Report
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Hazard zoning for Ísafjörður and Hnífsdalur
Technical report

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Contents

1 Introduction

This report is an assessment of avalanche hazard in Ísafjörður and part of the final report for the project *Pilot Hazard Zoning for Ísafjörður, Siglufjörður and Neskaupstaður* (Tilraunahættumat fyrir Ísafjörð, Siglufjörð og Neskaupstað). In 1999 it was decided to make the pilot hazard maps a basis for the final hazard maps of the three communities.

General information about the project and necessary background information for this report are included in a separate report (Thorsteinn Arnalds *et al.* 2001a). Among other things, it contains a short description of Icelandic and Austrian hazard zoning regulations and a discussion of uncertainty in the hazard evaluation. Technical reports for Neskaupstaður and Siglufjörður were published in May and December 2001, respectively (Thorsteinn Arnalds *et al.* 2001b,c). Similar reports have also been published for Seyðisfjörður and Eskifjörður where new hazard maps have recently been issued (Thorsteinn Arnalds *et al.* 2002a,b).

The report is split into eight main sections. The first part is general and contains an overview of topographic and climatic conditions, a summarised avalanche chronicle, a review of previous hazard maps and discussion of debris flow hazard. The next six sections deal with each of the main avalanche areas within the settlement. For each of these areas the following is described.

Topographic conditions: Physical characteristics of the starting zone, track, and runout area.

Climatic conditions: Weather indicative of avalanche danger and past weather patterns that have led to avalanches.

Assessment: Discussion of avalanche conditions and qualitative hazard analysis.

Model estimates: Model results that are the basis of the hazard zoning. For explanations of technical concepts and notation, refer to Appendix A.

Conclusion: Hazard evaluation and a proposed hazard zoning.

2 General

2.1 Topographic conditions

The villages Ísafjörður and Hnífsdalur are a part of the community Ísafjarðarbær. Ísafjörður is located around the fjord Skutulsfjörður extending to the southwest from the bay Ísafjarðardjúp. The valley Hnífsdalur is located by an inlet a little to the north of the fjord. The direction of Hnífsdalur is similar to the direction of Skutulsfjörður. Map 1 and Figure 1 show an overview of the area.

Skutulsfjörður is surrounded by steep mountains that reach up to about 700 m a.s.l. The mountain Ernir is located to the southeast of the fjord and to the southwest of Ernir is the mountain Kirkjubólsfjall. The slopes of these mountains are steep and carved by shallow gullies and cut by glacier valleys. At the head of the fjord is the mountain Kubbi that separates the valleys Engidalur and Dagverðardalur. The housing area Holtahverfi is below the northern hillside of Kubbi. To the northwest of Skutulsfjörður is the mountain Eyrarfjall with similar characteristics as the mountains on the other side of the fjord. Below Eyrarfjall is a peninsula where a large part of the settlement is located. Above the peninsula there is the large plateau Gleiðarhjalli at 400–500 m a.s.l. In the inner part of the fjord the hillside has a more westerly aspect where the plateau Seljalandsdalur is located at about 200 m a.s.l. The skiing area for Ísafjörður was located in Seljalandsdalur. Ski lifts in the area have several times been damaged by avalanches. Above Seljalandsdalur rises the mountain Breiðafell of equal height as Eyrarfjall.

The mountains surrounding Hnífsdalur rise up to about 600 m a.s.l. To the north is Búðarfjall cut by distinctive gullies. The outermost part of Búðarfjall is called Búðarhyrna. The easternmost part of Eyrarfjall to the south of Hnífsdalur is called Bakkahyrna. The slope of Bakkahyrna that faces Hnífsdalur is rather homogeneous and even.

Skutulsfjörður was probably settled in the early part of the tenth century. The farm Eyri is thought to have been settled during the early settlement of Iceland. Until the second half of the eighteenth century there were about twelve farms in Skutulsfjörður and Hnífsdalur.

Dense settlement started to form on the peninsula Skutulsfjarðareyri in the early nineteenth century. In the last years of the nineteenth century and the beginning of the twentieth century the settlement started to develop towards Eyrarfjall. The houses on the uppermost streets below Gleiðarhjalli are mostly built in 1970–1985.

The houses in the area of Holtahverfi, below Kubbi, were built in 1976–1983. The houses in the area of Seljalandshverfi, to the west of the farm Seljaland were built after 1990 but development of the area stopped in 1995 after a new hazard map was approved.

The road Skutulsfjarðarbraut connects the old settlement to the newer areas. Some industrial buildings that are located by the road below Seljalandshlíð have been hit by avalanches.

The village in Hnífsdalur started to form after the year 1880 and grew continuously until 1920. The first settlement was at the head of the inlet and in the early part of the twentieth century many domestic houses were built in the area. In the 1960's and 1970's the settlement developed further

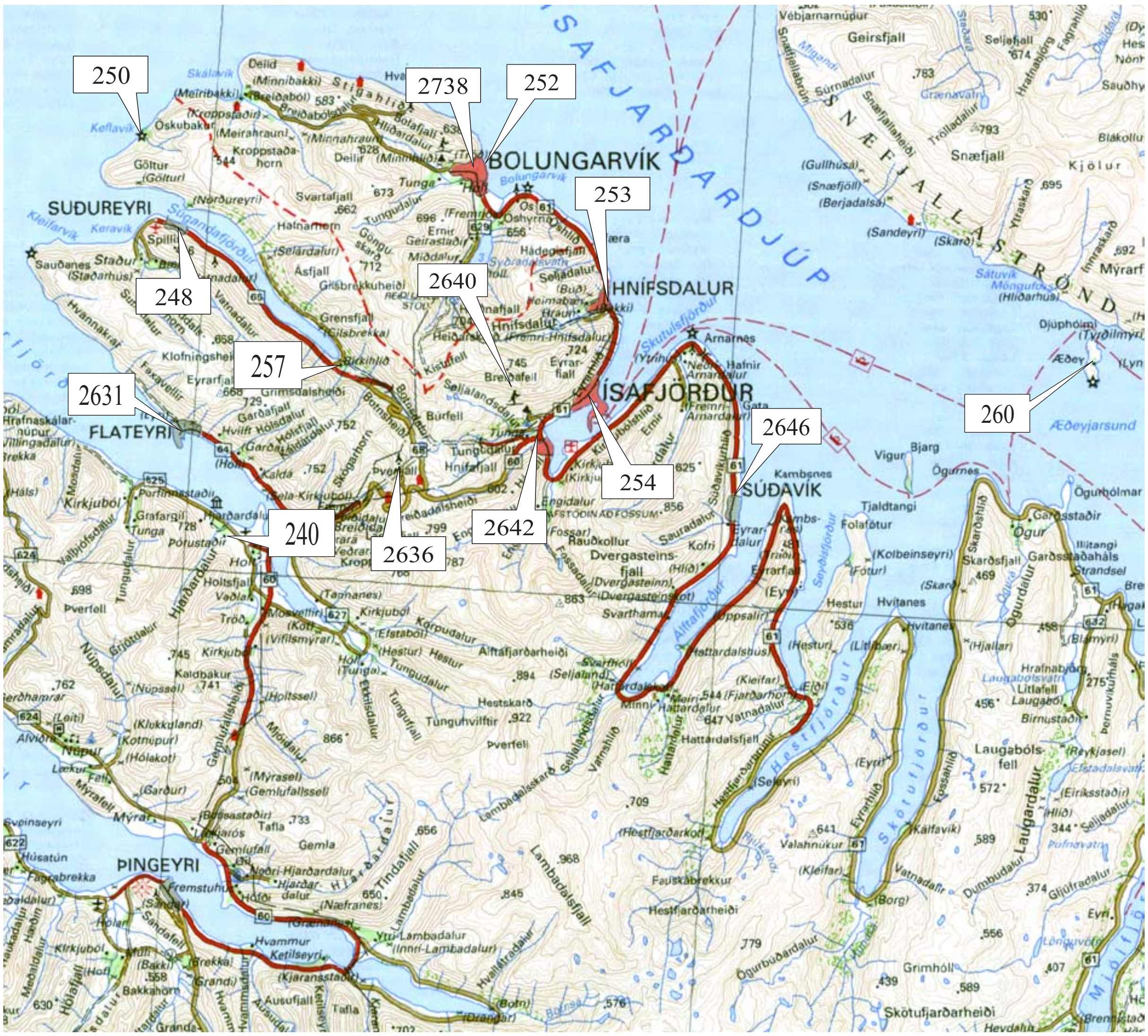

Figure 1. *An overview of the area around Ísafjörður and Hnífsdalur with the locations of meteorological stations indicated. © The National Land Survey of Iceland.*

to the west on the southern side of the river Hnífsdalsá. The houses in the area of Teigahverfi to the north of the river, below Traðargil, were built in 1978–1985. Many of the houses in this area were purchased by the community, with support from the Icelandic avalanche fund, in 1996 due to the avalanche hazard.

Building years and names of houses in Ísafjörður and Hnífsdalur have been documented in detail by Harpa Grímsdóttir (1999).

2.2 Chronicle

The Ísafjörður avalanche chronicle dates back to 1673 when an avalanche hit the house Búð in Hnífsdalur. Although it destroyed the house, some sheds, and fish-drying racks, the people living in the house survived. Only 3 avalanches are recorded before the year 1900, but as in most areas of Iceland, avalanche records exist primarily when people were injured or considerable property damage resulted. In the twentieth century, more avalanches have been recorded, but it is only in the past 20 years that systematic records have been kept. The position of snow observer in Ísafjörður was created in 1982 to, among other things, record avalanches in the region. One observer, Oddur Pétursson, has held the position throughout the entire period. The community of Ísafjörður employed him until 1995, after which he became a full time employee of the IMO. Because of his work, most avalanches falling close to the settlement of Ísafjörður after 1982 have been recorded and measured whenever possible.

Four fatal avalanches have hit houses in the area around Ísafjörður and Hnífsdalur. In 1818 an avalanche hit a farm named Augnavellir which was located about 600 m west of the farmhouse Hraun in Hnífsdalur. Four people died. In 1910 an avalanche from Búðargil in Hnífsdalur killed twenty people at Búð and the neighbouring area. In 1941, two people were killed when an avalanche hit the house Sólgerði below Seljalandshlíð and in 1994, an avalanche released in the mountain above the skiing area in Seljalandshlíð hit many summer houses in Tungudalur killing one person.

In recent years, 3 avalanches have caused the most significant property damage. The 1994 avalanche in Tungudalur damaged ski lifts in the skiing area as well as 40 summerhouses, in 1995 an almost new incinerator, Funi, in Engidalur was severely damaged, and in 1999 an avalanche damaged recently rebuilt ski lifts in Seljalandsdalur.

Many more avalanches have caused damage within the settlement, mostly in the area below Seljalandshlíð. Recorded avalanches in Ísafjörður and Hnífsdalur are listed in Sections 3.3, 4.3, 5.1, 6.3, 7.3, 8.2.3, 8.3.3, 8.4.3 and 8.5.3, and shown on Maps 2–5. An avalanche chronicle was compiled by Jón Gunnar Egilsson (1989) and is currently under revision at the IMO.

2.3 Previous hazard assessments

In 1984 Erik Hestnes from the NGI visited several communities in the western part of Iceland where avalanches had been recorded (Erik Hestnes, 1985). He examined the avalanche conditions in Ísafjörður and Hnífsdalur and calculated potential runout lengths for avalanches below Kubbi and Bakkahyrna.

In 1987 Óskar Knudsen investigated avalanche hazard at Seljaland. He concluded that it would be difficult to build defence structures in the area.

The first laws concerning avalanches and debris flows in Iceland were issued in 1985. The §2 of the laws states: "Hazard assessment shall be performed in communities where avalanches and debris flows have fallen into the settlement or close to it. The hazard assessment shall both cover settled areas, as well as areas that are due to be planned. The hazard assessment shall be taken into consideration in the entire planning process and shall be attached to planning proposals.". In §3 of the laws the Icelandic Civil Defence is made accountable for specifying further guidelines and regulations on hazard zoning, classification of hazard zones and the construction of defence structures. It was also given the role to supervise the preparation of hazard maps.

In regulation 247/1988 on hazard zoning it was specified that a particular physical model should be used for hazard zoning and guidelines on how to apply it were given. The model was developed by Þorsteinn Jóhannesson at Verkfræðistofa Siglufjarðar sf. (VS, 1986). During the next several years hazard zoning was done in several villages by independent consultants, supervised by the Icelandic Civil Defence.

Flosi Sigurðsson at VST hf. (VST, 1990) prepared a hazard map for Ísafjörður and Hnífsdalur based on the regulation from 1988. The hazard map was revised in 1992 (VST, 1992a) with minor changes to the original map. Based on the revised proposal the first official hazard map for Ísafjörður and Hnífsdalur was approved by the Minister of Social Affairs in October 1992, see Maps 6 and 7. According to the hazard map only houses in the northern part of Hnífsdalur and a few houses below Seljalandshlíð and Kubbi were within the hazard zone.

In 1992 VST proposed avalanche protection measures for endangered areas in Ísafjarðarbær (VST, 1992b). In 1994 defence structures for the northern part of Hnífsdalur (VST, 1994b) were designed in detail.

After an avalanche hit the skiing area in Seljalandsdalur and summer houses in Tungudalur in 1994, VST (1994a) prepared a new hazard map for the area based on the regulation from 1988. The proposal is shown on Map 6.

In 1994 Stefan Margreth at the Swiss Federal Institute for Snow and Avalanche Research (SLF) evaluated possibilities for avalanche prevention in the skiing area of Seljalandsdalur (SLF, 1994). He concluded that necessary measures to improve safety in the ski area would be very costly and probably impractical for that reason.

After an avalanche hit the village Súðavík in January 1995 the laws and regulations regarding avalanche hazard were revised. The same physical model was to be applied, but a major alteration was that two types of hazard zones were delineated:

i) Red zone where the calculated impact pressure of an avalanche (with density $\varrho = 0.35$) is more than 10 kN/m^2.

ii) Yellow zone, extending at least 50 m further than the red zone.

The hazard map for Seljalandsdalur from 1994 was revised by VST hf. in 1995 based on the new guidelines (VST, 1995a). In September 1995 a new proposal was made for Seljalandsdalur after a minor revision (VST, 1995b) and at the same time a hazard map for the northern part of Hnífsdalur (VST, 1995c) was proposed, see Maps 6 and 7. The Minister of Social Affairs approved these maps in October 1995. According to the maps the summer houses in Tunguskógur, the houses in Seljalandshverfi and most houses in the northern part of Hnífsdalur were located within the hazard zones.

In 1996 Árni Jónsson at Hnit hf. in cooperation with Karstein Lied at the NGI investigated avalanche hazard and proposed defence structures in the area of Seljaland (Hnit and NGI, 1996). Their result was that all the settlement in Seljalandshverfi is within a hazard zone. A proposal was made to build a 16 m high deflecting dam on the Seljalandsmúli ridge to protect the area below.

In 1996 the Icelandic Meteorological Office made plans for emergency evacuations of several communities in Iceland. The plans included a division of the communities into subareas and description of under which conditions each subarea should be evacuated. Such a plan was made for Ísafjörður and Hnífsdalur and revised in 1997 (IMO, 1996). According to the plan a large proportion of the settled area in Ísafjörður and Hnífsdalur is a part of evacuation zones that need to be evacuated under extreme conditions.

In 1996 the IMO investigated possibilities for avalanche protection measures in ten villages in Iceland (Tómas Jóhannesson *et al.*, 1996). Preliminary proposals were made for protection measures for all of the settlement in Ísafjörður and Hnífsdalur.

A ski lift in Seljalandsdalur was again destroyed by an avalanche in 1999. Avalanche hazard in the skiing areas in Tungudalur and Seljalandsdalur was assessed by Tómas Jóhannesson (2000), with the participation of Stefan Margreth at SLF, in connection with a relocation of the Alpine skiing area from Seljalandsdalur to Tungudalur. It has been decided that the skiing area at Seljalandsdalur will be abandoned and future Alpine skiing activities in Ísafjörður will be located in a new skiing area in Tungudalur.

Since IMO became responsible for hazard zoning in 1995 several temporary hazard assessments have been carried out in Ísafjörður and Hnífsdalur.

2.4 Climatic conditions

The Vestfirðir enjoy a rather remarkable climate, which is influenced by the rugged geography of the area, with high mountains and narrow fjords, and a location adjacent to the Denmark Strait which separates Iceland from Greenland and occasionally brings sea ice into the fjords.

Meteorological measurements have been made at a number of weather stations in the area for several decades. The weather station at Æðey has a rather complete record starting in 1953. Weather observations were made at Bolungarvík from 1934 to 1953 when the station was moved to Galtarviti where it resided until 1994, but then the station was moved back to Bolungarvík. The mean temperature from 1995–2001 at Bolungarvík is 0.4°C lower than the 1934 to 1953 average. These results must be interpreted with some caution since the intervals are of uneven duration and instrumentation has changed. However, it is generally true in Iceland that the period from 1930 to 1960 was warmer than the latter part of the twentieth century.

In recent years, several automatic weather stations have been established in the region. In 1994 a station was established at Þverfjall at an altitude of 753 m. In the following year an automatic station was established at Súðavík and during the next few years automatic stations were added at Ísafjörður, Flateyri, Bolungarvík, Hornbjargsviti, Seljalandsdalur (at 550 m a.sl.) and Straumnesviti. Summaries of station data can be found in Appendix C. The station at Þverfjall has been in continuous operation, but the one at Seljalandsdalur has experienced some difficulties. The station was hit by an avalanche and was inoperative from December 1998 to August 1999. Automatic precipitation gauges at some of these stations tend to measure less precipitation than is measured at manned stations, most likely resulting from systematic errors at the former stations, where the accumulation of snow may be underestimated.

Precipitation and snow cover are measured at manned weather stations at Ísafjörður and Hnífsdalur and from 1995 in Birkihlíð. At these stations the accumulation during the past 24 hours is measured at 9 a.m. every morning. Similar measurements were performed at Suðureyri from 1924 to 1989 and at Þórustaðir from 1952 to 1999. The annual record from Suðureyri does not show systematic changes during the period the station was in operation.

The annual mean temperature in the low lying coastal areas is 3–4°C with February and March the coldest months, but July and August the warmest months. The automatic stations at Seljalandsdalur and Þverfjall are both at high elevation, which allows for the calculation of a temperature lapse rate for the area. This was found to be 0.7°C/100 m. The annual range in temperature is 13.0°C at Þverfjall, 12.2°C at Súðavík and 11.9°C at Bolungarvík. Sea breeze tends to lower summer temperature at some of the coastal stations, yielding a reduced annual range in temperature. The coldest temperature measured at the coast is −20°C but −21.9°C at Þverfjall. Warmest temperatures in the region range from 18–23°C. In recent years, the highest recorded value is 21.9°C at Súðavík on 1 September 1998. At Þverfjall the maximum temperature rarely exceeds 16°C but it did reach 18.8°C on 13 August 1997.

Recorded wind speeds are lowest in July but highest in January. The annual mean wind speed is 4–5 m/s at the coast, with northeasterlies predominating. The 10 minute average winds at these locations can go as high as 24–28 m/s with gusts in the range 42–45 m/s. At higher elevation the mean wind speed is higher. At Þverfjall the annual mean is 8 m/s. From October to March the 10 minute average winds may reach 40 m/s and gusts go as high as 60 m/s or more. The highest gust recorded at Þverfjall was 73.7 m/s on 25 October 1995. The maximum 10 minute average wind on that day was 48.8 m/s from the northeast. A higher 10 minute average wind has only once been recorded at Þverfjall. This was 49.3 m/s on 2 February 1997, also from the northeast. At Seljalandsdalur the highest recorded 10 minute average wind is 28.0 m/s with gusts reaching 48.6 m/s, and occurred in southwesterly winds on 10 November 2001.

In the low lying coastal areas the orography exerts a strong influence on the wind, with wind directions in the fjords predominantly "inwards" or "outwards". In Ísafjörður the winds are usually from the northeast and from west-southwest. The northeasterlies are stronger and more common during winter. In Súðavík, the winds are along the slopes of the mountains surrounding

Álftafjörður. Northerly winds are strongest there and most common during winter. At Flateyri easterlies are most common (50°–140°) but winds from the northeast (40°) are the strongest. The weather station at Bolungarvík is situated at the northern edge of the town and the wind direction is influenced by the mountains north of the town and by the valley Tungudalur. As a result wind directions from 20° to 50° are most common and are also the ones with the strongest winds. During winter these are also the most common directions. However, when temperature is below 1°C and precipitation is occurring the predominant wind direction tends to be northeast. At the weather station in Æðey there is an anemometer but wind directions are estimated by the observer. The most common directions are winds from the northeast and southeast, and also winds from the northwest. The northwesterlies and southeasterlies at this location are steered by the mountains by Ísafjarðardjúp, but the northeasterlies stem from the valley Skjaldfannardalur. Just as in Bolungarvík, the northeasterly wind direction is the most common direction during winter in Æðey during episodes of precipitation and temperatures below 1°C. It has been found that these are the conditions most likely to result in avalanches in the area (Trausti Jónsson, 1996).

The high altitude station at Þverfjall is less affected by orography, although the valleys in Önundarfjörður probably do enhance the frequency of southwesterlies (230°) at the station. The most common wind direction at the station is northeast (30°–80°) and this is also the direction of the strongest winds. During winter the winds from 30° to 50° are most common. At Seljalandsdalur the station is sheltered from most of the northerly wind directions between 270° to 60° and as a result the most common directions are southwesterlies, easterlies, and winds from east-southeast. Of these the southwesterly winds are the strongest.

Precipitation is highly variable from location-to-location and from year-to-year. High winds and subzero temperatures, that are common in the area during winter, are also the conditions associated with the largest systematic errors in precipitation measurements. In general, precipitation tends to be underestimated in such conditions. In the western part of the area (*i.e.*, the stations at Galtarviti, Suðureyri and Þórustaðir) the precipitation amounts tend to be higher than in the stations around Ísafjarðardjúp (*i.e.*, the stations at Bolungarvík, Hnífsdalur and Ísafjörður). The annual precipitation total is 700–800 mm which is comparable to the precipitation measured at the automatic station in Ísafjörður. However, the manual precipitation measurements at Ísafjörður incicate higher annual totals, about 1000 mm per annum. During 2000 and 2001 the automatic precipitation measurements at Ísafjörður yielded 60-80% of the amount measured manually at another location in the town. The automatic measurements at Súðavík yielded 600 mm per annum during the same period. In Æðey, the annual precipitation is less, or about 550 mm.

