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Canada

Nazko Region Volcanic Hazard Map

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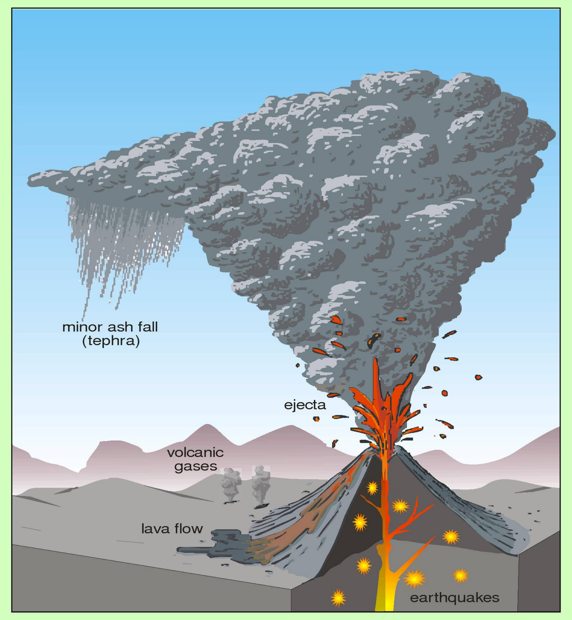

Figure 6. Hazards from a cinder cone eruption.

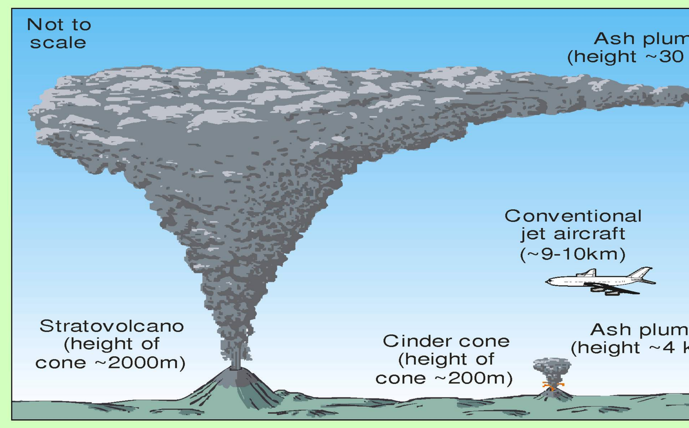

Figure 7. Relative heights of ash plumes from strato volcanoes and cinder cones relative to aircraft flight levels.

Nazko Earthquake Swarm October 2007 – May 2008

On Tuesday October 9, 2007, a swarm of small earthquakes commenced about 100 km west of Quesnel, British Columbia. This is the eastern end of the Anahim Volcanic Belt, which stretches from central BC to the coast. Volcanoes in the Anahim Belt get progressively younger eastward and include three large shield volcanoes and numerous small cinder cones, the youngest of which is probably Nazko Cone, 20 km from the earthquake swarm (Souther, 1986). Prior to this earthquake swarm, the eastern end of the Anahim Belt was seismically inactive. Eight microearthquakes of magnitude 2-3 occurred on October 10, and more than 1000 tremors of less than magnitude 2 occurred between early October and late November, when the earthquake frequency began to diminish. Since late December, there have been a few small earthquakes a month. All the earthquakes occurred at approximately 25 km beneath the earth's surface, or deeper.

In order to more easily pinpoint the location and depth of future tremors, Natural Resources Canada personnel installed additional seismic stations in the Nazko region (Figure 1). An infrasound station was installed to record low frequency sound waves below the threshold of human hearing. Carbon dioxide levels were also measured in the epicentral area (Inset Map 1). Carbon dioxide is commonly released along faults and fractures in volcanically active regions and may accumulate in soil or beneath snow, so elevated levels provide information about subsurface magmatic activity. However, all gas measurements were within the normal range, indicating no volcanic release of carbon dioxide.

Analysis of the seismic data suggested the earthquake swarm was caused by an intrusion of magma deep within the earth's crust. Similar sequences of events have occurred in other volcanic areas without being followed by eruptions. For example, in 2003, a swarm of deep (29-33 km) earthquakes was recorded beneath Lake Tahoe and attributed to magma (Smith et al., 2005).

Although the main Nazko earthquake swarm ended in late November 2007, the level of activity has not yet returned to normal. Intense seismic activity might again resume in the Nazko region, and be indicative of deep movement of magma, but it might also indicate the ascension of magma towards the surface. If the latter were to occur, it is anticipated that the size and number of earthquakes would increase significantly, providing a warning in the very unlikely event of an eruption. If an eruption were to occur, it would likely be a small cinder cone building event, similar to the most recent Nazko eruption about 7000 years ago. Given our present understanding of the seismicity, the volcanic vent would most likely be within a few kilometres of the epicentre of the earthquake swarm.

