ARTHUR I. MEARS, P.E., INC.
Natural Hazards Consultants
555 County Road 16
Gunnison, Colorado 81230
Tel/Fax: 970-641-3236
artmears@rmii.com

November 4, 2003

Mr. Michael J. Miller
Stoney-Miller Consultants
14 Hughes, Suite B-101
Irvine, CA 92618

RE: Avalanche mitigation analysis, Tamarack Road Lots, Mammoth Lakes, CA

Dear Mr. Miller:

At your request, I have completed an avalanche-dynamics and mitigation analysis of your lot and Terry Plum's lot on Tamarack Road in Mammoth Lakes. Details of this analysis are attached. My analysis is based on lot locations shown in the grading plan by Triad/Holmes Assoc., dated "7/24/2003;" substantial changes to this plan may invalidate my results.

I have concluded the following:

a. Avalanches will stop on the road and/or on the access extension assuming the proposed southward extension of Tamarack Road and the additional 20-foot access extension are both completed as shown on the grading plan and that these surfaces will be kept free of snow;
b. Houses located east of the road and access extension will not require additional mitigation, assuming the Tamarack Road and access extension have both been cleared of snow at the time of the avalanche;
c. However, if it cannot be safely assumed that snow clearing has taken place before the avalanche, both houses will require mitigation through structural reinforcement of the uphill-facing (west surfaces), as discussed in "mitigation."

Please contact me if you have any questions.

Sincerely,

Arthur I. Mears

Arthur I. Mears, P.E. (CO)
Avalanche-control engineer

1 TERRAIN AND FIELD OBSERVATIONS

The site studied is shown on four photographs (Figures 1 – 4) which provide perspectives from different directions. The largest avalanches begin at elevations of approximately 8,195 – 8,230 feet, approximately 250 – 280 feet above and west of the proposed building locations. The primary avalanche hazard will result from dry slab avalanches which will be formed by snow deposited by strong west to southwest winds. The avalanche starting zones[1] will be located between and below distinct bedrock outcroppings (Figures 1 and 3).

Inspection of terrain configuration on the lower slope (above the proposed Tamarack Road extension) suggest avalanches reached this area in the past, possibly reaching to the building sites. This is further confirmed by a) starting zone slopes in excess of 35° (sufficiently steep for avalanche initiation), b) a history of avalanches in the area and c) avalanche impact damage to trees (Figures 2 and 4). However, field evidence for avalanches on the lower slope could not be found.

2 AVALANCHE DYNAMICS AND RUNOUT

Avalanches with return periods on the order of 100 years[2] (the "design-magnitude" avalanche) have been computed to assess the need and feasibility of mitigation. This "100-year" return period has previously been considered in Mammoth Lakes and is an order of magnitude estimate of the true return period, which may lie between 30 and 300 years, approximately.

Without the proposed Tamarack Road extension in place, design-magnitude avalanches will terminate approximately 70 feet west of the eastern edge of the Snowcreek Golf Course, as determined by analysis. This runout distance, and the associated speeds and impact pressure potentials at a building site have been computed through statistical analysis of a large database of avalanches that occurred in the Eastern Sierra Nevada and application of an avalanche-dynamics model. The procedure applied three steps as follows:

a. The runout distance (or stopping point) was determined by constructing a detailed slope profile, identifying the starting point and 10° point on the profile, and predicting the runout from a regression equation which was derived from historical data on Sierra avalanches.
b. Avalanche speeds along the profile were computed by fitting a 3-component, stochastic, avalanche-dynamics model to the avalanche profile; this model simulated speeds along the profile.

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[1] *Starting zone – Slopes generally in excess of 30° inclination, where avalanches start, accelerate and increase in mass.*
[2] *Return periods up to 300 years for the design-magnitude avalanche are considered in some United States jurisdictions and are commonly considered in Europe and Canada.*

c. Impact-pressure potential, P, was then computed by the relationship P = ρV^2, where ρ is flowing snow density (150 kg/m^3) and V is computed speed.

Some details of the terrain and avalanche-dynamics analyses are summarized graphically in appendices "A" through "H."

3 RESULTS

Because the dry-snow avalanches which occur during the design event achieve speeds of only 17 m/s (38 mph) or less on the steep slopes, even during design conditions, internal friction will be high and avalanches will stop quickly when encountering objects in their paths. The dynamic analysis indicates the Tamarack Road extension and cut-de-sac at the south end will stop the avalanche, *provided this road is plowed clear of snow at the time of the avalanche*. The approximately 20-foot wide access easement to "MCWD and emergency vehicles" shown on the Triad/Holmes map will also stop the avalanche *if it is also plowed clear of snow* when the avalanche occurs. This will therefore provide mitigation for the buildings.