The greatest amount of precipitation measured during a 24 hour period was 114.3 mm in Ísafjörður on 20 September 1997. On this day more than half the precipitation of that month fell, which is unusual.

The 24-hour precipitation at Suðureyri has only once exceeded 100 mm which occurred in September 1952 when 139.8 mm were measured. Similarly, the only time the 24-hour precipitation at Þórustaðir exceeded 100 mm was in November 1965 when 128.6 mm were measured. At these locations, values between 70 mm and 100 mm are typical for the annual maximum 24-hour precipitation but 40–70 mm are more typical for the stations around Ísafjarðardjúp.

The snow fraction (sleet and/or snow) is 80% of all precipitation at Ísafjörður during October to April, and 74% in Bolungarvík. Only during the month of July is the precipitation composed solely of rain at Ísafjörður, but this does not occur during any month of the year at Bolungarvík. This is not dissimilar from the situation at Hveravellir in the interior of Iceland, at an altitude of 641 m. The fraction of snow and sleet is as expected highest during the coldest months, *i.e.* February and March.

The region as a whole receives above average snowfall. Measurements of snow depth have been made at Ísafjörður for the last 12 years, and the mean snow depth for this period is greatest in March, or 27 cm. There is considerable interannual variability in these depths, with the largest monthly means obtained 50 cm and 48 cm in February and March 1995. During some days of these months the snow depth went as high as 65 cm and 63 cm. In general, the months of January to March are those with greatest snow depths, with measurements sometimes exceeding 50 cm. Observations of snow cover in Ísafjörður show that the snow remains until late spring. Around the town of Ísafjörður the fraction of snow cover is more than 50% until May, and in the surrounding mountains this fraction remains above 50% until June or even July.

Kristján Jónasson and Trausti Jónsson (1997) calculated 5 year, 50 year and 200 year return values for snow depth at meteorlogical stations in Iceland, which are as follows for Ísafjörður and nearby weather stations.

	Ísafjörður	**Æðey**	**Þórustaðir**	**Suðureyri**	**Galtarviti**
5 year	65	60	97	94	85
50 year	116	121	161	160	150
200 year	146	156	198	197	188

The weather preceding avalanche cycles in Vestfirðir has been analysed by Halldór Björnsson (2002). Another study of several avalanche cycles was carried out by Tómas Jóhannesson and Trausti Jónsson (1996). According to these investigations the greatest avalanche hazard in Vesfirðir occurs during gale force northerly winds when cyclones (*i.e.* low pressure systems) pass north of Iceland, from the south or east. These cyclones direct a relatively warm air from the south, followed by intense precipitation, to the north of Iceland and cause extensive snow accumulation in the starting areas of many avalanche paths in Vestfirðir.

2.5 Snow depth measurements in starting areas

Regular monitoring of snow depth in the mountains above Ísafjörður was initiated in the winter 1996/1997. Before that time snow depth at one location in Seljalandshlíð (stake isse00) had been monitored since 1988/99, but with only a few readings in the first winters. The measurements have been carried out on 14–16 stakes since 1996/97. The stakes are 3.0 to 4.5 m high and placed in the elevation range from about 120 to 220 m a.s.l. in Brattahlíð in Kubbi above Holtahverfi, in the range 560 to 690 m a.s.l. in Seljalandshlíð, at about 300 m a.s.l. in Gleiðarhjalli and in the about 210 m a.s.l. in Bakkahyrna in Hnífsdalur.

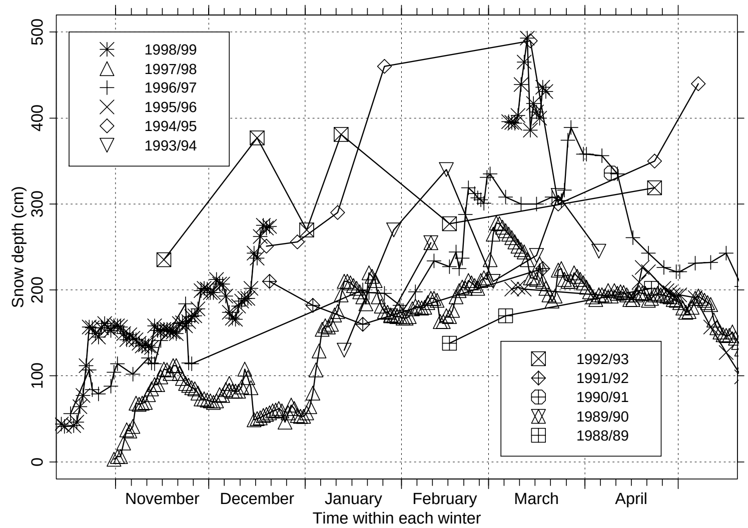

Figure 2. *Snow depth at the stake isse00 at 576 m a.s.l. in Seljalandshlíð above Seljalandsdalur. Data points, where the snow depth at buried stakes has been inferred, based on the measured variation of the snow depth at other nearby stakes, are denoted with a circle.*

The locations of the stakes are shown on Maps 8–11. Several stakes have been lost in avalanches and rock falls or due to other causes during the period of the measurements leading to some gaps in the snow depth time-series. The measurements are described by Sigurður Kiernan *et al.* (1998), Sigurður Kiernan and Tómas Jóhannesson (1998) and Sigurður Kiernan *et al.* (1999).

The maximum vertical snow depth measured on the stakes in the starting zones is typically in the range 1–3 m for the lower or more exposed parts of the slope and up to 5 m on the stakes with the greatest snow depths in the westernmost part of Seljalandshlíð. The greatest snow depths were measured in the winters 1994/1995 and 1999/1999. Most of the stakes are located in a relatively unconfined terrain and greater snow depths may be expected to have occurred in gullies and bowls that are located in several of the starting zones. No stakes are located in the main starting zones in the gullies Karlsárgil, Grænagarðsgil, Hrafnagil or Steiniðjugil in Seljalandshlíð nor in Hraunsgil, Traðargil or Búðargil in Búðarfjall in Hnífsdalur where the greatest snow depths may be expected.

Figure 2 shows the measured snow depth at stake isse00 at 576 m a.s.l. in Seljalandshlíð above Seljalandsdalur and Figure 3 shows the measured snow depth at stake isse01 at 596 m a.s.l. in Seljalandshlíð west of Seljaland for the winters since the start of the measurements at each location. Snow depth at stake isse00 is not shown after 1998/99. The figures clearly show the much greater snow depth in the westernmost part of Seljalandshlíð above Seljalandsdalur (isse00) compared with the easternmost part of the mountain east of the farm Seljaland (isse01).

Measurements and return period analysis of snow depth at lowland stations (Kristján Jónasson and Trausti Jónsson, 1997) indicate that the snow depth tends to vary approximately synchronously at the stations. The snow depths in 1994/1995 are relatively large when viewed over the 30–40 year period spanned by the data at the meteorological stations. The snow depth data at the

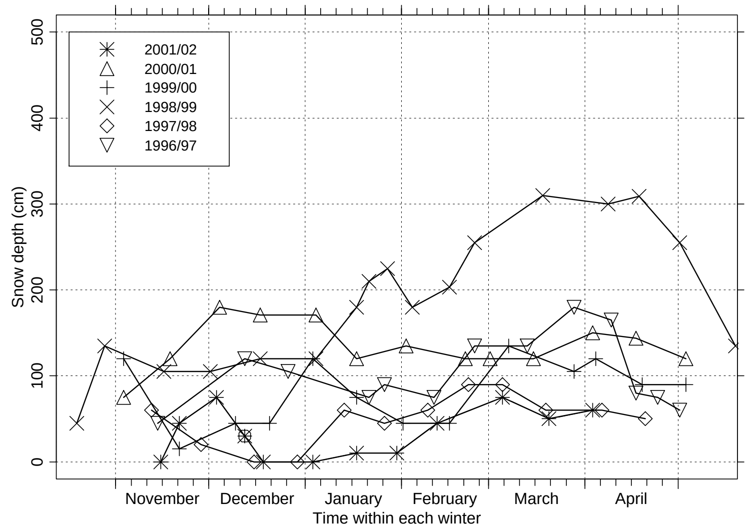

Figure 3. *Snow depth at the stake isse01 at 596 m a.s.l. in Seljalandshlíð east of Seljaland. Data points, where the snow depth at buried stakes has been inferred, based on the measured variation of the snow depth at other nearby stakes, are denoted with a circle.*

meteorological stations indicate that large snow depths on a time-scale of 30–40 years have been reached at these stations in the last few years. The greatest snow depths recorded in the mountains above Ísafjörður may, therefore, be expected to correspond to a return period on the order of several decades although the data from the mountains only extend over 13 years.

The snow depth measurements and other observations from the mountains show that drift snow is the main controlling factor for differences in the local snow depth in the mountainside. The measurements indicate that the snow depth does typically not exceed 2–3 m on the lower or more exposed parts of the hill. The measured snow depth is greatest in the westernmost part of Seljalandshlíð where it has reached about 5 m in an unconfined slope. In gullies and bowls in many of the starting zones the snow depth may be expected to be much larger than this. There, the snow depth seems to be mostly controlled by the depth of depressions and other landscape features, rather than by the local amount of precipitation that falls as snow.

2.6 Debris flow hazard and rockfall

The current Icelandic regulation on hazard zoning requires the same criteria to be used for debris flow/rockfall hazard zoning as for avalanche hazard zoning, *i.e.* individual risk. Furthermore, the combined risk should be presented on one map. Therefore, debris flow hazard zoning should be done in synchronisation with avalanche hazard zoning.

A debris flow chronicle for Ísafjörður has been compiled and a geological study has been conducted to evaluate the debris flow activity and potential (Halldór G. Pétursson and Þorsteinn

Sæmundsson, 1999; Þorsteinn Sæmundsson and Halldór G. Pétursson, 1999).

The only area where the debris flows affect the hazard zoning is the area below Gleiðarhjalli. In other areas of Ísafjörður and Hnífsdalur the debris flow hazard must be considered to be insignificant compared with the avalanche hazard. It is therefore concluded that taking debris flows specifically into account will not significantly alter the risk and the hazard zoning presented here would be unaffected in these areas. In spite of this it may be feasible or even advisable to take actions to prevent property damage due to debris flows at some locations within the village.

Figure 4. *Kubbi and Holtahverfi (Photo: Harpa Grímsdóttir).*

3 Brattahlíð (Kubbi above Holtahverfi)

3.1 Topographic conditions

The domestic area Holtahverfi is by the head of Skutulsfjörður. The houses in the area are mostly built in the years 1976–1980. South of the area the mountain Kubbi rises up to about 360 m a.s.l. The height of the mountain decreases above the outer part of the settlement towards the sea. The summit of Kubbi is rather flat and its slope facing Holtahverfi is unconfined. This slope is named Brattahlíð. Near the top of the slope there are cliffs, cut by small gullies or bowls. The houses are located on the flatland and some are located quite close to the mountain. Evacuation plans have been made for most of the houses in the area below the potential starting zone.

Figure 4 shows the area. It can also be seen on Maps 1 and 8 and longitudinal sections are shown in Drawings 16–19.

Starting area

The potential starting area is shown on Map 8, labelled 1.

The hill above the outermost part of the Holtahverfi housing area from the playground and outwards has an inclination lower than 30° and most of it lower than 25°. The height decreases from about 100 m a.s.l. above the playground down to almost nothing above the outermost part. Avalanche release is therefore very unlikely above that area.

Further to the west, the mountain is much higher and reaches up to 360 m a.s.l. Cascading cliffs with an average inclination around 50° are located between 280 and 360 m a.s.l. The cliffs are marked by two shallow bowls and a gully. The eastern bowl is about 80 m wide. The western bowl is more shallow and only about 50 m wide. The gully is narrow, several meters deep, very steep, and has an average inclination of more than 55°.

Below 280 m a.s.l. the mountain above the western part of the housing area is more even with an average inclination between 35° and 40°. The eastern part has a shallow depression, and according to the local snow observer, this depression is the main starting area for avalanches. The area of the depression is about 1 ha. West of the depression, the landscape is more concave. Below the gully there is a small depression.

The roughness according to the Swiss guidelines is 1.2 in the upper area and approximately 2 in the lower part. The total starting area is about 6.8 ha.

Track

The boundary between the starting area and the avalanche track is unclear because the slope is rather uniform. The beginning of the avalanche track is estimated to be at about 150 m a.s.l. The inclination of the track is 35° at the top and decreases to 30° at about 80 m a.s.l. The inclination then decreases gradually down to the β-point located at about 25–30 m a.s.l. The track is unconfined and slightly concave.

Runout area

The inclination of the runout zone is between 2° and 4°. The area is uniform and densely settled with houses and apartment buildings built around 1980.

3.2 Climatic conditions

In southwesterly winds, snow can drift along the eastern side of Kubbi and accumulate in the eastern part of Brattahlíð above Holtahverfi. It is possible for a snowdrift to form along the slope above Dagverðardalur and accumulate snow in the area above the westernmost houses of Holtahverfi. According to a windrose from Þverfjall, southwesterly winds are not as common as winds from the northeast, which is one of the two most common wind directions at Þverfjall. During northeasterly wind, the snow should be blown away from Brattahlíð. This agrees with information given by the local snow observer. He concluded that the 1984 avalanche was caused by an indraft of snow from the southwest.

3.3 Chronicle

Several avalanches are recorded from Brattahlíð above Holtahverfi. In the twenties, an avalanche stopped at a block wall above the farmhouse Góustaðir. In the sixties, an avalanche fell from Kubbi, directly above Góustaðir into a field breaking two fence posts. In 1981, four avalanches fell in the area. One reached the houses nearest to the mountain without causing any damage. In 1984, a dry avalanche stopped by the houses Kjarrholt 2 and 4 causing noticeable damage.

The avalanches recorded in the area are shown on Map 2 and listed in the following table.

Number Time *Runout index*	**Description**
3152 1920–1930 *14.9*	An avalanche from Kubbi stopped approximately 80 m above the farmhouse Góustaðir in the 1920's. The deposit was very thin and possibly partly formed by a powder avalanche.
3035 early 1960's *13.3*	An avalanche fell from Kubbi, directly above the farm Góustaðir early in the 1960's. The avalanche reached a pasture nearby and broke two fence posts.
3047 16.2.1981 *10.6*	Four avalanches fell from Kubbi above Holtahverfi, and one of them reached the uppermost houses.
3054 4.1.1984 *12.3*	A dry slab avalanche fell from Kubbi and stopped by the houses Kjarrholt 2 and 4. The avalanche burst through a door of Kjarrholt 4, and snow flowed through a corridor and into a bedroom damaging some furniture. The avalanche also hit a car that was standing on Holtabraut above Kjarrholt 2, carried it 30–40 m, and severely damaged it. The fracture height was about 0.8 m. The deposit was 75 m wide and 2.5 m thick.
3188 8.3.1997	Three small avalanches fell from Kubbi. One stopped about 10 m above the town fence at 33 m a.s.l. The width of each of the avalanches was about 10 m. They caused no damage.

3.4 Assessment

The avalanche in 1984 started below the cliffs. According to the local snow observer, the most probable starting area is below the cliffs, although he doesn't rule out the possibility that a cornice collapsing in the cliffs could create a small avalanche that would then release more snow further down. The inclination of the cliffs and their shape with bowls and a gully is such that an avalanche release is possible in the cliffs especially in the eastern bowl, although avalanches starting there should not be large due to the high inclination.

The roughly 2–3 ha starting area below the cliffs indicates that the potential size of an avalanche is limited. The shape of the starting zone in the eastern part of the hill and the avalanche chronicle both indicate that the risk is higher in the eastern part of the runout area than the western part. According to the chronicle, the 1984 avalanche had a deposit width of 75 m and a thickness of 2.5 m. A rough estimation of the deposit gives an avalanche volume of approximately 8,000 m^3. Given the 0.8 m high fracture line, a fracture area of 1.0 ha is probable. The snow densities in the starting area and the deposit are unknown. The impact pressure of the 1984 avalanche is also unknown, but the damage to the houses suggests that it was not high.

3.5 Model estimates

Map 8 shows the results of model calculations and the profiles used for the calculations. The profiles `isku02aa`, `isku03aa`, `isku05aa` and `isku07aa`, and the results of the calculations are shown in Drawings 16–19. The runout was calculated using runout indices, the α/β-model, the PCM-model and the SAMOS model.

The hill under investigation is low and the change from the avalanche track to the runout area is sudden and therefore the α/β-model gives short runout distances. It indicates that the 1984 avalanche reached the α-point and the longest recorded avalanche from the 1920's has a runout of almost $\alpha - 2\sigma$ and is therefore very extreme. The runout index produces opposite results and according to that transfer method, the avalanche of 1920's has runout $r = 14.9$ and therefore not nearly as extreme. Calculations with the PCM-model indicate that an avalanche in path `isku05aa` with $\mu = 0.15$ and $M/D = 200$ has a runout similar to the 1984 avalanche.

An attempt was made to use the risk estimation technique of RiskEst (Estimation of avalanche risk (Kristján Jónasson *et al.* 1999)). According to the avalanche chronicle, one avalanche with runout of $r = 12.3$ has fallen during the last 20 years when most of the houses in the area were built. Furthermore, two longer avalanches are recorded in this century, one of $r = 13.3$ and one with $r = 14.9$. One avalanche with $r \geq 12$ in 20 years, implies the avalanche frequency of about $F_{13} = 0.02$. Two avalanches in 100 years with r $\geq$ 13 also imply a frequency $F_{13} = 0.02$. These recorded avalanches were not wide enough to threaten the whole area. That is consistent with the assessment that only smaller avalanches are possible. Assuming an average width of 100 m in the approximately 300 m wide area reduces the risk by a factor of 3. Taking into account these two factors, risk calculations were performed using a lower frequency $F_{13} = 0.01$. The results of these calculations indicate that the risk is higher than $3 \cdot 10^{-4}$ in all of the housing area that is located below the potential starting zone.

The Austrian avalanche model SAMOS was applied to evaluate the direction of avalanches from the starting areas and the lateral extent of avalanches. The results are described by Tómas Jóhannesson *et al.* (2002).

3.6 Conclusion

Risk calculations based on the methods of RiskEst indicate that the risk in the area is very high and all of the housing area located under the potential starting zone is in the category C hazard zone. The methods of RiskEst have been developed using mostly avalanche data from slopes that are higher and with larger starting zones than Brattahlíð. The estimates obtained by the methods are therefore not considered applicable to this area without modifications. It seems that the return period of avalanches down to the housing area is longer than ten years but shorter than a century. It is difficult to estimate the destructiveness of potential avalanches from Brattahlíð compared with avalanches from higher slopes with larger starting zones. The high frequency does, however, strongly indicate that the risk is higher than $3 \cdot 10^{-4}$ a considerable distance into the housing area. Since the avalanches predicted in the area are relatively small, the risk is considered to decrease more rapidly than indicated by the RiskEst methods resulting in comparatively narrow hazard zones.

The border of the category C hazard zone was placed between runout indices 12.5 and 13.5 and each of the category B and A zones reach about 30–40 meters further into the settlement.

According to the Icelandic hazard zoning regulations, construction of residences within the boundaries of the category C hazard zone is not allowed. Since the destructiveness of the expected avalanches in the area is smaller than for higher slopes with larger starting zones, it can be argued that it would be possible to build reinforced houses within the delineated C zone that would result in acceptable risk for the inhabitants. If Austrian regulations were applied, reinforced houses would most probably be allowed in the area.

It should furthermore be mentioned that existing houses will provide some shelter for houses that are further away from the mountain. This is especially true for the apartment buildings. The actual risk away from the mountain is thus probably lower than the estimated risk.

The slope is an atypical avalanche path with records of avalanches and the uncertainty is considered to be medium (1).

The hazard zoning proposal is shown on Map 12.

Figure 5. *Seljalandshlíð and the outer part of Seljalandshverfi (Photo: Jón Gunnar Egilsson).*

4 Seljalandshlíð (Seljalandshverfi)

4.1 Topographic conditions

There are only a few houses in the sparsely settled Seljalandshverfi. Two apartment buildings stand nearest to the mountain, and five houses are located below them. All of these houses are built around and after 1990. Two older houses, built in 1927 and 1934, are located lower in the area together with two houses at the former farm Bræðratunga. Dense settlement has been planned in the area, which is referred to as Seljalandshverfi, but since an avalanche fell in Tungudalur in 1994 no houses have been built. The Seljaland farm is located in the eastern part of the area. A farmhouse has been standing there since the fjord was settled around or after the year 1000. It is possible that it was not located at the same spot throughout the entire period. The mountain above the area rises up to 700 m a.s.l. and is steep without distinguished gullies. Evacuation plans have been made for most of the houses in the area except Bræðratunga.

Figure 5 shows the area. It can also be seen on Maps 1 and 9 and longitudinal sections are shown in Drawings 1–4.

Starting area

The potential starting area of the mountainside under investigation is about 600 m wide. Its top is at the mountain ridge at around 700 m a.s.l. and the area reaches down to about 450 m a.s.l. with an area of 26 ha. The starting zone faces south and is fairly even except for two small gullies in the eastern part. Northeast of the starting zone, the top of Eyrarfjall is a plateau. Most of the starting area inclines between 35° and 40°. The area is labelled 2 on Map 9.

West of this starting zone there is another large starting zone above the former ski area, labelled 1 on Map 9. This starting area was delineated without field investigation to be used for model calculations.

Track

The border between the starting area and the avalanche track is unclear because the slope is uniform. The track is considered to begin at 300 m a.s.l. It reaches down to the β-line, which is located between 20 and 30 m a.s.l. A large ridge named Seljalandsmúli begins at a height of 190 m in the western part of the area where the ski hut Skíðheimar is situated. The ridge is directed NW–SE and reaches down to about 80 m a.s.l. The ridge is not high and behind it there is a small gully. The ridge fades out towards the east and is no longer visible somewhat to the west of Seljaland. The landscape will direct avalanches that are released in the western part of the starting area to the southeast. Below the ridge, the track inclines 15°–25° and is highest in the western part.

Runout area

The runout area begins between 20 and 30 m a.s.l. and inclines between 5° and 10° down to the river Tunguá. On the other side of the river, the runout area is almost flat and the easternmost part reaches into the sea.

