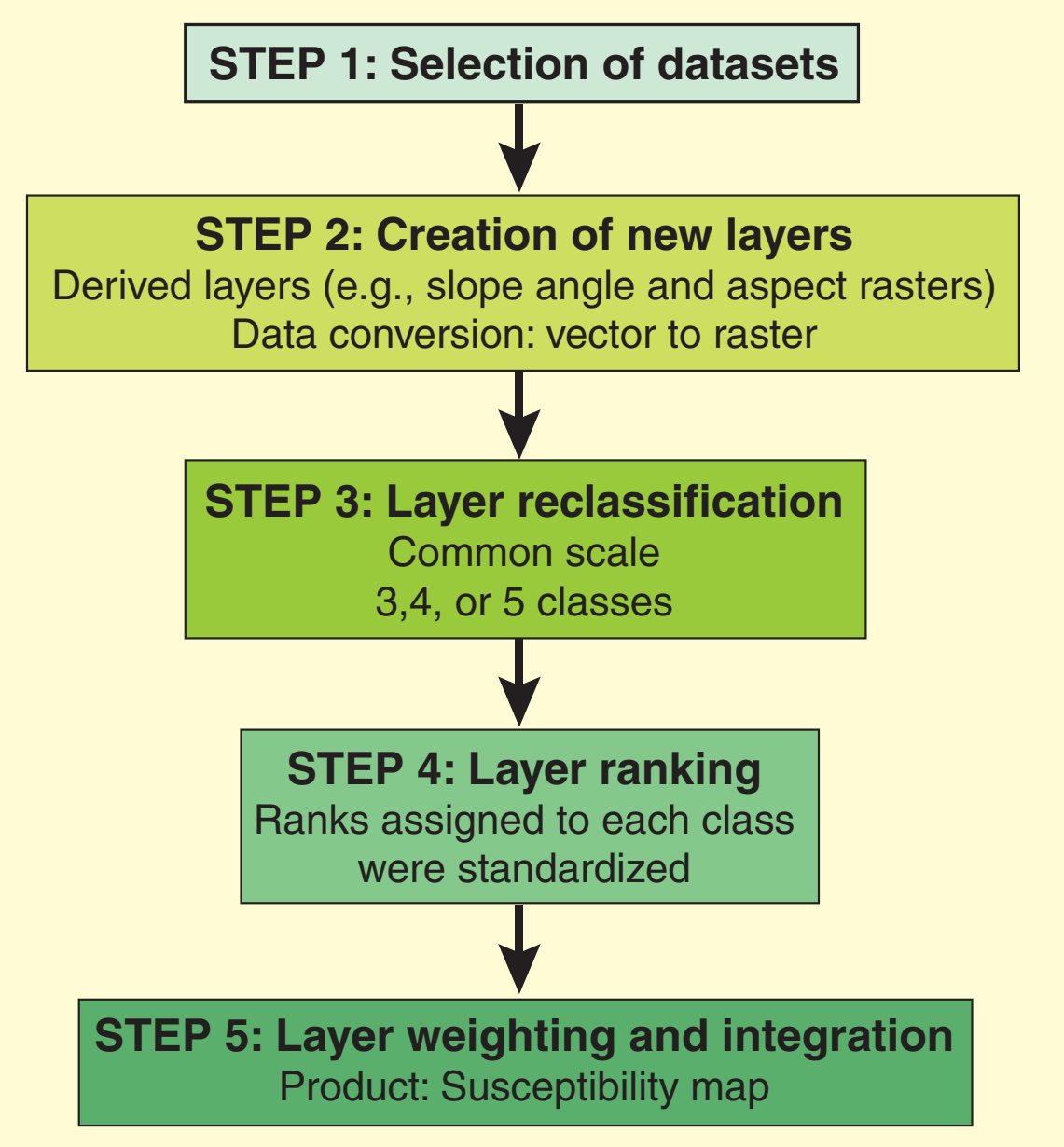


Abstract

Historically, the Sea to Sky Corridor has witnessed 155 reported landslide events in the last 154 years. As part of the Public Safety Geoscience Program at the Geological Survey of Canada, a preliminary landslide susceptibility mapping activity was undertaken. The resulting maps are presented as work-in-progress. The method used was a qualitative parametric approach based on the available landslide inventory and baseline information (Journeay and Monger, 1998; Riopel et al., 2006; Blais-Stevens, 2007; 2008abc; Blais-Stevens and Septer, 2008; Couture and Riopel, 2008). We divided the landslide susceptibility thematic mapping activity into producing two separate maps based on the more frequent types of landslides in the area and the fact that the parameters causing these types of landslides are very different from one another. One landslide susceptibility map was created for rock falls/rock slides and the other, for debris flows. In each map, a series of information layers (Fig. 1) was compiled from available documentation and/or derived from DEMs (Riopel et al., 2006; Couture and Riopel, 2008). From this information, a parametric equation was defined where the information layers served as parameters with each parameter being given a weight. The units within each layer of information were also given a rating (See examples of rating in Tables 1 and 2). The resulting equation gave a Susceptibility Index (SI) ranging between 0-1 for each (25 m x 25 m) pixel. For the final products, SI units were divided into four colour-coded categories, from Low (green), Medium-Low (yellow), Medium-High (orange), and High (red).



