VEÐURSTOFA ÍSLANDS

Report
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Tómas Jóhannesson
Þorsteinn Arnalds
Leah Tracy

Results of the 2D avalanche model SAMOS for Bolungarvík and Neskaupstaður

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BACKGROUND

The 2D avalanche model SAMOS, developed by the Advanced Simulation Technologies (AVL) of Graz, Austria, has been run for starting zones in the mountains above the villages Bolungarvík and Neskaupstaður. The runs are intended to shed light on the following aspects of the avalanche hazard situation in the villages:

1. The shortening of avalanche runout due to lateral spreading of avalanches. This is particularly relevant for the unconfined and partly convex slope below the main gullies in the upper part of the mountain above Bolungarvík and below the Urðarbotn area and the Brynjólfsbotnagjá gully in Neskaupstaður.
2. The difference in runout between avalanches from the main gullies due to the different sizes of the starting zones and different degree of lateral spreading.
3. The direction of the main avalanche tongues from the gullies.
4. The shape of the main avalanche tongues from the gullies.

The results of the runs will be used in the delineation of the hazard zones for the villages. The results for Bolungarvík will also be used in the ongoing work to design avalanche protection measures for the western part of the village (Hnit and NGI, 1999; Orion, Verkfræðistofa Austurlands and NGI, 1999). The results for Neskaupstaður will similarly be used in future work to design avalanche protection measures for the village (VST and Cemagref, 1998a,b).

The SAMOS model was developed for the Austrian Avalanche and Torrent Research Institute in Innsbruck by AVL and has recently been taken into operational use in some district offices of the Austrian Foresttechnical Service in Avalanche and Torrent Control. The model is based on similar assumptions regarding avalanche dynamics as other depth integrated 2D avalanche models that are used in Switzerland and France. Friction in the dense flow part of the model is assumed to be composed of a Coulomb friction term proportional to a coefficient $\mu = \tan(\delta)$ with $\delta = 16.0°$ ($\mu = 0.287$) and a turbulent friction term which may be represented by a coefficient $\xi = 446\,\mathrm{m}^2/\mathrm{s}$ (Sampl, personal communication). Rather than adding the two friction components as is done in the Swiss and French 2D models, the SAMOS model uses the maximum of the two friction terms and ignores the smaller term. This leads to slightly higher modelled velocities than for the Swiss and French 2D models for avalanches with similar runout. The velocities are, also, somewhat higher than corresponding velocities in the same path from the Swiss AVAL-1D model or the PCM model (Sauermoser, personal communication). The model runs are, furthermore, based on an assumed value $\rho = 200\,\mathrm{kg/m}^3$ for the density of flowing snow. The density is used to convert a given mass of snow in the starting zone to a corresponding volume or depth perpendicular to the terrain of the snow that is released at the start of the simulation.

MODELING OF AVALANCHE AT FLATEYRI ON 26.10.1995

The SAMOS model has not been used to model Icelandic avalanches before. The model was run for the catastrophic avalanche from Skollahvilft at Flateyri on 26 October 1995 (fig. 1) in order to check the applicability of the parameter values that are traditionally adopted for the model in Austria when the model is for the first time applied to Icelandic avalanches. The values for μ, ξ and ρ listed above were used. About 90,000 tons of snow were released from the starting zone between about 400 and 640 m a.s.l. based on measurements of the mass of the deposit of the avalanche and observations of the fracture height and density of the snow at the fracture line. The starting zone was divided into an upper and a lower area with a larger snow depth in the upper area. The run was defined by the following input data:

Input	Value
Map area of upper starting zone ($10^3 m^2$)	58
Map area of lower starting zone ($10^3 m^2$)	52
Total map area of starting zone ($10^3 m^2$)	110
Area of upper starting zone ($10^3 m^2$)	73
Area of lower starting zone ($10^3 m^2$)	63
Total area of starting zone ($10^3 m^2$)	136
Snow depth, upper area (d_u, m, $\rho = 200\,kg/m^3$)	4.3
Snow depth, lower area (d_l, m, $\rho = 200\,kg/m^3$)	2.0
Snow depth, average (m)	3.25
Mass ($10^3 t$)	89
Volume ($10^3 m^3$, $\rho = 200\,kg/m^3$)	440
Volume ($10^3 m^3$, $\rho = 350\,kg/m^3$)	220
Volume ($10^3 m^3$, $\rho = 420\,kg/m^3$)	210

The snow depth in the table is defined perpendicular to the terrain. The above values of the snow depth in the two subareas correspond to an average of 3.25 m with a density $\rho = 200\,kg/m^3$ over the whole starting zone or 1.85 m with a density $\rho = 350\,kg/m^3$. This higher value of the density may be assumed to have been close to the density of the snow in the fracture line before the release of the avalanche. The average density of the snow in the deposit in 1995 was close to $\rho = 420\,kg/m^3$.