4.2 Climatic conditions

As stated in the section on general climatic conditions, the prevailing wind directions at the mountain level in the area around Ísafjörður are northeast to east and southwest. The starting zone is on the lee side of the northerly winds. It is more difficult to assess the tendency for snow accumulation in northeasterly winds but according to snow depth measurements and observations of the local snow observer, there is substantially more snow accumulation in the mountainside above the skiing area than in this area during northeasterly winds. This is reflected in the much higher frequency of avalanches from the hill above the skiing area.

4.3 Chronicle

Some avalanches are recorded in Seljalandshlíð, but only one of them has reached the farmhouse Seljaland. That avalanche fell in 1947. It damaged the farmhouse and destroyed three summer cottages which were standing in Seljalandsmúli, but nobody was injured. In 1954 an avalanche damaged two summer cottages and in 1994, an avalanche fell down to the ski access road. Other recorded avalanches are smaller and caused no damage.

The avalanches recorded in the area are shown on Map 3 and listed in the following table.

Number Time *Runout index*	**Description**
3020 24.3.1947 *15.2*	An avalanche was released in Seljalandshlíð. The starting zone was a few hundred meters wide, above Seljaland and Seljalandsmúli. The avalanche destroyed three summer cottages in Seljalandsmúli. At Seljaland, the avalanche damaged a barn and slightly damaged a house, half filling it with snow.
3031 5.3.1954 *13.3*	One summer cottage was ruined and another was shifted from its foundations by an avalanche that fell from Seljalandshlíð above Seljaland.
3125 5.4.1994 *11.5*	Shortly after the large avalanche in Tunguskógur fell, another avalanche was released from the slope above Seljaland. It hit a snowcompactor, but men travelling in it were not injured. The avalanche stopped by the access road to the ski area. The deposit was about 400 m wide, its maximum thickness about 0.5 m, and the volume was estimated at 24 thousand m^3.
3185 22.2.1997 $\ll$ *11*	Two small avalanches on the slope above Seljaland are registered in reports about larger avalanches further east on the same day.
3210 12/13.1.1999 $\ll$ *11*	Two small avalanches fell above Seljaland.

4.4 Assessment

Due to the width and inclination of the starting area large avalanches are possible. As stated in the starting zone description, the starting area is 26.0 ha and therefore, avalanches of several hundred thousands m^3 are conceivable. The conditions favourable for snow accumulation are less frequent than further to the west because the prevailing northeasterly winds blow the snow from the starting area and accumulate it in the old skiing area and the slope above it. It is difficult to precisely quantify the relative frequency of large avalanches in this area compared to the skiing area, but they might be on the order of ten times less frequent. The location of the Seljalandsmúli ridge in the track may be expected to affect the flow of avalanches. The runup on the ridge is not high so the main effect of the ridge is caused by the lateral deflection. It directs avalanches more to the east in the direction of the Seljaland farm. The risk in the western part is then reduced, but correspondingly, the risk in the eastern part is increased. The existence of the Seljaland farmhouse in this more hazardous place does not invalidate this analysis. It does, however, lend support to the conclusion that large avalanches are rare. The avalanche track is gentle and the inclination does not change suddenly between the track and the runout area. This allows long runout distances for large avalanches. An avalanche can be expected to flow over the Seljalandsmúli ridge, but a shorter runout may be expected than in the western part of the area.

4.5 Model estimates

Map 9 shows the results of model calculations and the profiles used for the calculations. The profiles `isse24`, `isse14aa`, `isse33aa` and `isse09aa`, and the results of the calculations are shown in Drawings 1–4. The runout was calculated using runout indices, the α/β-model, the PCM-model and the SAMOS model.

The α/β-model gives very long runout distances in Seljalandshlíð when a β-point at the bottom of the Seljalandsmúli ridge is used. According to the model, the avalanche corresponding to the α-point would run over the entire residential area and pass runout index 16.5. The $\alpha - 2\sigma$ avalanche would run most of the way towards Holtahverfi. The model probably overestimates the potential runout and cannot be considered suitable for this area due to the atypical shape of the slope, a part of which is almost flat near 100 m a.s.l. at the height of the Seljalandsmúli ridge.

An avalanche with runout index $r = 14$–16 is needed to pass the ridge Seljalandsmúli and smaller avalanches should stop above the ridge. Since the calculations are done with a one-dimensional model they do not return a realistic indication of the effect of Seljalandsmúli.

The recorded avalanches with a runout index of 13 or greater are $r = 15.2$ in 1947 and $r = 13.3$ in 1954. Those avalanches fell in the eastern part of the area, above the farm Seljaland. If two avalanches have reached runout about 13 in 70 years, and one avalanche has runout over 15 in a 200–300 years period, which is the period when serious damage of a house is expected to be recorded, it indicates that the frequency down to runout index 13 is about 1.5–3 in a period of 100 years, or 0.015–0.03 per year in the profile `isse09aa`.

There are three recorded avalanches which have runout indices higher than 15 in the ski area Seljalandsdalur west of Seljalandshverfi. They fell in the years 1953, 1994, and 1999. According to RiskEst, three avalanches in a period of 50–100 years with runout indices of 15 or over indicates a frequency of 15 avalanches per about 100 years or 0.15–0.3 per year in runout index 13. The frequency in the hillside above Seljalandshverfi should be substantially lower than in the skiing area both according to local climate and observed avalanches, because snow tends to accumulate in the ski area in northeasterly winds. If the frequency above Seljalandshverfi is assumed to be 5–10 times lower than in the ski area then the frequency at runout index 13 is 0.015–0.06 avalanches per year.

The farm Seljaland has existed for at least 700 years and probably longer (possibly 1100 years). It is not certain whether the house has been standing on the same site throughout its history. Using the frequency $F_{13} = 0.025$, the return period to a point 50 m below the farmhouse is estimated as 340 years. The return period just above the house is then approximately 200 years. Assuming that an avalanche needs to pass a house by 50 m to cause enough damage and injuries for it to be recorded, the probability of the house standing for 700 years and being hit once or less by an avalanche is about 39%. Thus the adopted annual frequency of 0.025 is not inconsistent with the observation that the farm has probably only been damaged once in 700 years. Adopting a much higher frequency would, however, make it difficult to explain that the farm has not been damaged more often.

The Austrian avalanche model SAMOS was applied to evaluate the direction of avalanches from the starting areas and the lateral extent of avalanches. The results are described by Tómas Jóhannesson *et al.* (2002).

4.6 Conclusion

RiskEst is used to estimate the avalanche risk in the outer part of the area. The frequency of avalanches, the main parameter in the calculations, was chosen to be 2.5 avalanches per 100 years in runout index $r = 13$. This takes into account the avalanche history of the area and the neighbouring skiing area as well as the existence of the farm Seljaland and the fact that the ridge Seljalandsmúli increases the risk at Seljaland.

In the inner part of the area, delineation is somewhat more difficult due to the protective effect of the ridge. The protection of the ridge is considered to decrease the risk by a factor of 3–10. This is partly based on the results of the two-dimensional SAMOS model.

The outer part of the slope is a typical avalanche path with recorded avalanches so the uncertainty is considered to be low ($\frac{1}{2}$). In the inner part of the area, the uncertainty is higher and is estimated to be medium (1).

The hazard zoning proposal is shown on Map 12.

Figure 6. *Seljalandshlíð between Seljaland and Gleiðarhjalli (Photo: Jón Gunnar Egilsson).*

5 Seljalandshlíð (Between Seljaland and Gleiðarhjalli)

Detailed field investigations were not carried out for this area. The main avalanche paths are four gullies. Only one of them has an established name, Hrafnagil. The other ones are referred to here as Karlsárgil (the westernmost gully), Grænagarðsgil (next gully to the west of Hrafnagil) and Steiniðjugil (the easternmost gully). Numerous avalanches are recorded from all four gullies. Many of them have caused damage and some have reached into the sea. The runout zones of the avalanche paths more or less overlap. The avalanche chronicle thus makes it evident that the area is very hazardous. Furthermore, the area has already been ruled out as a potential building area. For these reasons, a detailed investigation was not performed. The entire area is defined as a zone requiring the highest alertness under hazardous conditions in the evacuation plan for the Ísafjörður community. Map 9 shows starting areas labelled 3–6 which were delineated based on inclination maps in order to perform the two-dimensional SAMOS simulations.

Figure 6 shows the area. It can also be seen on Maps 1 and 9 and longitudinal sections are shown in Drawings 5–8.

5.1 Chronicle

The avalanches recorded in the area are shown on Map 3 and listed in the following tables.

Karlsárgil

Number Time *Runout index*	**Description**
3021 24.3.1947 > *13.8*	An avalanche took the house Karlsá and moved it down to the seashore. Some stories claim that the house went 80 m out on the frozen sea. The housewife, who was home alone, was injured.
3254 29.12.1989	An avalanche released in Karlsárgil stopped at the top of the debris cone below the gully.
3097 13.11.1991 *10.4*	A slab avalanche was released in Karlsárgil and stopped about 100 m above the road Skíðavegur. The deposit was 90 m wide. It was thickest at 0.6 m, and the volume was around 7 thousand m^3.
3147 16.1.1995 > *13.5*	A slab avalanche fell from Karlsárgil down to the sea. The avalanche damaged a summer cottage, sheep shed, and a goose house. Five sheep and a few geese were killed. Four utility poles were toppled and 150 m of a fence was damaged. The tongue was widest at 230 m, but it was 140 m wide on the road. It was 1 m thick at its thickest.
3180 22.2.1997 *10.7*	An avalanche released in Karlsárgil reached the rim gate on the ski area access road. Its width was about 100 m and the depth was close to 0.2 m on average with a maximum depth of 0.5 m. The volume was estimated to have been 6000 m^3.
3197 22/23.10.1998 *8.1*	A small thin avalanche stopped at about 155 m a.s.l.
3224 21.2.1999 > *13.5*	An avalanche was released in Karslárgil and fell over Skutulsfjarðarbraut. The western boundary of the deposit was by the eastern side of the ruins of the house at Karlsá that was destroyed by an avalanche in 1947. The width of the deposit was about 150 m and the volume about 30000 m^3. The average thickness was about 0.5 m and the maximum thickness was about 2 m.
3228 11.3.1999 *10.2*	See avalanche no. 3229 in Hrafnagil.

Grænagarðsgil

Number Time *Runout index*	**Description**
3009 15.2.1916 *13.5*	An avalanche fell from the gully west of Hrafnagil, hit the farm Grænigarður, and went into the sea. The house was destroyed. The roof and one of the corners of the house were torn off. The avalanche moved the house to the sea. A mother and a daughter who were in the house escaped without injury. The description of this avalanche is inconsistent.
3019 24.3.1947 *12.5*	An avalanche fell from Seljalandshlíð between Karlsá and Grænigarður. The avalanche splintered a small summer cottage and destroyed a henhouse.
3037 10.11.1969 *12.7*	An avalanche was released above Grænigarður. It damaged summer houses and probably utility poles.
3038 10.11.1969 *12.4*	An avalanche fell on Seljalandsvegur. The location of the avalanche is very uncertain.
3045 12.2.1974 *13.5*	An avalanche was released in Grænagarðsgil. It destroyed a new large truck and transported it down to the sea. The avalanche also broke three utility poles.
3253 29.12.1989 *9.3*	A wet slab avalanche was released in Grænagarðsgil and stopped a short distance above the quarry.
3126 5.4.1994 *> 13.8*	A slab avalanche was released in the gully west of Hrafnagil, fell over the road Skutulsfjarðarbraut, and into the sea. The avalanche toppled two utility poles, damaged fences, and buried about 80 m of the road. The tongue was 190 m wide, 1 m thick at its thickest and the volume around 17300 m^3.
3144 17/18.12.1994 *9.5*	An avalanche was released in Grænagarðsgil. The avalanche report contains no detailed information on the avalanche, but judging from other avalanches recorded in the same cycle and photographs, it was probably a small thin avalanche.
3164 23.10.1995 *13.0*	A dry slab avalanche stopped by the crossing of Skíðavegur and Seljalandsvegur. The deposit was 100 m wide, with a maximum thickness of 0.8 m. The volume was 9000 m^3. The avalanche damaged 50 m of a fence.
3204 14/15.12.1998 *< 11*	A small avalanche fell from Grænagarðsgil.
3209 12/13.1.1999 *12.3*	An avalanche stopped 30 m above Seljalandsvegur. The tongue was 150 m wide and 0.3 m thick.

Number Time *Runout index*	**Description**
3218 21.2.1999 *9.4*	A rather small avalanche was released in Grænagarðsgil and stopped at about 60 m a.s.l. The tongue was about 35 m wide.
3273 31.12.1999 *9.2*	A small avalanche fell in Grænagarðsgil and stopped a short distance below the mouth of the gully.
3269 8.1.2000 *10.1*	A dry slab avalanche was released in Grænagarðsgil. It stopped just above the utility line. The deposit was about 45 wide and 0.3 m thick on average. The volume was about 1350 m^3.
3245 29.2.2000 *9.8*	An avalanche fell in Grænagarðsgil. It stopped at about 50 m a.s.l. The width of the depoit was about 120 m and the volume about 4800 m^3.

Seljalandshlíð: Grænigarður – Hrafnagil

Number Time *Runout index*	**Description**
3027 1.5.1952 *12.2*	An avalanche fell from Hrafnagil and destroyed a ski lift by Grænigarður.
3065 24.3.1987 *12.1*	A dry slab avalanche fell from Hrafnagil and stopped about 150 m above the house Grænigarður. The avalanche buried a tractor and the driver without harming either. About 50 m of a sheep fence were damaged. The deposit was about 100 m wide and the maximum thickness about 3 m. The volume was an estimated 23000 m^3.
3080 26.2.1989 *9.9*	A slab avalanche was released in Hrafnagil, fell down to a quarry, and stopped at around 50 m a.s.l. The tongue was 150 m wide and 4 m thick at its thickest.
3252 29.12.1989 *10.2*	A wet slab avalanche was released in Hrafnagil and stopped in the quarry.
3092 27.1.1990 *11.4*	A slab avalanche fell from Hrafnagil and stopped in a quarry above the road. The tongue was about 100 m wide, 4–5 m thick maximum, and around 8000 m^3 in volume.
3095 13.11.1991 *10.9*	A slab avalanche fell from Hrafnagil and stopped in a quarry above the road. The tongue was approximately 80 m wide and 3 m thick.

Number Time *Runout index*	**Description**
3113 13.1.1993 *12.7*	A slab avalanche fell from Hrafnagil and most of it stopped in the quarry. A narrower tongue stopped 20 m above the road Seljalandsvegur. The main tongue was 60 m wide and 0.6 m thick at its thickest. The volume was around 3000 m^3.
3143 17/18.12.1994 *9.8*	An avalanche fell from Hrafnagil. It was probably thin.
3149 18.1.1995 *13.4*	An avalanche surpassed Seljalandsvegur by 40 m and its width on the road was 140 m. The average depth of the tongue was 1 m and the volume was estimated at 17000 m^3. The avalanche hit a corner of Grænigarður and ran alongside the house without damaging it.
3163 23.10.1995 *12.6*	An avalanche stopped about 40 m above Grænigarður on Seljalandsvegur. It was around 90 m wide and approximately 1 m deep. The volume was 8000 m^3.
3179 22.2.1997 *9.8*	An avalanche stopped on the debris cone about 200 m below the mouth of the gully. It was almost 50 m wide and around 0.3 m deep with a maximum depth of 2 m. The volume was estimated at 2700 m^3.
3187 1.3.1997 *10.0*	A dry slab avalanche was released in Hrafnagil. It stopped by the quarry about 200 m down the ridge. The width of the deposit was about 60 m and the volume about 4800 m^3.
3192 8.2.1998 *9.4*	An avalanche was released in Hrafnagil. It stopped at about 80 m a.s.l. The deposit was about 45 m wide and 0.4 m thick on average. The volume was about 3600 m^3.
3203 14/15.12.1998 *7.8*	A small avalanche that was released in Hrafnagil stopped at about 120 m a.s.l.
3211 12/13.1.1999 *10.2*	A small avalanche stopped at around 55 m a.s.l.
3217 21.2.1999 *$<$ 11*	A small avalanche fell in Hrafnagil and stopped at about 90 m a.s.l.
3229 12.3.1999 *11.2*	A few wet avalanches were released at about 350 m a.s.l. in Hrafnagil. The longest avalanche stopped at about 80 m a.s.l.
3265 12.2.2000 *$<$ 11*	A small avalanche fell in Hrafnagil down to about 90 m a.s.l.

Number Time *Runout index*	**Description**
3249 24.2.2000 *10.5*	A dry slab avalanche fell in Hrafnagil and stopped at about 65 m a.s.l. The width of the deposit was about 45 m and it was about 0.3 m thick. The volume was about 2000 m^3.
3259 4.3.2001 *9.7*	A small avalanche fell in Hrafnagil down to about 65 m a.s.l.
3277 22.2.2002 *11.1*	A dry slab avalanche was released at about 450 m a.s.l. in Hrafnagil and stopped at about 40 m a.s.l. The deposit was about 50 m wide and 0.3 m thick with a volume of about 7000 m^3.

Seljalandshlíð: By Gleiðarhjalli above Steiniðjan

Number Time *Runout index*	**Description**
3018 2.3.1941 *13.6*	A 250 m wide avalanche moved the house Sólgerði to the seashore where it burned down. Two girls who were in the house died and a boy was injured. Five escaped from the house, some of them slightly injured. The avalanche also destroyed a corner of a sheep shed, filled it with snow, and killed 11 of 22 sheep.
3032 5.3.1954 *10.6*	An avalanche fell on the sheep roundup pen by Grænigarður.
3036 10.11.1969 *13.2*	A large part of the Steiniðjan carpentry shop was ruined in an avalanche from Seljalandshlíð. The avalanche burst through the roof and one wall of the workplace filling the building with snow.
3041 12.2.1973 *12.0*	An avalanche fell from Seljalandshlíð between Karlsá and Grænigarður. It toppled a utility pole. It hit a goose house and killed all but three geese.
3081 26.2.1989 *9.5*	A slab avalanche fell from the next gully east of Hrafnagil and stopped at 50 m a.s.l. The tongue was 100 m wide and 0.8 m thick at its thickest.
3139 29.12.1989 *8.1*	A small avalanche fell in Steiniðjugil and stopped at about 75 m a.s.l.
3091 27.1.1990 *9.6*	An avalanche fell from Steiniðjugil and stopped above the road. The tongue was around 100 m wide and 0.4 m thick maximum. The volume was around 300 m^3.

Number Time *Runout index*	**Description**
3096 13.11.1991 *10.2*	A slab avalanche was released in Steiniðjugil and stopped above the road. The tongue was around 150 m wide.
3106 26.11.1992 *10.8*	An avalanche was released in Steiniðjugil. It fell over the road, down to a quarry, and damaged a 100 m length of sheep fence. The tongue was about 150 m wide and 1 m thick at its thickest. The volume was around 7500 m^3.
3913 13.1.1993	
3148 17.1.1995 > *13.6*	An about 250 m wide slab avalanche was released in Steiniðjugil and reached the sea. The avalanche destroyed a new summer cottage standing east of Steiniðjan. It went into the upper floor of Steiniðjan and damaged the roof, some doors, windows, and machines. Three utility poles were toppled. The volume of the avalanche was about 25000 m^3.
3162 23.10.1995 *13.4*	A large avalanche with an estimated volume of 14000 m^3 reached down to the Skutulsfjarðarbraut road. It broke doors and windows in Steiniðjan and flowed into the building. Two high voltage power line poles were toppled and the line was severed. A sheep corral was damaged as well. The deposit was 140 m wide and almost 1 m thick. The avalanche was rocky and coloured by mud.
3183 22.2.1997 *8.0*	An avalanche stopped on the debris cone at about 80 m a.s.l. It was almost 60 m wide and around 0.2m deep with a maximum depth of 0.4 m. The volume was estimated around 1800 m^3.
3202 14/15.12.1998 *11.4*	An avalanche stopped at 15 m a.s.l. just above Seljalandsvegur. It was close to 90 m wide and around 0.3 m deep with a maximum depth of 0.6 m. The volume was estimated around 6750 m^3.
3212 12/13.1.1999 *9.6*	An avalanche reached the power line at about 40 m a.s.l. It was about 75 m wide.
3225 11/12.3.1999 *10.0*	Two or possibly more avalanches fell between Steiniðjugil and Hrafnagil. They stopped in the foot of the slope at about 50 m a.s.l.
3270 8.1.2000	A dry slab avalanche was released in Steiniðjugil and stopped at about 55 m a.s.l. The width of the deposit was about 45 m and the volume about 1350 m^3.

5.2 Model Estimates

Map 9 shows the results of model calculations and the profiles used for the calculations. The profiles `isse12aa`, `isse05aa`, `isse06aa` and `isse08aa`, and the results of the calculations are shown in Drawings 5–8. The runout was calculated using runout indices, an α/β-model and the SAMOS model.

To reach the shoreline an avalanche must have a runout index of about 14 and with the α/β-model, it measures to be a little more than $\alpha + \sigma$. There are on average 3 avalanches with $r \geq 13$ from each of the main gullies in the area. The increased frequency in the past few years indicates that the records are somewhat incomplete before systematic records were kept. The frequency F_{13} is therefore estimated to be in the region of 0.05–0.1 per year. Using a frequency of that order gives an annual risk at the shoreline of about $100 \cdot 10^{-4}$ at the shoreline directly below the gullies.

The Austrian avalanche model SAMOS was applied to evaluate the direction of avalanches from the starting areas and the lateral extent of avalanches. The results are described by Tómas Jóhannesson *et al.* (2002).

5.3 Conclusion

The risk in all of the area is considered to be more than $3 \cdot 10^{-4}$ and therefore the entire area is in the category C hazard zone.

The uncertainty of the assessment that all the area is in the category C hazard zone is practically zero since the boundary of the category C hazard zone is well beyond the shoreline. No conceivable reinterpretations of the data or changes in hazard zoning methods are likely to change this assessment. The uncertainty of the risk estimate as such is low ($\frac{1}{2}$) directly below the gullies, but somewhat higher between them.

The hazard zoning proposal is shown on Map 12.

Figure 7. *Eyrarfjall and Gleiðarhjalli (Photo: Jón Gunnar Egilsson).*

6 Gleiðarhjalli

6.1 Topographic description

Gleiðarhjalli is the name of a plateau in the mountain above the oldest settlement of Ísafjörður. The plateau is about 450 m wide at the center but becomes narrower towards the edges. Above Gleiðarhjalli steep cliffs rise up to about 750 m a.s.l. The hillside below Gleiðarhjalli ranges from 400 to 460 m a.s.l. The uppermost part consists of cliffs with bowls and narrow gullies in between. Below the cliffs the hillside is fairly even, but there are two ridges in the lower part, Stakkaneshryggur and Stórurð. Evacuation plans have been made for most of the houses in the top two rows of houses in the area.