STEP 1: Selection of datasets

STEP 2: Creation of new layers
Derived layers (e.g., slope angle and aspect rasters)
Data conversion: vector to raster

STEP 3: Layer reclassification
Common scale
3,4, or 5 classes

STEP 4: Layer ranking
Ranks assigned to each class were standardized

STEP 5: Layer weighting and integration
Product: Susceptibility map

Figure 1. Steps in the parametric method for production of a landslide susceptibility map.

Parametric Equations

The parameters chosen for the Rock fall/Rock slide (which also included the few rock avalanches) susceptibility map were based on the geological and historical information compiled from the landslide inventory, expert judgement, and documented similar studies in mountainous areas (Fig. 2).

The parametric equation for the rock fall/rock slide susceptibility map was:

$$SI=0.25R+0.5San+0.1Sas+0.15Su$$

Where parameters were R=rock type, San= Slope angle, Sas=Slope aspect, and Su=Surface unit. As shown in the equation, each parameter was given a weighting and the variable within the parameter was given a rating (Fig. 2; Tables 1 and 2). For example, the slope angle was considered the most important in this region based on historical information, expert judgement as well as similar studies in mountainous areas (Corominas et al., 2003). The second most important parameter was rock type (R). For example, the rock type argillite would have a higher rating (i.e., susceptibility) than a diorite. Unfortunately, there was not enough regional detailed documentation on faults, fractures and lineaments to use that information in the equation, which likely would have improved the results. Surface unit (Su) was also considered as a parameter in landslide susceptibility. Thus, as an example, exposed rock would have a higher susceptibility rating than a till veneer and in turn, a till blanket. Slope aspect (Sas) was also chosen as a parameter based on historical information, expert judgement and similar studies (Guzzetti et al., 1999; Yalcin, 2008). The resulting map for landslide susceptibility of rock falls/rock slides indicates that a high susceptibility zone (red to orange) represents a potential zone of initiation (only). Furthermore, it is important to note that the historical and geological landslide inventory (red dots and black outlines, respectively) overlain on the landslide susceptibility map indicates the area where the rock fall/slides/avalanche landed. Hence, there is generally a good correlation with the historical and geological information where most of the events are located downhill from a high (red) or medium-high (orange) landslide susceptibility zone.

The parametric equation for the debris flow susceptibility map was:

$$SI= 0.3DD+0.3San+0.2G1+0.15G2+ 0.05Sas$$

Where the parameters were: DD= Distance to drainage, San= Slope angle, Sas=Slope aspect, G1=Surficial deposit type, and G2=Surficial deposit thickness (Fig. 2). We considered that distance to drainage (DD) was equally important as slope angle given the channelized nature of a debris flow (Dai and Lee, 2001). Slope angle (San) was also important because most debris flows are usually initiated in steep streams. The surficial geology unit was split into two parameters, one for surface unit type (G1) and the other, surface unit thickness (G2). These together are considered important parameters because the type and thickness of a surface deposit contribute to triggering a debris flow (Dai and Lee, 2001). We considered that direction of slope (aspect; Sas) was a contributing parameter, albeit with less weight, because of the frequency of events with a similar slope aspect (Blais-Stevens and Septer, 2008) and the general weather patterns of precipitation coming from the west.

