VEÐURSTOFA ÍSLANDS

Report
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Hazard zoning for Seyðisfjörður

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Contents

1 Introduction

This report describes the results of a project carried out by the Icelandic Meteorological Office (IMO) with the aim to evaluate avalanche, debris flow and rockfall hazard in Seyðisfjörður. The result is a hazard zoning proposal for Seyðisfjörður based on the current Icelandic hazard zoning regulation.

Similar reports have been published for Neskaupstaður and Siglufjörður where new hazard maps have recently been issued (Thorsteinn Arnalds *et al.* 2001a,b,c).

1.1 Work process

The main participants in this project were Thorsteinn Arnalds, Tómas Jóhannesson, Esther H. Jensen and Kristján Ágústsson (IMO), Siegfried Sauermoser (Austrian Foresttechnical Service in Avalanche and Torrent Control, WLV) and Thomas Sönser (Ingenieurbüro für Naturraum-analyse und Naturgefahren-management, INN).

Other employees of the IMO contributed to the work. Preparation of climatic data and analysis of weather preceding avalanche cycles was carried out by Sigrún Karlsdóttir and Thóranna Pálsdóttir. Leah Tracy and Hörður Þór Sigurðsson drew maps for the report. The local snow observer in Seyðisfjörður, Emil Tómasson, participated in parts of the work.

Halldór Pétursson, Icelandic Institute of Natural History (Náttúrufræðistofnun), and Thorsteinn Sæmundsson, IMO, compiled debris flow chronicles.

Work on the project started formally in the winter 1999/2000 at the IMO with the collection of basis data. The work within the project was also founded on the field work and analysis carried out within the project *Pilot hazard zoning for Seyðisfjörður* (Tilraunahættumat fyrir Seyðisfjörð) (Thorsteinn Arnalds, 2001).

Additional field work on the south side of the fjord was carried out in the summer of 2000. On 24–28 June Thorsteinn, Esther, Siegfried, Thomas and Kristján visited Seyðisfjörður. The fieldwork was split into three parts; i) analysis of avalanche conditions in the southern part of Seyðisfjörður, ii) investigation of debris flow, torrent and rock fall hazard in the southern part of Seyðisfjörður focusing on two paths and iii) a discussion within the group on how to integrate the landslide hazard into a final hazard map. Thorsteinn, Siegfried and Kristján worked on part i), Esther and Thomas on part ii) and the whole group on part iii).

The scope and extent of the inspection of avalanche conditions was defined to be an examination of relevant areas in the field, review of avalanche chronicles and climatic information and to describe the following:

a) *Topographic conditions, i.e.* the topography of the starting zone, track and runout area.

b) *Climatic conditions* would be dealt with mostly on a regional basis, but locally the effect of the regional climate on snow accumulation in starting areas would be discussed.

c) *Assessment*. The group would give its general opinion of the avalanche hazard in a particular path. This would be done by quantifying the size of the starting areas and their relative frequency with respect to other paths.

These descriptions formed the basis of the final report for the project.

The debris flow work group applied a process orientated Austrian Method for assessing the hazard in the south part of the village. Their work was concluded with a separate report (Esther H. Jensen and Thomas Sönser, 2002). This work was extended to other paths in Seyðisfjörður and integrated into the final hazard zoning by the staff of the IMO. Section 4.5 discusses this work. A part of that work was a field trip to Seyðisfjörður on 11 November 2001 by Esther, Hörður and Tómas.

A regulation on avalanche and debris flow hazard zoning was issued in July 2000 (The Ministry for the Environment, 2000). According to the regulation a hazard zoning committee was to be formed for communities where avalanche and debris flow hazard should be evaluated. The committee consists of two representatives from the local government and two for the Ministry for the Environment. A hazard zoning committee for the community of Seyðisfjörður was established in February 2001.

The hazard zoning committee for Seyðisfjörður held its first meeting on 10 April 2001. At that meeting the IMO presented its work and some preliminary findings. A rough plan was laid out for the completion of the hazard map.

To strengthen the basis of the hazard zoning, two-dimensional model calculations were carried out by Advanced Simulation Technologies (AVL) of Graz, Austria (Tómas Jóhannesson *et al.*, 2002).

Weather preceding avalanche cycles in Seyðisfjörður was analysed by Sigrún Karlsdóttir (2002).

A decision was made to base the hazard zoning on the north side of Seyðisfjörður mostly on investigations that were carried out in 1997 and 1998 by experts from the Norwegian Geotechnical Institute, the Austrian Foresttechnical Service for Avalanche and Torrent Control (WLV) and the IMO (Thorsteinn Arnalds, 2001).

Based on the background data described above the hazard zones were delineated. The delineation was done by Thorsteinn and Tómas with Esther and Kristján participating in parts of the task. As a part of the finalisation of the hazard zoning Esther, Thorsteinn and Tómas made a field trip to Seyðisfjörður on 18–19 January 2002. They were accompanied by the local snow observer Emil Tómasson.

1.2 Organisation of the report

On the northern side of Seyðisfjörður the investigated area reaches from Nautabás in the east to the west of Skagi. On the southern part the investigated area reaches from Imslandsgil in the east and to west of Ytri-Hádegisá. The investigated area is shown on Map 1.

The report is split into four main sections. The first part contains an overview of topographic and climatic conditions, a summarised avalanche chronicle, a review of previous hazard maps and a brief discussion of debris flow hazard for the northern part of Seyðisfjörður. The two next sections deal with the northern and southern parts of Seyðisfjörður. For these areas the following is described:

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

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.

The discussion of the southern part is split into five subsections. The first four discuss the avalanche situation. The fifth discusses debris flow, rockfall, slushflow and torrent hazard.

Finally a short conclusion is given on the overall results of the project.

1.3 Methodologies and regulations

The hazard zoning presented in this report is based on Icelandic hazard zoning regulations that were issued in July 2000 after having been under development for several years. A summary of these regulations is included below.

Hazard zoning in Iceland has since 1995 been based on individual risk which is the yearly probability that a person living at a given place will be killed by an avalanche. The definition of hazard zones is based on the *local risk* defined as the annual probability of being killed given that a person is staying all the time in an unreinforced house. The *actual risk* can be found by taking into account the probability of the person being present in a house when an avalanche hits and the increased safety obtained by reinforcing houses. Increased safety by evacuations and other non-permanent safety measures are not taken into account in the hazard zoning. The authorities in Iceland have adopted the value $0.2 \cdot 10^{-4}$ per year as an accepted actual risk for avalanche hazard zoning (The Ministry for the Environment, 1997). This value corresponds to different values of the local risk for different types of constructions depending on the fraction of time people may be expected to spend in the buildings (typical values are assumed to be 75% in domestic houses, and 40% in commercial buildings). The regulations on hazard zoning (The Ministry for the Environment, 2000) defines three types of hazard zones, see Table 1.

These guidelines for zoning are tailored to attain the acceptable risk level of $0.2 \cdot 10^{-4}$ per year in residences when presence probability and increased safety provided by reinforcements have been taken into account. The risk in industrial buildings is probably somewhat higher.

The methodology used here to estimate avalanche risk in parts of Seyðisfjörður was developed at the University of Iceland and the Icelandic Meteorological Office in the period 1995–1998. The methods are described by Kristján Jónasson *et al.* (1999).

Table 1. *Icelandic hazard zone definitions*

Zone	Lower level of local risk	Upper level of local risk	Construction allowed
C	$3 \cdot 10^{-4}$/yr	–	No new buildings, except for summer houses*, and buildings where people are seldom present.
B	$1 \cdot 10^{-4}$/yr	$3 \cdot 10^{-4}$/yr	Industrial buildings may be built without reinforcements. Domestic houses have to be reinforced. Existing hospitals, schools *etc*. can be enlarged and then have to be reinforced.
A	$0.3 \cdot 10^{-4}$/yr	$1 \cdot 10^{-4}$/yr	Houses where large gatherings are expected, such as schools, hospitals *etc*., have to be reinforced.

*If the risk is less than $5 \cdot 10^{-4}$ per year.

The methodology for hazard zoning with regard to debris flows and rockfall is described by Tómas Jóhannesson and Kristján Ágústsson (2002) and summarised in Section 4.5.1.

This discussion is concluded by quoting §10 of the Icelandic regulations on how to proceed where formal risk calculation is impossible: "In areas, where it is not possible to estimate the risk formally due to insufficient information, a hazard map shall nevertheless be prepared according to §12 [§12 describes the risk zones of a hazard map]. In the preparation of the map an attempt should be made to estimate risk."

1.4 Uncertainty

The estimation of avalanche risk is difficult in many areas. This is especially the case when dealing with a slope that from the topographical point of view has the characteristics of an avalanche path, but where no avalanches have been recorded. Accurate records of avalanches have only been kept for a few years or decades in many areas and the settlement may be quite recent. In such a situation, it is almost impossible to rule out the possibility that an avalanche hitting the settlement might be released from the slope. An attempt must then be made to strike a compromise that balances the lack of recorded avalanches and the possibility of avalanche release.

Another problem that must be addressed is the estimation of avalanche hazard in non-typical or low avalanche tracks. The available data about Icelandic avalanches was mostly collected from hills between 500 and 800 m high with large starting areas. The runout potential of avalanches from smaller slopes, both with a lower fall height and smaller starting areas, is not as well investigated.

While delimiting the hazard zones, an attempt has been made to classify the uncertainty in each area by dividing the uncertainty into three classes according to the level of uncertainty in the area. An uncertainty of $\frac{1}{2}$ means that the estimation could be wrong by half a hazard zone, *i.e.* the hazard lines may misalign by approximately $\frac{1}{2}$ of a hazard zone. Since the risk varies by a factor of 3 between the risk lines of the hazard map, the risk may be over- or underestimated by factor of $\sqrt{3}$. Similarly, classes 1 and 2 certainty mean that the zoning could be wrong by 1 and 2 zones in either direction, respectively, meaning that the risk could be over- or underestimated by factor of 3 or 3^2 respectively. Considering the "nominal" nature of avalanche risk estimates, it is not possible to attach a given significance level in a statistical sense to these uncertainty indicators. They are intended to mean that the work group considers it "unlikely" that the risk is over- or underestimated by the indicated uncertainty, but the meaning of "unlikely" is not further quantified.

The three chosen classes of uncertainty and their characteristics are:

- $\frac{1}{2}$ Records of avalanches are available and the avalanche path is large and typical.
- 1 Some records of avalanches are available and the avalanche path is small or atypical.
- 2 No records of avalanches are available, but the topography indicates avalanche hazard.

The uncertainty of hazard zoning in areas where protective measures have been built will probably be in class 1 or 2.

2 General

2.1 Topographic description

The village Seyðisfjörður is located at the head of the fjord Seyðisfjörður, see Map 1 and Figure 1. The general direction of the fjord is ENE-WSW but the innermost part is directed NNE-SSW. By local convention the opposite sides of the fjord and the community are referred to as the south and north side irrespective of the actual compass directions. Similarily the directions along the fjord are referred to as east and west. This report adopts the local convention.

The mountain Bjólfur is to the north of the settlement. The summit of Bjólfur is Bjólfstindur reaching 1080 m a.s.l. Below Bjólfstindur and above the small peninsula Fjarðaralda there is about a 200 m wide shelf at about 650 m a.s.l. The edge of the shelf is Brún or Bjólfsbrún. Below Brún there is a small bowl called Kálfabotn and below Kálfabotn there is a small gully, Hlaupgjá. The gully Fálkagil is in the lower part of the slope above the innermost part of the settlement, Bakkahverfi. To the west of that there is a larger gully called Jókugil.

The mountainside south of Seyðisfjörður is characterised by varied terrain including three summits, large depressions, gullies, and cliffs. The outermost summit is Strandartindur. Next to Strandartindur is Miðtindur (also named Dagmálatindur or Litlitindur) and the third summit is Innri-Strandartindur. The hillside in the outer part of Strandartindur is steep in the upper part and a large part of it has an inclination greater than 30°. Sections of Strandartindur are marked by shallow gullies with small brooks running through them. On the outer base of Strandartindur there is a relatively flat area named Þófi where the inclination of the hillside is about 15° on average. Between Strandartindur and Miðtindur the inclination varies due to cliffs and shelves. The most distinctive shelves are called Efri-Botnar located at an elevation higher than 450 m a.s.l. West of Þófi at 200–350 m a.s.l the surface is covered with sediments marked mainly by three large and rapidly eroding gullies carved in the Strandartindur mountainside. Through these gullies run the small brooks Skuldarlækur and Stöðvarlækur and the river Búðará. To the west of the three gullies below Miðtindur there is another flat area named Neðri-Botnar. Most of the houses in the southern part of the settlement in Seyðisfjörður are below Neðri-Botnar. The hillside between Miðtindur and the area above Efri-Botnar is similar to the outer area between the Efri- and Neðri-Botnar. Below the outer part of Neðri-Botnar, cliffs rise continuously above the housing area to a large gap in the cliffs below the Neðri-Botnar called Nautaklauf. Below the inner side of Neðri-Botnar, the cliffs stop though the hillside remains steep. Many houses in the southern part of Seyðisfjörður are below this steep hillside. To the west of Botnabrún is the brook Dagmálalækur. The lower part of the slope to the west is Grákambur. Through Grákambur falls the river Hádegisá or Ytri-Hádegisá.

According to the book of settlement the first settler in Seyðisfjörður was Bjólfur. He probably built his house at or around the present location of the farm Fjörður. Most of the land in Seyðisfjörður is believed to have been settled by the year 1000. In the middle of the nineteenth century some trading business was started in Seyðisfjörður. Around 1870 small villages started to form around the traders. This development was mostly connected to herring fisheries managed by Norwegians. The majority of the houses that are within the boundaries of the current settlement were located in Fjarðaralda and Búðareyri. In addition to these, there were two small villages in

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

Vestdalseyri and Eyrar that have now been abandoned. Around the middle of the twentieth century houses had been built along most of the shoreline north and south of the fjord and in the valley along Fjarðará. After that the settlement started to develop up the mountainside and along the bottom of the valley. The most recently built houses are located in Bakkahverfi and around Botnahlíð. These houses are mostly built in the period 1975–1985.

The names of houses in Seyðisfjörður, and the year which they were built have been documented in detail by Harpa Grímsdóttir (1997).

2.2 Chronicle

Maps 2–4 show recorded avalanches and slushflows in Seyðisfjörður. Avalanches recorded during the current winter, 2001/2002, are neither included on the map nor in the avalanche lists for the investigated areas.