Figure 7 shows the area. It can also be seen on Maps 1 and 10 and longitudinal sections are shown in Drawings 9–15.

Starting area

Several potential starting areas have been delineated below Gleiðarhjalli. The areas are shown on Map 10, labelled 7–15.

The potential starting area is estimated to range from 280 m a.s.l. up to around 460 m a.s.l. below the Gleiðarhjalli plateau. The slope has an inclination of more than 30° down to about 160 m a.s.l. Due to the high inclination of the cliffs above the plateau and the width of the plateau, the cliffs are not considered to be a potential starting area for avalanches that would pass the plateau. The starting area under consideration above the houses is in total more than 1.2 km wide and interrupted by several small gullies and two larger bowls above the Stakkaneshryggur and Stórurð ridges. The inclination of the starting area is between 40° and 45° in the upper part, though some cliffs are nearly vertical. In the lower part of the starting area the inclination decreases to around 30° at about 160 m a.s.l. The starting area is convex and the aspect is from the SE in the western part to the ESE in the eastern part.

According to the cross profiles and the potential for snow accumulation, the two bowls (labelled 8 and 12) are the main potential starting areas of snow avalanches. Cornices at the top of both bowls in the spring of 1999 indicate that snow drifting from the plateau might accumulate there. The western bowl is approximately 120 m wide, and the eastern bowl is about 150 m wide. Their areas are 3.6 ha and 3.5 ha respectively.

Starting area 7 is about 120 m wide and the upper part is divided by three shallow gullies. The two western gullies are divided and have a V and a Y form. The gullies are not estimated to be deep enough to interrupt the fracture of a snow slab so the starting area is considered to reach all the way up to plateau.

Starting areas 9–11, between the bowls are 260 m wide in total and interrupted by several gullies that are deeper than the gullies in starting area 7. The gullies are 20–25 m deep and divided by cliffs. The cliffs reach from the plateau down to around 340 m a.s.l. so the starting area is estimated to extend from 340 m down to about 280 m a.s.l. The area below the cliffs is characterised by three shallow depressions that can be considered three separate starting areas for smaller avalanches or one larger starting area covering all three depressions for larger avalanches.

Starting areas 13–15 are about 450 m wide and have a similar morphology as areas 9–11. The areas are divided by several gullies in the upper part, and the lower part of the starting area is characterised by two shallow depressions.

According to the Swiss guidelines the roughness of the bowls is about 2 and higher than the roughness in the areas outside of the bowls that ranges from 1–2.

Track

The inclination below 160 m a.s.l. is less than 30° and it is higher than 10° down to 20–40 m a.s.l. at the β-line. This area, and the area between 280 and 160 m a.s.l. where the inclination is more than 30°, is considered to be the avalanche track. The area is fairly even and marked with several shallow debris cones and gullies. Many rocks that have fallen from the edge of the plateau and the cliffs below the plateau are scattered on the track. Two ridges located below the bowls interrupt the avalanche track. The western ridge, Stakkaneshryggur, is not high whereas the eastern one, Stórurð, is quite large, up to 35 m higher than the surroundings. The lower part of the avalanche track is covered with grass and partly with trees. Two shallow ditches have been dug to drain the soil and to provide some protection against debris flows.

Runout area

The runout area is below 20–40 m a.s.l. The inclination ranges from almost 10° down to 0°. The runout area is densely settled with houses. Some houses were built in the area before 1900, but the settlement started to form in the first three decades of the twentieth century. Most of the houses standing closest to the mountain are built around 1970 or later.

6.2 Climatic conditions

It is clear that snow accumulation from the plateau is not as likely as snow accumulation from the top of the mountain above the plateau. According to the topography, snow will be blown away from the starting zone in northeast to easterly winds. Observations of the local snow observer confirm this effect. On the other hand, it is not possible to rule out the possibility of snow accumulation in the upper part of the starting areas during north to northeasterly winds. Snow might then drift along the plateau and accumulate mostly in the western part of the starting area. Snow depth measurements in the past few years indicate that considerable snow accumulation is possible in the starting area and that it is more likely in the western part than in the eastern part.

6.3 Chronicle

There is firm evidence for only two avalanches from the hillside below Gleiðarhjalli. That is a small avalanche, which fell above Stakkaneshryggur in 1989, and a smaller one to the west of Stakkaneshryggur in the year 2000. In addition, there are unclear descriptions of a narrow avalanche that may have reached the area of the present settlement around 1950.

The avalanches recorded in the area are shown on Map 4 and listed in the following table.

Number Time *Runout index*	**Description**
3153 1944–1953 *12.1*	There are unclear descriptions of an avalanche from Gleiðarhjalli sometimes in the period 1944–1953 that is supposed to have stopped between Urðarvegur and Engjavegur between houses that were being built at the time.
3079 26.2.1989 *10.1*	A slab avalanche fell down the Stakkaneshryggur ridge and stopped at 40 m a.s.l. about 100 m above the uppermost houses. The tongue was around 70 m wide and 1 m thick at its thickest. A forest fence was damaged along a 40 m length.
3247 29.2.2000 *7.4*	An avalanche fell south of Stakkaneshryggur. It stopped at about 110 m a.s.l. The deposit was about 70 m wide and 0.15 m thick on average. The volume was about 2100 m^3.

6.4 Assessment

Due to the shape and size of the starting area, a large avalanche with a fracture covering the whole starting area is very unlikely. Smaller avalanches from individual parts of the starting areas are more likely. The areas that are most favourable for avalanche release are the two bowls (8 and 12). Due to the greater possibility of snow accumulation in areas 7 and 9–11 than in area 13–15, areas 7 and 9–11 are the second most favourable starting areas. Areas 13–15 are the least favourable.

Long runout distances are unlikely because the starting areas are small, snow accumulation is smaller than in starting areas higher up that have a larger catchment area, and the fall height of the avalanche is only 300–350 m. The avalanche chronicle furthermore indicates that the frequency of avalanches is low.

The potential release area in each bowl is estimated to be 1–3 ha. In the areas between the bowls, a release area of 0.5–2 ha is possible.

The location of the settlement is such, at the foot of the mountain, that even small avalanches with short runout distances are sufficient to threaten the houses and people living there. The most endangered houses are the ones below the bowls (8 and 12) due to the reasons stated above and the houses below areas 9–11 because the runout area there is steeper than in the rest of the settled area.

The Stórurð ridge provides some defence for the houses right below by dividing or directing avalanches released from the bowl above.

Above the Gleiðarhjalli plateau there is a potential starting area between about 600 and 700 m a.s.l. The area is steep with an average inclination of about 45°. Snow accumulation in the area is mainly possible during northwesterly winds. In the inner part of Gleiðarhjalli the plateau is not wide and medium sized avalanches could pass the plateau. The risk associated with such events is considered low. This risk is highest in the area of the highest avalanche hazard from the starting areas below Gleiðarhjalli.

6.5 Model estimates

Map 10 shows the results of model calculations and the profiles used for the calculations. The profiles `isey02ba`, `isey03ba`, `isey05ba`, `isey07ba`, `isey09ba`, `isey11ba` and `isey13ba`, and the results of the calculations are shown in Drawings 9–15. The runout was calculated using runout indices, an α/β-model and the SAMOS model.

The β-line is located close to the uppermost houses in most of the area. Similarly runout indices confirm that even small avalanches threaten the settlement with the uppermost houses located near runout index $r = 11$.

Direct frequency estimation to apply the methods of RiskEst is impractical in this area and the slope is, furthermore, dissimilar to the majority of the slopes used in the development of those methods. The methods of RiskEst are therefore not applied to the area.

The runout of the larger avalanche recorded with certainty in the area is $r = 10.1$. The two avalanches are the only ones recorded in the almost 20 years for which reliable avalanche accounts exist. The width of the larger avalanche was 70 m. The total width of the settlement below Gleiðarhjalli is about 1500 m. Assuming that this avalanche is representative for the average avalanche frequency in the area the yearly frequency at runout index 11 is lower than 1/400, but it also seems unlikely that it is lower than 1/1000.

The history of the settlement indicates that it is unlikely that the average yearly probability of avalanches with runout index 11 is higher than 1/300–1/100 per year.

One must be very cautious when interpreting the almost non existent avalanche chronicle for Gleiðarhjalli. The starting area is in fact several small starting areas. The event of an avalanche in one of the starting areas is not independent of the event of an avalanche in the other starting zones. The avalanche events in the area will therefore tend to occur more than one at a time. This decreases the probability of observing avalanches in a given time period from what it would have been if the avalanche events were independent.

The Austrian avalanche model SAMOS was applied to evaluate the direction of avalanches from the starting areas and the lateral extent of avalanches. The results are described by Tómas Jóhannesson *et al.* (2002).

6.6 Debris flow and rockfall

There are extensive historical records of debris flow and rockfall activity in the Gleiðarhjalli area and the geological evidence indicates high activity during the last decades. A total of 19 numbered debris flow paths have been mapped by Thorsteinn Sæmundsson and Halldór G. Pétursson (1999). It is clear that many large debris flows have occurred in the area, some of them reaching the sea. It is also clear that some paths are more active than others. Evidence of two large events, more like small rockslides, exist in the area, at the Stórurð and Stakkaneshryggur ridges. The size of the debris flows that could be expected in the area is not easily estimated. A debris flow, estimated to be around 2000–3000 m^3, fell down path number 5 in 1999. It is clear that even larger debris flows can occur in the area. The largest known debris flows in the Gleiðarhjalli area have occurred in the easternmost part of the area, in paths 15–19.

The residential area below the Gleiðarhjalli plateau may be divided into three parts. The outermost part covers Hjallavegur 1 to 23. In this area many debris flows have been observed during the last decades. Rockfall activity has also been high. A drainage ditch has been dug above the houses, which has proven useful both to stop and divert debris flows and also to prevent boulders reaching the houses. Even though the ditch has proven useful it needs to be redesigned and enlarged in order to improve the protection of the houses.

In the central part of the Gleiðarhjalli area, Urðavegur 2-10 and Hlíðarvegur 1-7, houses are located further from the slope than in the inner and outer parts. Many debris flows and rock fall events have occurred in this area during the last decades. No ditches have been made above the houses.

In the innermost part of the town, the area Urðavegur 16-80, houses are located closer to the mountainside than in the other parts. As in the outermost part a drainage ditch has been constructed above the houses at Urðarvegur 50-80. Many debris flows and rockfall events have occurred in this area during the last decades and the ditches have proved useful to prevent damages to the houses.

The area below the Gleiðarhjalli plateau is considered to be a high frequency area with respect to debris flows and rockfall. Both debris flows and rockfall can easily reach the houses. The hazard is somewhat higher in the inner and outer parts than in the central part.

6.7 Conclusion

The frequency estimate of 1/1000–1/100 for snow avalanches at runout index 11 is the best frequency estimate currently available. The border of the category C hazard zone is taken from runout index 10 to 11.5 depending on location within the area. Relative variations in the placement of the category C hazard line are determined by the location of potential starting zones for snow avalanches and the degree of debris flow and rockfall danger described above.

Since risk due to avalanches is thought to decrease by a factor of approximately 3 for a unit increment in runout index, the width of the category B and A hazard zones is taken to be approximately one runout index which in this area corresponds to about 40–70 m.

The risk of rockfall reaching the uppermost houses in the streets Urðarvegur and Hjallavegur clearly exists, and threatens houses and people. Debris flows can occur in the whole area and threaten houses especially in the inner and outer part. Ditches that have been dug in parts of the area have proven useful to prevent damages.

The estimated hazard zones in Gleiðarhjalli can in a vague sense be interpreted as risk estimates if houses were not reinforced at all. The same disclaimer should be made here as for Brattahlíð in Kubbi. With reinforcements it may be possible to attain an acceptable risk even within the category C zone. Existing houses will provide considerable defence for houses further below and the actual risk in a part of the area may therefore be expected to be smaller than the risk indicated by the hazard zoning.

During the fieldwork, a rough delineation of hazard zones was done using Austrian methods and regulations. This delineation is similar to that obtained above by considering the risk in the area and applying the Icelandic regulations.

The estimated risk is a sum of the risk due to avalanches released above Gleiðarhjalli, the risk caused by avalanches released below Gleiðarhjalli and the risk caused by debris flows and rockfall.

The slope is an atypical avalanche path with almost no records of avalanches and the uncertainty of the estimation is considered to be high (2).

The hazard zoning proposal is shown on Map 12.

Figure 8. *Bakkahyrna (Photo: Harpa Grímsdóttir).*

7 Bakkahyrna

7.1 Topographic conditions

The side of Bakkahyrna which faces the settlement in Hnífsdalur is uniform and without distinctive gullies. It rises from sea level just east of the settlement and reaches almost 500 m a.s.l. above the westernmost part of the settlement. The hillside is steep and inclines 30° to 45° above 100 m a.s.l. Evacuation plans have been made for most of the houses within 100 m of the bottom of the slope.

Figure 8 shows the area. It can also be seen on Maps 1 and 11 and longitudinal sections are shown in Drawings 24 and 25.

Starting area

The starting area can theoretically range from the mountain ridge down to about 100 m a.s.l. Due to snow accumulation conditions that are considered to be the most favorable in Bakkahyrna, only the top 150 m is defined to be a potential starting area. The mountain ridge is about 150 m high above the outermost houses and about 500 m high above the innermost ones. The inclination along the mountain ridge is between 35° and 40°. The mostly grassy starting area is even, slightly convex, and interrupted by several very small gullies.

The roughness according to the Swiss guidelines is higher than 2.5. Since the delimitation of the starting zone is unclear, it is difficult to quantify the area but it is estimated to be approximately 10–20 ha.

Track

As stated previously, the lower boundary of the starting area is unclear and the same applies to the track. The inclination down to about 100 m a.s.l. is 35°–40°. Below 100 m a.s.l. and down to about 40 m a.s.l. the inclination is around 25°. From 40 m a.s.l. down to the β-point, the inclination is 13–15°. The track is unconfined and interrupted by several small gullies.

Runout area

The runout area starts along the β-line located at 25 m a.s.l. in the middle of the area but 35–40 m a.s.l. at the boundaries. The inclination of the runout area averages 5° in the area of the houses but below the houses, an 8 m high bank edges the river Hnífsdalsá. The runout area is densely settled in the outer part and with a one row of houses in the inner part. The houses are mostly built in the 1960's and 1970's.

7.2 Climatic conditions

Snow accumulation is most likely during south to southeasterly winds, which may transport snow from the eastern side of Bakkahyrna to the northwest facing slope above the settlement. The wind tends to blow to the east along the hillside above Hnífsdalur during southwesterly winds with little tendency for snow accumulation on the slope above the settlement. The first of the two recorded avalanches in Bakkahyrna fell a few days prior to an avalanche in Kubbi in 1984. Part of the slab in Kubbi may have accumulated during the same time as the slab that was released in Bakkahyrna. This indicates that the weather favorable for avalanche release is similar in both slopes. Gullies in the higher part of Bakkahyrna on the other side might tend to reduce snow accumulation in the upper part of the hill.

7.3 Chronicle

Two avalanche are recorded from Bakkahyrna above the settlement. They are listed in the following table and one of them is shown on Map 5.

Number Time *Runout index*	**Description**
3053 30.12.1983 *10.7*	A dry slab avalanche fell from Bakkahyrna. It started at the top of the mountain above Hádegissteinn. The avalanche burst through a door on the house at Dalbraut 9 and filled a storage and a washing room. It also shattered two windows at the factory Eggver sf. and snow filled a storage room. The tip of the tongue was about 30 m wide and the maximum width was more than 100 m. The depth of the tongue was about 3 m around 200 m above Dalbraut 9, but by the house itself, the depth was approximately 0.5 m.
3059 23.12.1985	An avalanche fell from Bakkahyrna.

7.4 Assessment

Weather conditions that lead to an avalanche release in this slope are relatively infrequent. Furthermore, high snow accumulation on the smooth uniform starting area is not probable. Large avalanches are therefore considered unlikely. The settlement is so close to the mountain that even small avalanches can threaten the houses and residents. Small avalanches are infrequent but not impossible as the avalanche in 1983 demonstrates. It is unclear what the effect of the 13°–15° inclination above the β-point will be on such avalanches, but according to the Swiss guidelines, small avalanches might slow down on such slopes.

7.5 Model estimates

Map 11 shows the results of model calculations and the profiles used for the calculations. The profiles `hnsu01ba`, `hnsu03aa` and `hnsu05aa`, and the results of the calculations are shown in Drawings 23–25. The runout was calculated using runout indices, an α/β-model and the SAMOS model.

In the outer part of the area, the uppermost houses stand close to and above the β-line but in the inner part, the houses are a little further away from the mountain. The runout by the uppermost houses is around $r = 10$.

This slope is similar to Brattahlíð and Gleiðarhjalli in that the methods of RiskEst are not suitable for the hazard assessment.

The larger recorded avalanche was about 100 m wide and had a runout that measures $r = 10.7$. It is certainly the only avalanche threatening the settlement in the area in the past 20 years and probably the past 30–40 years. Assuming that the frequency is uniform in all of the area (about 600 m wide) and the observation period is 30 years, the frequency of avalanches with runout index about 11 is about 1/200. The area has only been settled for a short period of time and it is possible that the frequency is considerably higher or lower.

The Austrian avalanche model SAMOS was applied to evaluate the direction of avalanches from the starting areas and the lateral extent of avalanches. The results are described by Tómas Jóhannesson *et al.* (2002).

7.6 Conclusion

With respect to the crude frequency estimate mentioned above and comparing the hazard in the area to Brattahlíð and Gleiðarhjalli, the border of the category C hazard zone is placed at around runout index 11.

The width of the category B and A hazard zones is chosen to be about one runout index, corresponding to approximately threefold reduction in risk for a unit increase in runout measured by runout indices.

The slope is an atypical avalanche path with few records of avalanches. The uncertainty is evaluated as medium to high (1–2).

The hazard zoning proposal is shown on Map 13.

Figure 9. *Búðarhyrna and the northern part of the settlement in Hnífsdalur (Photo: Harpa Grímsdóttir).*

8 Búðarhyrna

8.1 Topographic conditions

Búðarhyrna rises up to about 600–650 m a.s.l. above the northern part of the settlement in Hnífsdalur. Three deep gullies characterise the area, Hraunsgil in the west, then Traðargil and finally Búðargil, which is the easternmost gully. Evacuation plans have been made for most of the houses in the area.

Figure 9 shows the area. It can also be seen on Maps 1 and 11 and longitudinal sections are shown in Drawings 20–22.

8.2 Búðargil

8.2.1 Topographic conditions

Starting area

The starting area is between 400 and 620 m a.s.l. It is facing southeast and formed as a deep cliff-like gully. The average width is about 120 m and the average depth of the gully is about 20 m. The gully is interrupted by several meter high cliff formations. The starting area is 4.9 ha. The average inclination is around 45°. The starting area is without vegetation, the roughness according to the

Swiss guidelines is 1.2.

Track

The track begins at 400 m a.s.l. with average inclination of 35° down to 200 m. Between 200 and 100 m a.s.l. the inclination is 30°, and between 100 m and the β-line (10°) the inclination decreases gradually. The avalanche track is confined by about a 10–20 m deep gully but below 110 m a.s.l. it opens on to the debris cone below the gully and there avalanches can spread. The obviously old debris cone is covered with grass.

Runout area

The runout area covers the rest of the debris cone and on the eastern side it goes into the sea, about 250 m from the β-point. The inclination of the runout zone ranges from 3° to 17° in a 10 m high step near the shoreline. No houses are in the middle of the runout area, but some horse sheds built in 1983 are along its eastern boundary. A few abandoned houses are located in the western part.

8.2.2 Climatic conditions

Snow accumulation in the starting area can occur when wind blows from northeast to northwest. It is clear that snow accumulation in the gully is frequent which is confirmed by the high avalanche activity.

8.2.3 Chronicle

Many avalanches are recorded from Búðargil. In 1910 there was a catastrophic accident when twenty people were killed and twelve injured in an avalanche released in Búðargil. Two other avalanches that damaged buildings are recorded.

The avalanches recorded in the area are shown on Map 5 and listed in the following table.

Number Time *Runout index*	**Description**
3001 2.1.1673 *> 14.7*	An avalanche hit Búð and sources describe the event like this: “A farm named Búð was destroyed and everything in it except the people who saved themselves under the shallow cave that was left of the living room. The bulls were also saved but the avalanche took all the hay with it. It also took all of the fish-drying racks belonging to the people who lived in the house, except for one, and took most of them with it to the sea.”.

Number Time *Runout index*	**Description**
3004 18.2.1910 *> 14.7*	A large avalanche fell from Búðargil and spread over the area from Heimabær to north of the farm Búð. The area was 150–160 arm spans wide. The avalanche fell into the sea and swept everything away on the way down including houses and sea barracks. Twenty people were killed and twelve were injured. A few were dug from the snow debris and from the slush in the sea.
3007 8.2.1916 *> 14.7*	A large avalanche fell from Búðargil and Traðargil. The avalanche fell down into the sea just east of Heimabær. The tongue reached further west but there it didn't reach as far down. The avalanche hit the two easternmost houses of Heimabær and shifted one from its foundation. A sheep shed, cow shed, and one or two barns were destroyed. One cow and 16–18 sheep were killed. The avalanche took a machine house and a carpenter's workshop with it into the sea, but the carpenter escaped alive before the workshop collapsed. He was caught by the avalanche and dug out alive an hour later. The avalanche also took a fish drying rack and a hut, and caused significant damage to the seamen's barracks.
3024 24.3.1947 *> 14.7*	An avalanche fell from Búðargil, went above the houses at Brekka and west of Búð, and flowed into the sea.
3051 14.12.1983 *> 14.7*	A dry avalanche fell from Búðargil and damaged 150 m of a fence. The main tongue stopped at the bottom of the pasture Pálstún, but a narrow 15 m wide tongue ran into the sea. The main tongue was around 140 m wide and 1 m thick. The volume was 15000–20000 m^3.
3058 23.12.1985 *12.7*	A dry slab avalanche fell from Búðargil and stopped on the pasture Búðartún. The tongue was about 150 m wide and 0.7 m thick.
3076 26.2.1989 *13.9*	A slab avalanche fell from Búðargil and stopped above the stables at the pasture Búðartún. The tongue was about 230 m wide and a maximum of 2 m thick.
3075 26.3.1989 *12.5*	A slab avalanche fell from Búðargil and stopped 10 m above the stables by the pasture Búðartún. The tongue was approximately 200 m wide and 6 m thick at its thickest. The volume was an estimated 25000 m^3.
3090 27.1.1990 *11.2*	A dry avalanche fell from Búðargil and reached past the ski lift. The avalanche damaged a shed at the end of the lift and a utility pole. About 30 m of a fence were also destroyed.
3099 13.11.1991 *9.5*	An avalanche fell from Búðargil and stopped on the debris cone at around 40 m a.s.l.