Background

Nazko Cone (Figure 3) is the youngest known volcano in the Anahim Volcanic Belt, and was first mapped by Souther et al. (1987). The first volcanism at Nazko Cone started about 340,000 years ago, with the eruption of a basaltic lava flow. This was followed by eruptions of basalt and breccia into glacial meltwater during the Fraser Glaciation (25,000-10,000 years ago). A final stage of eruption took place about 7200 years ago, after the disappearance of the continental ice sheet. This eruption involved the construction of a pyroclastic cone with three separate fountaining vents. Two separate streams of lava later breached this cone and were diverted around the north and south flanks of the central mound (Inset Map 1). Tephra associated with this final eruption was scattered to the north and east, in deposits up to 3 m thick near the cone and less than a few centimetres thick a few kilometres away (Inset Map 1; Figure 4). This limited distribution of volcanic ash suggests that the explosive fire fountaining phase was relatively brief. This last Nazko Cone eruption is probably a good analogue for what might happen if a new eruption were to occur in the vicinity of the earthquake swarm. Quarrying at Nazko Cone is ongoing, as the scoria is used as a lightweight aggregate, landscaping material, and agricultural soil additive (Figure 5). Outcrops of Chilcotin basalt assumed to be a few million years in age and a large post glacial lava flow of uncertain origin are also found in the area surrounding Nazko Cone.

Volcanic Hazards

Potential hazards posed by a volcanic eruption in the Nazko region (Figure 6) include volcanic ash (tephra), lava flows, lahars (volcanic mudflows), gas emissions, and minor steam explosions. Flooding may occur due to diversion of streams by lava flows. The most serious of these hazards is volcanic ash, because it can severely damage aircraft and other machinery and is commonly transported long distances. However, the style of eruption is expected to be "Hawaiian" (Figure 6), a low energy eruption that produces localized lava flows and ash plumes only a few hundreds of metres in height.

The hazard maps shown here are based on the premise that the eruption will occur close to the centre of the earthquake swarm. Given the spatial coincidence of spasmodic tremor (detected during the event) and volcano-tectonic earthquakes, this is the most likely scenario. Any escalation of earthquake activity, and any accompanying ground deformation or gas release will be closely monitored. Using all available tools, it should be possible to identify the eruption site more closely if the magma moves closer to the surface. When the eruption site is better known, new hazard maps and wind trajectories will be released based on the revised location.

Atmospheric winds have a strong influence on the movement of airborne volcanic ash and where ashfall is likely to take place if an eruption occurs. The circular patterns shown in Inset Map 1 show the distance that could be impacted by heavy ashfall and ballistic particles. The actual pattern on the ground will be influenced by the wind at the time of the eruption as is shown for Nazko Cone on Inset Map 2. During the eruption 7,200 years ago, wind carried the ash mostly to the north and east.

Winds can quickly change in time and space, and predicting correctly how they evolve over and near the volcano is a key part of determining the actual motion and eventual deposition of volcanic ash. To that end, the Meteorological Service of Canada uses winds predicted by a sophisticated numerical weather prediction model to feed a trajectory model and generate automatic, twice-daily updated low-level air / ash trajectory forecasts. In the event of an eruption, these would be used by Natural Resources Canada to determine regions or sectors around the volcano likely to be affected by ash over the next 12 to 24 hours. In some situations, rapid wind shifts take place near a volcano and dramatically alter the areas affected by ash over the course of a few hours. It is therefore important that the forecasts of winds and trajectories be updated twice daily. Inset Map 2 gives 4 examples of how the wind might behave near the cone. The lines depict how ash could be carried at elevations of 300, 900, and 1200 m above the cinder cone. The heights are typical of Hawaiian style eruptions and are well below the level of jet aircraft (Figure 7).

Tables A and B provides one year of wind strength data taken from the closest two weather stations to Nazko. The wind roses (Figures 9 and 11) show how often and how forcefully the wind blows in a given direction. The bar graphs (Figures 8 and 10) show the proportion of time the air is calm to windy. Note that the air is calm more than 60% of the time in Quesnel and more than 80% of the time at Puntzi Lake. These stations are a long way from the Nazko swarm, but they give an indication of what the local winds maybe like.