However it is not prudent to assume the road will always be plowed during the extremely heavy and prolonged storms which could be associated with the design event. At these times snow plowing operations within Mammoth Lakes and Mono County will be an on-going process. Strong winds and drifting snow will quickly fill in the previously-plowed roadway. Furthermore, the extension of Tamarack Road is located within an avalanche area consequently working on the road might exposed equipment operators to unnecessarily high risk.

Given the limitations to road plowing discussed above, and considering the reasonable assumption that the road may not be plowed during a major storm, the proposed houses should be reinforced at the uphill-facing walls for avalanche impact loads.

4 MITIGATION – IMPACT LOADS

Figure 5 illustrates schematically the vertical distribution of loads on the uphill faces of the Miller and Plum houses. Impact loads decrease linearly with height from a maximum of 100 lbs/ft^2 at the base of the wall to zero at a height of 12 feet above grade. The final design loads might be somewhat different than those shown, depending on final building position and orientation with respect to avalanche direction. Because impact is proportional to the square of sine of the deflection angle, the impact pressure will decrease quickly with impact angle. For example, if a wall intercepted the avalanche at a 45° angle, the loads would be decreased to 50 lbs/ft^2.

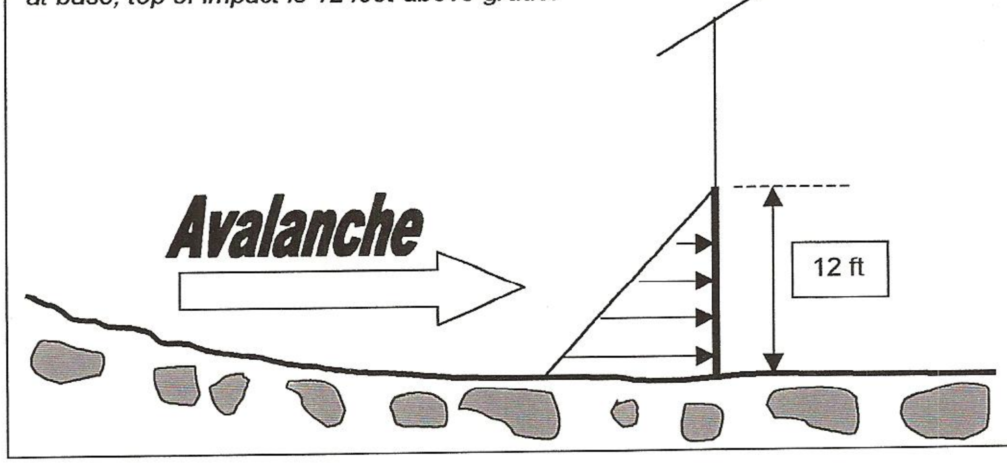
When designing avalanche mitigation into a building, the following additional factors must be considered:

a. Window and doors exposed to the avalanche should also be designed for avalanche impact;
b. Alternate entrances safe from avalanches should be planned;
c. Final loads may require adjustment by an impact factor;
d. Building orientation, shape, or other factors could change the loads;
e. Impact decreases linearly with height.

Report prepared by,

Arthur I. Mears, P.E. (CO)
Avalanche-control engineer

FIGURE 5. Reinforcement for avalanche impact loads, Miller and Plum residences, Mammoth Lakes. Impact pressure at base of triangle equals 100 psf at base; top of impact is 12 feet above grade.



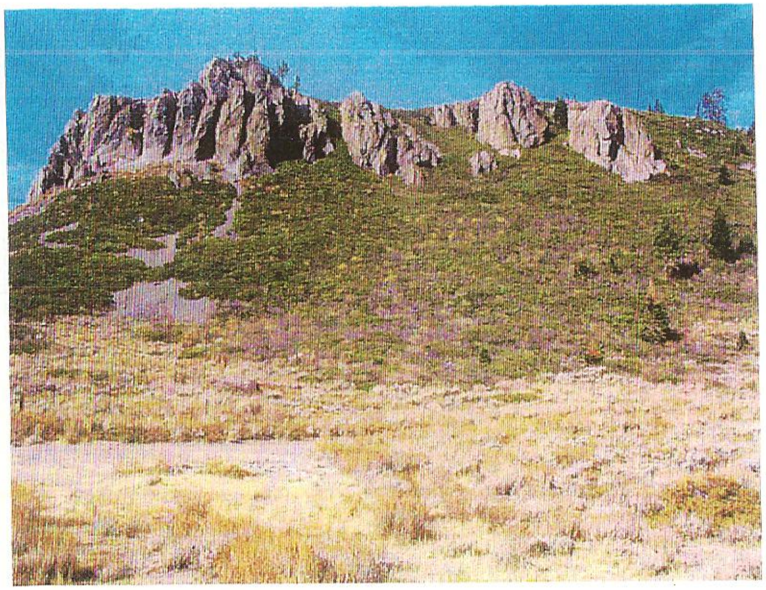


FIGURE 1. Largest avalanches begin between and below rock outcroppings; view is from building sites; view toward west.