Number Time *Runout index*	**Description**
3110 26.11.1992	An avalanche was released east of Búðargil, stopping at about 25 m a.s.l.
3107 26.11.1992 *10.0*	A mixed type avalanche fell from Búðargil, spread on the debris cone, and stopped at the base of the mountain 30–35 m a.s.l. The tongue was 160 m wide and a maximum of 1 m thick. The volume was about 8000 m^3.
3146 17/18.12.1994	An avalanche fell from Búðargil and past the pasture fence. The avalanche damaged 80 m of the fence. The deposit was about 140 m wide, 0.5 thick, and around 3000 m^3 in volume.
3168 23.10.1995 *10.8*	An avalanche passed the town fences. It was about 150 m wide, around 0.6 m deep, and an estimated 10000 m^3 in volume. The avalanche damaged 50 m of fences.
3205 14/15.12.1998 *11.0*	An avalanche fell down towards the horse stables and stopped at 22 m a.s.l. Its width was close to 60 m and the thickness about 0.25 m with a maximum of 0.6 m. The estimated volume was 2250 m^3. The avalanche caused no damage.
3214 12/13.1.1999 *$<$ 11*	A 35 m wide avalanche stopped at 55 m a.s.l.
3223 21.2.1999 *$>$ 14.7*	A dry slab avalanche was released in Búðargil and severly damaged a horse stable and fences. The avalanche reached the sea between the house Heimabær and the horse stables. The average width of the deposit was about 170 m and the volume about 35000 m^3.
3250 28.2.2000	An avalanche released in Búðargil damaged about 150 m of a fence. It stopped on the horse racetrack about 25 m away from the horse stables.
3255 3/4.3.2001 *12.4*	An avalanche released in Búðargil damaged about 100 m of a fence. It stopped on the horse racetrack about 60 from the horse stables. The deposit was about 100 m wide and its volume about 7500 m^3.

8.2.4 Assessment

It is evident from the avalanche chronicle that avalanches from Búðargil are frequent. Many avalanches have fallen into the sea confirming that large avalanches are possible from the gully. There is no doubt that the area directly below the gully is too dangerous to build houses. Avalanches from the gully can be expected to be up to 150 thousand m^3. The relatively gentle decrease in inclination along the track and runout area is favourable for long runout distances.

8.2.5 Model estimates

Map 11 shows the results of model calculations and the profiles used for the calculations. The profile `hnno05aa`, and the results of the calculations are shown in Drawing 22. The runout was calculated using runout indices, an α/β-model and the SAMOS model.

Below Búðargil, the seashore is at runout indices just over 13 to 14.7 and the α-point is in the sea.

The frequency of avalanches is high. During the twentieth century, 5 avalanches were observed with $r \geq 14.7$. Using the methods of RiskEst, an avalanche frequency $F_{13} \simeq 0.2$ is calculated. Using that frequency, the risk at the shoreline in profile `hnno05aa` is calculated to be about $50 \cdot 10^{-4}$.

The Austrian avalanche model SAMOS was applied to evaluate the direction of avalanches from the starting areas and the lateral extent of avalanches. The results are described by Tómas Jóhannesson *et al.* (2002).

8.2.6 Conclusion

It is evident that the avalanche risk below the gully is much more than $3 \cdot 10^{-4}$ all the way down to the shoreline and the entire area is therefore contained within the category C hazard zone. The risk at the inner boundary between Búðargil and Traðargil is discussed in the next section on Traðargil.

The uncertainty of the assessment that all the area is in the category C hazard zone is practically zero since the boundary of the category C hazard zone is well beyond the shoreline. As for Seljalandshlíð, no conceivable reinterpretations of the data or changes in hazard zoning methods are likely to change this assessment. The gully is a typical avalanche path with a known avalanche history and the uncertainty of the risk estimate as such is therefore classified as low ($\frac{1}{2}$).

The hazard zoning proposal is shown on Map 13.

8.3 Traðargil

8.3.1 Topographic conditions

Starting area

The starting area is between 400 and 630 m a.s.l. It faces southeast and forms a deep clifflike gully. The average width is about 160 m and the average depth of the gully is about 40 m. The gully is interrupted by several meter high cliff formations. The starting area is 5.5 ha and has an average inclination of around 40°. The starting area is without vegetation; the roughness according to the Swiss guidelines is 1.2.

Track

The track begins at 400 m a.s.l. with average inclination of 35° down to 200 m. Between 200 and 100 m a.s.l. the inclination is 28°. Between 100 m and the β-line, the inclination decreases gradually. The avalanche track is confined by a 30 m deep gully in the upper part. The depth decreases in the lower part to 5 m. Below 120 m a.s.l., the track is on the debris cone below the gully where avalanches can spread. The obviously old debris cone is covered with grass.

Runout area

The runout area covers the rest of the debris cone and down to the river Hnífsdalsá. In most of the lower runout area, the inclination is between 3° and 5°. Several houses were built in the runout area around 1980.

8.3.2 Climatic conditions

Snow accumulation in the starting area can occur when the wind is blowing from northeast to northwest as in Búðargil. Due to the general climatic conditions snow accumulation is frequent which is confirmed by the high avalanche activity.

8.3.3 Chronicle

Many avalanches are recorded from Traðargil as from Búðargil. The settlement below Traðargil has not existed for as long as below Búðargil so the chronicle does not reach as far back in time. The first recorded avalanche, and the largest one, is from 1947. At that time, no houses were located in the area, but the avalanche damaged a sheep shed and a fence as well as some huts which were close to the houses by the road Heimabæjarstígur.

The avalanches recorded in the area are shown on Map 5 and listed in the following table.

Number Time *Runout index*	**Description**
3022 24.3.1947 *15.7*	An avalanche fell from Traðargil and burst through the wall of a sheep shed killing five sheep. The avalanche also took a smokehouse and wood shed, damaged a cowshed and stables, and destroyed a fence and a storage shed. The deposit was about 200 m wide and reached the river Hnífsdalsá. At Heimabær, a great air blast caused some ceramics to fall from shelves.
3052 14.12.1983 *12.8*	A loose dry avalanche fell from Traðargil and stopped 40 m above the sheep roundup. The avalanche toppled two utility poles. The tongue was around 100 m wide and 1 m thick.

Number Time *Runout index*	**Description**
3055 14.1.1984 *12.5*	A loose dry avalanche fell from Traðargil down to 20–25 m a.s.l. The tongue was about 100 m wide and 1 m thick at its thickest.
3072 14.2.1989 *12.1*	An avalanche fell from Traðargil and stopped about 150 m from the house Heimabær. The tongue was approximately 150 m wide and thickest at 0.5 m.
3077 26.2.1989 *12.5*	A loose avalanche fell in Traðargil and stopped around 30 m a.s.l., about 35 m above the road to the farm Hraun. The deposit was around 200 m wide.
3135 29.12.1989 *9.9*	A wet slab avalanche was released in Traðargil. The deposit was about 50 m wide and 2000 m^3.
3100 13.11.1991 *< 11*	A small avalanche fell from Traðargil and stopped on the debris cone at around 70 m a.s.l.
3108 26.11.1992 *11.7*	An avalanche fell from Traðargil to the debris cone below and stopped around 30 m a.s.l. The tongue was about 140 m wide, 1 m thick, and around 7000 m^3 in volume.
3123 4.4.1994 *10.7*	A slab avalanche fell from Traðargil to around 135 m a.s.l. The tongue was about 130 m wide, 0.8 m thick at its thickest, and the volume was around 9000 m^3.
3145 17/18.12.1994	An avalanche fell from Traðargil and stopped close to the uppermost fences. The deposit was thin.
3169 23.10.1995 *11.2*	An avalanche reached the town fences. It was about 180 m wide, close to 0.6 m thick, and estimated 11000 m^3 in volume.
3184 22.2.1997 *13.6*	An avalanche passed the road towards Hraun and stopped about 100 m from the house Heimabær. It was about 175 m wide and around 0.2 m thick with a maximum thickness of 0.6 m. The estimated volume was 12000 m^3.
3198 22/23.10.1998 *< 11*	An avalanche fell from Traðargil about 200 m down the debris cone. The width was 90 m, and the deposit about 0.5 m thick.
3213 12/13.1.1999 *10.2*	An avalanche was released in Traðargil. It was almost 75 m wide and stopped about 150 m above the road towards Hraun at about 40 m a.s.l.
3219 21.2.1999 *15.0*	A large dry slab avalanche was released in Traðargil. It damaged a shed and broke windows in a car storage at Fitjateigur 4. The avalanche stopped between the area Teigahverfi and the community house. The deposit was about 145 m wide and 24000 m^3.

Number Time *Runout index*	**Description**
3258 28.3.2001 *10.2*	A dry slab avalanche fell in Traðargil and stopped at about 20 m a.s.l. The deposit was about 65 m wide and 1.5 m thick. The volume was about 11000 m^3.
3283 1.5.2002	An avalanche fell in Hraunsgil and stopped at about 45 m a.s.l. about 150 m from the road to Hraun.

8.3.4 Assessment

It is evident from the avalanche chronicle that avalanches from Búðargil are frequent, and probably as frequent as from Traðargil. Big avalanches are possible from the gully. The area directly below the gully is clearly too dangerous to build houses. Avalanches from the gully can be expected to be up to 200 thousand m^3. The relatively gentle inclination along the track and runout area is favorable for long runout distances.

8.3.5 Model estimates

Map 11 shows the results of model calculations and the profiles used for the calculations. The profile `hnno04aa`, and the results of the calculations are shown in Drawing 21. The runout was calculated using runout indices, an α/β-model and the SAMOS model.

The runout by the uppermost houses measures between runout indices 14 and 15. They are slightly closer to the mountain than the α-line.

Two avalanches are recorded with runout index greater than 15 (1947, $r = 15.7$; 1999, $r = 15.0$). Due to the existence of houses in the area prior to the event in 1947, it can safely be assumed to be the only such long avalanches in the twentieth century. During the past 20 years, one more avalanche with runout greater that $r = 13$ is recorded (1997, $r = 13.6$). From RiskEst, two avalanches with $r \geq 15$ in 100 years, and two avalanches with $r \geq 13$ in 20 years give frequency $F_{13} \simeq 0.1$. It is proposed that a frequency of $F_{13} = 0.1$ be used. The risk in Teigahverfi is then estimated to range from $20 \cdot 10^{-4}$ to $80 \cdot 10^{-4}$.

The Austrian avalanche model SAMOS was applied to evaluate the direction of avalanches from the starting areas and the lateral extent of avalanches. The results are described by Tómas Jóhannesson *et al.* (2002).

8.3.6 Conclusion

It is clear that the risk in this area is very high. Because the starting area is not large, extremely large avalanches are not possible and it is likely that the methods of RiskEst overestimate the risk in the area. The hazard lines computed by RiskEst are pulled back about $\frac{1}{2}$ runout index directly below the gully in the proposed hazard zoning for this reason.

The runout area of Traðargil almost coincides with parts of the runout areas for Hraunsgil and Búðargil. Between Traðargil and Búðargil the farmhouse Heimabær was located for a long period. This shows that the risk is much lower between the gullies and avalanches from them seem to have a very confined direction. It is not, however, deemed possible to evaluate probable directions of avalanches so accurately that the border of the category C hazard zone could be drawn towards or even above the location of Heimabær. Due to this, the risk between the gullies could be greatly overestimated by the hazard map.

The slope is a typical avalanche path with known avalanche history so the uncertainty is considered low ($\frac{1}{2}$). The uncertainty is, however, much higher for the areas between the gullies as mentioned above.

The hazard zoning proposal is shown on Map 13.

8.4 The area between Traðargil and Hraunsgil

8.4.1 Topographic conditions

Starting area

The starting area extends from 400 m a.s.l. to about 560 m a.s.l. The width of the area is around 80 m with an average inclination of 39°. The area is 2.1 ha, fairly even and only interrupted by a shallow gully. Some cliffs top the starting zone. Other sections of the starting area are covered with coarse loose material.

Track

The track begins at 400 m a.s.l. and terminates at the β-line at about 50 m a.s.l. The track inclines around 28° with a width of about 250 m.

Runout area

The runout area is between the debris cones of Traðargil and Hraunsgil. The inclination of the first 200 m below the β-point is around 7° and decreases to zero towards the valley bottom.

8.4.2 Climatic conditions

Snow accumulation in the starting area between the gullies occurs mainly in northerly winds. It is most probable during north or northwesterly winds though it is clear that snow accumulation is much more likely in the adjacent gullies.

8.4.3 Chronicle

The avalanches recorded in the area are shown on Map 5 and listed in the following table.

Number Time *Runout index*	**Description**
3101 13.11.1991 *< 11*	A small avalanche was released in Sauðahryggsgil.
3109 26.11.1992 *9.2*	A wet loose avalanche was released in Sauðahryggsgil, stopping about 70 m above the sheep roundup. The deposit was about 100 m wide and the volume about 5000 m^3.

8.4.4 Assessment

Large avalanches are unlikely from the starting area, and the adjacent gullies are considered to be the dominant sources of risk in the area.

8.4.5 Model estimates

Map 11 shows the results of model calculations and the profiles used for the calculations. The runout was calculated using runout indices, an α/β-model and the SAMOS model.

8.4.6 Conclusion

As was stated in Section 8.4.4, the adjacent gullies are considered to be the dominant sources of risk in the area.

8.5 Hraunsgil

8.5.1 Topographic conditions

Starting area

The starting area ranges from 350 m a.s.l. up to 670 m a.s.l. It is around 300 m wide with an average inclination of about 35°. The starting area has the form of a large cone shaped bowl. The average depth of the bowl is 50–70 m. There is a deep gully in the eastern part of the starting area. Steep cliffs above a small plateau between 540 and 510 m a.s.l. characterise the uppermost western part. The plateau averages 60 m wide with an inclination of about 15°. Below the plateau, a small gully merges with the eastern gully at about 280 m a.s.l. Between the gullies, the landscape is even and only interrupted by isolated rocks. The starting area is 20.6 ha.

Track

The 200 m wide track begins at 350 m a.s.l. The width of the track narrows to 80 m about 200 m a.s.l. where the gully is about 25 m deep. Just below, the track is on the debris cone below the gully. The track terminates in the β-line near 50 m a.s.l. The average inclination of the track is 23°. Between 350 and 140 m a.s.l. avalanches are deflected by the western ridge of the gully which has a deflecting angle of about 25° and averages 25 m high. At the top of the debris cone, about 180 m a.s.l., avalanches are deflected to southeast by smaller ridges on the debris cone.

Runout area

The runout area, which covers the large debris cone below Hraunsgil, starts at 50 m a.s.l. and continues down to the Hnífsdalsá river. The inclination along the debris cone is higher than 5° down to about 20 m a.s.l. and decreases to 0° by the river. The surface of the debris cone is interrupted by several small ridges and depressions and covered with grass and rocks. Small rocks are scattered on the upper part of the debris cone indicating high avalanche activity. Several large rocks that may have been transported by avalanches are in the lower part of the runout area. The rocks farthest away from the mountain are at approximately 20 m a.s.l. Directly below the gully stands the Hraun farm about 40 m a.s.l. It is claimed that a farmhouse at Hraun has been at the same location as the old farmhouse, built around 1900, for at least 300 years.

8.5.2 Climatic conditions

Snow accumulation in the starting area can occur when wind comes from northeast to northwest. High avalanche activity clearly indicates that snow accumulation in the gully is frequent.

8.5.3 Chronicle

Many avalanches are recorded from Hraunsgil, and some of them have a long runout. In all cases the avalanches have either been divided on the debris cone below the gully, or fallen on either side of it. An avalanche has never hit the farmhouse Hraun, which has been located right beneath the gully for at least 300 years, although avalanches have fallen much further down on both sides of it.

The avalanches recorded in the area are shown on Map 5 and listed in the following table.

Number Time *Runout index*	**Description**
3003 1890 *11.1*	An avalanche fell in Hraunsgil to west across Hraunshryggur.
3008 14.2.1916 *14.3*	Two avalanches fell east of Hraunshryggur. A man was slightly injured by one of the avalanches.
3023 24.3.1947 *14.7*	An avalanche fell from Hraunsgil and east of Hraunshryggur. The tongue was about 200 m wide and stopped around 10 m a.s.l.
3057 23.12.1985 *13.0*	A dry slab avalanche was released in Hraunsgil and divided on the debris cone below the gully. The inner tongue stopped at around 55 m a.s.l., and the other tongue stopped at 40–45 m a.s.l. Each tongue was about 25 m wide and 0.5 m deep.
3063 23.3.1987 *14.0*	A large avalanche fell from Hraunsgil west of the ridge Hraunshryggur. The starting area was the inner part of the starting area in Hraunsgil. The avalanche stopped at a little less than 25 m a.s.l., 35 m below the road to Hraun, and damaged 100 m of a fence. The volume was around 39000 m^3.
3963 23.3.1987 *12.8*	At a similar time as avalanche no. 3063 was released, another avalanche was released in the inner part of the starting area, falling towards east across Hraunhryggur.
3078 26.2.1989 *12.6*	A loose snow avalanche fell in Hraunsgil and stopped 75 m above the road to the farm Hraun. The avalanche fell east of the debris cone, and the tip of the tongue was at 80 m a.s.l.
3136 29.12.1989 *12.5*	A dry slab avalanche fell east of Hraunshryggur and stopped at about 50 m a.s.l. The deposit was about 40 m and 2000 m^3.
3098 13.11.1991 *12.4*	A dry slab avalanche fell from Hraunsgil, east of the debris cone. It stopped around 70 m above the road to the farm Hraun. The tongue was 60 m wide and 1 m thick at its thickest. The volume was around 6500 m^3.
3151 12.2.1995 *10.9*	Two men on snowmobiles were driving in the mountain in Hraunsgil. When they stopped, a dry slab avalanche was released about 150 m above them. One of the men was caught by the avalanche and carried 50 m. His collarbone was broken and his snowmobile was destroyed. The other man drove out of the avalanche on his snowmobile. The tongue was around 100 m wide, 1 m thick at its thickest, and approximately 4000 m^3.

Number Time *Runout index*	**Description**
3170 23.10.1995 *12.4*	A slab avalanche stopped on the alluvial fan above and east of the farmhouses at Hraun. The avalanche was approximately 90 m wide, about 1.5 m thick, and the volume an estimated 7500 m^3.
3216 21.2.1999 *< 11*	A rather small, dry slab avalanche fell east to the east of Hraunshryggur and stopped at about 100 m a.s.l.
3246 24.2.2000 *< 11*	A small avlanche was released in Hraunsgil and stopped in the mouth of the gully.

8.5.4 Assessment

It is evident from the avalanche chronicle that avalanches from Hraunsgil are frequent. Large avalanches from the gully can be expected to be up to several hundred thousand m^3. The relatively gentle inclination decrease along the track and the runout area is favorable for long runout distances. Due to the deflecting ridge in the avalanche track and the deflecting ridges on the debris cone, avalanches tend to be deflected from south-southeast to southeast or south. This is consistent with the observation that the farm Hraun, which is to the south-southeast of the track has never been hit by an avalanche. The deflecting ridges on the debris cone are not considered high enough to prevent the spread of a large avalanche from the whole starting area over the entire debris cone including the farm.

8.5.5 Model estimates

Map 11 shows the results of model calculations and the profiles used for the calculations. The profile `hnno01aa`, and the results of the calculations are shown in Drawing 20. The runout was calculated using runout indices, an α/β-model and the SAMOS model.

An avalanche with runout of $r = 13$ or $\alpha + \sigma$ will reach the farmhouse Hraun. Avalanches with runout of $r = 16$ will reach the river in the valley bottom. In the 20 years that systematic records have been kept two avalanches with $r \geq 13$ have been recorded. Three avalanches with $r \geq 14$ were observed during the twentieth century. This indicates a frequency F_{13} of about 0.1. This seems to contradict the existence of Hraun for the past 300 years. The ridge above the farmhouse as well as the shape of the starting area must therefore provide some protection against smaller and medium sized avalanches. It is however difficult to evaluate how this affects the frequency estimate, since larger avalanches may be just as frequent at Hraun as they are east and west of the farm. For risk calculations a value of $F_{13} = 0.1$ was chosen. This gives a risk of $250 \cdot 10^{-4}$ at the elevation of the farm.

The Austrian avalanche model SAMOS was applied to evaluate the direction of avalanches from the starting areas and the lateral extent of avalanches. The results are described by Tómas Jóhannesson *et al.* (2002).

8.5.6 Conclusion

The risk in the area is in part due to medium sized avalanches starting in parts of the great bowl and also due to very large avalanches from the whole starting area. The shape of the track and the ridge above the farm Hraun seem to protect the farm against the medium sized events. It would probably not offer much protection against larger avalanches.

The fact that Hraun has been standing below the gully for 300 years indicates that in that period no such larger events have occurred. This does not however suffice to reduce the risk in Hraun enough for the border of the category C hazard zone to come near it. Removing the proportion of the risk corresponding to the medium sized events will not reduce the total risk dramatically. The return period of avalanches at Hraun can be up to several hundred years, with the risk still higher than $3 \cdot 10^{-4}$.

For the area the results of RiskEst calculations are applied with the modification that the border of the category C hazard zone is drawn about 50–100 m towards the mountain directly below the farm Hraun.

The hazard zoning proposal is shown on Map 13.

9 Conclusion

All the settled areas in Ísafjörður and Hnífsdalur, which were considered within this project, have houses located in hazard zones.

In Holtahverfi numerous houses are located in hazard zones below Kubbi. It should be made a priority to increase the safety in the area.

The most recently built area, Seljalandshverfi, is located below a large and typical avalanche-path. The area is not fully settled, since development of the area was stopped after a large avalanche fell a little to the west in Tunguskógur. The risk in the houses closest to the slope is quite high and it should also be made a priority to increase the safety in the area. This could both be achived by building defence structures or by abandoning the houses. If defence structures were to be built it is not advisable to increase the population in the area significantly.