The avalanche chronicle of Seyðisfjörður dates back to 1882 when slushflows are recorded at several locations below Bjólfur. The slides caused various damages and one of them killed two children.

In February 1885 there was a large avalanche cycle in eastern Iceland. It was preceded by continuous snowfall for several weeks with winds from east and northeast. During this cycle several avalanches in Seyðisfjörður caused damage. On 18 February a large avalanche started in Bjólfur. The exact location is not known but it is said to have extended from Jókugil to the east of Hlaupgjá. A total of 86 people got buried by the avalanche and of those 24 were killed. No other avalanche in Iceland is known, with certainty, to have caused more fatalities.

In February 1904 slushflows fell in both Bjólfur and Strandartindur damaging houses and boats.

In 1912 several wet avalanches started in Bjólfur. One of the avalanches damaged a warehouse belonging to the trading company Framtíðin. It also damaged boats and a sheepshed killing 17 sheep.

In February 1914 an avalanche fell from Bjólfur and damaged a domestic house and a stable by Fornistekkur.

At the end of March 1967 an avalanche fell from Bjólfur above Nautabás. It damaged a fish meal storage house belonging to Hafsíld. Part of the house and merchandise in the house was transported out to the sea.

In 1975 an avalanche from Bjólfur broke down about a 20 m long part of a wall of the Hafsíld factory. The roof of the house mostly collapsed.

In 1993 an avalanche damaged the meal storage house of Hafsíld.

In March 1995 an avalanche fell in Bjólfur and hit the fish meal factory of Hafsíld. The meal storage house was destroyed and the factory house was partly damaged and filled by snow. Eleven people narrowly escaped.

Before 1995 systematic records were not kept on avalanches in Seyðisfjörður. Existing records are therefore probably quite incomplete before this time, and mostly damage causing avalanches are recorded. The position of snow observer for Seyðisfjörður was established at the IMO in 1995. The snow observer is responsible for keeping records of avalanches. This means that after 1995 most avalanches falling close to the settlement have been recorded and measured when possible.

An avalanche chronicle for Seyðisfjörður was compiled at the IMO by Kristján Ágústsson (1988, 2002).

A debris flow chronicle for Seyðisfjörður was compiled by Halldór G. Pétursson and Thorsteinn Sæmundsson (1998). Esther H. Jensen and Thomas Sönser (2001) summarise the chronicle.

2.3 Previous hazard assessments

In January 1975 Gunnlaugur Jónasson (1975) compiled a list of avalanches in Seyðisfjörður. He made an assessment of the hazard and drew a corresponding map.

In 1975 the Icelandic Civil Defence hired M. R. de Quervain from the Swiss Avalanche Institute (SLF) to assess the avalanche hazard in Siglufjörður, Seyðisfjörður and Neskaupstaður (SLF, 1975) following the catastrophic avalanche accidents in Neskaupstaður in 1974. He analysed the hazard situation and discussed possible measures to increase the safety of people.

The first law concerning avalanches and debris flows was issued in 1985. §3 of the law 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 where settlement is 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 responsible 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 of supervising 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 Thorsteinn Jóhannesson at Verkfræðistofa Siglufjarðar sf. (VS, 1986). In the next few years hazard zoning was done in several villages by independent consultants, supervised by the Icelandic Civil Defense.

Thorsteinn Jóhannesson at Verkfræðistofa Siglufjarðar (VS) prepared a hazard map for Seyðisfjörður based on the regulation from 1988 (VS, 1989). The hazard map showed delineation between a hazard area and a "safe" area as the regulation required, see Map 5. Based on the proposal of VS the first official hazard map for Seyðisfjörður was approved by the Minister of Social Affairs in October 1991. According to the map only a few of the domestic houses in Seyðisfjörður were within the hazard zone.

In 1992 VS together with Verkfræðistofa Austurlands (VA) proposed a catching dam to protect against avalanches in the harbour area of Seyðisfjörður (VS and VA, 1992).

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 evacuation zones and description of the conditions in which zones should be evacuated. Such a plan was made for Seyðisfjörður (IMO, 1996) and revised in 1997. According to the plan a large part of the settled area in Seyðisfjörður is a part of evacuation zones that need to be evacuated under extreme conditions. The evacuation plan laid out by the IMO was partly based on a plan made by the local authorities.

In 1996 the IMO became responsible for avalanche hazard zoning. The first hazard zoning project was *Pilot hazard zoning for Seyðisfjörður* (Tilraunahættumat fyrir Seyðisfjörð). It was intended to present a comparison between the result of Icelandic versus Austrian and Norwegian hazard zoning methods and regulations. Three separate groups of experts delineated hazard zones in the northern part of Seyðisfjörður based on Icelandic (Kristján Jónasson and Thorsteinn Arnalds, 1997), Norwegian (NGI, 1997) and Austrian (WLV, 1997) regulations and methods. The results indicate that the Icelandic regulations are somewhat stricter than the Norwegian and Austrian regulations. Based on that assumption the three groups combined their findings. The resulting hazard map indicated that almost all of the settlement in the northern part of Seyðisfjörður is within a hazard zone (Thorsteinn Arnalds, 2001).

A protection plan for the northern part of Seyðisfjörður was laid out in 1998 by VA in cooperation with the Norwegian Geotechnical Institute (NGI) (VA and NGI, 1998). The plan included a combination of deflecting and catching dams.

In 2001 Stefan Margreth from the SLF investigated the possibility to build supporting structures in the starting zone of Kálfabotn (SLF, 2001). The main result was that the construction of such structures in the area is not feasible. This is due to very large snow depths, difficult geotechnical conditions and the danger that avalanches released from the upper starting zones in Bjólfstindur might flow over the structures and destroy them. Even if a catching dam was to be built on the shelf at Brún such overflow could not be ruled out. Margreth concluded that the topography of the avalanche path from Bjólfstindur, over the shelf at Brún and through Kálfabotn and Hlaupgjá was typical for several avalanche paths in the Alps that released extreme avalanches during the catastrophic winter 1998/1999. In most winters small and moderately large avalanches in such paths terminate on the shelf, but in an extreme situation large avalanches are able to traverse the plateau and release or entrain significant additional snow mass from the steep slopes below.

2.4 Climatic conditions

Several meteorological parameters were recorded in Seyðisfjörður in 1906–1953. Observations started again in 1957 and since then a climatic observation station has been operated in Seyðisfjörður. In the years 1994 and 1995 automatic weather stations were set up in Seyðisfjörður, Neskaupstaður, Dalatangi, Gagnheiði, Fjarðarheiði and Oddsskarð. Synoptic observations have been carried out at Dalatangi since 1938. The observations from these stations are used to analyse the climatic conditions in Seyðisfjörður. The locations of the stations is shown in Figure 1.

Appendix C shows several tables and figures that summarise the available climatic information. These include average, maximum and minimum temperature, average and maximum wind speed, and maximum gusts in the period 1997–2001. The same information plus average precipitation, maximum monthly precipitation and maximum daily precipitation is given for the manual observation sites of Seyðisfjörður, Dalatangi and Neskaupstaður in 1971–2000. It should be noted that observations were carried out continuously during the period at Dalatangi, several months of observations are missing in Seyðisfjörður and observations in Neskaupstaður were started in 1975. The monthly precipitation, and maximum 24 hour accumulated precipitation is shown for the manual observations in Seyðisfjörður. Some figures show the frequency of wind directions and wind directions with precipitation in Seyðisfjörður and the frequency of wind directions at Gagnheiði, Oddsskarð and Fjarðarheiði when there is precipitation and the temperature is less than 1°C at Dalatangi during the winter months. Since information on snow depth in Seyðisfjörður is incomplete, the average snowcover in the mountains (at more than 600 m a.s.l.) and in the lowland is found both for the whole year and the winter months, November through April. These observations give an indication on the snowcover in each year.

The average temperature in Seyðisfjörður is about 3.5°C which is comparable to Dalatangi but about half a degree lower than in Neskaupstaður. In Seyðisfjörður the difference between seasons is larger than at the other stations and it is colder there during the winter. The minimum observed temperature is approximately -18°C and the maximum temperature about 28°C. The temperature gradient is about 0.7° per 100 m when comparing to Gagnheiði and Fjarðarheiði but a little less or 0.6° per 100 m when comparing to Oddsskarð. This is due to Oddsskarð being further south and closer to the sea. Precipitation has been measured in Seyðisfjörður since 1935 with a gap during 1953–1956. The annual precipitation is about 1600 mm on average at the manual observation site. The automatic observations give about 20% less, 1300 mm on average. The difference is mainly caused by measurement techniques and different locations. Precipitation is a very local phenomena and the measurement equipment is sensitive to the weather, especially frost and high windspeeds. The maximum yearly precipitation recorded was 2495 mm in 1974 and 2437 mm in 1972. These were the only years when the yearly precipitation was exceeded 2000 mm. The minimum yearly precipitation was 1023 mm in 1967. A monthly precipitation of more than 500 mm has been recorded several times and the maximum daily precipitation was 140.6 mm in February 1974. A daily precipitation of more than 100 mm has been recorded in almost every month of the year.

Wind directions are always affected by the local topography. In Seyðisfjörður this causes winds from the west and east-northeast to be dominating. During the winter the east-northeasterly winds are more frequent and are directed a little more towards the north than in the summer. The east-northeasterly winds are usually the strongest. The average windspeed at the automatic station in Seyðisfjörður is 4.4 m/s. Gusts can be very strong, especially during the winter months of November through April. The maximum gust recorded in recent years was 53.3 m/s in January. In westerly Föhn winds the temperature can often be quite high in Seyðisfjörður. During such conditions the temperature can reach more than 13°C at any time during the year. The automatic weather station at Gagnheiði is located at 949 m a.s.l. and gives the best indication of the wind direction above the area. The most common wind directions during the winter are west-southwesterly, easterly and north-northeasterly. This agrees with the results of Trausti Jónsson (1998) that the frequency of gale force winds, accompanied by freezing temperatures, in the east of Iceland is highest during northerly and northeasterly winds.

The most frequent wind direction with precipitation in Seyðisfjörður is northeasterly. Present weather, wind direction, wind speed and precipitation has been observed at Dalatangi for a long period. The wind direction at Fjarðarheiði and Gagnheiði was analysed for those observations when there was precipitation and temperature lower than 1°C at Dalatangi. The most common wind direction during such conditions was between north and north-northeast. These wind directions also had the highest wind speed under these conditions. The highest wind speeds are usually observed from west and west-northwest winds in Seyðisfjöður. Observations of the snowcover since 1996 indicate that a fair amount of snow can accumulate during the winter. More snow can be expected in the lowland in Seyðisfjörður than at Dalatangi or in Neskaupstaður. The snowcover is between 50% and 90% most of the winters in the lowland areas although there are exceptions. Kristján Jónasson and Trausti Jónsson (1997) found that the expected 50 year snowdepth in Egilsstaðir is 108 cm, 133 cm in Neskaupstaður and 87 cm at Dalatangi. More snow could be expected in Seyðisfjörður. Recent analysis by Tómas Jóhannesson (2001) estimated the 50 year snow depths to be 89 cm, 154 cm and 206 cm at Dalatangi, Neskaupstaður and Seyðisfjörður, respectively.

Avalanche cycles in Seyðisfjörður have been analysed by Sigrún Karlsdóttir (2002). She finds that most of the avalanches are preceded by a continuous and heavy precipitation. A large proportion of the avalanches is released after a thaw but several after the temperature has fallen. Avalanches are most frequent during northeasterly winds. In the last few years several recorded avalanches have been preceded by southerly winds. This is probably due to improved recordings of avalanches. The runout lengths of avalanches tend to increase if they are preceded by high wind speed and heavy precipitation.

2.5 Snow depth measurements in starting areas

Regular monitoring of snow depth in the mountains above Seyðisfjörður was initiated in the winter 1996/1997. The measurements were carried out on 11 stakes in the first winter, 16 stakes in the next winter and on 23–26 stakes after that. Few readings were taken during the first two winters and the measurements of those winters are therefore of limited value. The stakes are 3.0 to 4.2 m high and placed in the elevation range from about 250 m to 685 m a.s.l. in Bjólfur on the northern side of the fjord and in the range 410 to 510 m a.s.l. in Strandartindur on the southern side of the fjord. Additional stakes have recently been installed near 100 m a.s.l. in Botnabrún on the southern side of the fjord.

The locations of the stakes are shown on Maps 6, and 7. 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), Sigurður Kiernan *et al.* (1999) and Tómas Jóhannesson (2001, 2002). The report by Tómas Jóhannesson (2001) includes a discussion of snow depth measurements at meteorological stations in the neighbourhood of Seyðisfjörður and Neskaupstaður.