No entrainment was specified and therefore the total mass of the avalanche in the model is smaller than for the real avalanche. This is typical in avalanche models of this kind.

The results of a run of the dense flow model for Flateyri with the above specification of input parameters are displayed as coloured contour plots of the depth and velocity of the flowing avalanche at 10 s intervals (file fl.ppt on the attached CD). The modelled location and geometry of the deposit at the end of the run (denoted as "h6") is in a fair agreement with the outlines of the 1995 avalanche (fig. 1). The eastward margin of the deposit is close to the buildings at Sólbakki in a good agreement with the observed outline of the avalanche. The western margin extends slightly further to the west than the observed outline. This may be caused by the retarding effect of the buildings in the village on the runout of the avalanche, but it could also be caused by slightly too high modelled velocities as the avalanche flows out of the gully at about 200 m a.s.l. The outline to the east of the gully at about 300 m a.s.l. seems to be too high and too far from the centerline of the gully compared with the measured outline, indicating too high velocities at that location of the path. The maximum velocity of the avalanche below the Skollahvilft gully is close to 60 m/s, which is higher than obtained with the Swiss 2D model for the 1995 avalanche (about 45 m/s). The channelization of the avalanche as it flows into the gully and the direction of the avalanche out of the gully seem to be well modelled.

A coupled dense flow/powder flow simulation was also made for the 1995 avalanche from Skollahvilft using a rather high grain size parameter (2 mm) which leads to a comparatively little transfer of snow into the powder part of the avalanche. This is believed to be appropriate for Icelandic conditions. The results for the dense core of the coupled dense flow/powder flow model were essentially the same as for the previously described run with dense core model. Maximum powder pressures reached about 10 kPa in the gully at 2.5 m above the avalanche and 2-3 kPa in the uppermost part of the village.

It was concluded from the runs for Flateyri that the same input parameters can be used for the SAMOS model for Icelandic conditions as are traditionally used in Austria. The dense core model can be used without the powder part for modeling the dense core of avalanches without this leading to significant changes in the model results. The model appears to take the effect of the geometry of the avalanche path on the flow of the avalanche into account in a realistic manner. This applies to the channelization of the flow into the gully, the spreading of the avalanche on the unconfined slope and the deflection of the avalanche when it flows at an angle to the fall line of the terrain. The modelled speed of the avalanche may be slightly too high although it is not possible to determine whether the speeds of the SAMOS model or the Swiss 2D model are more realistic without further analysis.

RESULTS FOR BOLUNGARVÍK

Avalanche starting zones were defined in the 5 main gullies above Bolungarvík and also in 2 smaller starting zones a little lower in the mountain. The starting zones are numbered from 1-7 on the maps. The outermost gully is believed to accumulate slightly less snow than the other 4 gullies and the lowermost 2 zones are believed to accumulate less snow than the outermost gully. Therefore the starting snow depth was reduced by a factor of 2/3 in the outermost gully with respect to the other 4 gullies and by a factor of 1/2 for the lowermost 2 zones. Two runs with the SAMOS model were made, one with a starting zone snow depth of 1.25 m perpendicular to the terrain in the 4 innermost gullies and the other with a snow depth of 2.5 m. The runs were defined by the following input data:

Input	run1	run2
Snow depth in areas 1, 2, 3 and 6 (m)	1.25	2.5
Total mass (10^3t)	25	50
Total volume (10^3m^3, $\rho = 200$ kg/m^3)	126	252

The mass and volume are total values for all the avalanches in the 7 different starting zones.