Lava flows, fire fountaining (the ejection of lava into the air), and noxious gases pose a threat only in the immediate vicinity of a volcanic vent, although they could ignite forest fires that could potentially spread great distances. Inset Map 1 shows the areas most likely to be affected by lava flows. The extent of the lava flow was determined using an estimation of the volume of the nearby postglacial flow, and local topographic variation in the vicinity of the likely eruption site. This probably represents the maximum volume. If the vent is not located near the seismic swarm centre, the area indicated by lava could vary significantly from that shown on the map. In addition, the interaction of hot volcanic materials with snow and loose wet sediment, or the disruption of rivers by volcanic materials, could cause lahars (volcanic mudflows) and flooding, both of which would affect areas downstream of the volcano tens of kilometres away. Small steam explosions and volcanic gas emissions (most commonly water vapour, carbon dioxide, or sulphur dioxide) could potentially occur in the vicinity of the vent.

References

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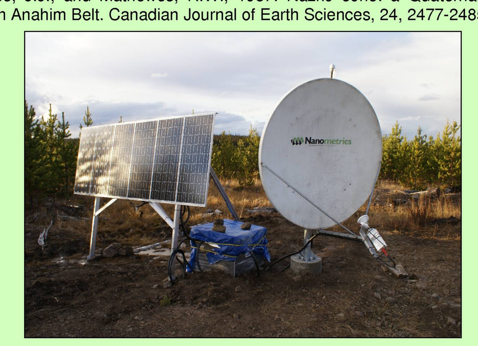


Figure 1. Seismic station near the epicentre of the 2007 Nazko region earthquake swarm.

Figure 2. Geologists taking carbon dioxide measurements in the area of the Nazko region earthquake swarm, November 2007.

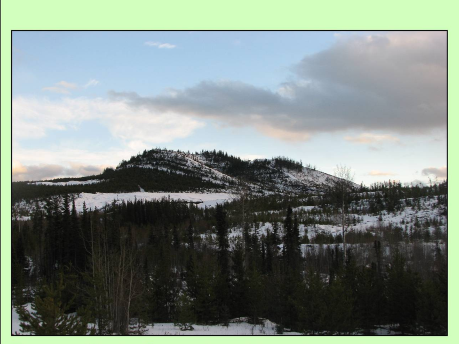


Figure 3. Nazko Cone, viewed from the north.

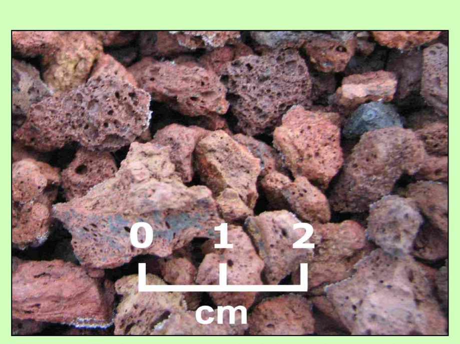


Figure 4. Tephra from postglacial eruptions at Nazko Cone.