The maximum vertical snow depth measured on the stakes in the starting zones is typically in

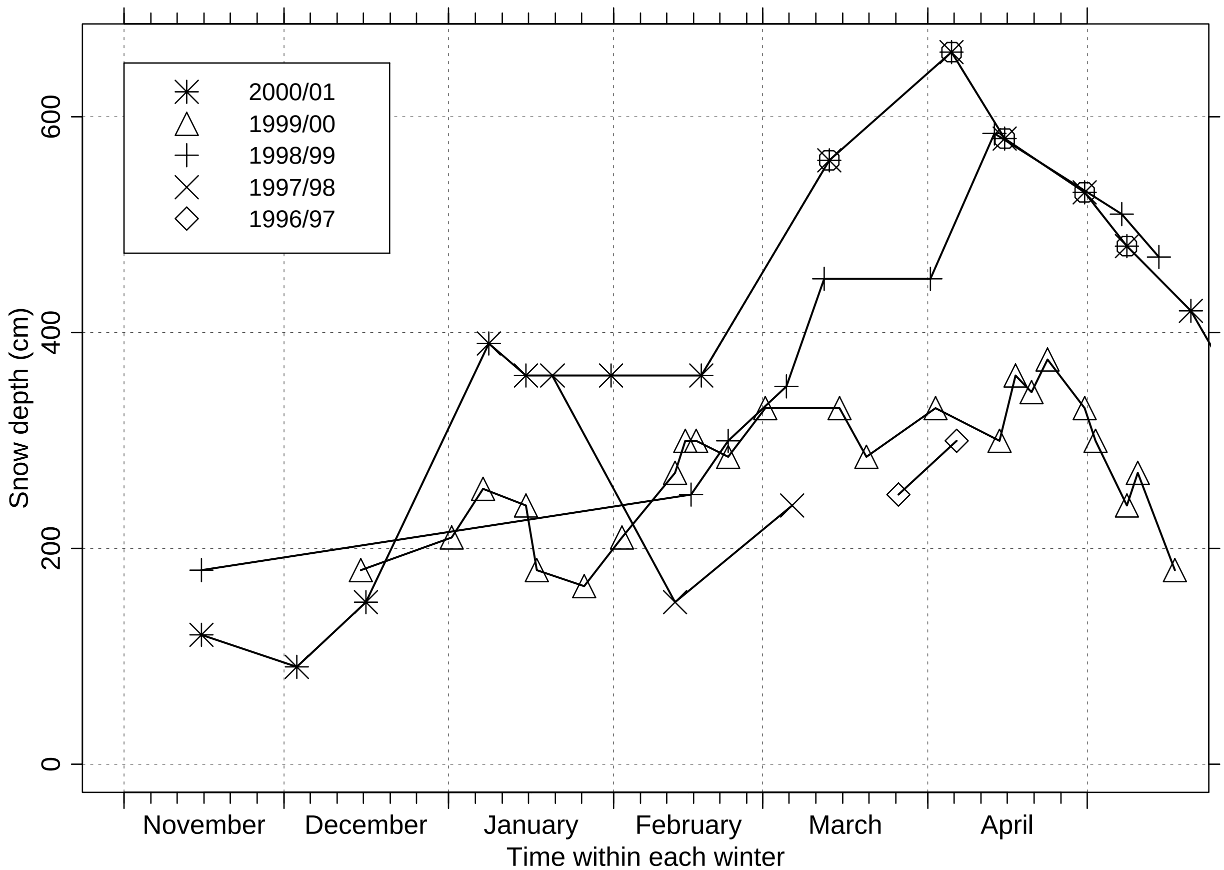

Figure 2. *Snow depth at the stake seka01 at 602 m a.s.l. in Kálfabotn in Bjólfur. Data points, where the snow depth at buried stakes has been inferred, based on the measured variation of the snow depth at other nearby stakes, are denoted with a circle.*

the range 2–3 m for the lower or more exposed parts of the slope up to more than 6 m on the stakes with the greatest snow depths in the bowl Kálfabotn in Bjólfur. The greatest snow depths were measured in the winters 1998/1999 and 2000/2001. Most of the stakes are located in a relatively unconfined terrain and greater snow depths may be expected to have occurred in the gullies that are located in several of the starting zones. No stakes are located in the main starting zones above the shelf above Brún in Bjólfur due to difficult conditions to maintain fixed stakes in this part of the mountain because of rockfall and avalanches. Photographs and scattered observations from a distance by snow observers during field trips to the shelf at Brún indicate that great snow depths are reached in this part of the mountain, perhaps similar to the measured snow depths in Kálfabotn. Figure 2 shows the measured snow depth at stake seka01 at 602 m a.s.l. in Kálfabotn for the winters since the start of the measurements in the 1996/1997.

Snow depth in Kálfabotn in Bjólfur has also been measured manually in late winter along lines near the stakes. These measurements are described in the reports referenced above. They show the distribution of snow depth at a specific point in time in more detail than the stake measurements and confirm that the snow depth distribution indicated by the measurements at the stakes is representative for the bowl as a whole.

Snow depth in Kálfabotn has once been measured geodetically from vertical aerial photographs that were taken on 12 May 1999. Contours were drawn showing the surface of the snow pack. They seem to be sufficiently accurate to allow the determination of the vertical snow depth. The maximum snow depth of the winter may have been about 1.0 m higher than the snow depth indicated by the aerial photogrammetry. According to these results, the vertical snow depth appears to have reached about 7.0 m in the upper, northeastern part of Kálfabotn, indicating a maximum vertical snow depth of about 8.0 m for the winter 1998/1999 at that location.

Measurements and return period analysis of snow depth at lowland stations in the neighbourhood of Seyðisfjörður (Kristján Jónasson and Trausti Jónsson, 1997; Tómas Jóhannesson, 2001) indicate that the snow depth tends to vary approximately synchronously at the stations. This is as expected since the stations are all located in a comparatively small area. The snow depths in 1966, 1989, 1995 and 2000 are relatively large when viewed over the 30–40 year period spanned by the data. This is not in agreement with snow depth measurements in the mountains above Seyðisfjörður described above, which have the largest snow depths in the winters 1998/1999 and in 2000/2001 as mentioned above. The snow depth data at the meteorological stations, nevertheless, 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 Seyðisfjörður may, therefore, be expected to correspond to a return period longer than say 10 years although the data from the mountains only extend over 5 years.

Available information on snow depth in Kálfabotn was summarised and interpreted by Stefan Margreth (SLF, 2001). He investigated conditions for supporting structures in Kálfabotn which is one of the starting areas in Iceland where supporting structures have been proposed as possible avalanche protection measures. Guidelines for the design of such structures for Icelandic conditions have been formulated based on a pilot project that was implemented in Siglufjörður in 1996 (Tómas Jóhannesson and Stefan Margreth, 1999). Margreth concluded that the return period of the observed snow depth on the stakes in Kálfabotn from 1998/1999 and 2000/2001 is longer than 10 years and that the 100 year snow depth could be greater than the observed snow depth from these years by a factor of about 1.7.

The snow depth measurements and other observations from the mountains clearly 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 unconfined or concave parts of the hill and the 100 year snow depth may be larger than this by a factor of 1.5–2. In gullies and depressions below Brún in Bjólfur and in Strandartindur and in the large bowl shaped area above Brún the snow depth can, however, become many times 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. Observations in Kálfabotn show that maximum vertical snow depth has reached 8 m in this bowl and it is likely that maximum local vertical snow depth in other bowls and gullies is also very great.

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, landslide hazard zoning should be done in combination with snow avalanche hazard zoning.

A debris flow chronicle for both the north and south sides of Seyðisfjörður 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). A more detailed study of the south side was carried out by Esther H. Jensen and Thomas Sönser (2002).

The debris flow hazard in the southern part of Seyðisfjörður is addressed in Section 4.5.

The debris flow hazard in the inhabited area in the northern part of Seyðisfjörður below Bjólfur is 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.

Figure 3. *Bjólfur and the names of main landmarks. (Photo: Thorsteinn Sæmundsson).*

3 Northern part, Bjólfur

The following discussion is partly based on investigations carried out in 1997 and 1998 (Kristján Jónasson and Thorsteinn Arnalds, 1997; NGI, 1997; WLV, 1997). The results of these investigations have been summarised by Thorsteinn Arnalds (2001).

3.1 Topographic description

The northern part of the investigated area is below the mountain Bjólfur which is more than 1080 m high. In the innermost part of the investigated area the avalanche hazard is caused by starting areas in the lower part of the mountain mainly located between 300–650 m a.s.l. In the middle of the area, at Bakkahverfi, Fjörður and Fjarðaralda, avalanches both starting in the lower part below 650 m a.s.l. and in the upper part above the plateau threaten the settlement. In the outermost part there is no shelf in the mountain but the height of the mountain ridge decreases gradually towards the east. Figure 3 shows most of the slope. It can be seen on Maps 1 and 6 and longitudinal sections (`seha21aa`, `seha19aa`, `sebj33aa`, `sebj36aa`, `sebj31aa`, `sebj31ca`, `sebj41aa`, `sebj44aa` and `sebj48aa`) are shown in Drawings 1–9.

Starting area

The potential starting areas in the lower part have been split into subareas. These are summarised in the following table. The areas are shown on Map 6 with the number of each subarea indicated.

No.	Upper border (m a.s.l.)	Lower border (m a.s.l.)	Average incli-nation	Average width	Surface area
6	415	300	38°	430 m	7.9 ha
7	480	390	39°	140 m	1.4 ha
8	625	400	35°	200 m	8.6 ha
9	660	580	31°	200 m	3.1 ha
10	535	395	36°	50 m	1.3 ha
11	580	400	35°	140 m	4.3 ha
12	590	420	39°	70 m	1.9 ha
13	640	425	38°	220 m	6.5 ha
14	640	490	37°	80 m	2.0 ha
15	640	435	37°	165 m	4.5 ha
16	660	500	40°	350 m	7.6 ha
17	425	225	38°	50 m	1.6 ha

The aspect of the areas is east to east-southeast. Due to the clarity of the hazard situation in the area east of starting area 16 it was not considered to be necessary to delineate starting areas there.

In the upper part of Bjólfur in Bjólfstindur the potential starting area was also split into subareas shown on Map 6, labelled 1–5. The areas are summarised in the following table.

No.	Upper border (m a.s.l.)	Lower border (m a.s.l.)	Average incli-nation	Average width	Surface area	Aspect
1	860	775	41°	120 m	1.6 ha	ESE
2	970	740	37°	330 m	10.4 ha	E
3	860	750	34°	110 m	2.1 ha	ESE
4	840	700	37°	300 m	7.0 ha	SE
5	835	700	41°	110 m	2.3 ha	E

Track

The track from starting areas 6–8 and 10 starts at between 300 and 400 m a.s.l. and terminates in the β-point at 70–90 m a.s.l. The inclination of the track is mostly 25–40° but a little below 200 m a.s.l. there is a small rockband.

The track below starting areas 11 and part of 9 starts at about 400 m a.s.l. The inclination down to 300 m a.s.l. is about 45° on average. Part of the track passes through the lower part of Jókugil between 220 and 300 m a.s.l. Below 200 m a.s.l. the inclination decreases gradually and is on average 18°. Between 40 and 70 m a.s.l. there is a bank with an inclination of about 30°. The track terminates in the β-point at about 30 m a.s.l.

The track for starting area 12 and a part of area 9 passes through the gully Jókugil, below Jókugil the track is comparable to the track for starting area 11.

The track below starting area 13 starts at about 440 m a.s.l. A small part of the track in the innermost part passes through Jókugil and coincides with the track of area 11. Between 440 and

320 m a.s.l. the average inclination is 36°. At around 300 m a.s.l. there is a rockband. Part of the track passes through the gully Fálkagil between 220 and 180 m a.s.l. The average inclination is 20° at 180–80 m a.s.l. and about 30° at 80–60 m a.s.l. Below that, the inclination decreases gradually down to the β-point at about 35 m a.s.l.

Below starting areas 14–16 the track starts at about 450–500 m a.s.l. The inclination is 30–45° down to a rockband at about 200 m a.s.l. The inclination is 25–35° down to another rockband at about 100 m a.s.l. The inclination decreases below the rockband and the β-point is at the shore in the outermost part and at about 30 m a.s.l. in the innermost part below starting area 14.

The track for starting area 1 starts at about 780 m a.s.l. Between there and about 640 m a.s.l. the inclination varies between 5–30° and the average is about 20°. Below 640 m a.s.l. this track passes through starting areas 9 and 12 and follows the tracks of those.

The tracks of starting areas 2 and 3 start at about 740 m a.s.l. The inclination is 20–30° down to about 680 m a.s.l. The inclination then decreases gradually down to about 660 m a.s.l. where there is an approximately 200 m wide shelf with an about 10 m high hill near the edge. Across the hill the inclination rises again and at about 640 m a.s.l. the track merges with starting zones 14 and 15.

The inner part of the track below starting area 4 is similar to the track below starting area 3. In the outer part, the track starts at about 700 m a.s.l. The average inclination is about 30° down to 660 m a.s.l. The track then passes through a shallow depression until it merges with starting area 16 at about 640 m a.s.l.

The inclination of the track below starting area 5 is about 20° between 700 and 650 m a.s.l. Between 650 and 600 m a.s.l. the average inclination is about 45°. Below 600 m a.s.l. the inclination decreases gradually and is about 12° at 20–0 m a.s.l. with the β-point located at the shoreline.

Runout area

The runout area in the innermost part of the investigated area below starting areas 6–11 starts at 70–90 m a.s.l. The upper part of the runout area has an inclination of about 5–8°. The lower part of the runout area is almost flat and terminates near the road at about 10 m a.s.l. There are a few horse sheds located in the area but no domestic houses.

The runout area below starting area 13 starts at about 35 m a.s.l. The inclination decreases gradually and below 20 m a.s.l. the area is nearly flat. The housing area Bakkahverfi, where houses were mostly built in 1975–1985, is located in the runout area.

The runout area below starting area 14 starts at about 30 m a.s.l. The farm Fjörður is located at about 10 m a.s.l., and it is claimed that some houses may have been located in the area since about the year 1000. Along the seashore there are several houses mostly built before 1900.

Below Kálfabotn, *i.e.* starting area no. 15, the runout area starts at about 15 m a.s.l. There are some commercial buildings located on the flat land near the sea. A large part of that area is a landfill.

To the east of Kálfabotn there is hardly any runout area below the potential starting zones.

3.2 Climatic conditions

During northerly winds snow will drift along the lower starting areas and mostly accumulate in the deeper depressions such as Kálfabotn. On ridges and relatively even areas snow accumulation is possible in light winds.

The large bowl shaped area in Bjólfstindur above the shelf at Brún can be expected to accumulate snow during northerly and northeasterly winds which are the most frequent wind directions when it is snowing.

The southern slope of the valley Vestdalur will act as a catchment area for snowdrift accumulating snow in the area of Öxl.

3.3 Chronicle

There are no avalanches recorded in the innermost part of the area, *i.e.* to the west of the settlement. It is thought that a part of a large avalanche in 1885 entered the area where Bakkahverfi is currently located. The farm Fjörður has probably not been hit by an avalanche for the past 1000 years. To the east of Fjörður a swarm of avalanches are recorded. All recorded avalanches in Bjólfur are listed in the following table. Most of the avalanches are shown on Map 2.

Number Time *Runout index*	**Description**
4004 13.1.1882 *> 14.4*	A slushflow fell from Bjólfur and hit Hótel Ísland. Two people were caught by the slushflow but escaped without injury.
4005 13.1.1882 *> 14.1*	A slushflow was released in Bjólfur. It destroyed the house Baldurshagi. A total of five people were caught by the flow and two children died.
4006 13/14.1.1882	A swarm of slush avalanches fell in the mountain Bjólfur. The flows caused considerable damage. See also no. 4004 and 4005.
4007 2.2.1885 *> 11.6*	An avalanche was released below Raðarflug. It damaged some huts by Fornistekkur and took their roofs down to the sea.
4008 8.2.1885 *> 11.0*	An avalanche fell in Nautabás. It broke some sheds and carried debris out to the sea.