The following table summarizes the area of each starting zone and the volume of the avalanches released from each of them in the two runs. Runout indices (Jónasson *et al.*, 1999) along longitudinal profiles down the mountain are given for the avalanches from starting zones 1, 2, 3, 6 and 7. The runout indices refer to the runout of the longest tongue of the avalanche. They are found by projecting the location of the tongue onto the respective paths, perpendicular to the direction of propagation of the avalanche. It should be noted that avalanches from zones 4 and 5 interact with the avalanche from zone 6 and lead to slightly longer runout than would otherwise be obtained for the avalanche from zone 6. Similarly, there is some interaction between the avalanches from zones 6 and 7 which presumably leads to slightly longer runout of these avalanches compared with avalanches that are released independently from each of the starting areas.

Starting zone		Map area	Area	Relative	Volume (10^3m^3)		Runout idx	
id	name	(10^3m^2)	(10^3m^2)	snow depth	run1	run2	run1	run2
1	Innragil	17.0	21.2	1	26.5	53.1	14.1	15.4
2	Traðargil	17.5	22.8	1	28.5	57.0	14.1	15.5
3	Ytragil	13.7	17.6	1	22.0	44.0	13.6	14.8
4	—	2.3	3.0	1/2	1.9	3.8	—	—
5	—	4.7	5.9	1/2	3.7	7.4	—	—
6	—	17.3	22.6	1	28.3	56.5	13.4	15.0
7	—	14.0	17.8	2/3	14.8	29.7	14.0	15.2
8	—	26.9	32.1	0	0	0	—	—
Total, excl. zone 8		86.5	111	—	126	252	—	—

The lowest starting zone with id=8 was not used in the model computations. It should be noted that, as in the model computations for Flateyri described above, snow entrained in the lower part of the path is not considered in the computations. Therefore, the volume of the avalanches is smaller than for real, large avalanches that might be released from the mountain. The gullies corresponding to starting zones 1, 2 and 3 are traditionally called Innragil, Traðargil and Ytragil, respectively. The other starting zones shown on the maps do not have established names.

The results of the two runs are displayed as coloured contour plots of the depth and velocity of the flowing avalanche at 10 s intervals as for Flateyri (files bo_run1.ppt and bo_run2.ppt on the attached CD). Plots of the maximum dynamic pressure (given by $p = \rho u^2$) along the paths were also made (also on the CD). Some of the results are shown on figs. 2-5 (the flow depths are in m and the maximum pressure in kPa on the figures).

As expected, the runs illustrate a tendency of the avalanches to form tongues in consistent locations below the gullies. In terms of runout indices, the runout of the avalanches from zones 3 and 6 is about 0.5 index units shorter than the runout from zones 1, 2 and 7. This may be attributed to more lateral spreading of avalanches from zones 3 and 6 compared with avalanches from the other starting zones. Spreading of the avalanche from zone 6 in the irregular terrain at about 200 m a.s.l. is also likely to be a part of the explanation of the relatively short runout of avalanches from zone 6.

The maximum velocity of the avalanches is obtained between 200 and 300 m a.s.l. and is about 47 m/s for run1 and 51 m/s for run2. The maximum velocity is slightly higher for the avalanches from Traðargil (starting zone 2) than for the avalanches from the other gullies. The speed of the avalanche with an initial snow depth of 2.5 m from Traðargil is close to 35 m/s at the location of the uppermost buildings at Dísarland. This avalanche flows through the current settlement and extends more than 100 m beyond the road Þjóðólfsvegur that runs along the bottom of the valley. The corresponding avalanche from Ytragil (starting zone 3) from run2 has a speed close to 31.5 m/s near the uppermost houses below the gully at the same elevation. This indicates that avalanches from Traðargil are more difficult to stop by a dam or by other retarding constructions compared with avalanches from Ytragil.

The simulated main directions of the avalanches from Innragil, Traðargil and Ytragil (zones 1, 2 and 3) seem to be too a large degree determined by the direction of the lower part of the gullies between 350 and 400 m a.s.l. These avalanches propagate long distances down the lower part of the mountain at a 5-10° angle to the fall line of the terrain below 350 m a.s.l. The direction of the avalanches may be expected to be sensitive to the amount and distribution of snow on the ground in the lower part of the gullies when the avalanches fall and perhaps also to entrainment of snow from the lower part of the mountain by the avalanches, which is neglected in the computations as mentioned above. The direction of avalanches that are released in the lower part of the mountain may be expected to be closer to the fall line of the terrain than the simulated directions shown in figures 4 and 5. Some recorded avalanches from Ytragil, furthermore, indicate a direction closer to the fall line of the lower part of the mountain than the simulated directions shown in figures 4 and 5. The simulated directions should therefore be interpreted such that they indicate a potential direction of propagation rather far to the east, but a more westward main direction of propagation, closer to the fall line of the terrain, is not excluded by the simulations.