FIGURE 2. View is looking east from starting zones to building sites and golf course.

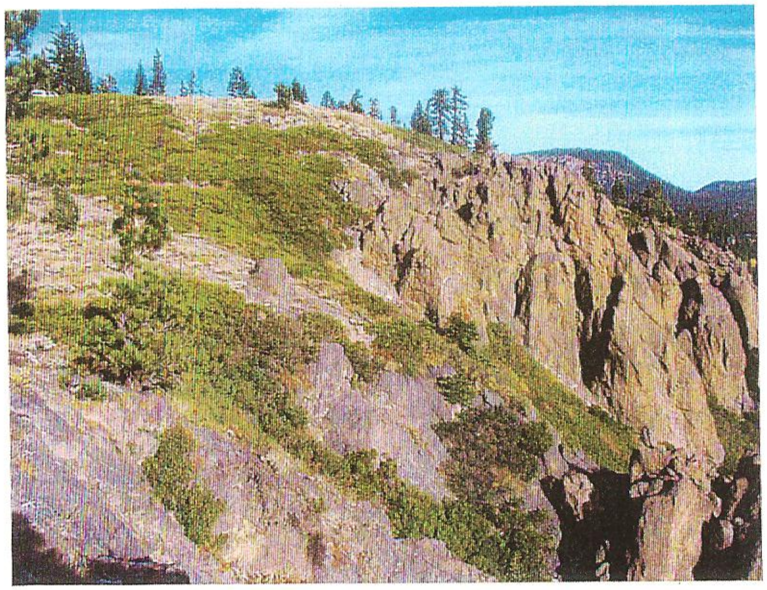


FIGURE 3. Blowing snow is transported from left to right into steep areas between and below rock outcroppings.

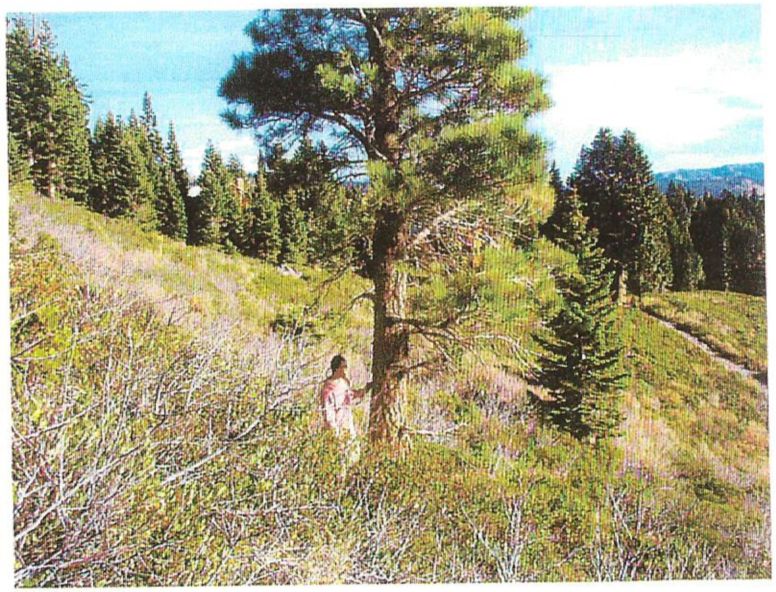
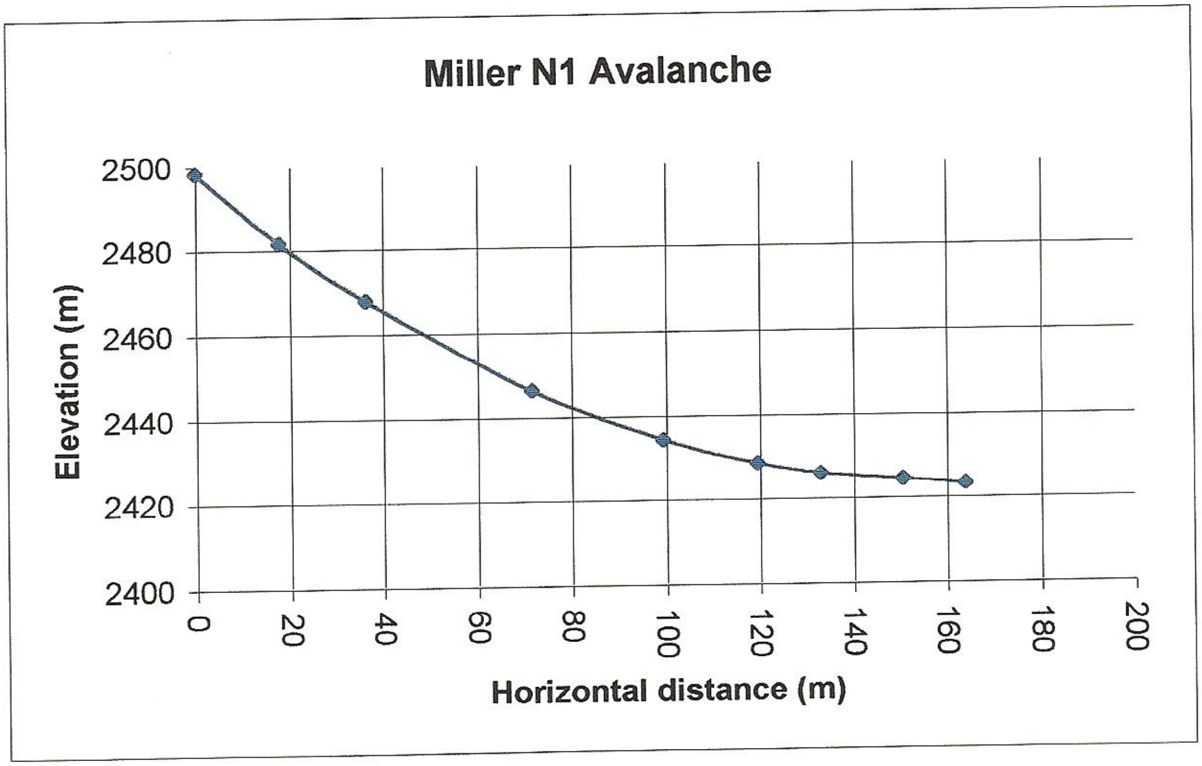