Number Time *Runout index*	**Description**
4009 18.02.1885 *> 14.4*	A large avalanche fell from Bjólfur reaching from Jókugil to further out than Hlaupgjá. Many houses were destroyed and 24 people were killed. Some sources say that in the town the extent of the avalanche was from Fjörður and out towards Liverpool. The starting zone is thought to have been in Kálfabotn (some say in Hlaupgjá below Kálfabotn or that the avalanche was released from the upper starting zone near the top of Bjólfur). The avalanche reached the sea. Some references state that the avalanche split on a small hill around Fjörður and the inner tongue reached Fjarðará. Separate sources say that part of the avalanche overran the area below Fálkagil where houses have since been built.
4010 18.2.1885	An avalanche fell from Bjólfur outside of the village into the sea. Fish drying racks were damaged.
4013 27–31.10.1892	Several avalanches fell in Seyðisfjörður. The location of the avalanches is unknown but the most propable release location is in Bjólfur.
4014 31.1.1894 *> 14.4*	A dry avalanche with similar runout zone as the one in 1885 fell, but it started lower down and had a (much) narrower tongue. It destroyed a storagehut.
4111 around 1900 *∼15?*	There is somewhat vague information about an avalanche that is said to have fallen southwest of Fjörður in the area below Fálkagil and Jókugil and these records state that it reached Fjarðará. The date of this avalanche is very unclear.
4019 21.2.1904 *11.6*	Several slush avalanches fell in Seyðisfjörður.
4020 21.2.1904 *11.2*	A slushflow fell from Bjólfur in the vicinity of Bræðraborg.
4021 21.2.1904 *10.7*	A slush avalanche fell from the mountain Bjólfur close to the house Hjarðarholt.
4022 21.2.1904 *12.8*	A slush avalanche fell from the gully Hlaupgjá in Bjólfur.
4025 4.12.1909	An avalanche fell between Aldan and Vestdalseyri. The most probable location is around Nautabás or Fornistekkur. A telephone post was broken.
4026 3.3.1912 *> 12.3*	A wet avalanche fell a little bit further out than the avalanche of 1885. It reached the sea and destroyed a warehouse, merchandise, boats and a sheepshed, killing 12 sheep.

Number Time *Runout index*	**Description**
4027 3.3.1912 *10.9*	An avalanche stopped below Neðstuklettar a little to the east of Liverpool.
4030 3.2.1914 *11.0*	A dry avalanche damaged the farm Fornistekkur and its stable.
4035 1928 > *11.0*	An avalanche at Nautabás damaged 5–7 telephone poles. The fishmeal factory Hafsíld was later located in the area.
4039 1935–1937	Two men were caught by an avalanche in the area between Skagi and Liverpool. Both men escaped.
4040 1938–1940	Sheep and a dog were caught by an avalanche above Jókugil.
4042 19.3.1946 > *11.8*	An avalanche fell just northeast of Bræðraborg. It was about 200 m wide where it reached the sea. It overran a sheepshed but did not damage it (it was buried in snow before the avalanche fell).
4043 1951 *11.7*	Several avalanches fell from the mountain Bjólfur, some of them around Bræðraborg and Hjarðarholt.
4046 27.3.1967 > *11.0*	An avalanche fell above Nautabás from Djúpugil all the way down to the sea. It started below the rock belts at 350–400 m a.s.l. The avalanche hit a large warehouse belonging to the factory Vestdalsmjöl. The warehouse was seriously damaged and parts of it were transported into the sea. The avalanche also damaged a telephone line.
4053 8–12.2.1974	Many dry avalanches fell from Bjólfur. The references state that "avalanches fell from every gully".
4071 26.12.1985 *11.0*	A dry avalanche fell from Bjólfur damaging an oil pipe leading to the fishmeal factory of Ísbjörninn (formerly Hafsíld/Vestdalsmjöl). About 300–400 m^3 of oil were spilled into the sea. The avalanche was about 45 m wide and a narrow tounge reached the sea.
4072 22.1.1986 *8.6*	A dry avalanche fell from Fálkagil and stopped at about 120 m a.s.l. about 100 m from the uppermost houses.
4074 1.2.1988 *9.3*	A dry avalanche started below Hlaupgjá. The avalanche stopped about 30 m a.s.l. and was about 25 m wide.
4076 4.2.1988 *10.6*	An 1100 m long avalanche fell in the area of Fornistekkur. Its tongue forked into two smaller tongues. One stopped on the buildings of the fishmeal factory Vestdalsmjöl, and the other fell down Fornastekksgil, over the road, and just beyond the oil tanks.

Number Time *Runout index*	**Description**
4077 6.2.1988 *> 11.0*	An avalanche was released below Raðarflug at about 450–500 m a.s.l. The avalanche was about 1100 m long and 100 m wide. Part of it stopped on the fishmeal storehouse of Vestdalsmjöl and some of it went into the sea east of the factory.
4080 mars 1988	An avalanche from from the gully Jókugil in the mountain Bjólfur.
4081 1990 *11.8*	A slushflow fell in Bjólfur to the west of Sunnuver. A part of the slush passed the road above Sunnuver and stopped at about 20 m a.s.l. The width of the tongue was about 20 m.
4101 24.1.1993 *10.6*	A dry avalanche fell in Bjólfur and hit the fishmeal factory of Vestdalsmjöl in Nautabás. The fishmeal storage house was damaged. The avalanche stopped at 7 m a.s.l. The deposit was 125 m wide with a maximum thickness of 4.5 m.
4087 20.2.1995 *9.3*	An avalanche fell from Bjólfur above Fornistekkur. It started at about 150 m a.s.l. in the next gully to the west of Fornastekksgil. It stopped at about 20 m a.s.l. and was about 20 m wide.
4088 20.2.1995 *9.5*	A small avalanche fell in Bjólfur above Fornistekkur. It started about 100 m a.s.l., stopped at about 50 m a.s.l. and was about 70 m wide.
4090 2.3.1995 *11.8*	An avalanche started at about 575 m a.s.l. and fell down to the outermost part of Aldan. The avalanche stopped at about 10 m a.s.l. a little to the west of the youth hostel Hafaldan. The deposit was 55 m wide and about 1m thick.
4091 17.3.1995 *> 10.5*	An avalanche fell at Fornistekkur. It reached into the sea and was 150 m wide on the road but wider further up. The starting zone was 500 m a.s.l. with an average fracture height of 0.7 m.
4092 19.3.1995 *> 11.0*	A dry avalanche hit the fishmeal storehouse of Vestdalsmjöl. The house was completely destroyed and the neighbouring factory was also damaged. The avalanche started at 450 m a.s.l. with an average fracture height of 2.1 m. The deposit was about 250 m wide and several meters thick.
4093 1996 *8.5*	An avalanche fell from Bjólfur above Liverpool and stopped at 58 m a.s.l., about 100 m above the road.
4094 1996 *8.6*	An avalanche fell from Bjólfur above Liverpool and stopped at about 50 m a.s.l. which is about 100 m above the road.

Number Time *Runout index*	Description
4095 18.1.1997 *10.1*	A dry avalanche started at 660 m a.s.l. in Bjólfur above Fornistekkur. The fracture was 200 m wide with an average height of 0.7 m. Most of the avalanche stopped at about 100 m a.s.l. but about a 80 m wide tongue passed the road and stopped at about 20 m a.s.l. The deposit was 80 m wide and 0.8 m thick.
4096 19.1.1997 *8.2*	A dry avalanche started at about 650 m a.s.l. in Bjólfur above Liverpool. The fracture was 35 m wide and 0.3 m high on average. The avalanche stopped at about 120 m a.s.l. above the youth hostel.
4102 7.1.1999	A dry avalanche started in Bjólfstindur at about 900 m a.s.l. The fracture was about 100 m wide and 3 m high on average. It stopped on the shelf at 650 m a.s.l.
4097 19.4.1999 *12.2*	A dry avalanche started at about 900 m a.s.l. in Bjólfstindur and stopped on the shelf at about 660 m a.s.l.
4106 25.4.1999 *7.1*	A dry avalanche started at 860 m a.s.l. in Bjólfstindur. The fracture was 90 m wide and its average height about 0.3 m. The avalanche stopped at about 740 m a.s.l. The deposit was 2 m thick on average and 130 m wide.
4107 11.5.1999	Sevaral small wet avalanches fell from Bjólfstindur.
4114 7.1.2000 *12.7*	A dry avalanche started at about 900 m a.s.l. in Bjólfstindur. The fracture was 100 m wide and 0.3 m high on average. The avalanche stopped on the shelf at 650 m a.s.l. The deposit was 100 m wide and 2.5 m thick on average.
4108 21.2.2000 *8.3*	A dry avalanche started at 900 m a.s.l. in Bjólfstindur. It stopped at the foot of the hill at 760 m a.s.l. The deposit was on average 0.3 m thick and 30 m wide.
4109 27.2.2000 *9.0*	A wet avalanche started in Bjólfur above the youth hostel. It stopped at 30 m a.s.l. about 20 m above the road. The deposit was 18 m wide and 1.75 m thick on average. The volume was estimated at 1200 m^3.
4112 27.2.2000 *8.4*	A wet avalanche fell in Bjólfur above Fornistekkur and stopped at about 170 m a.s.l.
4113 27.2.2000 *8.6*	A wet avalanche fell in Bjólfur to the west of Fornistekkur and stopped at 135 m a.s.l.
4115 Feb 2000 *8.1*	An avalanche fell from the summit of Bjólfur and stopped on the shelf at about 660 m a.s.l. The deposit was 20 m wide on average.

Number Time *Runout index*	**Description**
4116 2.1.2001 *13.8*	An avalanche fell from the summit of Bjólfur and stopped on the shelf at 660 m a.s.l. The deposit was 30 m wide on average.
4130 3.1.2001	A dry avalanche started in Bjólfstindur at about 900 m a.s.l. and stopped at the foot of the slope above the shelf.
4117 6.1.2001 *14.8*	An avalanche started at 900 m a.s.l. in the summit of Bjólfur. The fracture was 90 m wide and on average 2 m high. The avalanche stopped on the shelf at 660 m a.s.l. on top of the ridge above Kálfabotn. The deposit was 110 m wide with a maximum thickness of 3 m. The volume was estimated at 1000 m^3.
4120 8.1.2001 *8.7*	A small avalanche fell from Jókugil and stopped at 205 m a.s.l. just below the mouth of the gully.
4124 4.3.2001 *8.2*	An avalanche started at 550 m a.s.l. above Fálkagil. The avalanche stopped at about 120 m a.s.l. and the tongue was about 25m wide.
4129 Apr 2001 *10.9*	A dry avalanche started at 900 m a.s.l. in Bjólfstindur. The starting area was 50 m wide. The avalanche stopped on the shelf at 670 m a.s.l. Another avalanche probably fell to the west of this one.

3.4 Assessment

Potential avalanches starting in the lower starting areas are mostly expected to be in the range 10–50 thousand m^3. The potential of starting area 15 in Kálfabotn is considered to be unique compared to the other areas, allowing a release of avalanches with volume on the order of 100 thousand m^3.

The upper starting areas are considered to be potential starting zones for large avalanches with volumes in the range 50–300 thousand m^3. Due to the topography avalanches will not have reached terminal velocity before they reach the plateau at Brún. Only large avalanches will pass the plateau and a large proportion of their mass will be deposited on the plateau. When such avalanches pass the lower starting areas a large amount of snow could be entrained, partly compensating for the deposition of snow on the plateau.

The upper starting areas and Kálfabotn are considered to be the primary source of avalanche risk for the settlement. Avalanches that have been recorded in the past three years seem to confirm that the frequency of avalanches from the upper starting areas is much higher than for the lower ones. This makes it probable that the avalanche of 1885 started in the summit Bjólfstindur although this is by no means certain.

In the outer part of Bjólfur avalanches of up to 100 thousand m^3 are to be expected.

The gullies Jókugil and Fálkagil will offer some protection for the houses below. The uppermost of these houses are, however, located quite close to the slope.

The farm Fjörður is close enough to the slope for medium to large avalanches to reach the houses. It is thus a little surprising that the farm has been located there for such a long time (about 1000 years). The starting area directly above Fjörður is unconfined with depressions on both sides and there is a ridge in the lower mountainside above the farm that tends to deflect smaller avalanches away from the area. The area where the farm is located is, nevertheless, considered to be far from “safe”.

To the east of Fjörður the avalanche chronicle alone gives a clear indication of a very high hazard.

3.5 Model estimates

Map 6 shows the results of model calculations and the profiles used for the calculations. The profiles (`seha21aa`, `seha19aa`, `sebj33aa`, `sebj36aa`, `sebj31aa`, `sebj31ca`, `sebj41aa`, `sebj44aa` and `sebj48aa`) are shown in Drawings 1–9. The runout was calculated using runout indices and an α/β-model. For explanation see Appendix A.

In the area to the west of Fjörður avalanches with runout index of about 16 will reach the road.

The uppermost house in Bakkahverfi is located at $r = 12$ and an avalanche of less than $\alpha + \sigma$ will reach the house. Direct frequency estimation cannot be done since no avalanches are recorded.

Avalanches released in the upper starting area need to have a runout index $r > 14$ in order to pass the plateau at Brún. Estimating the frequency of avalanches from the upper area on the basis of data from the past three years would give high estimates. Two avalanches with runout index a little more than 14 have been recorded without passing the plateau. The avalanche in 1885 is the only recorded event where it is possible that an avalanche has been released from the summit and reached the settlement. It seems plausible to assume that the frequency of avalanches from the summit, mainly above Kálfabotn is similar to the frequency of avalanche in Neskaupstaður, *i.e.* $F_{13} = 0.05$.

Avalanches from the lower starting areas with $r = 13$ and runout angle $\alpha - \sigma$ will reach Fjörður. If buildings have been located where the farm Fjörður is for about 1000 years, and the area has never been hit by an avalanche, the return period of avalanches there should be at least on the order of few hundred years.

To the east of Kálfabotn small to medium sized avalanches, with runout indices in the range 11–14 will reach the shore.

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

The hazard zones in the innermost part are delineated so that the boundary of the category A hazard zone is located at about $r = 14$. The uncertainty of the estimate is considered to be medium to high (1–2).