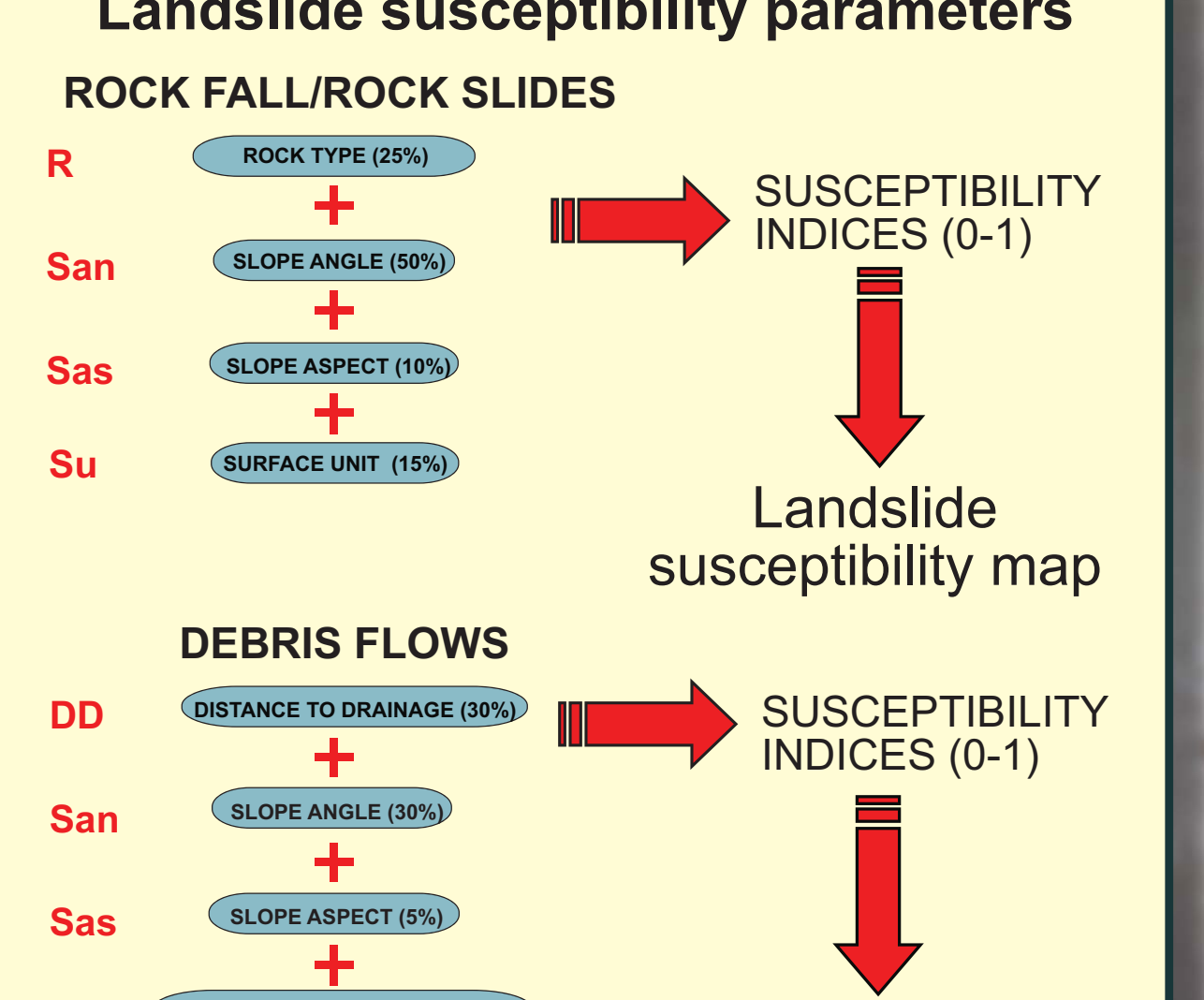
As with the rock fall/rock slide susceptibility map, susceptibility index ranges were overlain on a satellite image. The available historical and geological landslide inventories were then overlain (red dots and black outlines, respectively) on the landslide susceptibility map for correlation. It is important to note that the landslide susceptibility map displays zones of initiation (only) of areas that could be susceptible to debris flows. The historical and geological information of landslide events displays the location of the landslide deposit. Hence, there is generally a good correlation with the documented historical and geological occurrences being located downstream from high (red) to medium-high (orange) landslide susceptibility zones.

Slope angle (San) °	Class	Rating (0.1, 0.3, 0.7, 1)
0-15	L	0.1
>15-30	L-M	0.3
31-45	M-H	0.7
>45	H	1.0

Table 1. Slope angle class and rating.

Surface unit	Class	Rating (0, 0.5, 1)
Alluvium	L	0
Till veneer	M	0.5
Till blanket	L	0
Glaciofluvial/marine veneer	M	0.5
Glaciofluvial/marine	L	0
Colluvium veneer	M	0.5
Colluvium	L	0
Rock	H	1.0
Organics	L	0
Anthropogenic deposit	L	0

Table 2. Surface unit class and rating.



Landslide susceptibility parameters

ROCK FALL/ROCK SLIDES

R ROCK TYPE (25%)
+
San SLOPE ANGLE (50%)
+
Sas SLOPE ASPECT (10%)
+
Su SURFACE UNIT (15%)

→ SUSCEPTIBILITY INDICES (0-1) → Landslide susceptibility map

DEBRIS FLOWS

DD DISTANCE TO DRAINAGE (30%)
+
San SLOPE ANGLE (30%)
+
Sas SLOPE ASPECT (5%)
+
G1 SURFICIAL GEOLOGY UNIT (20%)
+
G2 SURFICIAL GEOLOGY THICKNESS (15%)

→ SUSCEPTIBILITY INDICES (0-1) → Landslide susceptibility map

Figure 2. Diagram showing the integration of each information layer as well as the weight given to each layer in the parametric equation for the production of rock fall/ rock slide and debris flow susceptibility maps.