FIGURE 4. Conifer tree on slope a short distance above Tamarack Road extension has broken limbs which suggests avalanche impact

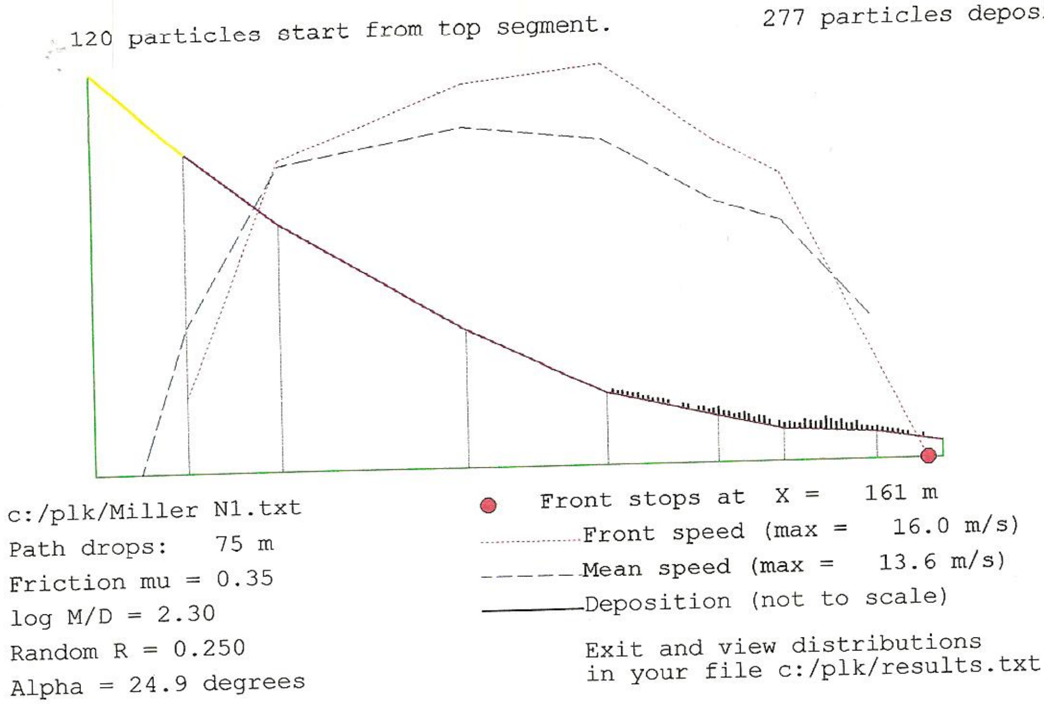
Avalanche Profile and x/y coordinates

Mike Miller N1

Raw Data in feet		Data in meters		Segment Data			
X-feet	Y-feet	X-meters	Y-meters	L-meters	Ang - Deg	Sum L	Avg Angle
0	8195	0	2498			0	
58	8140	18	2482	24	43.5	24	43.5
119	8095	36	2468	23	36.4	47	40.0
235	8025	72	2447	41	31.1	89	35.9
326	7985	99	2434	30	23.7	119	32.8
392	7966	120	2429	21	16.1	140	30.3
436	7958	133	2426	14	10.3	154	28.5
494	7953	151	2425	18	4.9	171	26.1
538	7949	164	2423	13	5.2	185	24.6