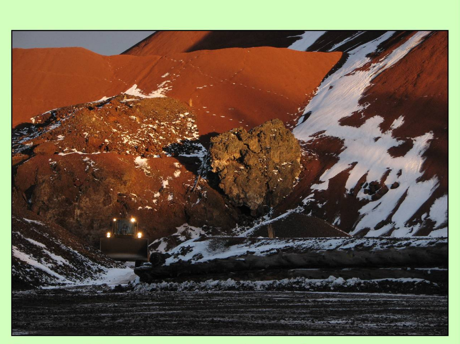
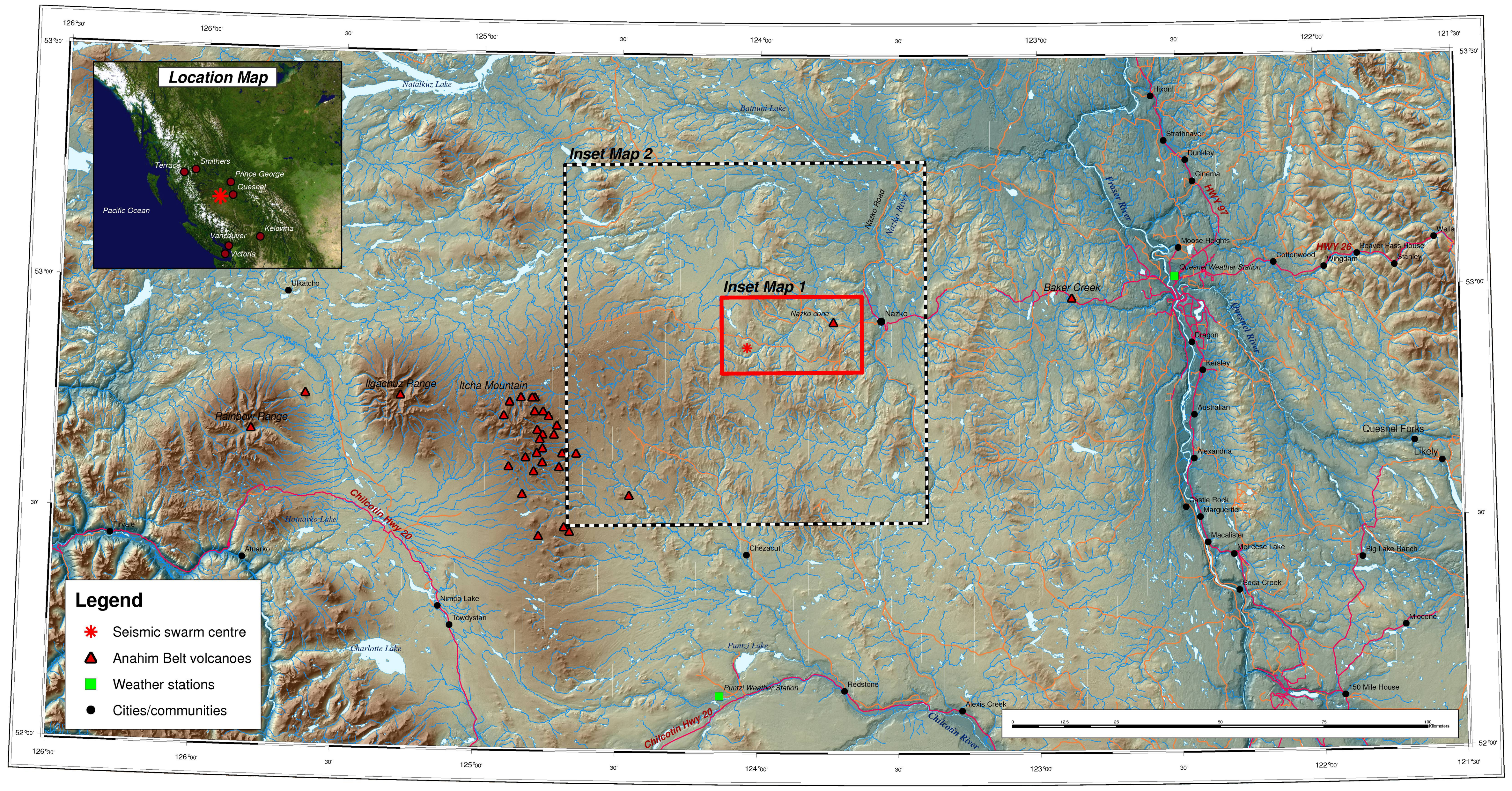
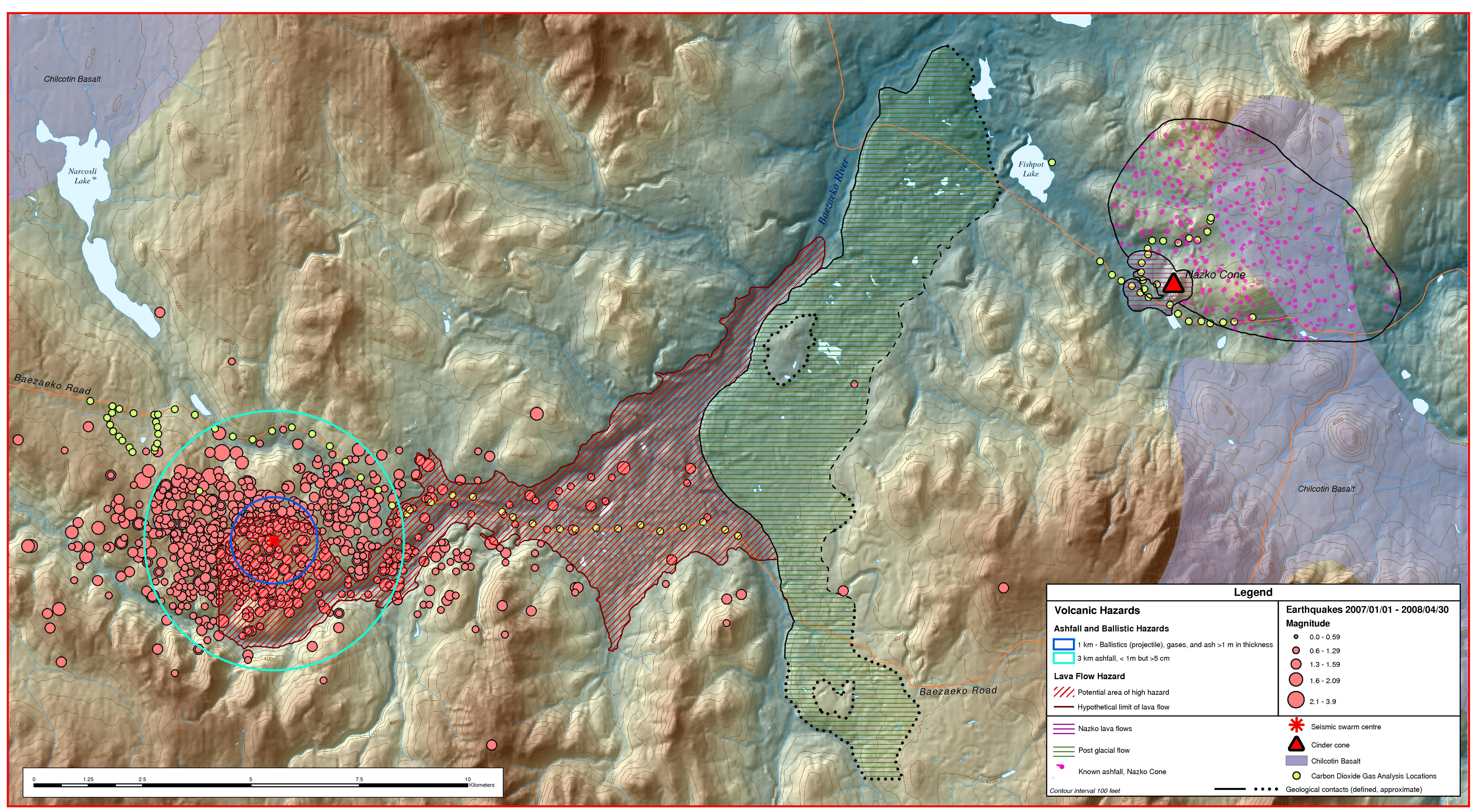