In the area west of Bakkahverfi the boundary of the category A hazard zone is set at about $r = 16$. This is a little further away from the slope than at Bakkahverfi. The hazard zones are narrower in this area than at Bakkahverfi. This partly reflects the outcome of the two-dimensional calculations. The uncertainty of the estimate is considered to be medium (1).

At Bakkahverfi and Fjörður the boundary of the category A hazard zone is set at about 15.7–16.4. There is indication from the two-dimensional simulations that runout of avalanches in the area is shorter than to the east and west. This effect is in part exaggerated by the "unrealistical" simultaneaous release of avalanches from starting zones 9 and 11 in the simulations. There is information that an avalanche may have reached the river Fjarðará in the area immediately to the east of Bakkahverfi. This is in contradiction to the results of the SAMOS simulations which indicate that avalanches will have a relatively short runout in the area. The uncertainty of the estimate is considered to be medium (1).

The SAMOS simulations indicate that the runout of avalanches released from Bjólfstindur will be shorter than in other areas in Iceland where similar simulations have been carried out. This is probably caused by deposition of snow on the shelf at Brún, lateral spreading and the relatively high β-angle. The reduction in runout is probably overestimated since entrainment below the shelf is not taken into account. As discussed above the frequency of avalanches in the area is estimated to be $F_{13} = 0.05$ per year and risk calculations were performed using that frequency. The delimitation of the hazard zones, however, takes account of the results of the two-dimensional simulations and the limits of the hazard zones are set a little closer to the slope than corresponding to the results of the risk calculations. The uncertainty of the estimate is considered to be low to medium ($\frac{1}{2}$–1).

The risk in all the area east of Fornistekkur is considered to be more then $3 \cdot 10^{-4}$ per year 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 low 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 to medium ($\frac{1}{2}$–1).

The hazard zoning proposal is shown on Map 9.

Figure 4. *Strandartindur and the names of main landmarks. (Photo: Thorsteinn Sæmundsson).*

4 Southern part, Strandartindur/Botnabrún/Grákambur

The discussion on the southern part of Seyðisfjörður is split into six main subsections. The first four describe potential starting areas for snow avalanches. The fifth discusses debris flow hazard and finally a conclusion is given with the hazard zoning proposal.

4.1 Ytri-Strandartindur

4.1.1 Topographic description

The northern (northwestern) side of Ytri-Strandartindur has some potential starting areas. These areas mostly impose a hazard for the area east of Stöðvarlækur. Figure 4 shows the area. It can also be seen on Maps 1 and 7 and longitudinal sections (`sest09aa`, `sest08bb`, `sest16aa`, `sest05ca` and `sest05bb`) are shown in Drawings 10–14.

Starting area

The potential starting area is between 720 and down to about 460 m a.s.l. The average inclination is about 34–38°. The area is in total about 500 m wide. The area is terraced by cliffs and divided by ridges. It is mainly covered with weathered debris. The aspect is northwest to west. There are several depressions and bowls that are more likely starting areas than others and the total area of those is 15.5 ha. An avalanche is not expected to be released simultaneously in the whole of that area. These smaller areas can be seen on Map 7 labelled 5–8. The following table lists key characteristics of these areas.

No.	**Upper border (m a.s.l.)**	**Lower border (m a.s.l.)**	**Average incli-nation**	**Average width**	**Surface area**	**Aspect**	**Shape**
5	720	550	35°	400 m	11 ha	W	Large shallow bowl with several smaller gullies and depressions.
6	655	580	34°	100 m	1.4 ha	NW	Shallow depression in a scree.
7	565	480	36°	100 m	1.4 ha	NW	Shallow depression in a scree.
8	580	480	34°	100 m	1.8 ha	NW	Shallow depression in a scree.

There are more potential starting areas further to the east. These have runout areas in the easternmost part of the investigated areas. The hazard situation in that area was considered to be quite clear so that detailed investigation of the starting areas was not carried out further to the east.

Track and runout area

The track of avalanches starting in area 5 is the whole mountainside above the plateau Þófi. The average inclination is about 33° down to the plateau at about 160 m a.s.l. and then 14° down to 80 m a.s.l. From there and down to the sea it inclines about 32°. The track is slightly confined down to the plateau and after that it is quite convex. In the northern part of the plateau there is a gully and in the southern part a depression with a ridge between them.

The track of avalanches starting in areas 6–8 leads down the mountainside to the gullies of Skuldarlækur, Hörmungarlækur and Hæðarlækur and partly to the plateau Þófi. The average inclination is about 25° down to about 120 m a.s.l., below that there is a small step with a rockband in the area to the west (southwest) of Þófi. Below the step the average inclination is about 20° down to the sea. The upper part is partially confined, mostly by the gully of Skuldarlækur, and below that the track is slightly convex.

There is no runout area.

4.1.2 Climatic conditions

During northeasterly winds snow can drift over the mountain ridge to the northeast of the area and accumulate in the starting area. This was confirmed by observations during a field investigation in mid June 2000. A large amount of snow was still in gullies and depressions on the lee side to northeasterly winds.

4.1.3 Chronicle

A total of twelve avalanches and slushflows are recorded in the area. The runout area of all these have been either to the east or west of Þófi. The avalanches are shown on Map 3 and listed in the following table:

Number Time *Runout index*	**Description**
4018 Apr 1899 *> 11.5*	A wet avalanche damaged Imsland's fishmeal factory and transported parts of it into the sea. The damaged building was probably located below Imslandsgil where other buildings belonging to the factory were located.
4024 21.2.1904 *> 12.2*	A slush avalanche fell in Hörmungarlækur or Skuldarlækur or both. Damage was caused to four boats.
4098 21.2.1904 *13.6*	A slushflow fell in Hæðarlækur and damaged two houses.
4033 24.4.1919	An avalanche fell in Strandartindur at an unknown location to the east of Búðareyri. It hit a house that had been evacuated.
4038 1930–1943 *12.9*	An avalanche fell in Strandartindur around Þófalækur. It ran through the ground floor of the house Strandarvegur 26–28.
4055 15.2.1974 *12.9*	A dry avalanche fell from the gully Þófagil in the mountain Strandartindur.
4056 15.2.1974 *10.8*	An avalanche fell from Strandartindur close to the house Neptún.
4062 26.4.1977 *12.9*	Wet avalanches fell from Strandargil, Imslandsgil, and more gullies to the east. Some of the avalanches were large.
4063 26.4.1977 *10.8*	A wet avalanche fell from mountain Strandartindur close to the house Neptún. It probable fell from the next gully to the east of Imslandsgil.
4104 28.3.1978 *12.2*	A slushflow fell in Skuldarlækur and/or Hörmungarlækur. It stopped at about 40 m a.s.l.
4078 14.2.1988 *13.9*	A large and thick wet avalanche fell from Hörmungarlækur and Skuldarlækur closing the road between Fiskvinnslan (the freezing plant) and SR (the fishmeal factory).

Number Time *Runout index*	**Description**
4086 17.3.1991 *10.6*	A 50 m wide and 600 m long wet avalanche fell from Strandartindur stopping on the road next to Neptún.

4.1.4 Assessment

Avalanches of 50–100 thousand m^3 are considered possible. Due to the aspect and other topographic conditions the probability of such events is not to be underestimated. Although avalanches may be spread or partially deflected on the plateau Þófi it does not offer sufficient protection for any of the area below and this is confirmed by the results of two-dimensional simulations. The shape of the track furthermore increases the width of the potential hazard zone.

4.1.5 Model estimates

Map 7 shows the results of model calculations and the profiles used for the calculations. The profiles `sest09aa`, `sest08bb`, `sest16aa`, `sest05ca` and `sest05bb` and the results of the calculations are shown in Drawings 10–14. The runout was calculated using runout indices and an α/β-model. For explanation see Appendix A.

In the areas on each side of Þófi avalanches with runout indices 11–12 will reach the shore. The plateau Þófi will stop medium sized avalanches with $r \leq 13$.

The β-point is located almost by the shore and avalanches with runout angle in the range $\alpha + 2\sigma$ to $\alpha + \sigma$ will reach the sea.

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). These results indicate that larger avalanches will not be deflected and stopped by the Þófi plateau and would reach the shore with relatively high velocities.

4.2 Below Neðri-Botnar

4.2.1 Topographic description

Below the shelf Neðri-Botnar there are a few small areas which are considered as potential starting areas. The area can be seen on Maps 1 and 7 and longitudinal sections (`sebh02aa`, `sebh10aa` and `sebh11aa`) are shown in Drawings 16–18.

Starting area

From the edge of the plateau Neðri-Botnar at about 120–140 m a.s.l. and down to the rockband, which is located between 60 and 100 m a.s.l, there is a potential starting area. The total width of the investigated potential starting area is 1.3 km. The inclination is mostly 30–32° in the upper part and decreases gradually to 25–27° in the lower part. There are several small bowls and depressions which are more favourable for snow accumulation than other parts of the area. The bowls are mostly vegetated as opposed to the ridges between which are bare. This is caused by wind blowing along the slope. The widths of the bowls are between 30 and 120 m and their area between 0.2 and 1.1 ha. The slope is facing to the northwest. The surface is debris, partly covered with vegetation, and the roughness according to the Swiss guidelines is 2–3. The areas are shown on Map 7 labelled 13–23. The following table summarises the characteristics of the areas.

No.	**Upper border (m a.s.l.)**	**Lower border (m a.s.l.)**	**Average incli-nation**	**Average width**	**Surface area**
13	160	115	30°	120 m	1.1 ha
14	155	85	32°	70 m	1.0 ha
15	135	95	28°	85 m	0.7 ha
16	145	100	30°	35 m	0.3 ha
17	135	100	30°	30 m	0.2 ha
18	135	100	27°	45 m	0.4 ha
19	135	90	31°	40 m	0.4 ha
20	135	100	29°	35 m	0.2 ha
21	125	80	28°	40 m	0.4 ha
22	125	80	29°	100 m	0.9 ha
23	105	70	29°	60 m	0.7 ha

Track and runout area

The track starts with a rockband. Below there is a scree covered with vegetation that mostly has an inclination of 15–25°. Below the scree the inclination decreases gradually. The uppermost houses are located on the boundary between the track and the runout area. The track is mostly unconfined although below several small depressions it is slightly confined. There are no indications that avalanches have fallen in the area. The outer part of the area was populated in the nineteenth century and the beginning of last century. The houses in the innermost area around Botnahlíð were built mostly in the 1970's.

4.2.2 Climatic conditions

Snow accumulation is most likely in the depressions and gullies when wind is blowing along the mountainside from north to south or vice versa. Snow accumulation from above, *i.e.* east is unlikely due to the topography.

4.2.3 Chronicle

There are no avalanches recorded in the area.

4.2.4 Assessment

Due to the low elevation, the small size of the starting areas and rather unfavourable conditions for snow accumulation small avalanches of 1–5 thousand m^3 are possible but unlikely. Starting zones 13 and 14 are considered to be the most favourable ones.

4.2.5 Model estimates

Map 7 shows the results of model calculations and the profiles used for the calculations. The profiles `sebh02aa`, `sebh10aa` and `sebh11aa` and the results of the calculations are shown in Drawings 16–18. The runout was calculated using runout indices and an α/β-model. For explanation see Appendix A.

Most of the uppermost houses in the area are located closer to the slope than runout index 11. Small to medium sized avalanches do thus threaten the settlement.

The β-point is located close to the uppermost houses in most of the area. An avalanche with runout angle α will reach about 50–150 m into the settlement.

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).

4.3 Other areas in Strandartindur

The following discussion focuses on starting areas in the slope between Ytri-Strandartindur and Innri-Strandartindur and above Neðri-Botnar.

4.3.1 Topographic description

Above the plateau Neðri-Botnar there is a slope, which in the outer part is covered with deposits of sediment, marked by three gullies, and with an inclination of about 25–30°. Parts of this slope are considered to be potential starting areas.

Above the inner part of Neðri-Botnar there are about 100 m high cliffs. Above this slope there are multiple shelfs called Efri-Botnar. The eastern shelves are also called Ytri-Dagmálabotn and the western Fremri-Dagmálabotn. The areas between the summits Ytri-Strandartindur, Miðtindur and Innri-Strandartindur are bowl shaped. Near the top there are cliffs but below the cliffs there are about 100–200 m high areas with gentler inclination but still higher than 30°. These areas are potential starting areas.

Figure 4 shows the area. It can also be seen on Maps 1 and 7 and a longitudinal section (`sest11aa`) is shown in Drawing 15.

Starting area

Between Neðri-Botnar and Efri-Botnar most of the slope inclines less than 27° or consists of cliffs. Area no. 12 on Map 7 is the area of main concern with regard to the release of dry avalanches. The three gullies where areas no. 9–11 are delineated are mainly considered to be possible starting areas for wet avalanches and slushflows. The areas and some characteristic values are listed in the following table.

No.	Upper border (m a.s.l.)	Lower border (m a.s.l.)	Average incli-nation	Average width	Surface area
9	335	205	26°	90 m	2.8 ha
10	330	235	30°	50 m	1.1 ha
11	335	240	33°	60 m	1.2 ha
12	400	325	32°	130 m	2.2 ha

A small proportion of the bowls above Efri-Botnar have inclination in the range 28–50°. The areas are mostly in scree, below the cliffs, although some gullies and depressions in the cliffs above can be considered to be potential starting areas. The areas are quite large, but a simultaneous release of avalanches from the whole areas is unlikely. Two possible starting areas where delineated in each bowl, labelled 1–4 on Map 7. An avalanche with a fracture covering the whole of each of these 4 areas is also considered to be unlikely. The following table lists the areas and some of their properties.

No.	Upper border (m a.s.l.)	Lower border (m a.s.l.)	Average incli-nation	Average width	Surface area
1	900	675	35°	400 m	13.3 ha
2	850	690	37°	450 m	10.0 ha
3	815	670	34°	250 m	5.7 ha
4	800	690	35°	400 m	13.3 ha

Track and runout area

The track of an avalanche from the lower starting area no. 12 starts at about 325 m a.s.l. The average inclination is about 27° down the plateau Neðri-Botnar. From a β-point at about 110 m a.s.l. the shelf is about 150 m wide with an average inclination of about 6°. Below the shelf the slope increases and is about 20° on average down to a small rockband at about 95 m a.s.l. Below the rockband the inclination decreases gradually down to a second β-point at about 7 m a.s.l. close to the uppermost houses. The runout area is 150 m wide down to the sea with an average inclination of about 3°. The houses in the runout area are mostly built in the first part of the last century.