Appendix A. Slope profile used in avalanche dynamics analysis (above Miller, no new road)

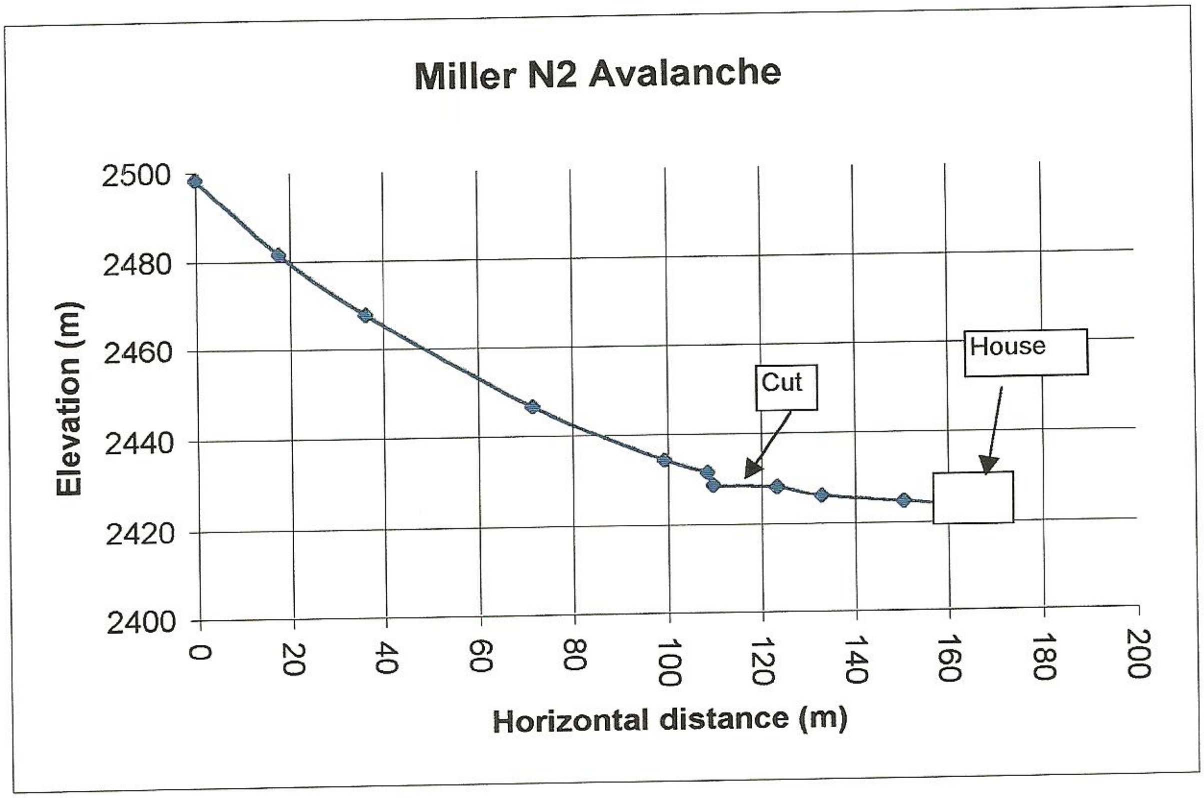


Appendix B. Dynamics graphical output, N1 avalanche.

Avalanche Profile and x/y coordinates

Mike Miller N2

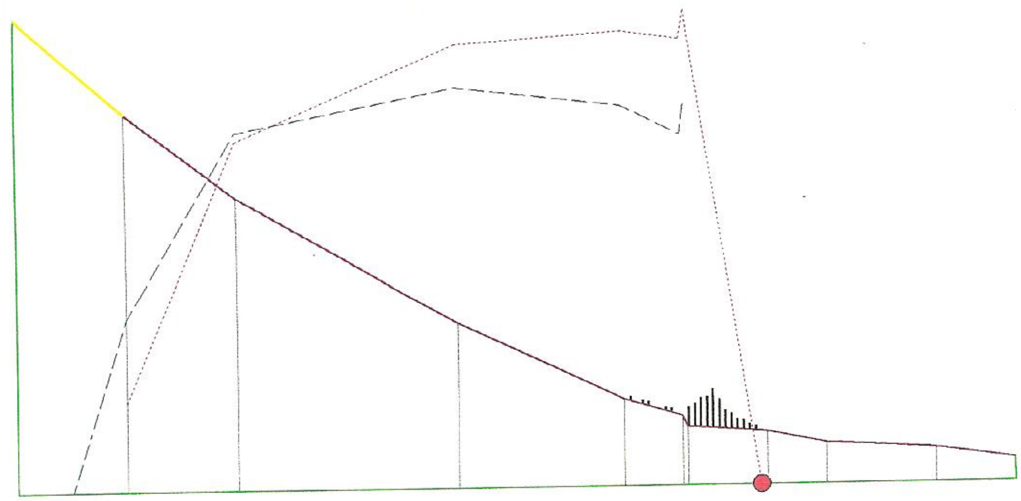
Raw Data in feet		**Data in meters**		**Segment Data**			
X-feet	Y-feet	X-meters	Y-meters	L-meters	Ang - Deg	Sum L	Avg Angle
0	8195	0	2498			0	
58	8140	18	2482	24	43.5	24	43.5
119	8095	36	2468	23	36.4	47	40.0
235	8025	72	2447	41	31.1	89	35.9
326	7985	99	2434	30	23.7	119	32.8
356	7975	109	2431	10	18.4	129	31.7
360	7966	110	2429	3	66.0	132	32.5
405	7964	123	2428	14	2.5	145	29.7
436	7958	133	2426	10	11.0	155	28.5
494	7953	151	2425	18	4.9	173	26.1
538	7949	164	2423	13	5.2	186	24.6