The situation below Gleiðarhjalli is difficult. There is a high number of houses located within the hazard zones, although only a few are in the category C hazard zone. The area should be monitored closely and evacuated if necessary. Some action should be taken to protect the settlement against debris flow and rock fall hazard.

The situation in Hnífsdalur is also difficult. Most of the settlement is located within the hazard zones. A number of houses closest to the mountain in the northern part of the village have been purchased and abandoned in order to improve safety in the area.

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A Technical concepts and notation

α**-angle:** The slope of the line of sight from the stopping position of an avalanche to the top of the starting zone (see Figure 10).

β**-angle:** The slope of the line of sight, from the location in the avalanche path where the inclination of the slope is 10°, to the top of the starting zone (see Figure 10).

α/β**-model:** A topographical model used to predict avalanche runout or to transfer avalanches between paths. The model uses the β-angle to predict the α-angle of the longest recorded avalanche in a given path. The model was first derived by Lied and Bakkehøi (1980). The version of the model used in this project was derived by Tómas Jóhannesson (1998a, 1998b) using data on 45 Icelandic avalanches. The formula of the model is

$$\alpha = 0.85 \cdot \beta, \qquad \sigma = 2.2°$$

where σ is standard deviation of the residuals from the model. It is customary to denote an avalanche with an α-angle $n\sigma$ lower than the predicted α- value as an avalanche with runout of $\alpha - n\sigma$ and conversely $\alpha + n\sigma$ if the α-angle is higher than given by the above equation. Note that as the α-angle is lower the runout is longer, and therefore $\alpha - \sigma$ corresponds to an avalanche with a longer runout distance than α.

PCM-model: A one-dimensional physical model used to simulate the flow of avalanches. The model has two parameters, μ, a Coulomb friction coefficient, and, M/D, an inverse drag coefficient. It was developed by Perla *et al.* (1980).

Runout index: The runout measured in hectometers of an avalanche that has been *transferred* (Sven Sigurðsson *et al.*, 1997) to the *standard path* making use of some transfer method. The runout index is in this report is obtained by using the PCM-model with parameters lying on a predefined parameter axis. An avalanche that has a runout index of r_0 is referred to as an avalanche with $r = r_0$. The method was developed by Kristján Jónasson *et al.* (1999).

$F_{r_0}(F_{13})$**:** The expected frequency of avalanches with a runout index greater or equal than r_0. The value F_{13} is most often used, *i.e.* the frequency at the runout index $r_0 = 13$.

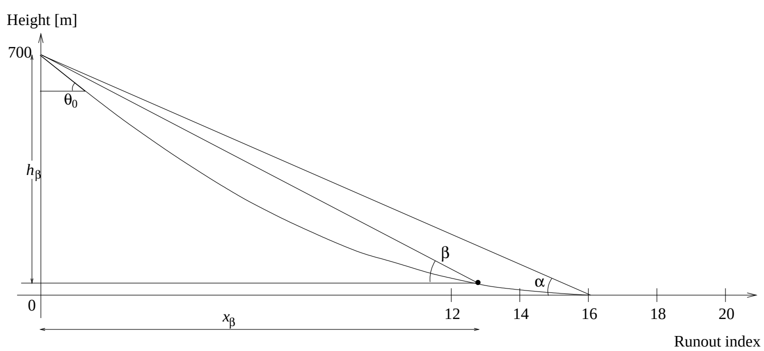


Figure 10. *The standard path. The α-angle is the expected runout angle of an avalanche according to the α/β-model.*

B Maps

Map 1. An overview of Ísafjörður and Hnífsdalur and the boundary of the investigated area (A3, 1:25 000).

Map 2. Recorded avalanches in Kubbi (A4, 1:10 000).

Map 3. Recorded avalanches in Seljalandshlíð (A3, 1:10 000).

Map 4. Recorded avalanches below Gleiðarhjalli (A4, 1:10 000).

Map 5. Recorded avalanches in Hnífsdalur (A4, 1:10 000).

Map 6. Previous hazard maps, Skutulsfjörður (A3 1:10 000)

Map 7. Previous hazard maps, Hnífsdalur (A4 1:10 000)

Map 8. Results of model estimates, Kubbi (A4, 1:10 000).

Map 9. Results of model estimates, Seljalandshlíð (A3, 1:10 000).

Map 10. Results of model estimates, Gleiðarhjalli (A3, 1:10 000).

Map 11. Results of model estimates, Hnífsdalur (A4, 1:10 000).

Map 12. Proposed hazard zoning for the investigated area in Skutulsfjörður (A3, 1:10 000).

Map 13. Proposed hazard zoning for the investigated area in Hnífsdalur (A4, 1:10 000).

C Climatic data

The following abbreviations are used:

t: temperature (°C), **tx:** maximum temperature (°C), **tn:** minimum temperature (°C),
f: wind speed (m/s), **fx:** maximum wind speed, **fg:** gust speed (m/s), **r:** precipitation, **rx:** maximum 24 hour precipitation, **avg:** average, **AWS:** Automatic weather station. * Observations missing.

Summary statistics: Temperature, wind and precipitation

Bolungarvík (252), September 1934–September 1953

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	−0.9	−1.6	−0.7	0.7	5.2	8.2	10.0	9.6	7.2	4.0	1.5	0.3	**3.6**
avg(r)	73.6	67.7	62.5	40.4	26.9	35.7	37.7	53.6	95.3	88.1	68.6	89.9	**739.9**
max(rx)	25.1	25.8	35.6	23.4	20.1	29.3	38.2	31.6	44.6	29.7	30.6	31.3	**44.6**

Bolungarvík (252), 1995–2001

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	−0.3	−2.2	−2.0	0.6	4.4	7.5	9.7	9.6	7.3	3.0	0.8	0.1	**3.2**
max(tx)	10.3	9.7	10.8	12.5	15.2	18.7	20.4	19.9	19.6	13.7	17.8	13.7	**20.4**
min(tn)	−12.4	−14.4	−14.9	−9.3	−5.9	−0.9	1.8	0.8	−2.9	−7.5	−10.9	−12.4	**−14.9**
avg(r)	79.7	68.5	63.3	21.4	39.9	32.5	40.2	63.6	65.9	108.8	71.4	68.7	**723.9**
max(rx)	30.5	26.7	31.3	11.0	24.2	28.3	29.9	43.6	30.4	33.3	29.3	20.5	**43.6**
avg(f)	7.2	6.5	6.5	5.3	4.6	4.4	3.8	3.5	5.1	6.7	6.1	6.3	**5.5**

Æðey (260), 1961–1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	−1.7	−1.4	−1.9	0.6	4.2	7.6	9.5	9.2	6.1	3.2	0.3	−1.2	**2.9**
max(tx)	9.0	9.3	9.4	11.3	18.2	18.6	21.5	21.0	16.2	14.0	11.3	10.5	**21.5**
min(tn)	−18.2	−17.2	−19.8	−16.6	−9.3	−3.1	1.6	0.3	−3.0	−10.0	−11.5	−15.0	**−19.8**
avg(f)	6.7	6.3	6.3	4.8	3.9	3.4	2.9	3.3	4.8	5.7	6.2	6.3	**5.1**
avg(r)	62.0	49.1	16.1	31.6	28.3	31.2	33.3	43.4	57.3	78.1	72.5	51.6	**554.5**
max(rx)	49.4	27.8	17.0	17.9	48.4	64.2	49.7	62.8	60.8	67.0	84.5	28.3	**84.5**

Galtarviti (250), 1961–1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	−0.9	−0.5	−1.4	1.0	4.1	7.0	8.7	8.8	6.1	3.6	1.0	−0.6	**3.1**
max(tx)	11.4	12.0	10.7	14.8	16.5	16.6	22.5	21.7	16.8	15.3	13.6	15.7	**22.5**
min(tn)	−17.5	−16.4	−18.4	−15.0	−7.8	−2.2	0.5	0.7	−4.4	−9.6	−10.9	−15.9	**−18.4**
avg(f)	6.6	6.7	6.3	5.4	4.3	4.3	3.8	4.0	5.1	5.7	6.5	6.6	**5.4**
avg(r)	136.0	108.7	115.9	78.1	49.7	51.9	48.7	63.7	124.9	157.6	154.9	124.6	**1214.7**
max(rx)	47.7	40.5	43.6	36.0	43.8	91.8	35.3	31.1	79.9	54.3	74.4	35.6	**91.8**

Monthly precipitation, mm

Bolungarvík (252)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1994								27.5	72.0	116.4	93.2	90.9	
1995	98.1	61.3	84.6	26.5	12.0	21.1	39.9	57.3	47.7	148.9	24.5	75.0	**696.9**
1996	60.9	55.3	46.0	37.5	3.4	24.0	17.7	82.4	104.3	165.6	28.9	21.1	**647.1**
1997	53.0	67.9	72.5	21.5	14.2	63.9	38.1	71.1	110.7	118.2	26.6	80.1	**737.8**
1998	121.3	43.0	37.1	17.9	31.0	2.1	27.4	94.9	38.5	64.9	72.1	109.8	**660.0**
1999	65.5	89.1	43.9	11.9	96.9	69.3	78.7	39.0	89.0	95.4	79.2	106.4	**864.3**
2000	75.2	92.1	131.4	19.7	66.0	27.0	24.3	43.1	33.1	61.9	112.3	26.7	**712.8**
2001	83.9	70.8	27.5	14.5	55.8	20.1	55.2	57.6	38.3	106.7	155.9	62.0	**748.3**
2002	86.9	135.1	114.3	97.7									
1996–2001	76.6	69.7	59.7	20.5	44.6	34.4	40.2	64.7	69.0	102.1	79.2	67.7	**728.4**

Hnífsdalur (253)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1995										168.2	24.5	80.5	
1996	50.5	83.3	48.2	53.1	1.8	26.0	13.8	43.9	104.8	207.3	33.9	13.1	**679.7**
1997	67.1	114.8	133.2	22.2	14.6	25.7	30.7	81.6	77.4	108.0	34.8	88.7	**798.8**
1998	135.7	89.2	74.6	18.1	43.3	5.1	21.3	66.8	35.7	82.1	76.4	177.8	**826.1**
1999	61.3	93.0	104.4	17.2	71.4	34.8	61.1	22.7	98.0	97.7	103.4	109.4	**874.4**
2000	98.4	102.1	156.2	32.1	56.8	20.8	30.5	20.9	30.1	63.6	87.0	32.2	**730.7**
2001	69.1	80.0	33.6	19.1	43.3	8.6	177.6	45.7	28.5	67.0	135.3	78.6	**786.4**
2002	88.1	82.3	50.7	59.6									
1996–2001	80.4	93.7	91.7	27.0	38.5	20.2	55.8	46.9	62.4	104.3	78.5	83.3	**782.7**

Ísafjörður (254)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1984	120.0	139.1	60.7	82.9	34.4	21.9	50.8	48.6	90.1	95.4	47.4	119.9	**911.2**
1985	49.6	49.3	86.7	47.3	32.5	9.9	59.5	14.4	50.1	180.6	63.2	44.9	**688.0**
1986	112.3	58.7	116.8	32.9	71.9	36.1	39.0	12.3	75.1	163.0	138.1	112.5	**968.7**
1987	120.6	50.2	136.5	109.0	21.3	0.4	39.4	20.1	84.6	74.1	94.3	51.3	**801.8**
1988	67.9	87.3	58.1	24.7	54.5	39.5	21.2	79.0	85.7	191.2	93.1	146.1	**948.3**
1989	226.0	240.6	59.5	29.5	148.3	4.8	31.0	83.9	86.5	38.2	54.8	138.2	**1141.3**
1990	234.2	96.3	95.6	37.7	38.4	13.7	7.7	71.2	111.5	75.1	72.0	183.8	**1037.2**
1991	148.8	139.2	117.8	100.7	35.0	8.0	24.5	96.3	84.3	89.4	219.5	186.5	**1250.0**
1992	170.1	207.2	108.0	15.4	43.9	60.0	43.9	83.5	134.5	30.3	177.9	250.3	**1325.0**
1993	104.8	175.7	106.9	43.7	75.4	37.2	61.0	38.1	39.4	50.3	267.3	106.5	**1106.3**
1994	123.3	89.8	124.1	120.4	17.6	12.8	33.1	24.7	41.4	115.2	138.7	172.1	**1013.2**
1995	95.4	94.4	96.4	9.7		4.0	26.0	58.2	41.0	308.0	25.9	139.9	
1996	66.4	110.5	58.2	72.5	1.4	37.3	17.0	55.9	147.3	270.8	37.5	37.2	**912.0**
1997	105.5	145.8	160.7	27.7	16.5	18.5	36.3	81.1	211.2	112.0	84.1	104.9	**1104.3**
1998	131.3	93.7	95.6	18.3	64.4	10.0	41.2	98.9	41.1	104.7	126.9	197.9	**1024.0**
1999	125.4	152.2	127.1	22.3	50.4	29.2	51.9	40.4	127.2	157.7	140.1	167.2	**1191.1**
2000	134.4	162.2	185.7	36.7	68.1	22.7	28.1	34.9	35.2	110.5	127.7	66.0	**1012.2**
2001	141.9	134.8	59.2	33.4	70.6	15.6	71.9	56.0	30.9	92.8	195.5	98.1	**1000.7**
2002	125.0	139.9	62.8	73.9									
1996–2001	117.5	133.2	114.4	35.2	45.2	22.2	41.1	61.2	98.8	141.4	118.6	111.9	**1040.7**

Birkihlíð (247)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1995										168.2	24.5	80.5	
1996	50.5	83.3	48.2	53.1	1.8	26.0	13.8	43.9	104.8	207.3	33.9	13.1	**679.7**
1997	67.1	114.8	133.2	22.2	14.6	25.7	30.7	81.6	77.4	108.0	34.8	88.7	**798.8**
1998	135.7	89.2	74.6	18.1	43.3	5.1	21.3	66.8	35.7	82.1	76.4	177.8	**826.1**
1999	61.3	93.0	104.4	17.2	71.4	34.8	61.1	22.7	98.0	97.7	103.4	109.4	**874.4**
2000	98.4	102.1	156.2	32.1	56.8	20.8	30.5	20.9	30.1	63.6	87.0	32.2	**730.7**
2001	69.1	80.0	33.6	19.1	43.3	8.6	177.6	45.7	28.5	67.0	135.3	78.6	**786.4**
2002	88.1	82.3	50.7	59.6									

Ísafjörður, AWS (2642)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1998										64.5	118.1	106.6	
1999	67.2	81.9	20.8	16.0	51.5	20.9	40.6	29.9	92.1	109.3	83.2	106.1	**719.5**
2000	73.6	88.5	166.2	34.9	47.4	17.9	22.2	27.6	25.3	89.5	63.7	23.8	**680.6**
2001	131.4	121.5	16.5	22.0	74.0	6.7	45.0	43.2	27.5	73.1	160.1	102.5	**823.5**

Súðavík, AWS (2646)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1999									16.9	97.5	85.7	112.6	
2000	58.0	121.9	129.1	27.9	34.4	16.7	22.3	32.9	20.4	71.4	36.9	24.2	**596.1**
2001	85.8	84.4	32.8	13.2	37.0	14.5	57.0	33.5	19.3	31.2	114.8	81.3	**604.8**

Maximum 24 hour precipitation, mm

Bolungarvík (252)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1994								16.3	30.3	37.4	19.8	13.6	
1995	12.0	20.4	31.3	6.2	2.8	8.0	11.4	8.5	15.9	33.3	6.7	15.7	**33.3**
1996	30.5	8.8	9.3	11.0	1.7	10.7	3.1	43.6	30.4	31.8	5.1	6.5	**43.6**
1997	14.2	18.5	22.2	4.7	3.0	28.3	11.6	10.6	27.5	19.0	5.7	20.5	**28.3**
1998	24.4	6.8	6.7	7.3	9.8	0.6	7.0	38.5	13.7	17.6	14.0	17.2	**38.5**
1999	13.3	14.3	8.6	4.0	24.2	22.9	29.9	10.9	19.2	16.8	13.2	18.6	**29.9**
2000	13.2	26.7	19.8	7.6	16.4	11.6	8.4	11.6	7.0	14.4	29.3	9.9	**29.3**
2001	21.3	20.9	8.9	2.6	14.0	15.1	21.0	27.1	8.4	23.2	21.9	13.5	**27.1**
2002	15.1	19.8	55.6	21.7									

Hnífsdalur (253)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1995										29.3	6.8	16.4	
1996	19.6	10.3	11.7	10.7	0.5	8.2	3.1	8.0	34.5	44.0	6.3	5.7	**44.0**
1997	9.8	25.2	30.5	5.0	2.8	10.5	9.7	14.6	21.5	23.4	7.9	27.7	**30.5**
1998	25.5	12.5	13.1	5.6	14.4	2.2	6.8	20.1	9.1	13.5	14.8	33.4	**33.4**
1999	9.9	14.6	28.8	5.6	15.7	9.0	23.5	5.6	21.1	16.9	13.0	24.5	**28.8**
2000	22.6	16.3	18.2	13.5	15.2	10.2	9.2	6.4	9.3	19.1	25.1	15.8	**25.1**
2001	17.8	23.9	11.6	3.5	12.0	4.3	110.0	23.1	6.8	18.5	16.0	27.6	
2002	15.8	14.1	11.6	10.2									

Ísafjörður (254)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1984	14.1	21.8	11.2	15.2	7.6	4.9	18.6	14.7	30.6	36.1	9.8	15.9	**36.1**
1985	8.4	10.2	23.9	17.0	10.0	4.8	19.5	5.4	13.0	37.3	21.9	10.9	**37.3**
1986	17.8	15.2	20.1	6.1	24.0	16.0	13.9	8.2	25.0	37.8	23.1	14.4	**37.8**
1987	37.7	6.1	28.8	14.6	7.8	0.4	16.2	5.6	22.5	13.0	17.5	9.2	**37.7**
1988	12.7	19.5	14.1	8.1	20.7	6.0	7.9	18.0	21.0	69.5	22.3	17.4	**69.5**
1989	26.0	40.0	19.7	12.2	63.1	3.9	6.7	20.2	11.3	8.2	14.5	27.2	**63.1**
1990	36.9	15.5	22.9	8.4	16.7	6.2	4.1	23.4	22.9	13.1	36.0	27.0	**36.9**
1991	24.1	28.7	16.5	18.3	13.1	3.4	6.7	28.5	13.8	20.0	62.8	23.5	**62.8**
1992	25.4	58.4	18.2	5.1	12.5	17.5	11.5	22.9	27.5	10.0	29.5	23.8	**58.4**
1993	18.9	15.5	14.7	11.1	22.3	7.4	20.5	8.3	23.2	11.8	30.3	28.8	**30.3**
1994	16.9	30.4	33.6	18.8	7.0	4.9	7.5	11.8	8.8	31.4	29.4	23.0	**33.6**
1995	20.8	20.1	13.6	2.6		2.3	12.8	9.1	15.3	48.0	6.7	46.8	
1996	21.0	15.4	12.7	22.5	0.7	14.0	6.0	13.6	63.3	46.0	5.4	10.4	**63.3**
1997	23.4	31.2	32.0	6.7	4.4	11.1	15.2	13.8	114.3	21.2	16.1	33.4	**114.3**
1998	47.5	9.5	12.7	5.7	19.1	5.8	21.0	25.3	14.3	24.0	45.8	28.0	**47.5**
1999	21.0	28.3	29.3	5.0	10.5	7.0	17.0	16.4	22.9	48.4	16.0	30.0	**48.4**
2000	17.6	28.7	22.0	13.4	22.4	10.5	11.9	9.0	10.3	18.7	18.5	35.8	**35.8**
2001	23.7	35.5	11.3	5.0	27.5	4.5	23.0	27.2	6.9	20.2	22.5	29.0	
2002	21.0	24.2	10.0	10.3									

Birkihlíð (247)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1995										29.3	6.8	16.4	
1996	19.6	10.3	11.7	10.7	0.5	8.2	3.1	8.0	34.5	44.0	6.3	5.7	**44.0**
1997	9.8	25.2	30.5	5.0	2.8	10.5	9.7	14.6	21.5	23.4	7.9	27.7	**30.5**
1998	25.5	12.5	13.1	5.6	14.4	2.2	6.8	20.1	9.1	13.5	14.8	33.4	**33.4**
1999	9.9	14.6	28.8	5.6	15.7	9.0	23.5	5.6	21.1	16.9	13.0	24.5	**28.8**
2000	22.6	16.3	18.2	13.5	15.2	10.2	9.2	6.4	9.3	19.1	25.1	15.8	**25.1**
2001	17.8	23.9	11.6	3.5	12.0	4.3	110.0	23.1	6.8	18.5	16.0	27.6	
2002	15.8	14.1	11.6	10.2									

Ísafjörður, AWS (2642)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1998										13.6	29.3	22.2	
1999	15.7	11.5	5.9	3.3	15.4	8.0	9.3	8.0	25.9	21.7	12.9	18.3	**25.9**
2000	15.7	15.3	23.9	10.7	8.6	9.0	9.4	8.6	8.8	23.0	13.1	10.0	**23.9**
2001	22.7	32.1	2.4	4.9	30.1	2.4	12.1	15.4	6.4	16.2	34.1	22.4	**34.1**

Súðavík, AWS (2646)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1999									14.8	20.1	11.3	24.4	
2000	11.4	39.0	25.1	8.7	7.7	9.6	9.8	9.5	7.3	19.8	11.6	7.8	**39.0**
2001	11.4	18.4	5.3	3.3	7.5	4.2	18.1	10.8	4.6	9.2	15.7	14.9	**18.4**

Automatic weather stations, 1999–2001

Average temperature, °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Þverfjall (2636)	−5.2	−7.2	−7.9	−4.5	−0.6	2.8	5.6	5.3	2.3	−1.4	−4.5	−5.3	**−1.7**
Flateyri (2631)	1.1	−0.9	−2.0	1.3	5.3	8.0	10.1	10.3	8.1	4.6	1.7	0.9	**4.0**
Ísafjörður (2642)	0.6	−1.5	−2.5	0.7	5.1	7.7	9.9	9.8	7.2	3.7	1.0	0.2	**3.5**
Súðavík (2646)	0.4	−1.5	−2.3	0.6	5.0	7.9	10.1	10.2	7.4	4.0	1.1	0.3	**3.6**
Seljalandsdalur (2640*)	−3.8	−6.5	−6.3	−2.2	1.5	4.8	7.0	6.7	3.5	−0.4	−2.7	−3.4	**−0.1**
Bolungarvík (2738*)	0.8	−2.3	−2.3	0.9	4.5	7.6	9.7	9.7	7.7	3.8	1.1	0.3	**3.5**