The following conclusions may be drawn from the model results:

1. The runout of avalanches from the gullies above Bolungarvík is consistently shorter (in terms of runout indices or locations with respect to the results of an α/β model) than the runout with the same initial snow depth from larger starting zones, for example in Neskaupstaður (see the next section). This may be attributed to transverse spreading of the avalanches on the unconfined slope below the narrow gullies.

2. The runout from Ytragil is shorter than from Traðargil due to a smaller starting zone and due to the shape of the terrain below Ytragil which leads to more lateral spreading than below Traðargil.
3. The direction of fast flowing avalanches from Ytragil seems to be more to the east than indicated by the outlines of recoded avalanches. Thus, a comparatively wide tongue should be used in the hazard zones below Ytragil in order to capture a possible direction of large avalanches to the east of the main direction indicated by the avalanche history. The situation seems to be similar below Traðargil, although there are no available indications from the avalanche history about a direction of propagation to the west of the simulated direction.
4. The model computations indicate that avalanches have a tendency to be deflected away from the central part of the village, between Ytragil and the next gully to the east.

The model computations provide an objective reference point to estimate the reduction in runout at locations between the main gullies. Due to uncertainties in the model computations, the modelled differences in runout should not be fully reflected as differences in the distance of hazard lines from the mountain. Relative differences in the runout between different locations along the slope derived from the model computations are, however, based on relatively well established physical arguments. They can, therefore, be used to some degree to adjust the location of hazard zones so that the hazard in areas away from the main direction of avalanches from the gullies is estimated to be lower than directly below the gullies.

RESULTS FOR NESKAUPSTAÐUR

Avalanche starting zones were defined in the main bowls and gullies above the inhabited area in Neskaupstaður and also above the main industrial area to the west of the settled area. A total of 23 different subareas were defined and they are numbered from 1-23 on the maps. The main bowls and deepest gullies near the top of the mountain are believed to accumulate more snow than shallower bowls and gullies at lower elevations. The different snow accumulation conditions in the starting zones were described by classifying the zones into four classes as defined in the following table:

Class	Relative snow depth	Comment
I	1	Large deep bowls or gullies near the top of the mountain
II	2/3	Shallow bowls or relatively flat areas near the top of the mountain
III	1/2	Small and shallow bowls at comparatively low elevations
IV	1/4	Other parts of the mountain above 400 m a.s.l.

This classification is similar as the classification used in Bolungarvík, which is described in the preceding section, except that no snow was released from the area outside the defined starting zones in bowls and gullies in Bolungarvík.

Five runs with the SAMOS model were made in Neskaupstaður. The first two runs are similar as the two runs in Bolungarvík. Run 1 was started with a starting zone snow depth of 1.25 m perpendicular to the terrain in class I starting zones and run 2 was started with a snow depth of 2.5 m in the class I zones. The snow depth in other subareas in runs 1 and 2 was determined from the relative snow depth class for the respective subareas as given in the above table. Snow with a relative snow depth of 1/4 was also released in runs 1 and 2 from areas above 400 m a.s.l. outside the delineated starting areas (see below).

Three additional runs were made in order to further investigate the channelization of the avalanches by the geometrical form of the mountain indicated by runs 1 and 2. In run 3, a uniform layer of snow with a thickness of 1.25 m perpendicular to the terrain was released from the entire mountain slope above 400 m a.s.l. In runs 4 and 5 the interaction of neighbouring starting zones was investigated by releasing avalanches from subsets of the starting zones in order to reduce the mixing of snow from adjacent release areas.

The following table gives the total mass and volume of snow for each of the runs:

Input	run1	run2	run3	run4	run5
Snow depth in areas with the highest snow depth (m)	1.25	2.5	1.25	1.25	1.25
Total mass (10^3t)	463	926	964	84	108
Total volume (10^3m^3, $\rho = 200$ kg/m^3)	2315	4631	4821	421	542

The mass and volume are total values for all the avalanches in the different starting zones. The snow was released simultaneously from the multiple starting zones in each run in order to simplify the model computations and in order to make them more economical in terms of computer time and time needed to set up the runs. This aspect of the simulations should not be taken to indicate that simultaneous release of this kind is likely to occur in nature.