Appendix C. Slope profile used in avalanche-dynamics analysis (above Miller, new road in place)

120 particles start from top segment.

237 particles deposited.



c:/plk/Miller N2.txt

Path drops: 74 m

Friction mu = 0.35

log M/D = 2.30

Random R = 0.250

Alpha = 29.8 degrees

● Front stops at X = 121 m

.... Front speed (max = 16.0 m/s)

– – – – – – Mean speed (max = 13.5 m/s)

________ Deposition (not to scale)

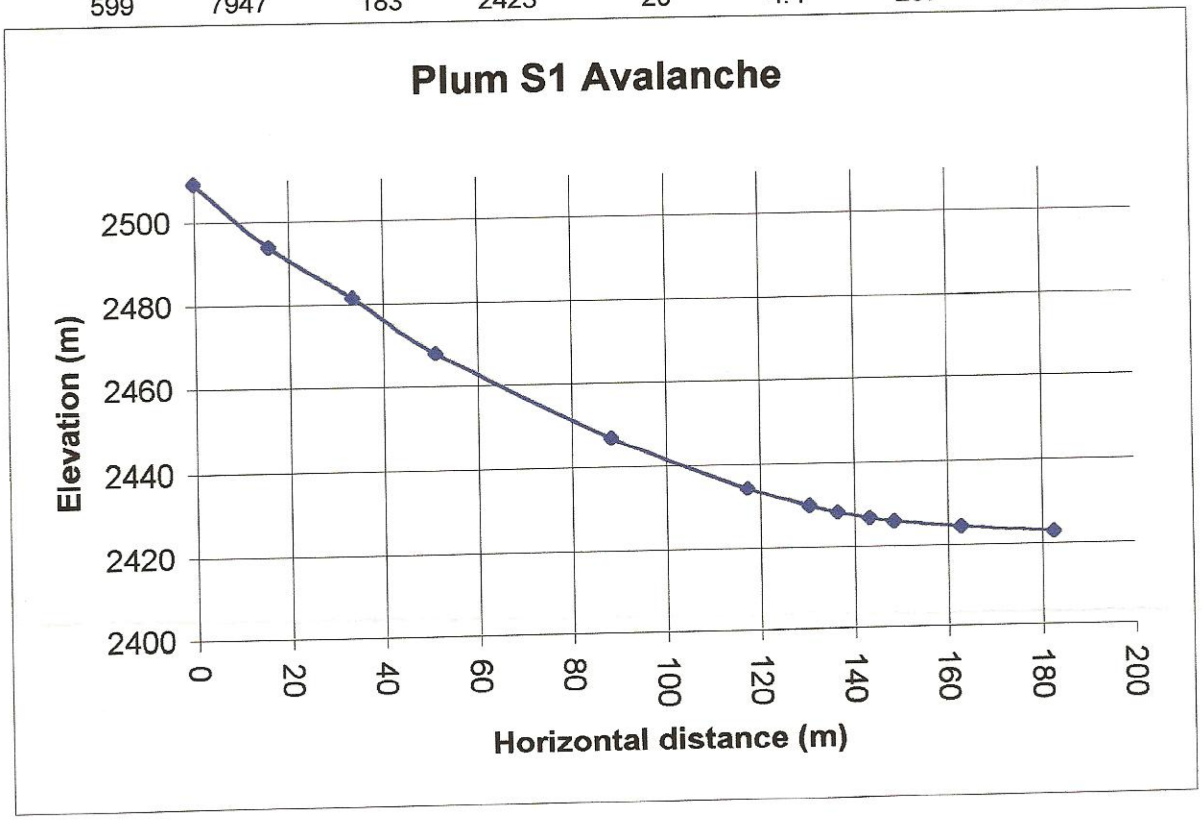
Exit and view distributions
in your file c:/plk/results.txt

Appendix D. Dynamics graphical output, N2 avalanche.