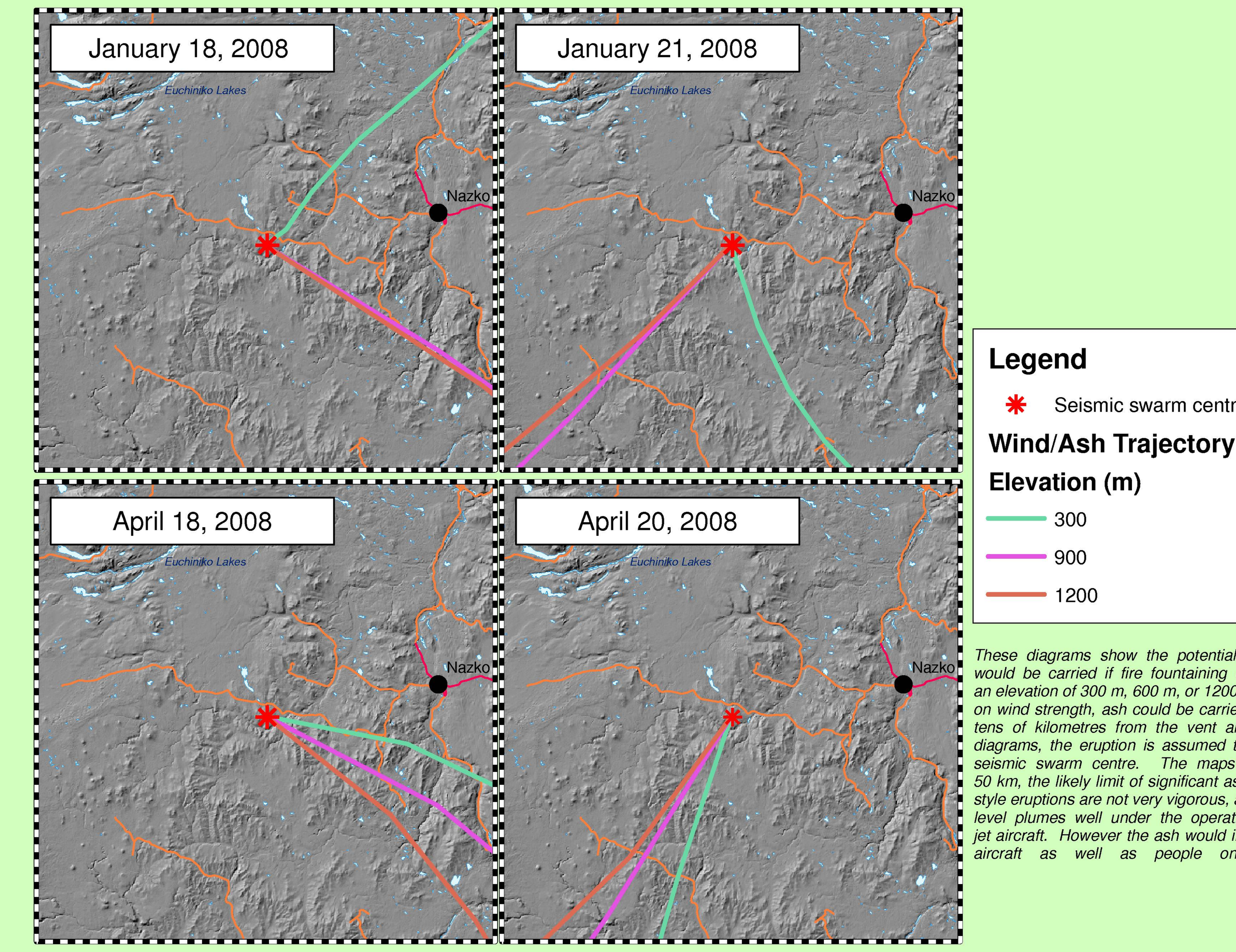
Figure 5. Mining of tephra at Nazko Cone.