The table on the next page summarizes the area and the relative snow depth for each of starting zones in Neskaupstaður. The last column of the table lists the runs where snow was released from the zone.

Detailed delineation of starting zones has not been carried out in Bræðslugjár between the main settlement and the industrial area because the avalanche hazard was judged to be so high in the area below this part of the mountain that detailed hazards zoning would not be needed. Therefore no snow was released from this part of the mountain in runs 1 and 2.

Subareas 30, 40 and 50 encompass the entire slope above 400 m a.s.l. As mentioned above, subareas 30 and 40 contribute some additional snow to the avalanches released from areas 1-23 in runs 1 and 2. This is indicated by the "+" in two of the last three lines in the table and means that snow with a thickness of 1/4 of the class I snow depth was release from the part of subareas 30 and 40 which is outside the main subareas 1-23.

Subareas 1-23 were not directly used in run 3 although they are all implicitly included as each of them is a part of either subarea 30 or subarea 50. The Bræðslugjár area, that is subarea 40, was included in run 3 because this could be done in spite that detailed delineation of starting zones had not been done for this part of the mountain.

It should be noted that avalanches from several of the starting zones in Neskaupstaður in runs 1 and 2 interact with neighbouring avalanches and this leads to longer runout than would otherwise be obtained as previously mentioned for Bolungarvík. This effect is especially strong for avalanches from Brynjólfsbotnagjá and Sultarbotnagjár, for Urðarbotn and Sniðgil and for Drangagil and Skágil. The magnitude of this effect can be analysed from the results of runs 4 and 5.

As in the simulations for Flateyri and Bolungarvík described above, snow entrained in the lower part of the path is not considered in the computations. Therefore, the volume of the avalanches from each starting zone is smaller than for real, large avalanches that might be released from the corresponding part of the mountain.

The results of the five runs are displayed as coloured contour plots of the depth and velocity of the flowing avalanche at 10 s intervals as for Flateyri and Bolungarvík (files ne_run1-5.ppt on the attached CD). Plots of the maximum dynamic pressure (given by $p = \rho u^2$) along the paths were also made (also on the CD). Some of the results are shown on figs. 6-15 (the flow depths are in m and the maximum pressure in kPa on the figures).

Starting zone id	 name	Map area ($10^3 m^2$)	Area ($10^3 m^2$)	Relative snow depth	Runs
1	Gunnólfsskarð	70.8	90.6	1	1,2,5
2	Brynjólfsbotnagjá, upper part	17.9	22.8	1	1,2,4
3	Brynjólfsbotnagjá, lower part	27.8	40.5	2/3	1,2,4
4	Innri-Sultarbotnagjá	103.3	138.5	1	1,2,5
5	Ytri-Sultarbotnagjá	57.1	78.8	1	1,2,4
6	Gully east of Ytri-Sultarbotnagjá	14.5	22.5	1	1,2,5
7	Miðstrandarskarð	92.3	115.7	1	1,2
8	Klofagil	33.7	46.6	1	1,2
9	Area between Klofagil and Tröllagil, lower part	37.5	46.7	1/2	1,2,5
10	Area between Klofagil and Tröllagil, upper part	6.0	7.6	2/3	1,2,5
11	Innra-Tröllagil	72.0	92.0	1	1,2
12	Ytra-Tröllagil	56.3	69.7	1	1,2
13	Area between Tröllagil and Urðarbotn	10.3	12.7	1/2	1,2,5
14	Urðarbotn, western part	64.3	80.4	2/3	1,2,4
15	Urðarbotn, eastern part	41.2	50.4	2/3	1,2,5
16	Sniðgil	29.9	38.6	2/3	1,2,4
17	Area west of Drangagil	35.4	43.0	2/3	1,2,4
18	Drangagil	91.9	112.6	1	1,2,5
19	Skágil	54.6	70.0	1	1,2,4
20	Nesgil	104.8	129.1	1	1,2
21	Bakkagil	63.4	77.7	1	1,2
22	Uxavogslækjargil	45.2	57.5	1/2	1,2,4
23	Stóralækjargil	146.6	179.9	1	1,2
Total		1276.7	1623.8	—	—
30	Gunnólfsskarð to Sultarbotnagjár	908.5	1184.1	1/4	1+,2+,3
40	Bræðslugjár	585.1	781.7	1/4	3
50	Miðstrandarskarð to Stóralækjargil	1505.9	1880.8	1/4	1+,2+,3
Total, 30+40+50		3000	3846.6	—	—