Avalanche Profile and x/y coordinates

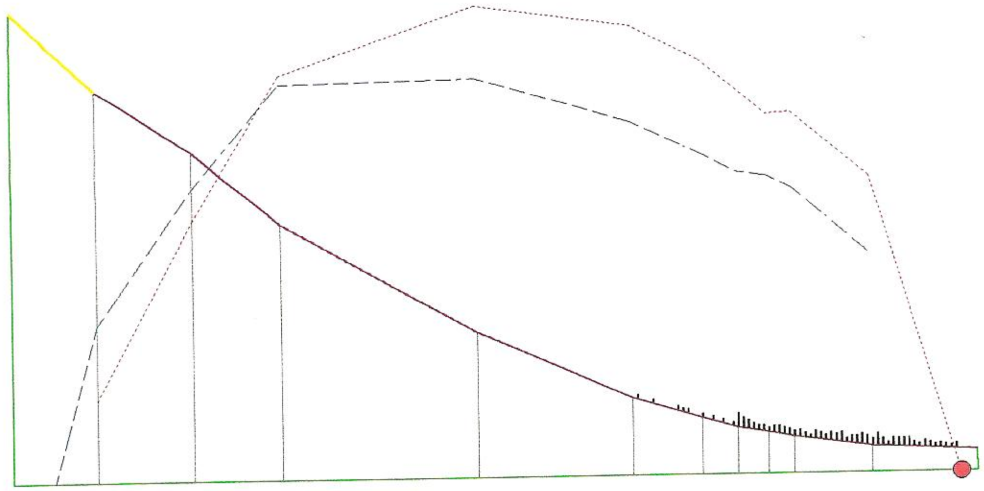
Terry Plum S1

Raw Data in feet		**Data in meters**		**Segment Data**			
X-feet	Y-feet	X-meters	Y-meters	L-meters	Ang - Deg	Sum L	Avg Angle
0	8230	0	2509			0	
52	8180	16	2494	22	43.9	22	43.9
110	8140	34	2482	21	34.6	43	39.3
168	8095	51	2468	22	37.8	66	38.8
290	8026	88	2447	43	29.5	109	35.1
385	7985	117	2434	32	23.3	140	32.5
428	7970	130	2430	14	19.2	154	31.3
448	7965	137	2428	6	14.0	160	30.6
470	7960	143	2427	7	12.8	167	29.9
487	7957	148	2426	5	10.0	172	29.3
534	7952	163	2424	14	6.1	187	27.5
599	7947	183	2423	20	4.4	207	25.3



109 particles start from top segment.

291 particles deposited.



c:/plk/Miller S1.txt

Path drops: 86 m

Friction mu = 0.35

log M/D = 2.30

Random R = 0.250

Alpha = 25.5 degrees

Front stops at X = 180 m

Front speed (max = 17.0 m/s)

Mean speed (max = 14.4 m/s)

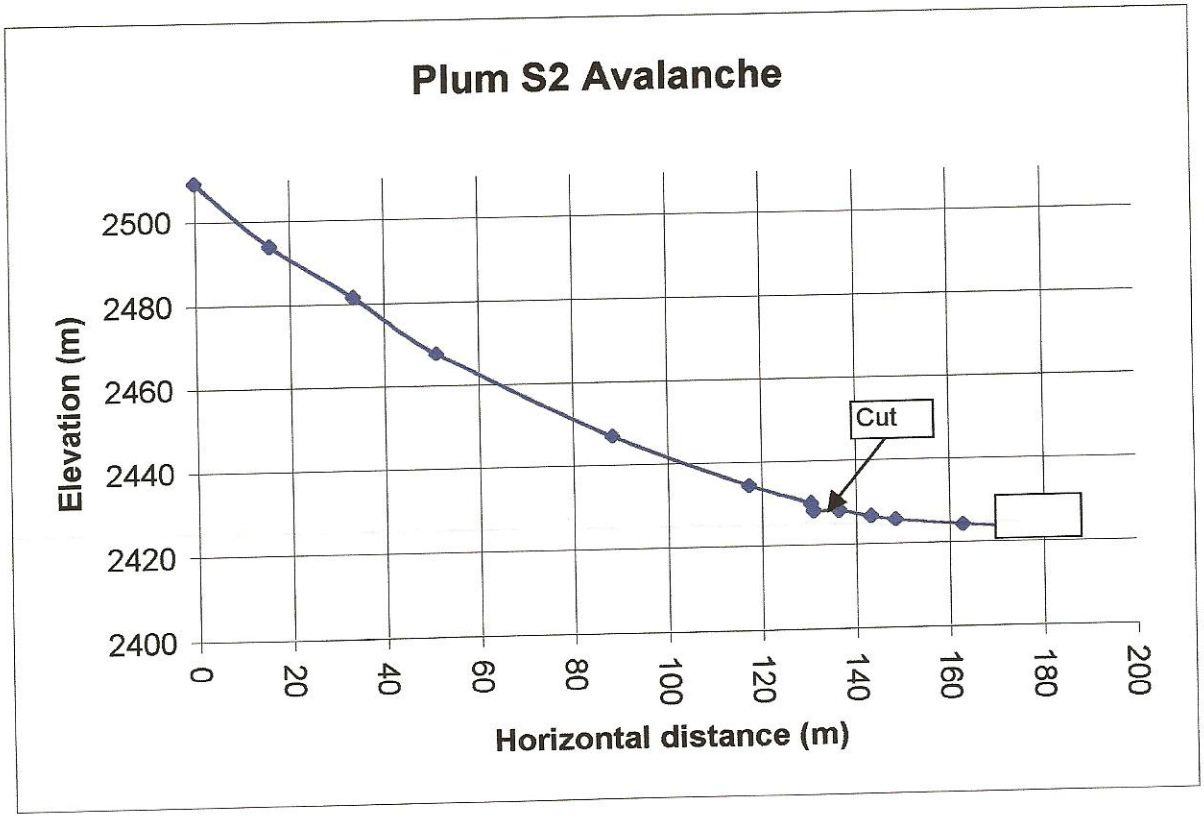
Deposition (not to scale)