The track of avalanches released in the bowl above Ytri-Dagmálabotn first passes these plateaus where the inclination is 7.5° on average for about 120 m at about 550 m a.s.l. and also 7.5° on average for about 150 m at about 460 m a.s.l. Below 400 m a.s.l. the track merges with starting area 12 and later with the track below that area, which is described above.

4.3.2 Climatic conditions

The aspect of the uppermost starting areas is from southwest to northwest. Thus, the areas may be expected to accumulate less snow than southwest to southeast facing starting zones in northerly to northeasterly winds. These are the main wind directions associated with avalanche cycles in Seyðisfjörður. Snow accumulation in easterly or even southeasterly winds can, however, be very high, but snowfall in these wind directions is not common in eastern Iceland.

4.3.3 Chronicle

In the last two years a few avalanches have been recorded from the starting areas in Efri-Botnar. Avalanches recorded during the winter 2001/2002 are not included in the list. The avalanches are shown on Map 3 and listed in the following table:

Number Time *Runout index*	**Description**
4119 3.1.2001 *12.9*	Two avalanches were released from Strandartindur above Efri-Botnar. The larger one stopped at 480 m a.s.l. and was 150 m wide on average.
4122 1.3.2001	A few small avalanches started at about 800 m a.s.l. in Ytri-Dagmálabotn and stopped halfway down the slope at about 700 m a.s.l.
4123 1.3.2001	Three small avalanche fell in Fremri-Dagmálabotn. They started at about 800 m a.s.l. and stopped at the foot of the slope at about 700 m a.s.l.

4.3.4 Assessment

The potential volume of avalanches from the starting zones above Efri-Botnar is considered to be on the order of 50 thousand m^3. Avalanches released simultaneously from a large part of each area could have larger volumes. Such avalanches are considered unlikely given the potential snow accumulation and the topography of the zones. An avalanche released in the area will be spread by the topography of the track and will have to pass plateaus which are quite wide, especially in the inner bowl, Fremri-Dagmálabotn. The probability of an avalanche released from above Ytri-Dagmálabotn to pass Neðri-Botnar is estimated to be low and practically zero for an avalanche that is released above Fremri-Dagmálabotn.

The potential size of an avalanche from starting area 12 below Efri-Botnar is estimated on the order of 10 thousand m^3. Such an avalanche is not expected to pass the plateau Neðri-Botnar.

Starting areas 9–11 are not considered to be likely starting areas of dry avalanches. Areas 9 and 10 are furthermore in the track of avalanches released in areas 6 and 8 in Ytri-Strandartindur. Those areas are considered to be much more hazardous and are dominating for the risk in the area below.

4.3.5 Model estimates

Map 7 shows the results of model calculations and the profiles used for the calculations. The profile `sest11aa` and the results of the calculations is shown in Drawing 15. The runout was calculated using runout indices and an α/β-model. For explanation see Appendix A.

An avalanche from starting area 12 will have to have a runout $r > 13$ to pass the plateau at Neðri-Botnar. This corresponds to a runout angle of about 21.5° which is about $\alpha - 0.5 \cdot \sigma$. An avalanche with $r = 14$ will pass the plateau and almost reach the sea.

An avalanche from the bowl above Ytri-Dagmálabotn will have to have a runout of about $r = 15$ to reach the settlement.

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). These indicate that a catastrophic avalanche released from a large part of the starting zone above Ytri-Dagmálabotn may reach the settlement.

4.4 Grákambur

4.4.1 Topographic description

South of Botnabrún and Neðri-Botnar there is an approximately 350 m high slope called Grákambur (Figure 4). The area can be seen on Maps 1 and 8 and longitudinal sections (`segr14aa`, `segr16aa` and `segr18aa`) are shown in Drawings 19–21.

Above Grákambur there is a large plateau, Hádegisbotnar, and above the plateau the mountain reaches up to about 1000 m a.s.l. The investigated area reaches 1.1 km to the south from the brook Dagmálalækur to a small unnamed brook. Through the middle of the area runs the river Hádegisá or Ytri-Hádegisá. A characteristic of the slope are three main, and some smaller rockbands which interrupt the slope and divide it into steps. Between these rockbands is weathered material partly covered with vegetation. The uppermost rockband, which is a dike, starts at about 260 m a.s.l. in the north and rises to about 340 m a.s.l. in the southern part. This rockband is on average 10–20 m high and above it the slope has a lower inclination, mostly less than 25°, so only small parts of the area above the cliffs can be considered to be a potential starting area. Between the rockbands a lot of loose material has accumulated. The average inclination of these areas is about 35°.

Starting areas

With respect to inclination most of the area between about 320 m a.s.l. and down to 100 m a.s.l. can be considered as a potential starting area. However the release of an avalanche in the whole starting zone is unlikely and therefore smaller areas which are thought to be more favorable for avalanche release are delineated. Those areas are labelled 24–28 on map 8.

The aspect of the area is northwest.

Starting area 24 is in the northernmost part of Grákambur. It starts at 105 m a.s.l. and reaches up to 170 m a.s.l. The upper border of the starting area is marked by a high rockband. The width of the area is 300 m and the area is 2.2 ha. The average inclination is 34°.

Starting area 25 is above the uppermost rockband and below the plateau. It starts at 250 m a.s.l. and reaches up to 320 m a.s.l. The average inclination is 32° but the upper part is somewhat more level, with an average inclination of 28°. The area is slightly convex with an average width of about 180 m. The area is 2.5 ha. To both sides of the area the slope inclines less and thus this is the only area above the dike that is considered to be a potential starting area.

Starting area 26 is north of the river Hádegisá. In this area the slope is more even than further to the north. Therefore the potential starting area is thought to start above the lowest rockband at 180 m a.s.l. and reach up to the dike at 280 m a.s.l. The average inclination is 36°, the area is 180 m wide and 3.4 ha in size. It is somewhat difficult to determine the northern boundary of the potential starting area.

Starting area 27 is between Hádegisá and the small unnamed brook in the south. The potential starting area is considered to be located between the lowermost and uppermost rockbands. The roughness increases gradually to the south where the slope is more interrupted. The lower boundary of the area is at 160 m a.s.l. and reaching up to 345 m a.s.l. The area is 350 m wide and 8.7 ha in size. The average inclination is 34°. The area is unconfined.

Starting area 28 was delineated without field investigation based on inclination. The area is intended to give an indication of the maximum extent of avalanches by two-dimensional calculations. The lower boundary of the area is at 200 m a.s.l. and it reaches up to about 370 m a.s.l. The width is about 800 m and the area is 17.6 ha.

Track

The track starts extends down to the β-line which is located at 20–40 m a.s.l. depending on the location within the area. The inclination decreases gradually, except for some small steps and rockbands.

Runout area

The runout area starts at the β-line and continues all the way down to the valley bottom. The upper part is formed by many overlapping debris cones. It is rather flat, mostly less than 5°. It is uniform and covered with grass. There is no settlement in the area. No signs indicating recent avalanches can be seen in the area.

4.4.2 Climatic conditions

At the elevation of the starting area the wind can be expected to blow mostly along the valley and therefore large snow accumulation in the starting area is unlikely. Snow accumulation from southeast is also unlikely due to topographic conditions. Most of the snow coming from southeast will tend to accumulate higher in the mountain and furthermore the inclination decreases rather gradually from the plateau above and down to the starting area.

4.4.3 Chronicle

One slushflow is recorded in the area, shown on Map 4 and summarised below:

Number Time *Runout index*	**Description**
4023 21.2.1904 *15.2*	A slush avalanche from the Hádegisá creek is reported to have reached the river Fjarðará at the valley bottom.

4.4.4 Assessment

As mentioned above avalanches are not expected to start over the whole area, not even in all of the smaller areas defined as starting areas. Due to climatic conditions large snow accumulation in the area is unlikely and the potential snowdepth in the starting areas is not high. Small avalanches of size around 10 thousand m^3 seem to be possible although the frequency of such events is assumed to be low.

4.4.5 Model estimates

Map 8 shows the results of model calculations and the profiles used for the calculations. The profiles `segr14aa`, `segr16aa` and `segr18aa` and the results of the calculations are shown in Drawings 19–21. The runout was calculated using runout indices and an α/β-model. For explanation see Appendix A.

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).

4.5 Debris flows, rockfall, slushflows and torrents

In addition to dry and wet snow avalanches, there is a danger of debris flows, rockfall, slushflows and torrents on the south side of Seyðisfjörður. Hazard zones for this area with respect to slides other than dry and wet snow avalanches were delineated based on a landslide chronicle, geomorphological mapping of loose materials, an estimate of the volume of loose materials in potential source areas for debris flows, modelling of the volume debris flows and the runout of rockfall, and an estimate of extreme torrents in the watersheds of the mountainside.

4.5.1 General guidelines for the hazard zoning

Hazard zones in Iceland shall according to the hazard zoning regulation of July 2000 (Ministry for the Environment, 2000) take into account hazard due to debris flows and other landslides, rockfall and torrents in addition to snow avalanches and slushflows. Guidelines for hazard zoning with regard to such processes have been formulated by IMO (Tómas Jóhannesson and Kristján Ágústsson, 2002). The guidelines attempt to formulate a zoning procedure where the delineation of hazard zones reflects the risk that people are exposed to due to the respective events.

The principle problem encountered in this type of hazard zoning is how to treat the risk in areas where neither the landslide chronicle nor geological investigations directly indicate an impeding danger to the settlement. Another problem is the widely different probability of death for people that encounter the different types of events. It is, for example, clear that the torrents pose a much smaller risk to the lives of people than snow avalanches. Thus, the probability or return period corresponding to a set value of acceptable risk is widely different for the different events.

According to the guidelines, the landslide chronicle and geological investigations are first used to identify potential areas of high risk where the danger of catastrophic landslide events may be directly inferred from such investigations. The delineation of hazard zones with regard to the results of these investigations cannot be formulated beforehand and must be subjectively determined by the experts performing the zoning.

It is assumed that hazard zones with regard to *rockfall* will typically be of type A (the lowest risk zones), except in special circumstances where the danger of rockfall is judged very high. It is recommended that the hazard line with regard to rockfall is drawn where the return period of rockfalls is on the order of 50–100 years. This return period should reflect an area of the size of a building or a typical lot on which a building stands. This location may be estimated by a statistical or a dynamical rockfall model. The model should be calibrated to reproduce the runout distance corresponding to observed loose rocks below source areas of rockfall that have fallen during the last decades or century.

The avalanche chronicles of Eskifjörður and Fáskrúðsfjörður in eastern Iceland indicate some danger of *slushflows and wet snow avalanches* from unconfined, relatively featureless mountainsides with slopes down to 20°. Under such circumstances, the guidelines generally recommend the delineation of hazard zone A down to level terrain below the slope.

The avalanche chronicles of Seyðisfjörður, Eskifjörður and Fáskrúðsfjörður also indicate that *slushflows and debris flows* pose a threat to human lives in essentially all paths of rivers and brooks in mountainsides with slopes higher than 10–20°. The guidelines propose the following classification of such paths.

1. **A well confined path of a river or a brook** such that a landslide may be expected to be largely limited to the course of the river. A less powerful part of it may overflow the banks and spread into nearby areas. The area of the watershed of paths in this class is on the order of 10–30 hectares up to and over 100 hectares and extreme floods may range from a few m^3/s up to tens of m^3/s.

2. **A partly confined path of a river or a brook** where landslides do not follow a predetermined direction and may take different directions when they enter the endangered area. The area of the watershed and the size of extreme floods is similar as in class 1.

3. **A gully or the path of a small brook** which may be dry for a part or most of the year. The watersheds of these paths are smaller than in the first two classes, *i.e.* on the order of a hectare or a few hectares, and extreme floods are on the order of a m^3/s or less.

The guidelines propose that type C hazard zones will in general be delineated for the centre parts of paths of class 1, type B hazard zones will be defined for the wide paths of type 2 and type A hazard zones in areas affected by paths of type 3. A delineation of watersheds and an estimation of extreme floods in the main rivers and brooks of the mountainside is recommended as a part of the preparation of a hazard zoning for paths of this kind.

In some areas there is a danger of *debris flows* outside of the courses of rivers or brooks that are classified above. Unless there are special indications of high danger, such debris flows are considered to be much less dangerous than snow avalanches. The guidelines propose that the hazard line with regard to debris flows in such areas corresponds to a return period of several hundred years, *i.e.* a much shorter return period than for snow avalanches but longer than for rockfall.

According to the guidelines, river floods should only be considered in steep paths where there is a danger of debris flows or slushflows. General river flooding problems are not to be considered as a part of the snow- and landslide hazard zoning according to the Icelandic hazard zoning regulation of July 2000.

Hazard zones on the south side of Seyðisfjörður were delineated on the basis of the ideas described above. In spite of these rough guidelines, much is left to the subjective judgement of the experts responsible for the hazard zoning. The final result is intended to reflect the risk that landslides pose to the local population in a nominal sense, but it can clearly not be considered to be the result of an exact statistical computation.

4.5.2 Geological investigations

An overall description of the geology of Seyðisfjörður, including a detailed description of the main debris flow paths and an evaluation of the debris flow activity in each of them, is given by Þorsteinn

Table 6. *Accumulated precipitation over 1, 2, 3, and 5 day periods (P_{1d}, P_{2d}, P_{3d} og P_{5d}) with a return period T (1, 2, 5, 10, 20 og 50 years) at the meteorological station Seyðisfjörður (station 615) for the time period 1961–1996.*

T	$\mathbf{P_{1d}}$	$\mathbf{P_{2d}}$	$\mathbf{P_{3d}}$	$\mathbf{P_{5d}}$
1	72	103	122	150
2	87	124	146	177
5	106	151	177	213
10	120	171	201	240
20	134	191	224	267
50	153	218	255	302

Sæmundsson and Halldór G. Pétursson (1999).

A geomorphological mapping of loose materials and an investigation of landslide hazard for the south side of Seyðisfjörður was carried out by Esther H. Jensen and Thomas Sönser (2002). Their report summarises the landslide chronicle of Seyðisfjörður by Halldór G. Pétursson and Þorsteinn Sæmundsson (1998). In addition to an overview investigation and mapping of the whole area, they investigated the paths Þófalækur and Búðará in detail. They estimated the volume of loose materials in potential source areas for debris flows in these paths and modelled the volume of loose materials that might be released as debris flows under different conditions. The investigated conditions included short intensive precipitation events and prolonged precipitation periods that extend for several days. They also modelled the runout of rockfall for several characteristic longitudinal sections in the Botnabrún area.