Maximum temperature, °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Þverfjall (2636)	4.4	3.5	5.9	6.6	11.5	15.0	15.7	16.0	13.3	12.1	10.0	6.5	**16.0**
Flateyri (2631)	10.9	10.0	11.4	11.2	13.5	17.0	18.3	16.8	17.5	14.0	16.8	12.7	**18.3**
Ísafjörður (2642)	10.6	10.7	10.9	10.6	15.3	17.9	18.5	17.9	16.9	13.6	16.8	13.2	**18.5**
Súðavík (2646)	12.1	8.7	9.7	11.8	15.6	17.6	19.1	18.6	17.0	12.6	15.9	12.5	**19.1**
Seljalandsdalur (2640*)	6.7	4.4	7.4	19.3	18.8	19.8	17.7	14.9	15.8	11.1	11.4	9.0	**19.8**
Bolungarvík (2738*)	11.9	9.4	11.5	11.5	15.3	18.7	19.3	17.9	17.4	13.8	17.7	13.8	**19.3**

Minimum temperature, °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Þverfjall (2636)	−14.7	−17.2	−17.5	−14.6	−10.2	−6.3	−1.8	−1.1	−6.5	−10.2	−13.8	−17.1	**−17.5**
Flateyri (2631)	−9.1	−11.2	−11.2	−9.6	−3.0	0.0	4.1	3.0	0.6	−3.8	−8.0	−10.7	**−11.2**
Ísafjörður (2642)	−11.1	−14.3	−12.5	−11.4	−4.8	−1.7	2.5	0.9	−3.6	−7.9	−10.5	−13.0	**−14.3**
Súðavík (2646)	−9.0	−12.1	−10.9	−9.1	−4.3	0.2	4.5	2.3	−1.8	−5.8	−9.3	−11.2	**−12.1**
Seljalandsdalur (2640*)	−15.1	−20.3	−20.4	−12.7	−8.8	−5.0	−0.9	0.4	−4.0	−8.8	−12.5	−15.8	**−20.4**
Bolungarvík (2738*)	−10.7	−13.0	−13.1	−9.4	−4.9	−0.5	3.8	1.5	−2.4	−6.6	−11.3	−11.8	**−13.1**

Average wind speed, m/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Þverfjall (2636)	11.0	10.1	10.0	7.2	7.6	5.3	4.7	4.5	6.9	8.6	10.5	9.4	**8.0**
Flateyri (2631)	5.7	5.5	5.3	4.2	4.3	3.9	3.7	3.4	4.1	5.1	5.5	5.5	**4.7**
Ísafjörður (2642)	5.5	5.1	4.9	3.3	3.9	3.2	3.1	2.8	3.3	4.0	5.3	4.8	**4.1**
Súðavík (2646)	5.5	5.3	5.2	3.5	4.4	3.6	3.1	2.8	3.6	4.2	5.5	5.1	**4.3**
Seljalandsdalur (2640*)	4.7	4.5	3.8	2.7	3.0	2.0	2.1	1.9	2.4	2.5	4.0	3.7	**3.1**
Bolungarvík (2738*)	6.7	6.7	6.3	4.8	4.4	3.5	3.0	3.0	3.7	5.6	6.3	6.0	**5.0**

Maximum 10 minutes wind speed, m/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Þverfjall (2636)	43.9	42.2	45.4	27.2	26.0	23.2	22.1	19.0	25.5	31.4	38.1	36.1	**45.4**
Flateyri (2631)	21.6	21.9	24.8	19.7	19.0	14.8	14.1	14.5	17.5	21.6	20.9	23.5	**24.8**
Ísafjörður (2642)	26.2	28.0	23.6	18.1	20.4	15.4	12.9	14.6	15.6	19.4	26.9	19.9	**28.0**
Súðavík (2646)	26.1	22.3	22.5	19.9	18.8	19.0	15.1	13.8	19.5	21.4	23.1	20.7	**26.1**
Seljalandsdalur (2640*)	26.2	28.8	23.6	17.6	18.3	12.0	12.9	10.7	12.0	14.8	28.0	22.2	**28.8**
Bolungarvík (2738*)	21.7	22.5	24.8	19.3	17.4	16.7	13.6	15.8	16.6	20.4	26.0	18.7	**26.0**

Maximum 3 seconds gust, m/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Þverfjall (2636)	66.8	59.5	55.9	44.8	44.1	36.0	32.9	29.5	38.6	48.0	64.5	52.2	**66.8**
Flateyri (2631)	39.6	37.6	32.0	33.3	33.0	25.2	22.9	22.0	28.3	32.2	42.4	44.3	**44.3**
Ísafjörður (2642)	37.7	41.0	32.1	29.1	27.2	26.2	21.0	23.8	30.4	33.2	43.4	34.3	**43.4**
Súðavík (2646)	42.6	35.5	31.9	25.4	30.8	32.3	25.8	24.5	28.6	27.2	40.1	35.7	**42.6**
Seljalandsdalur (2640*)	40.3	41.6	38.9	27.1	30.0	17.7	19.2	19.5	22.2	28.6	48.6	38.1	**48.6**
Bolungarvík (2738*)	38.4	36.1	35.8	27.9	26.7	27.5	23.4	23.9	24.5	28.9	44.6	34.6	**44.6**

*Observations for a few months missing.

Þverfjall (2636), 1995–2001

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	−5.9	−7.8	−7.5	−4.4	−0.8	2.6	5.2	5.1	2.1	−2.5	−4.5	−5.3	**−2.0**
max(tx)	4.4	4.4	6.3	6.6	12.3	15.0	15.7	18.8	13.3	12.1	10.0	6.8	**18.8**
min(txn)	−17.8	−21.9	−21.9	−14.6	−11.4	−7.3	−3.2	−3.6	−8.2	−14.6	−14.5	−17.1	**−21.9**
avg(f)	11.3	10.3	10.2	7.7	6.7	5.5	4.9	4.8	7.6	9.6	9.1	9.9	**8.1**
max(fx)	45.1	49.3	45.4	28.7	26.0	23.2	28.5	22.0	29.2	48.8	38.1	37.4	**49.3**
max(fg)	66.8	65.0	66.9	52.4	44.1	37.4	42.3	39.4	42.9	73.7	64.5	60.5	**73.7**

Súðavík (2646), 1996–2001

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	0.1	−1.9	−1.7	1.2	5.1	7.9	10.3	10.0	7.8	3.5	0.7	0.3	**3.6**
max(tx)	12.1	8.7	10.1	12.2	15.6	21.0	19.4	20.5	21.7	12.8	15.9	12.5	**21.7**
min(txn)	−11.0	−14.3	−14.2	−9.1	−4.3	−0.5	3.9	1.5	−1.8	−7.2	−9.5	−11.2	**−14.3**
avg(f)	5.4	5.2	5.3	3.7	3.9	3.6	3.2	3.0	3.9	4.5	4.8	4.9	**4.3**
max(fx)	26.1	26.3	22.6	19.9	18.8	19.0	18.3	17.3	19.8	22.4	26.5	20.7	**26.5**
max(fg)	42.6	38.5	37.1	30.5	30.8	32.3	25.8	24.9	36.0	45.0	40.1	35.7	**45.0**

Snow depth in Ísafjörður (254)

Monthly average snow depth, cm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	39	57	59	51						3	11	18
1991	25	12	35	29						12	30	15
1992	6	27	30	–	–						11	29
1993	21	22	23	4						4	9	8
1994	19	13	15	25						5	9	16
1995	35	50	48	10					3	18	8	4
1996	6	9	14	9						9	4	3
1997	7	19	34	32	3				4	3	3	5
1998	10	12	13							10	11	6
1999	20	17	25	14						3	14	14
2000	18	15	24	10								2
2001	3	11	9	3								22
Avg	17	22	27	19						7	11	12

Maximum observed snow depth, cm

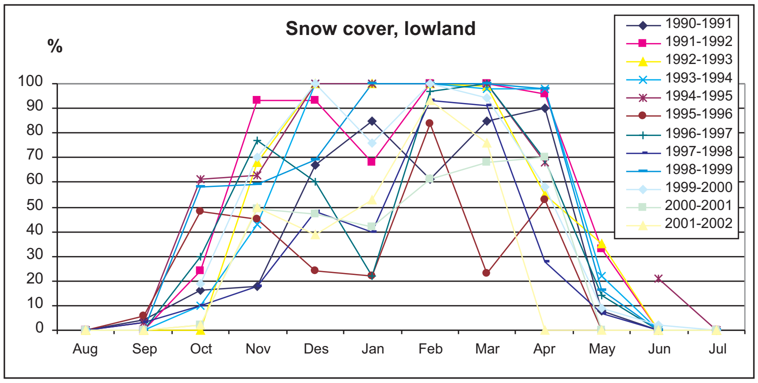
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	59	61	63	55						3	15	55
1991	50	20	52	43						15	51	34
1992	10	45	38	–	0						30	43
1993	25	40	40	15	3					5	20	15
1994	35	18	23	42						10	15	30
1995	48	65	63	16					3	36	14	6
1996	20	18	15	15						15	10	5
1997	12	47	48	38	3				4	3	4	14
1998	10	15	18							17	14	12
1999	38	35	35	20						4	22	37
2000	22	30	35	15								3
2001	3	22	14	4							25	35
Max	59	65	63	55	3				4	36	51	55

Average snow cover in lowland, %

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	72	100	100	100	42	0	0	0	4	16	18	67
1991	85	61	85	90	8	0	0	0	0	24	93	93
1992	68	100	100	96	33	0	0	0	0	0	68	100
1993	100	100	99	55	35	0	0	0	0	10	43	100
1994	100	100	98	98	22	0	0	0	3	61	63	100
1995	100	100	100	68	–	21	0	0	6	48	45	24
1996	22	84	23	53	0	0	0	0	0	30	77	60
1997	22	97	100	69	14	0	0	0	3	10	18	48
1998	40	93	91	28	7	0	0	0	0	58	59	69
1999	100	100	100	98	16	0	0	0		19	70	100
2000	76	100	94	58	9	2	0	0	0	2	49	47
2001	42	61	68	70	0	0	0	0	0	2	50	39
Avg	69	91	88	74	17	2	0	0	1	23	54	71

Average snow cover in mountains, %

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	81	100	100	100	81	38	11	0	38	42	34	81
1991	90	86	93	100	69	39	3	0	5	57	97	100
1992	98	100	100	100	–	58	29	19	77	45	96	100
1993	100	100	100	100	–	81	35	25	6	27	70	100
1994	100	100	100	100	95	74	30	0	14	90	100	100
1995	100	100	100	100	–	75	45	15	30	100	100	77
1996	100	100	92	98	56	22	0	1	0	69	100	98
1997	79	100	100	100	62	31	5	9	24	69	99	91
1998	82	98	100	83	66	13	0	0	28	70	100	96
1999	100	100	100	100	97		14		22	47	80	100
2000	100	100	98	100	60	52	5		8	63	100	92
2001	84	91	100	98	65	43				39	68	69
Avg	93	98	99	98	72	48	16	8	23	60	87	92


Snow cover, lowland
%
100
90
80
70
60
50
40
30
20
10
0
Aug
Sep
Oct
Nov
Des
Jan
Feb
Mar
Apr
May
Jun
Jul
1990-1991
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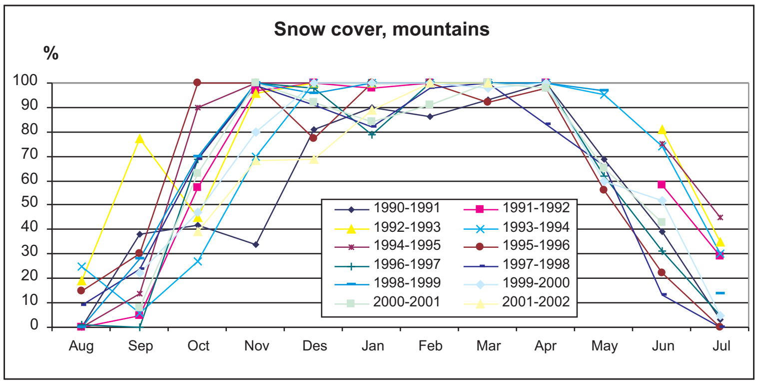
1998-1999
1999-2000
2000-2001
2001-2002


Snow cover, mountains
%
100
90
80
70
60
50
40
30
20
10
0
Aug
Sep
Oct
Nov
Des
Jan
Feb
Mar
Apr
May
Jun
Jul
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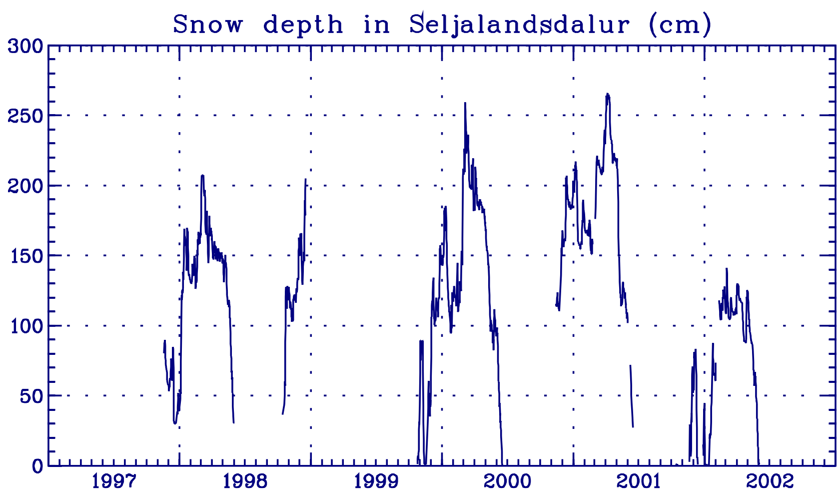
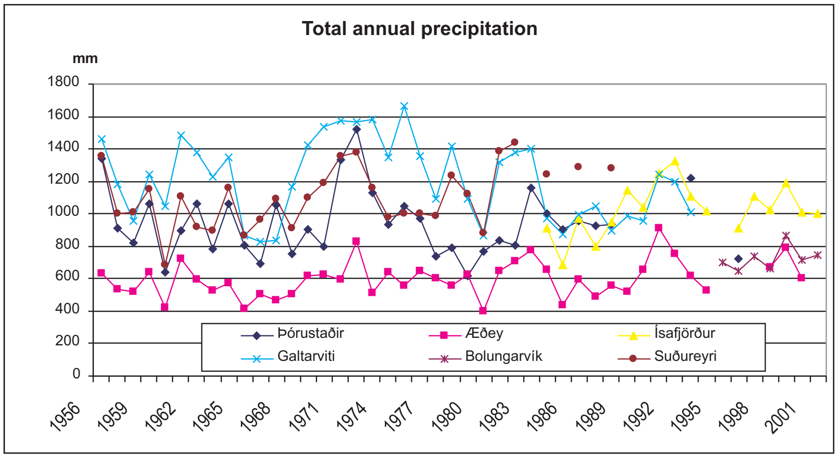
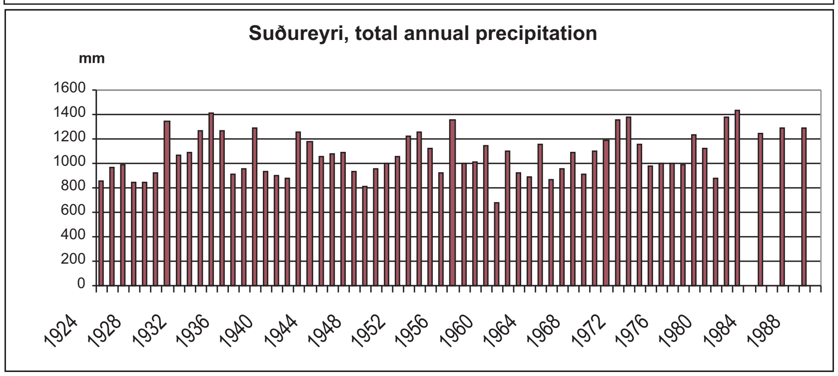
1997-1998
1998-1999
1999-2000
2000-2001
2001-2002


Snow depth in Seljalandsdalur (cm)
300
250
200
150
100
50
0
1997
1998
1999
2000
2001
2002

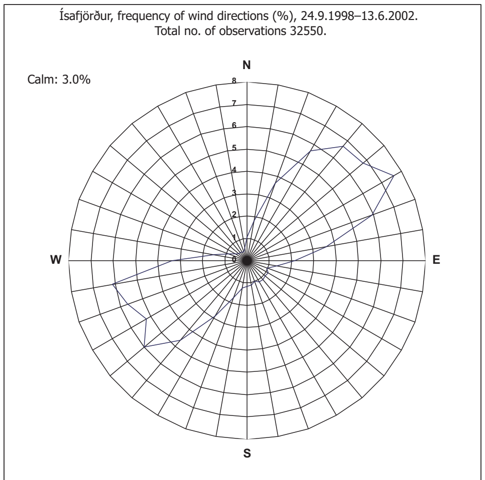
Precipitation

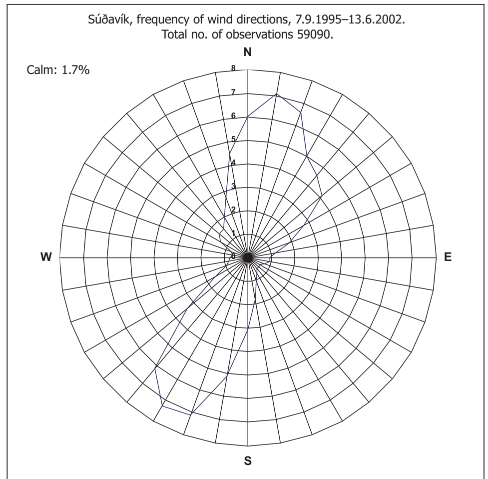


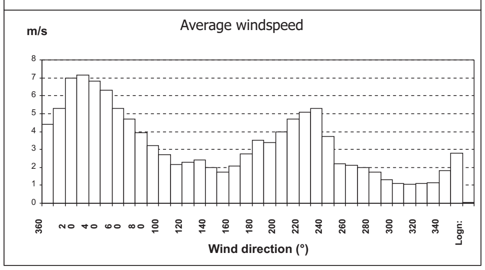


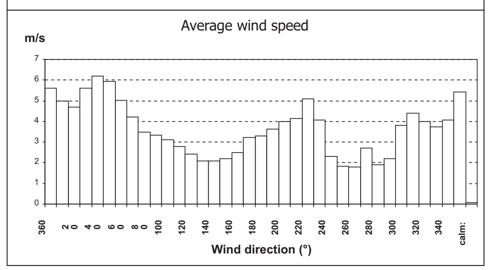
	Ísafjörður 1984–2001				Bolungarvík 1995–2001			
	precip, mm	rain %	sleet %	snow %	precip, mm	rain %	sleet %	snow %
Jan	126.6	21.8	30.4	47.8	79.7	26.8	44.0	29.2
Feb	123.7	9.9	32.3	57.8	68.5	4.6	39.2	56.2
Mar	103.0	9.7	34.8	55.5	63.3	14.2	38.5	47.3
Apr	48.0	23.1	31.4	45.5	21.4	29.0	37.1	33.9
May	49.7	49.2	41.9	8.9	39.9	49.6	47.3	3.1
Jun	21.2	82.7	17.3	0.0	32.5	54.7	44.3	1.0
Jul	38.0	100.0	0.0	0.0	40.2	85.7	14.3	0.0
Aug	55.4	95.2	4.8	0.0	63.6	96.0	4.0	0.0
Sep	84.3	68.4	31.5	0.2	65.9	73.7	25.4	0.9
Oct	125.5	38.7	46.0	15.2	108.8	59.2	35.2	5.6
Nov	116.9	23.6	44.4	32.0	71.4	26.2	52.9	20.8
Dec	129.1	16.6	40.8	42.6	68.7	21.1	59.3	19.6
Year	1021.3	44.9	29.6	25.5	723.9	45.1	36.8	18.1
Oct–Apr	772.8	20.5	37.2	42.4	481.7	25.9	43.7	30.4

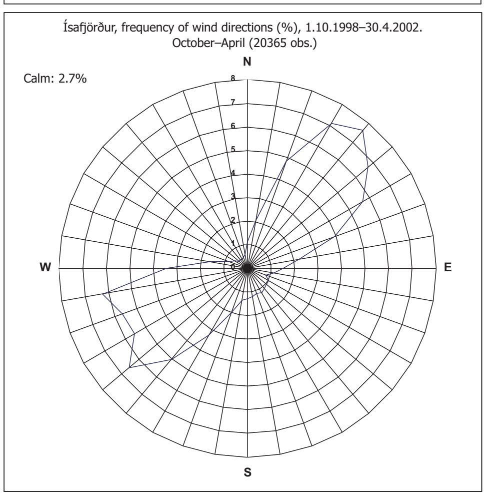
Wind roses

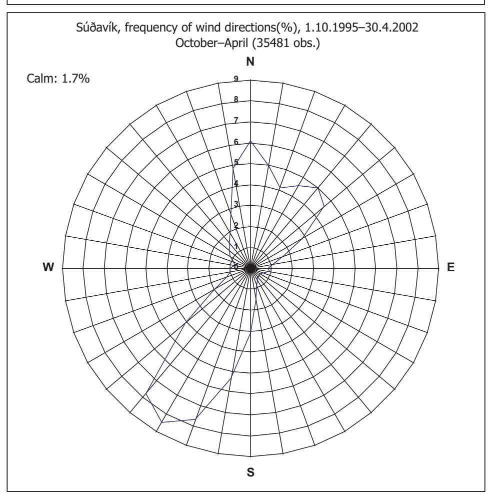

Ísafjörður, frequency of wind directions (%), 24.9.1998–13.6.2002.
Total no. of observations 32550.
Calm: 3.0%
N
W
E
S