Exit and view distributions
in your file c:/plk/results.txt

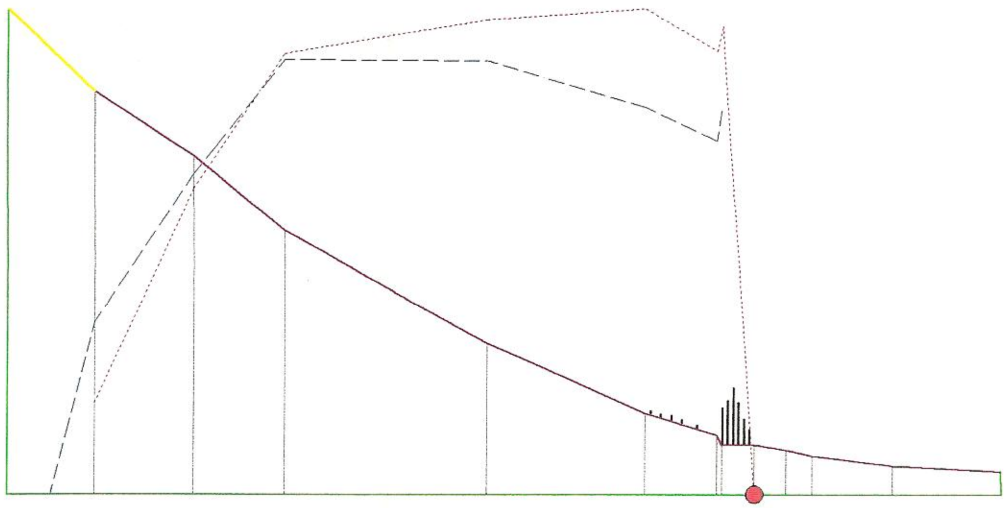
Appendix F. Dynamics graphical output S1 avalanche.

Avalanche Profile and x/y coordinates
Terry Plum S2

Raw Data in feet		Data in meters		Segment Data			
X-feet	Y-feet	X-meters	Y-meters	L-meters	Ang - Deg	Sum L	Avg Angle
0	8230	0	2509			0	
52	8180	16	2494	22	43.9	22	43.9
110	8140	34	2482	21	34.6	43	39.3
168	8095	51	2468	22	37.8	66	38.8
290	8026	88	2447	43	29.5	109	35.1
385	7985	117	2434	32	23.3	140	32.5
428	7970	130	2430	14	19.2	154	31.3
430	7965	131	2428	2	68.2	156	31.6
448	7965	137	2428	5	0.0	161	30.6
470	7960	143	2427	7	12.8	168	29.9
487	7957	148	2426	5	10.0	173	29.3
534	7952	163	2424	14	6.1	188	27.5
599	7947	183	2423	20	4.4	208	25.3



109 particles start from top segment.   247 particles deposited.



c:/plk/Miller S2.txt

Path drops: 86 m

Friction mu = 0.35

log M/D = 2.30

Random R = 0.250

Alpha = 30.5 degrees

● Front stops at X = 138 m

.... Front speed (max = 16.0 m/s)

_ _ _ _ Mean speed (max = 14.3 m/s)

________ Deposition (not to scale)

Exit and view distributions
in your file c:/plk/results.txt

Appendix H. Dynamics graphical output S2 avalanche.