The runs illustrate a persistent tendency of the avalanches to form tongues below the gullies and bowls that constitute the main starting zones in the mountain. This is particularly evident from the results of run 3 where no assumptions are made about a preferred accumulation of snow into the main bowls and gullies in the upper part of the mountain. In spite of this, the main avalanche tongues are located in essentially the same parts of the runout area as found in runs 1 and 2.

The release volume ($\rho = 200\,\mathrm{kg/m^3}$) and runout index for different parts of the mountain for each of the five Neskaupstaður simulations is summarized in the following table. Some adjacent starting zones are merged into one entry in the table where avalanches from more than one zone merged and formed one tongue in the runout area. A runout index is not given for some of the smaller starting zones in cases when snow released from these zones did not form an independent tongue in the runout area.

Starting zone		Volume (10^3m^3)				Runout index			
id	name	rn1	rn2	rn3	rn4/5	rn1	rn2	rn3	rn4/5
1	Gunnólfsskarð	137	274	207	113	16.5	17.2	17.0	15.9
2+3	Brynjólfsbotnagjá	146	292	414	62	16.6	18.3	18.0	14.3[1]
4	Innri-Sultarbotnagjá	248	497	473	173	16.2	16.8	17.7	15.5[1]
5+6	Ytri-Sultarbotnagjá+gully	191	382	384	—	14.3	15.9	15.7	—
5	Ytri-Sultarbotnagjá, only	—	—	—	99	—	—	—	14.6
6	Gully east of Ytri-Sultab.g.	—	—	—	28	—	—	—	13.7
40	Bræðslugjár	—	—	977	—	—	—	>18	—
7+8	Miðstrandarskarð, Klofagil	239	478	349	—	17.5	>18	>18	—
9+10	Btwn. Klofagil and Tröllagil	54	109	130	36	—	—	—	14.0
11	Innra-Tröllagil	134	267	189	—	17.1	>18	17.8	—
12	Ytra-Tröllagil	98	196	130	—	16.2	>18	16.2	—
13	Btwn. Tröllag. and Urðarb. 8	16	0	8	—	—	—	—	13.3
14+15+16	Urðarbotn, Sniðgil	172	343	333	—	15.9	17.5	17.5	—
14	Urðarbotn, western part	—	—	—	67	—	—	—	15.0
15	Urðarbotn, eastern part	—	—	—	42	—	—	—	15.2
16	Sniðgil	—	—	—	32	—	—	—	<15
17+18+19	Drangagil and neighb. areas	314	628	482	—	16.6	18.0	17.2	—
17	Area west of Drangagil	—	—	—	36	—	—	—	15.5
18	Drangagil only	—	—	—	141	—	—	—	15.8
19	Skágil	—	—	—	87	—	—	—	15.5
20	Nesgil	180	361	237	—	16.3	17.1	16.6	
21	Bakkagil	119	238	185	—	16.5	17.3	17.0	—
22	Uxavogslækjargil	38	76	56	36	14.3	15.2	15.2	14.3
23	Stóralækjargil	234	467	260	—	17.0	>18	17.5	—
Total		2312	4624	4808	960	—	—	—	—

[1] Note that although the runout of avalanches from the starting zones in Brynjólfsbotnagjá (zones 2 and 3) is relatively short in run 4 (runout index 14.3), an avalanche from Innri-Sultarbotnagjá in run 5 with the same starting zone snow depth reaches runout index 15.5 in the runout area below Brynjólfsbotnagjá.

It should be noted that the volumes given in the last line of the above table are not completely consistent with the volumes given in the preceding table that summarizes the mass and volume of snow in each run. This discrepancy, which is in all cases less than 1%, is caused by discretization errors in the computational grid because the delineation of the starting zones does not run along grid cell boundaries.