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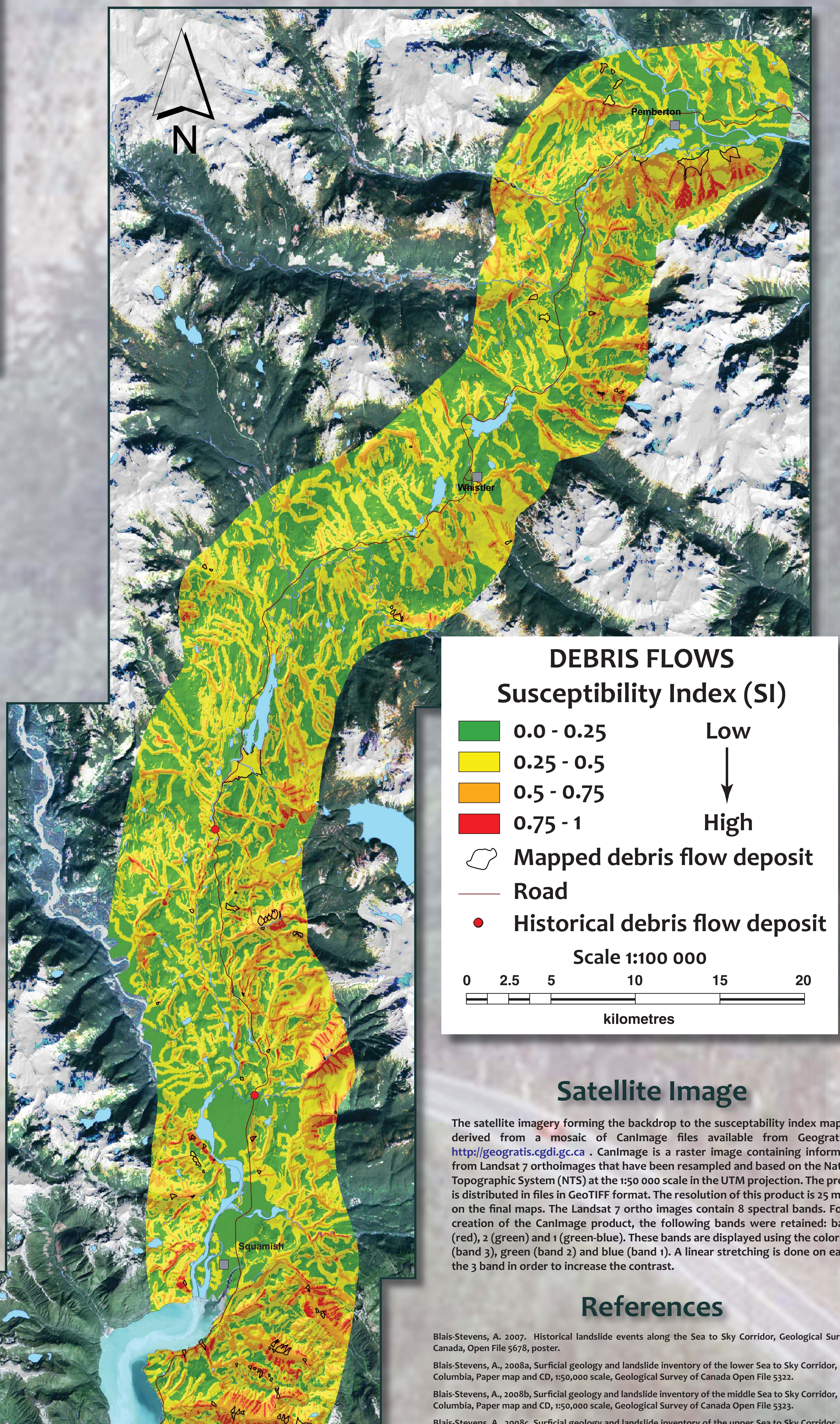

Satellite Image

The satellite imagery forming the backdrop to the susceptability index maps are derived from a mosaic of CanImage files available from Geogratis at http://geogratis.cgdi.gc.ca . CanImage is a raster image containing information from Landsat 7 orthoimages that have been resampled and based on the National Topographic System (NTS) at the 1:50 000 scale in the UTM projection. The product is distributed in files in GeoTIFF format. The resolution of this product is 25 metres on the final maps. The Landsat 7 ortho images contain 8 spectral bands. For the creation of the CanImage product, the following bands were retained: band 3 (red), 2 (green) and 1 (green-blue). These bands are displayed using the colors: red (band 3), green (band 2) and blue (band 1). A linear stretching is done on each of the 3 band in order to increase the contrast.

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