Inset Map 1: Close Up Region of the Recent Nazko Seismic Activity

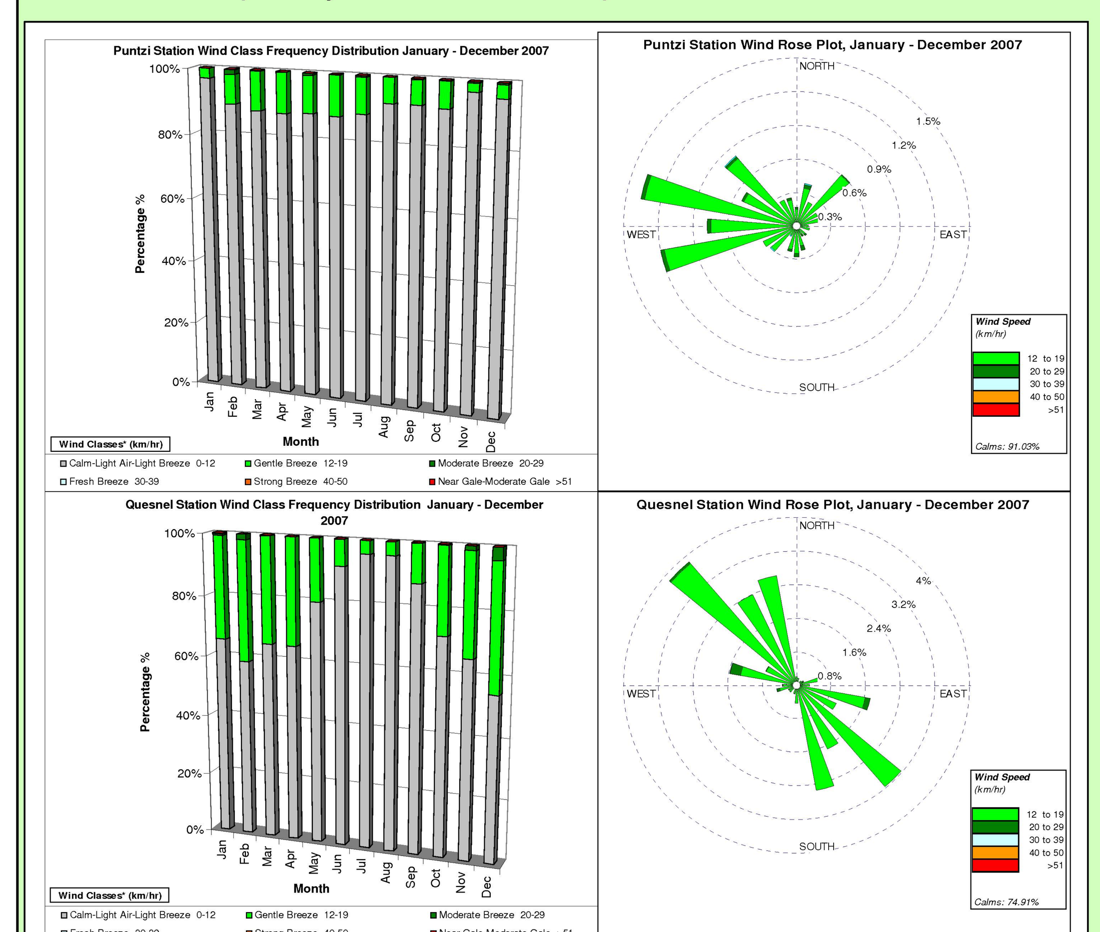


Inset Map 2: Examples of Possible Ash Trajectories
1:800 000, 50 km Range



These diagrams show the potential direction ash would be carried if fire fountaining ejected ash to an elevation of 300 m, 600 m, or 1200 m. Depending on wind strength, ash could be carried kilometres to tens of kilometres from the vent area. In these diagrams, the eruption is assumed to occur at the seismic swarm centre. The maps are cut off at 50 km, the likely limit of significant ashfall. Hawaiian style eruptions are not very vigorous, and produce low level plumes well under the operational levels of jet aircraft. However the ash would impact low flying aircraft as well as people on the ground.