The following conclusions may be drawn from the model results:

1. The direction of avalanches from Innri-Sultarbotnagjá and Ytri-Sultarbotnagjá appears to be strongly affected by the shape of the lower part of the gullies below the starting zones. This effect may be expected to depend to some extent on the thickness of snow on the ground when avalanches are released from these starting zones. The direction of avalanches from these zones may, therefore, under some circumstances be different from the results of the simulations, which are run without snow on the ground. The simulations indicate that avalanches from Innri-Sultarbotnagjá may reach the runout area below Brynjólfsbotnagjá. Therefore, one may not use the relatively small starting zones in Brynjólfsbotnagjá as an argument for drawing hazard lines at that location closer to the mountain than in the neighbouring Gunnólfsskarð and

Sultarbotnagjá areas.

2. The runout of avalanches from Urðarbotn is about 0.5 runout index shorter than in the neighbouring Drangagil area in runs 1 and 2. This is mainly a consequence of the reduction by a factor of 2/3 in the release snow depth in Urðarbotn (class II) compared with the snow depth in Drangagil. Releasing avalanches in Urðarbotn independently in the three starting zones reduces the runout by about 1 additional runout index. If it is assumed that avalanches from Urðarbotn are in fact released independently in the three starting zones and with a smaller starting snow depth than in Drangagil this indicates that runout of avalanches from Urðarbotn may be on the order of 1.5 runout indices shorter than in Drangagil if one additionally assumes that avalanches in Drangagil are released from a larger area than the central area only (zone 18). This does, however, not take into account possible frequency differences between these two areas.
3. The simulated runout of avalanches from Nesgil is 0.2-0.4 runout indices shorter than in Bakkagil in runs 1-3. The simulated absolute runout distance in metres is, however, somewhat longer for avalanches from Nesgil. This is partly caused by a larger starting area in Nesgil and partly by the longitudinal geometry of the avalanche paths. The results of the simulations indicate that differences in absolute runout between Nesgil and Bakkagil derived from runout indices are slightly too large. The SAMOS simulations do, however, indicate a longer absolute runout of avalanches from Nesgil than from Bakkagil, which is in an overall agreement with the difference in runout distance derived from runout indices.
4. The simulated direction of avalanches in the runout area below Nesgil indicates that there is a tendency for the avalanches to follow the natural depression in the landscape that runs through the settlement.

The persistent location of the main tongues in all the runs indicates that the simulated form of the tongues may be used to determine tongues in hazard lines in a hazard zoning of the village as was concluded for Bolungarvík in the preceding section. The direction of the tongues below Brynjólfsbotnagjá and Innri- and Ytri-Sultarbotnagjá, however, indicates that one should be careful not to overinterpret the tongue forms in the hazard zoning. Thus only an appropriate fraction of the runout differences between the central tongues and the intermediate areas indicated by the simulations should be used in the hazard zoning. The appropriate fraction to use is a matter of subjective judgement, but a value of about 1/2 could be used.

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Figure 1. The outline of the catastrophic avalanche at Flateyri in 1995. The outlines of the avalanches on Flateyri in 1999 and 2000 are also shown. The channelized flow of the 1999 avalanche from Skollahvilft along the deflecting dam is indicated with a dashed curve. Hypothetical outlines of the avalanches in 1999 and 2000 in the absence of the deflecting dams are shown as dotted curves.

Figure 2. Simulated final snow depth in run 1 in Bolungarvík (m).

Figure 3. Simulated final snow depth in run 2 in Bolungarvík (m).

Figure 4. Simulated maximum dynamical pressure in run 1 in Bolungarvík (kPa).

Figure 5. Simulated maximum dynamical pressure in run 2 in Bolungarvík (kPa).

Figure 6. Simulated final snow depth in run 1 in Neskaupstaður (m).

Figure 7. Simulated final snow depth in run 2 in Neskaupstaður (m).

Figure 8. Simulated final snow depth in run 3 in Neskaupstaður (m).

Figure 9. Simulated final snow depth in run 4 in Neskaupstaður (m).

Figure 10. Simulated final snow depth in run 5 in Neskaupstaður (m).

Figure 11. Simulated maximum dynamical pressure in run 1 in Neskaupstaður (kPa).

Figure 12. Simulated maximum dynamical pressure in run 2 in Neskaupstaður (kPa).

Figure 13. Simulated maximum dynamical pressure in run 3 in Neskaupstaður (kPa).

Figure 14. Simulated maximum dynamical pressure in run 4 in Neskaupstaður (kPa).

Figure 15. Simulated maximum dynamical pressure in run 5 in Neskaupstaður (kPa).