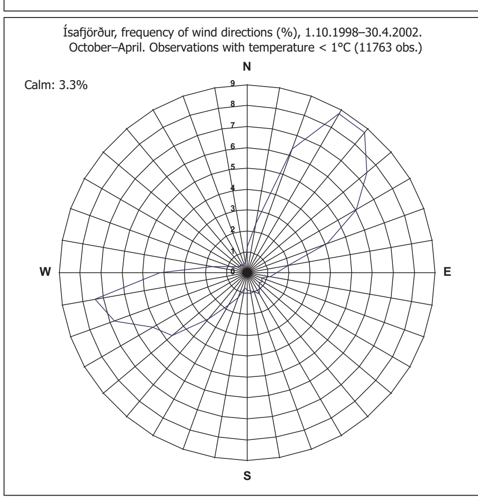

Súðavík, frequency of wind directions, 7.9.1995–13.6.2002.
Total no. of observations 59090.
Calm: 1.7%
N
W
E
S

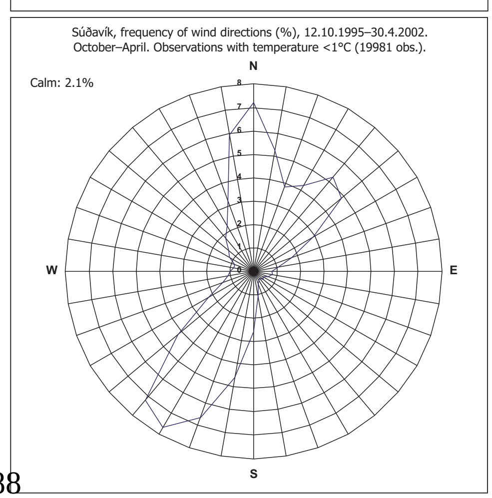

Average windspeed
m/s
Wind direction (°)
Logn:


Average wind speed
m/s
Wind direction (°)
calm:

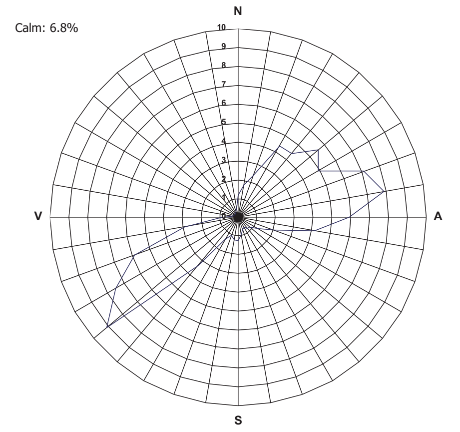

Ísafjörður, frequency of wind directions (%), 1.10.1998–30.4.2002.
October–April (20365 obs.)
Calm: 2.7%
N
W
E
S


Súðavík, frequency of wind directions(%), 1.10.1995–30.4.2002
October–April (35481 obs.)
Calm: 1.7%
N
W
E
S

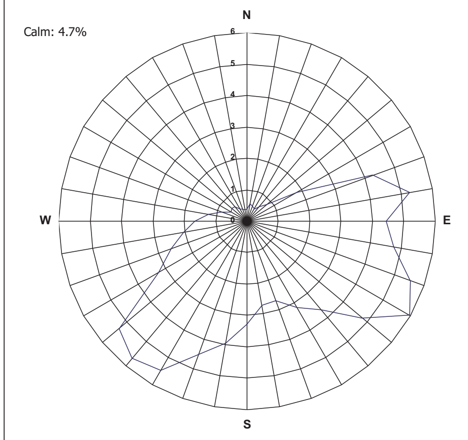

Ísafjörður, frequency of wind directions (%), 1.10.1998–30.4.2002.
October–April. Observations with temperature < 1°C (11763 obs.)
Calm: 3.3%
N
W
E
S


Súðavík, frequency of wind directions (%), 12.10.1995–30.4.2002.
October–April. Observations with temperature <1°C (19981 obs.).
Calm: 2.1%
N
W
E
S

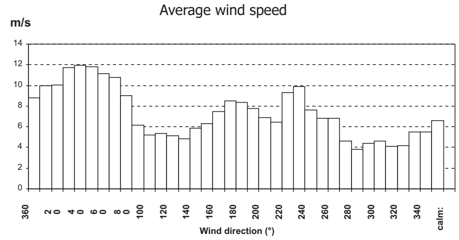
Þverfjall, frequency of wind directions (%), 25.3.1994–28.5.2002.
Total no. of observations 71436.



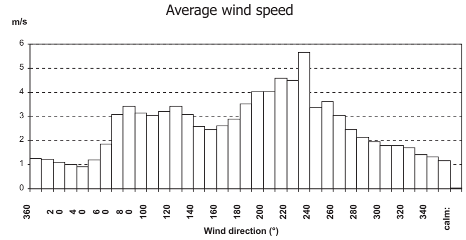
Seljalandsdalur, frequency of wind directions (%). 18.11.1997–12.6.2002.
Total no. of observations 32749.



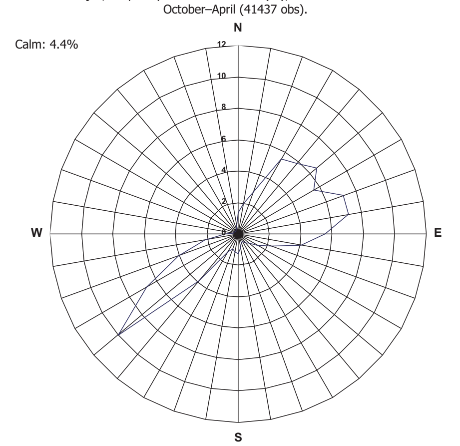
Average wind speed



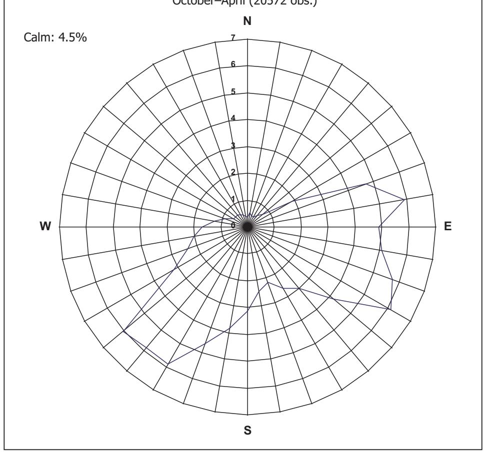
Average wind speed



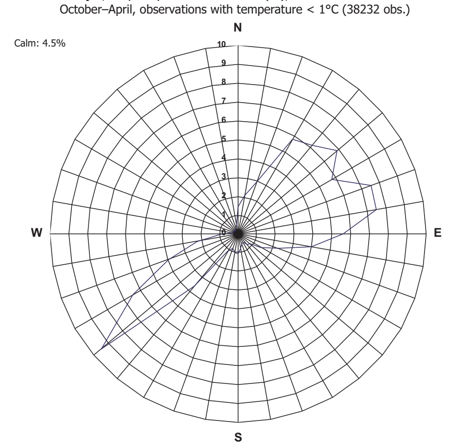
Þverfjall, frequency of wind directions (%), 25.3.1994–30.4.2002.
October–April (41437 obs).



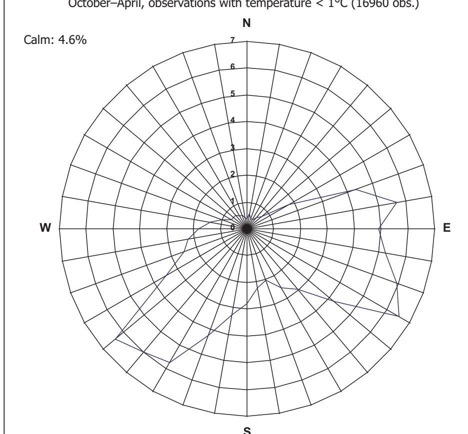
Seljalandsdalur, frequency of wind directions (%), 18.11.1997–30.4.2002.
October–April (20572 obs.)

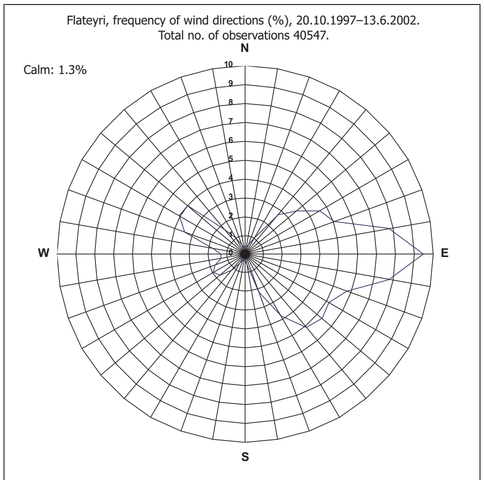


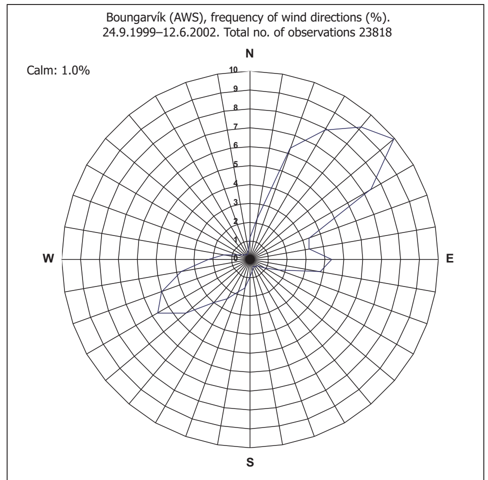
Þverfjall, frequency of wind directions (%), 25.3.1994–30.4.2002.
October–April, observations with temperature < 1°C (38232 obs.)

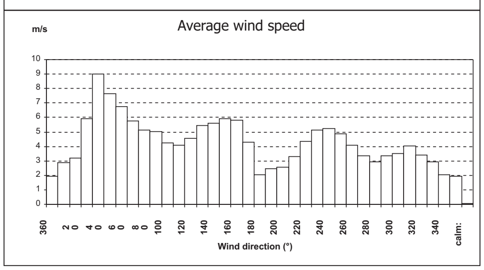


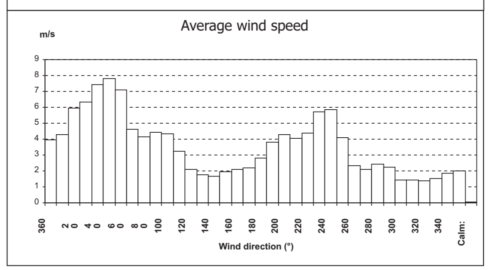
Seljalandsdalur frequency of wind directions (%), 18.11.1997–30.4.2002.
October–April, observations with temperature < 1°C (16960 obs.)

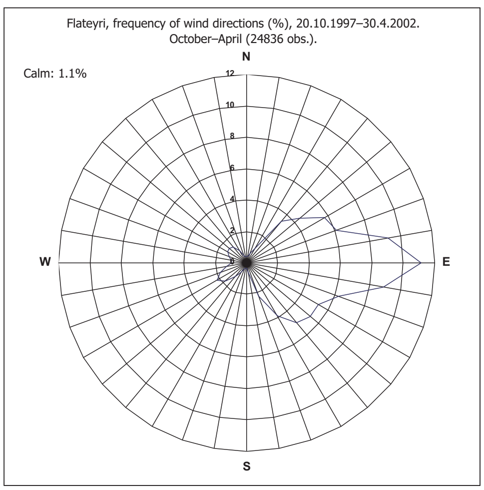


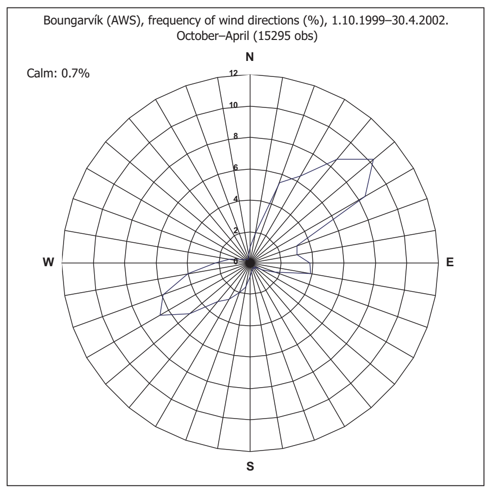

Flateyri, frequency of wind directions (%), 20.10.1997–13.6.2002.
Total no. of observations 40547.
Calm: 1.3%
N
E
S
W

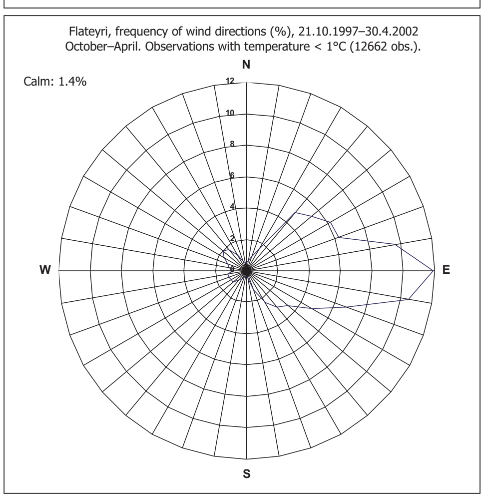

Boungarvík (AWS), frequency of wind directions (%).
24.9.1999–12.6.2002. Total no. of observations 23818
Calm: 1.0%
N
E
S
W

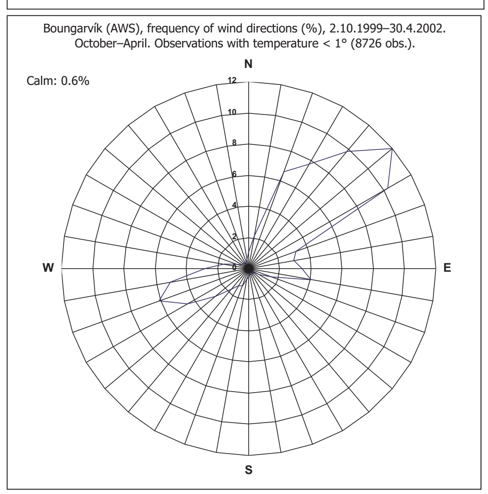

Average wind speed
m/s
Wind direction (°)
calm:


Average wind speed
m/s
Wind direction (°)
Calm:

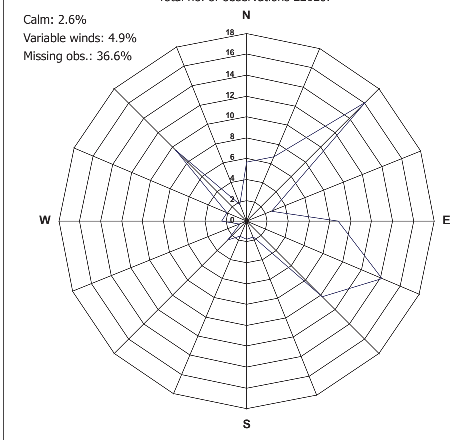

Flateyri, frequency of wind directions (%), 20.10.1997–30.4.2002.
October–April (24836 obs.).
Calm: 1.1%
N
E
S
W


Boungarvík (AWS), frequency of wind directions (%), 1.10.1999–30.4.2002.
October–April (15295 obs)
Calm: 0.7%
N
E
S
W

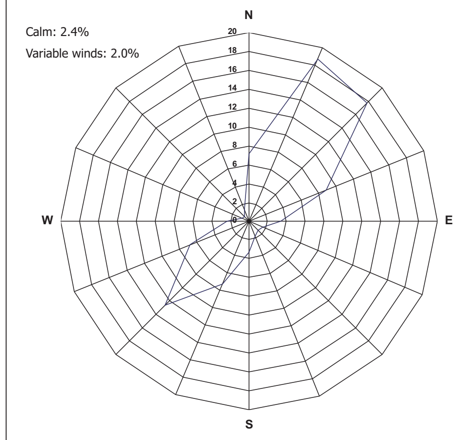

Flateyri, frequency of wind directions (%), 21.10.1997–30.4.2002
October–April. Observations with temperature < 1°C (12662 obs.).
Calm: 1.4%
N
E
S
W


Boungarvík (AWS), frequency of wind directions (%), 2.10.1999–30.4.2002.
October–April. Observations with temperature < 1° (8726 obs.).
Calm: 0.6%
N
E
S
W

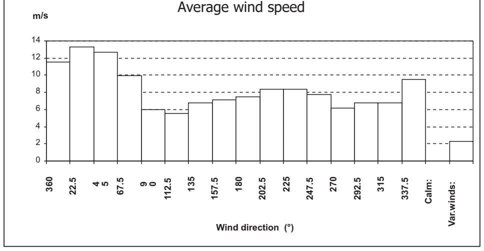
Æðey, frequency of wind directions (%), 1.7.1994–31.5.2002
Total no. of observations 22120.



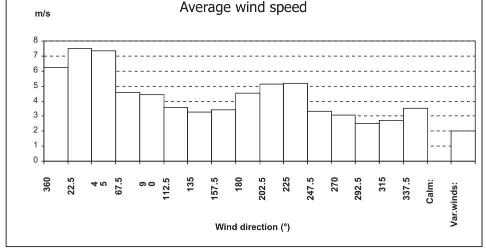
Bolungarvík, frequency of wind directions (%), 1.7.1994–31.5.2002.
Total no. of observations 22790.



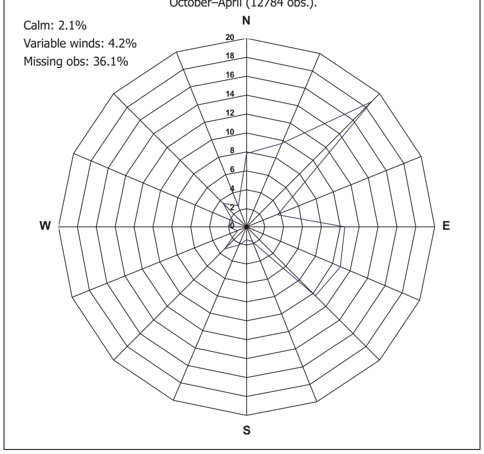
Average wind speed



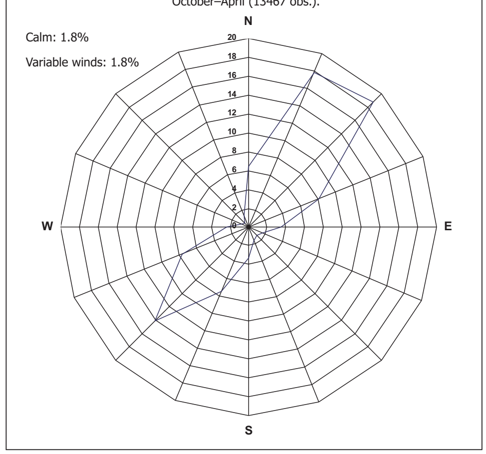
Average wind speed



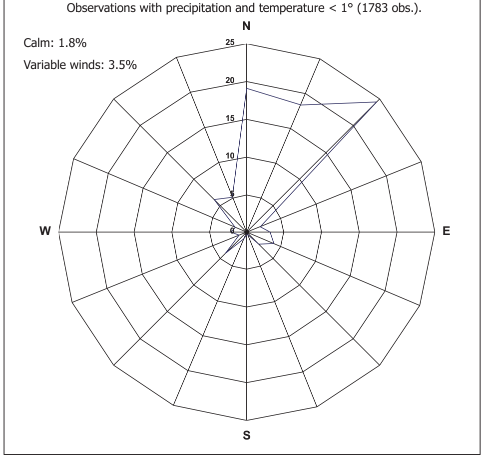
Æðey, frequency of wind directions (%), 1.10.1994–30.4.2002.
October–April (12784 obs.).



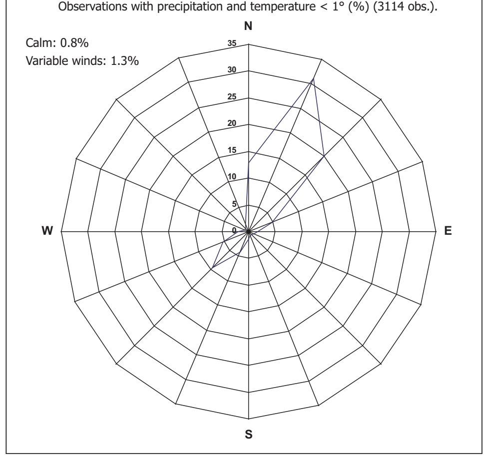
Bolungarvík, frequency of wind directions (%), 1.10.1994–30.4.2002.
October–April (13467 obs.).



Æðey, frequency of wind directions, October–April, 6.10.1994–30.4.2002.
Observations with precipitation and temperature < 1° (1783 obs.).



Bolungarvík, frequency of wind directions, October–April, 6.10.1994–31.12.2001.
Observations with precipitation and temperature < 1° (%) (3114 obs.).



D Profile drawings

Drawing no.	Profile ID	Avalanche path
1	isse24aa	Seljalandshlíð, path of 1994 avalanche
2	isse14aa	Seljalandshlíð, by Skíðheimar
3	isse33aa	Seljalandshlíð, Seljalandshverfi
4	isse09aa	Seljalandshlíð, Seljaland
5	isse12aa	Seljalandshlíð, “Karlsárgil”
6	isse05aa	Seljalandshlíð, “Grænagarðsgil”
7	isse06aa	Seljalandshlíð, Hrafnagil
8	isse08aa	Seljalandshlíð, “Steiniðjugil”
9	isey02ba	Gleiðarhjalli, near western margin
10	isey03ba	Gleiðarhjalli, Stakkaneshryggur
11	isey05ba	Gleiðarhjalli, between Stakkaneshryggur and Stórurð
12	isey07ba	Gleiðarhjalli, Stórurð
13	isey09ba	Gleiðarhjalli, above Skutulsfjarðareyri
14	isey11ba	Gleiðarhjalli, near western margin of settlement
15	isey13ba	Gleiðarhjalli, west of settlement
16	isku02aa	Kubbi, Hafrabrekkuháls
17	isku03aa	Kubbi, Hafrafellsháls
18	isku05aa	Kubbi, Brattahlíð, middle of settlement
19	isku07aa	Kubbi, Brattahlíð, near western margin of settlement
20	hnno01aa	Hnífsdalur, Hraunsgil
21	hnno04aa	Hnífsdalur, Traðargil
22	hnno05aa	Hnífsdalur, Búðargil
23	hnsu01ba	Hnífsdalur, Bakkahyrna, outer part of settlement
24	hnsu03aa	Hnífsdalur, Bakkahyrna, middle of settlement
25	hnsu05aa	Hnífsdalur, Bakkahyrna, near inner margin of settlement