Beaufort Scale Figures, 2007 Annual Wind Rose Plots and Frequency Distribution Graphs for the Puntzi and Quesnel Wind Stations



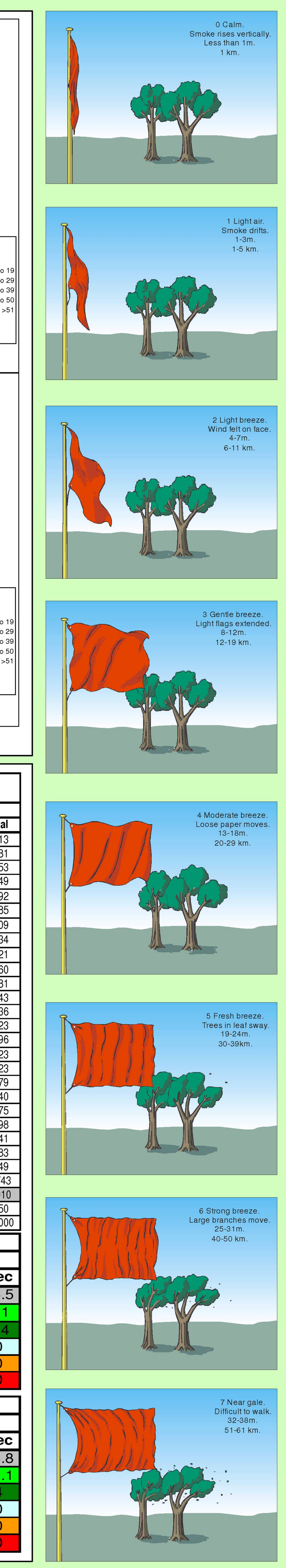


Table A: Puntzi Weather Station Frequency Distribution
January - December 2007

Compass Degrees	12 to 19	20 to 29	30 to 39	40 to 50	>51	Total
	Wind Classes (km/hr)					
352.5 - 7.5	0.151	0.022	0.000	0.000	0.000	0.172
7.5 - 22.5	0.345	0.032	0.011	0.000	0.000	0.388
22.5 - 37.5	0.237	0.000	0.000	0.000	0.000	0.237
37.5 - 52.5	0.593	0.011	0.000	0.000	0.000	0.603
52.5 - 67.5	0.205	0.000	0.000	0.000	0.000	0.205
67.5 - 82.5	0.205	0.000	0.000	0.000	0.000	0.205
82.5 - 97.5	0.108	0.000	0.000	0.000	0.000	0.108
97.5 - 112.5	0.119	0.000	0.000	0.000	0.000	0.119
112.5 - 127.5	0.032	0.000	0.000	0.000	0.000	0.032
127.5 - 142.5	0.097	0.022	0.000	0.000	0.000	0.119
142.5 - 157.5	0.086	0.022	0.000	0.000	0.000	0.108
157.5 - 172.5	0.183	0.043	0.000	0.000	0.000	0.226
172.5 - 187.5	0.248	0.032	0.000	0.000	0.000	0.280
187.5 - 202.5	0.215	0.022	0.000	0.000	0.000	0.237
202.5 - 217.5	0.097	0.000	0.011	0.000	0.000	0.108
217.5 - 232.5	0.291	0.000	0.011	0.000	0.000	0.302
232.5 - 247.5	0.323	0.000	0.000	0.000	0.000	0.323
247.5 - 262.5	1.164	0.032	0.000	0.000	0.000	1.196
262.5 - 277.5	0.743	0.032	0.000	0.000	0.000	0.776
277.5 - 292.5	1.336	0.032	0.000	0.000	0.000	1.368
292.5 - 307.5	0.506	0.022	0.000	0.000	0.000	0.528
307.5 - 322.5	0.786	0.022	0.011	0.000	0.000	0.819
322.5 - 337.5	0.259	0.000	0.000	0.000	0.000	0.259
337.5 - 352.5	0.237	0.022	0.000	0.000	0.000	0.259
Sub-Total	8.565	0.366	0.043	0.000	0.000	7.339
Calm Winds						74.430
Missing/Incomplete						18.230
Total						100.000