4.5.3 Extreme precipitation intensity

Extreme accumulated precipitation in Seyðisfjörður over 1, 2, 3, and 5 day periods has been analysed by Tómas Jóhannesson (2001) and the results are given in Table 6. These results were used by Esther H. Jensen and Thomas Sönser (2002) in their analysis of debris flows and torrents from Þófalækur and Búðará.

In an analysis of debris flows and torrents from small watersheds it is necessary to obtain an estimate of precipitation intensity on much shorter time-scales than one day, which is the shortest time window given in Table 6. Maximum intensity over a time period T_c (in minutes) shorter than a day may according to Páll Bergþórsson (1968, 1977) be estimated by Wussov's formula as

$$I_{T_c} = I_{24h} \cdot (1/1440) \cdot \sqrt{T_c \cdot (2880 - T_c)}$$

where I_{24h} is the 24 hour intensity (in mm) with an appropriate recurrence interval, *e.g.* 50 or 100 years. The highest return period given in Table 6 is 50 years. The P_{1d} value for Seyðisfjörður corresponding to a return period of 100 years was estimated by Esther H. Jensen and Sönser (2002) to be 172 mm.

Table 7. *Runoff coefficients C for different types of catchments.*

Type of surface	C
Concrete and asphalt	0.75–0.95
Brick covered surfaces	0.70–0.80
Bare bedrock	0.60–0.80
Gravel roads	0.30–0.70
Cultivated fields	0.05–0.25
Meadows, parks	0.10–0.20
Forested areas	0.05–0.15

4.5.4 Extreme torrents from the main watersheds

Extreme flood discharges were estimated for the watersheds of rivers and brooks on the south side of Seyðisfjörður in order to provide a comparison with the results of Esther H. Jensen and Sönser (2002) for Þófalækur and Búðará. This estimate was based on a methodology that is used by the Icelandic Public Roads Administration for the calculation of design floods for culverts and bridges for small watersheds (Helgi Jóhannesson, personal communication). According to this methodology, an extreme flood from a small catchment may be estimated as

$$Q_x = C \cdot I_{T_c} \cdot A$$

where Q_x (m^3/s) is the flood discharge, C is a runoff coefficient, I is the precipitation intensity over the time of concentration T_c for the catchment and A is the catchment area. The time of concentration T_c is estimated with the Kirpich equation

$$T_c = 0.0078 \cdot (3.28 \cdot \sqrt{l^3/h})^{0.770}$$

where l and h are the length and altitude range of the watershed, respectively. The value of the precipitation intensity over the time of concentration T_c was computed from Wussov's formula based on an estimate of the extreme precipitation with a return period of 100 years as described above.

The runoff coefficients C are roughly estimated from the guidelines given in Table 7. At the Icelandic Public Roads Administration, the value $C = 0.4$ is used for steep, sparsely vegetated hillsides of the type encountered in Seyðisfjörður.

The runoff per unit area $q_x = Q_x/A$ in units of m^3/s/km^2 is computed as a part of the flood discharge computations. This is often on the order of 10 m^3/s/km^2 in computations of this kind in Iceland. Values much above 10 are sometimes considered “unrealistically high” based on subjective judgement and the limited available flood discharge measurements in small watersheds in Iceland.

Increase of precipitation with altitude in mountainous terrain is usually not explicitly taken into account in flood discharge computations of this kind. Snowmelt is also not considered although

Table 8. *Watersheds and extreme floods from the main watersheds on the south side of Seyðisfjörður. For each watershed the table specifies the length l (km), the surface area A (km^2), the altitude range h (m), the estimated extreme flood Q_x (m^3/s) and the runoff per unit area q_x (m^3/s/km^2).*

Gully/watershed	**l**	**A**	**h**	$\mathbf{Q_x}$	$\mathbf{q_x}$
Imslandsgil	1.4	0.12	818	2.1	17
Strandargil	1.3	0.12	708	2.2	18
Þófalækur	1.4	0.24	763	3.9	18
Hæðarlækur	1.7	0.27	796	4.2	15
Hörmungarlækur	1.2	0.17	554	2.8	17
Skuldarlækur	1.5	0.17	662	2.6	16
Stöðvarlækur	1.7	0.17	697	2.5	15
Búðará	2.2	1.33	745	17.0	13
Nautaklauf	1.6	0.36	544	5.3	15
Dagmálalækur	2.2	1.67	765	21.4	13
Small brook west of Dagmálalækur	1.9	0.21	628	2.8	14
Small brook east of Ytri-Hádegisá	1.1	0.07	452	1.1	17
Ytri-Hádegisá	3.1	2.83	817	30.4	11

this may be expected to add some water to the floods if an extreme precipitation event occurs over snow covered terrain. The runoff coefficient may to some extent be considered an effective value taking such effects into account in a very rough way.

The above formulae were applied to 13 catchments in Strandartindur, Botnar and Grákambur in southern Seyðisfjörður, using a 100 year one day precipitation of 172 mm. The results are given in the Table 8.

The values of the runoff per unit area q_x are all above 10 m^3/s/km^2 which is generally considered quite high as mentioned above. After some consideration it was decided to accept these results and not reduce q_x to 10 as is sometimes done. For small, steep watersheds of the kind encountered here, the runoff per unit area tends to be larger than in larger watersheds and using these high q_x values may be considered as taking snow on the ground and precipitation gradient with altitude in the rather high lying catchments into account in a crude way. The resulting Q_x may, thus, be considered to be quite high values. They should nevertheless be, within a factor of 2, say, similar to flood discharge values that are used in engineering applications in similar watersheds in Iceland.

4.6 Conclusion

In most of the area below Grákambur the delineation of hazard zones is based on the avalanche hazard. Taking into account that no avalanches are recorded in the area and that the starting zones are not favourable for snow accumulation, the boundary of the category A hazard zone is located at runout index of 13–14. An exception of this is Hádegisá as discussed below.

Based on the guidelines described above and the compilation of geological and hydrological information about the area, hazard zones of type C are delineated far into the bottom of the valley along the paths of the main rivers Ytri-Hádegisá, Dagmálalækur and Búðará that have watersheds of over 1 km^2. A type C hazard zone is also delineated along the path of Stöðvarlækur where large debris flows have fallen according to the debris flow chronicle.

A type B hazard zone is delineated below Nautaklauf which has a much smaller watershed than the abovementioned three main rivers.

The hazard zones between these largest paths are mainly determined by potential snow avalanches, but the danger of rockfall and debris flow also influences the hazard zoning between Dagmálalækur and Nautaklauf, near Búðará on the western (southern) side and between Stöðvarlækur and Búðará.

Most of the delineated starting areas in Botnabrún are very small and hardly steep enough for the release of dry slab avalanches. Below most of the zones no houses are thus located in the category C hazard. An exception to this are areas 13 and 14 which are among the largest and partly formed as shallow depressions. Many houses are located too close to the slope and are in category B and A hazard zones.

It is possible that avalanches released in the starting zones above Ytri-Dagmálabotn can reach the settlement. Such avalanches would only fall under exceptional conditions and the risk associated with these events is considered to be minimal.

Below Þófi, from Hörmungarlækur to Imslandsgil, snow avalanches and debris flows from Imslandsgil, Þófalækur and Hæðarlækur, and also from Hörmungarlækur and Skuldarlækur immediately to the east of Þófi, are known to have reached the lowland or beyond the shoreline. The hillside bears clear marks of rockfall and movement of loose materials. A part of the road along the shore and buildings in the area are constructed on landfills or on areas where space has been made for constructions by digging into the hillside. Snow avalanche modelling indicates that snow avalanches released from the starting zones in the upper part of the hill need not to be confined to the gullies and may flow directly over the edge of Þófi between Þófalækur and Hæðarlækur. A recent discovery of long fresh cracks at 120–140 m a.s.l. in Þófi indicates extensive movement of thick loose materials in this part of the mountainside (Esther H. Jensen, 2001). Such movement may lead to a sudden slide from the edge of Þófi during periods of intensive precipitation and consequent high pore pressure in the loose materials near the edge. Fresh cracks indicating an impending danger of such slides were indeed observed at 85–95 m a.s.l. east of Hæðarlækur in the fall of 2001 after an intensive rainfall period (Esther H. Jensen, 2001). In the area east of Skuldarlækur, a hazard zone of type C is delineated into the sea due to these various hazardous snow and landslide processes that endanger this area.

The uncertainty of the hazard zoning for the south side of Seyðisfjörður is considered to be medium to high (1–2). The uncertainty of the assessment that all the area below Þófi is in the category C hazard zone is low.

The hazard zoning proposal is shown on Map 9.

5 Conclusion

Most of the settlement in the northern part of Seyðisfjörður is within the boundaries of hazard zones. Although a relatively small proportion of the houses is located within the category C hazard zone it is still important to increase the safety in the area by permanent protection measures.

South of the river the situation is better and a large core of the settlement at the head of the fjord is outside the boundaries of hazard zones. In spite of that, there are many houses located too close to the slope and thus in the hazard zones. Few houses are located in the category C hazard zone.

Along the coast towards the east the number of houses in the category C hazard zone increases and to the east of Búðará all houses are in a hazard zone. At the industrial area below Þófi one of the principal employers in Seyðisfjörður, SR fish meal factory, is located in a category C hazard zone. In that area there is both snow avalanche and landslide hazard.

A new harbour area is being developed on a landfill outside the hazard zones. This will permit a development of commerce in a "safe" area.

There are various uncertainties that have to be dealt with in hazard zoning for Seyðisfjörður. To strengthen the basis of future hazard zoning project it is necessary to monitor environmental factors related to avalanches and landslides. The monitoring will also be valuable for the execution of emergency evacuations, which are necessary until permanent measures have been taken to increase the safety of the inhabitants.

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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 5).

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 5).

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 $r_0 = 13$.

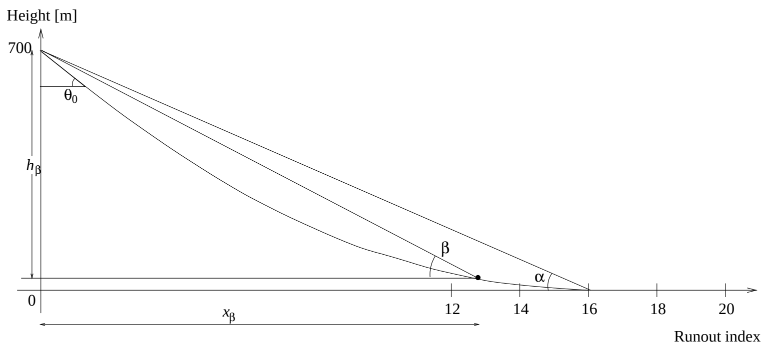


Figure 5. *The standard path. The α-angle is the expected runout angle of an avalanche according to the α/β-model.*

B Maps

Map 1. An overview of Seyðisfjörður and the boundary of the investigated area (A4, 1:25 000).

Map 2. Recorded avalanches in the northern part, Bjólfur (A3, 1:10 000).

Map 3. Recorded avalanches in the southern part, Strandartindur (A3, 1:10 000).

Map 4. Recorded avalanches in the southern part, Grákambur (A4, 1:10 000).

Map 5. A hazard map for Seyðisfjörður from 1992 (A3, 1:10 000).

Map 6. Results of model estimates in the northern part, Bjólfur (A3, 1:10 000).

Map 7. Results of model estimates in the southern part, Strandartindur (A3, 1:10 000).

Map 8. Results of model estimates in the southern part, Grákambur (A4, 1:10 000).

Map 9. Proposed hazard zoning for the investigated area (A3, 1:10 000).

C Climatic data

Summary statistics: Temperature, wind and precipitation

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.

Seyðisfjörður (AWS), no. 4180, 92 m a.s.l., 65°16'N 14°00'W (1997–2001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	0.8	−1.2	−1.6	0.3	5.2	6.5	9.7	9.9	7.6	4.2	2.0	0.4	**3.7**
min(tn)	−13.8	−15.3	−17.4	−11.7	−5.8	−2.1	2.2	2.8	−1.3	−6.5	−10.0	−14.9	**−17.4**
max(tx)	14.6	13.6	15.8	13.8	20.7	21.6	24.8	21.8	21.9	16.7	21.4	15.8	**24.8**
avg(f)	5.9	6.3	5.3	3.7	3.8	3.6	2.9	2.9	4.0	3.9	4.8	5.3	**4.4**
max(fx)	25.4	22.6	28.5	23.5	22.0	20.7	20.0	19.8	20.0	18.1	24.1	20.5	**28.5**
max(fg)	53.3	41.6	43.7	49.7	46.8	37.4	27.7	27.8	32.8	34.3	43.9	44.7	**53.3**

Dalatangi (AWS), no. 4193, 10 m a.s.l., 65°16'N 13°34'W (1997–2001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	1.6	0.0	−0.6	0.7	4.2	5.5	8.1	9.0	7.7	4.9	3.1	1.6	**3.8**
min(tn)	−10.9	−14.7	−14.7	−8.0	−5.7	−1.7	2.8	3.8	0.0	−2.9	−7.7	−11.4	**−14.7**
max(tx)	19.6	15.3	15.3	14.5	18.6	22.2	23.9	22.1	18.2	14.9	23.2	13.2	**23.9**
avg(f)	6.3	5.9	5.4	5.0	4.7	4.9	4.2	4.2	5.4	5.5	5.8	6.3	**5.3**
max(fx)	27.1	28.0	23.7	19.3	23.3	19.0	14.7	18.7	21.9	18.8	26.1	23.7	**28.0**
max(fg)	45.1	38.0	43.5	27.4	29.6	31.1	29.3	21.9	35.7	27.6	45.7	36.8	**45.7**

Gagnheiði (AWS), no. 4275, 949 m a.s.l., 65°13´N 14°16´W (1997–2001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	−5.4	−7.7	−7.7	−5.3	−0.7	1.1	5.0	5.1	1.8	−1.9	−4.1	−5.6	**−2.1**
min(tn)	−19.2	−22.7	−23.9	−16.1	−12.8	−9.4	−3.4	−2.8	−7.8	−12.8	−16.5	−21.1	**−23.9**
max(tx)	7.3	6.3	9.4	10.3	11.7	15.8	17.8	19.6	12.9	9.4	12.1	9.3	**19.6**
avg(f)	12.2	12.0	9.6	8.8	8.3	6.6	6.3	5.3	9.6	9.4	11.2	11.2	**9.2**
max(fx)	54.2	48.1	43.3	34.4	30.2	33.6	24.6	26.2	43.2	38.1	54.7	44.7	**54.7**
max(fg)	67.3	65.9	58.7	40.4	37.4	37.3	29.8	32.7	47.4	45.2	67.6	58.0	**67.6**