Table B: Quesnel Weather Station Frequency Distribution
January - December 2007

Compass Degrees	12 to 19	20 to 29	30 to 39	40 to 50	>51	Total
	Wind Classes (km/hr)					
352.5 - 7.5	0.213	0.000	0.000	0.000	0.000	0.213
7.5 - 22.5	0.181	0.000	0.000	0.000	0.000	0.181
22.5 - 37.5	0.053	0.000	0.000	0.000	0.000	0.053
37.5 - 52.5	0.149	0.000	0.000	0.000	0.000	0.149
52.5 - 67.5	0.149	0.043	0.000	0.000	0.000	0.192
67.5 - 82.5	0.521	0.064	0.000	0.000	0.000	0.585
82.5 - 97.5	0.309	0.000	0.000	0.000	0.000	0.309
97.5 - 112.5	1.617	0.117	0.000	0.000	0.000	1.734
112.5 - 127.5	1.021	0.000	0.000	0.000	0.000	1.021
127.5 - 142.5	3.160	0.000	0.000	0.000	0.000	3.160
142.5 - 157.5	1.681	0.000	0.000	0.000	0.000	1.681
157.5 - 172.5	2.543	0.000	0.000	0.000	0.000	2.543
172.5 - 187.5	0.436	0.000	0.000	0.000	0.000	0.436
187.5 - 202.5	0.213	0.011	0.000	0.000	0.000	0.223
202.5 - 217.5	0.064	0.021	0.011	0.000	0.000	0.096
217.5 - 232.5	0.213	0.011	0.000	0.000	0.000	0.223
232.5 - 247.5	0.202	0.021	0.000	0.000	0.000	0.223
247.5 - 262.5	0.404	0.064	0.011	0.000	0.000	0.479
262.5 - 277.5	0.319	0.021	0.000	0.000	0.000	0.340
277.5 - 292.5	1.319	0.245	0.011	0.000	0.000	1.575
292.5 - 307.5	0.777	0.021	0.000	0.000	0.000	0.798
307.5 - 322.5	3.788	0.053	0.000	0.000	0.000	3.841
322.5 - 337.5	2.383	0.000	0.000	0.000	0.000	2.383
337.5 - 352.5	2.649	0.000	0.000	0.000	0.000	2.649
Sub-Total	24.364	0.692	0.032	0.000	0.000	22.743
Calm Winds						67.910
Missing/Incomplete						9.350
Total						100.000

Table C: Puntzi Weather Station Monthly Wind Speed, January - December 2007

	Percentage %											
Wind Class (km/hr)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Calm-Light Air-Light Breeze 0-11	96.9	89.5	87.9	85.2	88	87.6	88.8	92.3	92.3	91.8	97	95.5
Gentle Breeze 12-19	2.9	8.9	12	12	11.4	12.3	11	7.7	7.4	8	2.6	4.1
Moderate Breeze 20-29	0	1.5	0	0	0.6	0.1	0.3	0	0.3	0.1	0.4	0.4
Fresh Breeze 20-39	0.1	0.1	0.1	0.1	0	0	0	0	0	0.1	0	0
Strong Breeze 40-50	0	0	0	0	0	0	0	0	0	0	0	0
Near Gale-Moderate Gale >51	0	0	0	0	0	0	0	0	0	0	0	0

Table D: Quesnel Weather Station Monthly Wind Speed, January - December 2007

	Percentage %											
Wind Class (km/hr)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Calm-Light Air-Light Breeze 0-11	65.5	58.6	65	65	79.8	91.4	95.8	95.7	87.6	71.9	65.4	54.8
Gentle Breeze 12-19	33.9	39.5	34.9	34.9	20.2	8.4	4.2	4.3	12.3	27.9	33.2	41.1
Moderate Breeze 20-29	0.4	1.8	0.1	0.1	0	0.1	0	0	0.1	0.3	1.4	4
Fresh Breeze 30-39	0.3	0	0	0	0	0	0	0	0	0	0	0
Strong Breeze 40-50	0	0	0	0	0	0	0	0	0	0	0	0
Near Gale-Moderate Gale >51	0	0	0	0	0	0	0	0	0	0	0	0

* Wind classes and description based on the Beaufort Scale to give users a visual clue to wind strength. Calm winds (0-11 km/hr) are not shown on the wind rose plots. For more information on the Beaufort Scale please visit: http://www.metoffice.gov.uk/weather/marine/guide/beaufortscale.html

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Geological Survey of Canada, Open File 5978, scale 1: 650 000.

Universal Transerve Mercator Projection
North American Datum 1983

Projection transverse universelle de Mercator
Système de reference géodésique nord-américain, 1983

Digital base map from data compiled by Geomatics Canada

Digital base map supplied by National Atlas Information Service (NAIS), Geomatics Canada, modified by ESS Info

Mean Magnetic declination 2008, 19º 16' E, decreasing 15.2' annually
Readings vary from 19º 24' E in the SW corner to 19º 60' E in the NE corner of the map

Elevations in metres above mean sea level

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