Neskaupstaður (AWS), no. 5990, 50 m a.s.l., 65°10´N 13°40'W (Nov 1997–2001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	1.3	−0.4	−1.0	0.6	6.0	7.0	9.6	9.9	7.9	5.1	2.6	1.3	**4.2**
min(tn)	−11.9	−14.3	−14.4	−10.1	−2.8	−1.4	0.0	2.0	−0.7	−5.0	−10.5	−13.1	**−14.4**
max(tx)	17.0	12.8	15.6	13.9	20.4	23.5	25.5	21.9	19.3	16.1	20.8	15.1	**25.5**
avg(f)	4.5	4.7	4.1	2.8	2.7	2.6	2.4	2.5	3.1	3.6	3.7	3.8	**3.4**
max(fx)	26.8	25.1	21.9	15.4	13.3	15.5	12.8	14.6	18.1	17.6	23.2	18.7	**26.8**
max(fg)	47.8	48.7	43.8	32.2	32.1	29.6	28.3	22.0	28.2	39.6	41.0	43.1	**48.7**

Oddsskarð (AWS), no. 34087, 520 m a.s.l., 65°06´N 14°54’W (1997–2001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	−1.6	−3.8	−4.1	−1.9	2.5	4.3	8.0	8.2	5.1	1.6	−0.5	−1.9	**1.3**
min(tn)	−15.0	−18.5	−18.5	−12.6	−8.5	−5.5	0.4	0.7	−4.3	−8.7	−12.8	−16.3	**−18.5**
max(tx)	12.6	9.5	14.5	11.6	15.1	18.2	21.6	21.3	17.0	12.7	15.9	11.0	**21.6**
avg(f)	6.4	7.2	5.9	4.2	3.8	3.7	3.2	3.4	4.7	5.1	5.5	5.5	**4.9**
max(fx)	38.2	33.1	39.8	20.3	26.3	23.6	19.5	19.4	25.2	24.7	39.3	26.6	**39.8**
max(fg)	55.4	42.7	62.0	42.4	48.3	48.7	32.1	34.2	44.2	45.3	56.3	49.7	**62.0**

Fjarðarheiði (AWS), no. 34175, 600 m a.s.l., 65°15’N 14°14´W (1997–2001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	−3.2	−5.5	−5.7	−3.1	1.3	3.4	7.7	7.8	4.6	0.4	−1.9	−3.4	**0.2**
min(tn)	−19.6	−20.3	−23.9	−19.4	−9.8	−6.5	−1.3	−0.2	−4.8	−11.9	−18.2	−19.3	**−23.9**
max(tx)	10.0	7.4	9.5	8.4	14.4	18.8	20.7	22.2	16.2	10.4	13.8	12.0	**22.2**
avg(f)	9.0	9.2	7.5	6.1	6.0	5.0	4.8	4.9	6.4	6.2	7.4	7.4	**6.7**
max(fx)	37.7	29.9	28.2	21.7	20.9	21.1	18.4	18.7	29.9	24.2	30.6	29.5	**37.7**
max(fg)	46.7	41.8	41.5	32.0	28.2	27.1	22.9	24.4	38.1	30.4	41.8	39.4	**46.7**

Seyðisfjörður (climatic station), no. 615, 3 m a.s.l., 65°15’N 14°00’W (1971-2000*)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	−0.4	−0.1	0.3	1.7	5.0	7.8	9.9	10.0	7.1	4.0	1.2	−0.2	**3.8**
min(tn)	−18.0	−15.6	−18.0	−12.6	−8.4	−3.5	1.0	0.0	−5.7	−9.9	−15.0	−17.5	**−18.0**
max(tx)	17.5	16.0	15.4	21.0	21.5	26.6	28.0	27.0	25.0	22.0	20.7	18.0	**28.0**
avg(f)	4.3	4.3	4.3	3.9	3.3	3.4	3.0	3.4	3.8	3.8	3.8	4.3	**3.8**
max(fx)	26.7	30.8	26.7	22.6	26.7	22.6	19.0	30.8	26.7	26.7	30.8	30.8	**30.8**
avg(r)	224.4	157.1	168.7	97.9	72.0	62.0	64.6	85.1	155.0	206.1	172.0	187.3	**1631.8**
max(r)	444.7	443.9	444.6	222.0	204.2	222.9	195.2	256.6	384.2	524	336.3	515.0	**2494.9**
max(rx)	110.8	140.6	114.8	78.2	68.0	61.6	94.6	108.0	137.9	128.6	120.8	135.3	**140.6**

Dalatangi (synoptic station), no. 620, 9 m a.s.l., 65°16’N 13°34’W (1971-2000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	0.5	0.6	0.5	1.4	3.7	6.2	8.2	8.7	6.9	4.5	2.2	0.8	**3.7**
min(tn)	−15.5	−11.5	−16.3	−9.7	−7.4	−1.9	1.5	2.9	−1.4	−5.7	−9.7	−15.4	**−16.3**
max(tx)	18.8	18.1	14.1	17.3	20.5	21.4	23.5	25.1	25.8	23.5	22.7	16.6	**25.8**
avg(f)	7.0	6.5	6.5	5.6	5.2	4.8	4.6	5.0	5.8	6.1	6.3	6.8	**5.9**
max(fx)	31.4	31.9	36.0	25.2	26.8	22.6	25.2	23.1	29.3	33.9	31.9	31.9	**36.0**
avg(r)	146.1	110.3	124.7	85.6	86.5	81.1	99.7	115.6	177.2	195.2	150.0	127.6	**1499.6**
max(r)	274.5	265.5	250.5	191.3	227.2	249.3	311.3	480.5	353.2	504.4	261.8	325.2	**1985.4**
max(rx)	83.5	73.3	65.9	70.9	68.4	73.9	149.3	104.0	159.8	200.0	85.9	55.4	**200.0**

Neskaupstaður (climatic station), no. 625, 29 m a.s.l., 65°09’N 13°40’W (1975-2000*)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
avg(t)	0.0	0.2	0.5	1.8	4.9	7.9	10.0	9.8	7.1	4.2	1.8	0.5	**4.1**
min(tn)	−15.6	−12.8	−16.6	−11.9	−7.1	−2.6	0.6	1.1	−4.1	−8.8	−10.8	−14.0	**−16.6**
max(tx)	16.0	13.3	14.0	20.1	21.2	24.7	27.4	25.2	24.5	21.7	20.2	14.3	**27.4**
avg(f)	3.8	3.6	3.7	3.8	2.8	2.6	2.2	2.4	2.8	3.1	3.0	3.6	**3.1**
max(fx)	26.8	30.8	26.7	22.6	19.0	15.4	15.4	22.6	22.6	26.7	30.8	30.8	**30.8**
avg(r)	205.3	154.6	182.6	96.6	84.4	74.5	81.8	104.5	187.7	269.1	197.6	175.5	**1820.9**
max(r)	428.5	288.9	355.9	261.1	221.6	291.6	236.7	370.9	390.9	577.2	474.7	362.2	**2183.7**
max(rx)	115.6	59.4	115.4	103.8	88.1	98.4	186.1	96.3	125.2	154.4	185.9	105	**186.1**

Precipitation in Seyðisfjörður (AWS), no. 4180

Monthly precipitation, mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1995												30	
1996	113	133	32	200	87	65	36	46	95	277	91	120	**1296**
1997	68	128	62	28	18	72	58	118	153	254	140	90	**1188**
1998	327	62	49	58	28	38	33	24	296	129	232	228	**1505**
1999	205	42	122	69	72	51	23	42	279	180	27	86	**1198**
2000	88	144	65	57	20	20	8	66	171	222	270	173	**1303**
2001	156	110	147	91	45	26	39	150	91	457	42	72	**1426**
1996–2001	160	103	80	84	45	45	33	74	181	253	134	114	**1319**

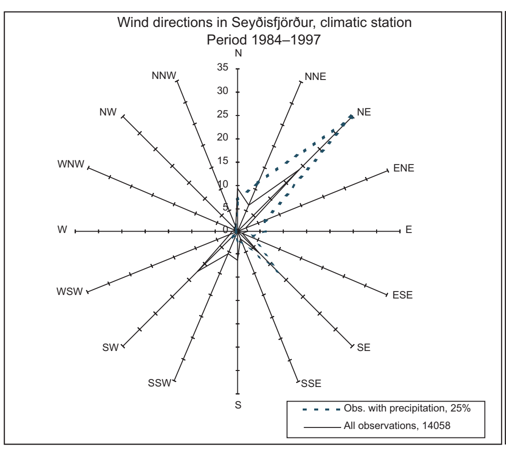
Maximum 24 hour precipitation, mm

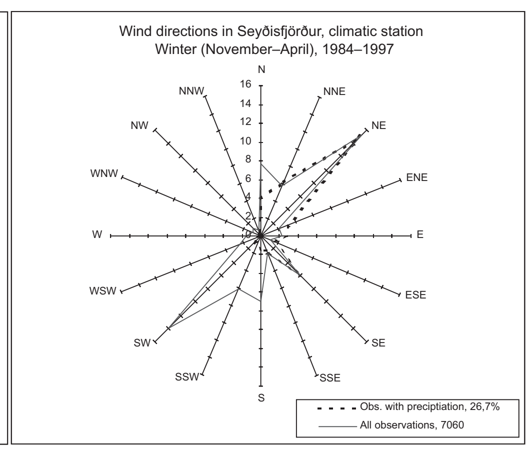
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1995												15.5	
1996	20.6	22.5	6.6	80.2	59.3	26.6	9.0	20.5	23.1	74.3	30.9	55.9	**80.2**
1997	16.3	40.6	15.3	11.8	5.5	11.7	14.3	20.9	42.0	87.9	16.0	39.2	**87.9**
1998	43.9	13.8	11.4	18.9	14.1	11.7	5.6	5.5	119.4	47.5	47.8	67.1	**119.4**
1999	58.7	11.7	33.6	25.0	28.9	9.9	9.3	20.2	101.1	38.2	7.1	17.4	**101.1**
2000	24.6	22.3	22.3	10.1	5.5	6.4	2.2	22.6	53.1	35.8	57.9	36.2	**57.9**
2001	37.9	25.7	31.3	19.0	12.9	14.3	9.9	61.2	40.7	153.6	12.7	17.8	**153.6**
1996–2001	58.7	40.6	33.6	80.2	59.3	26.6	14.3	61.2	119.4	153.6	57.9	67.1	**153.6**

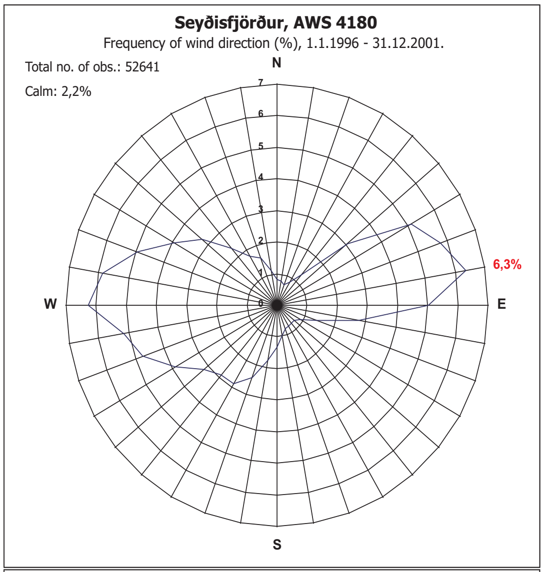
Maximum 1 hour precipitation, mm

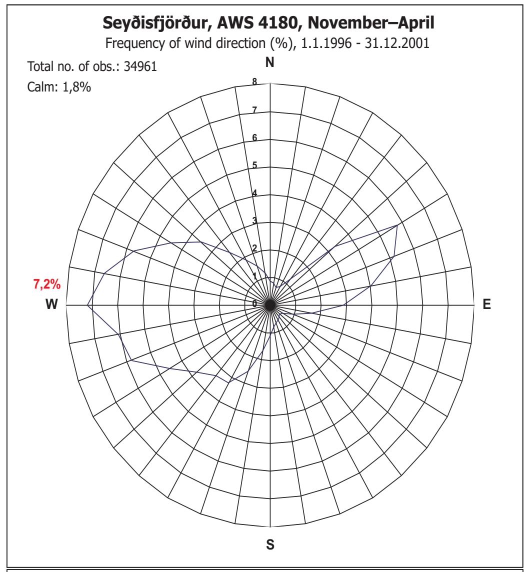
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1995												4.0	
1996	7.7	11.3	2.2	38.1	7.0	3.7	3.0	7.3	12.1	6.4	4.7	11.3	**38.1**
1997	7.9	4.3	6.7	5.1	1.6	3.5	3.6	5.1	6.8	10.4	4.4	5.7	**10.4**
1998	9.8	4.9	2.6	6.6	1.8	2.7	2.0	2.3	9.6	5.9	5.4	10.0	**10.0**
1999	6.7	2.5	5.5	10.1	4.5	2.9	2.6	2.2	24.4	8.3	1.2	3.9	**24.4**
2000	5.5	3.0	2.8	2.8	2.5	1.6	0.8	4.3	4.7	5.5	6.9	4.5	**6.9**
2001	3.3	4.8	3.5	2.3	2.4	2.2	2.3	8.1	5.2	16.6	2.3	2.8	**16.6**
1996–2001	9.8	11.3	6.7	38.1	7.0	3.7	3.6	8.1	24.4	16.6	6.9	11.3	**38.1**

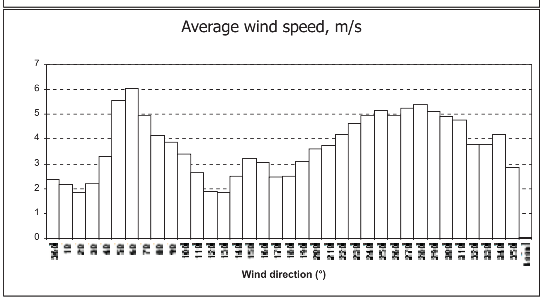
Wind roses

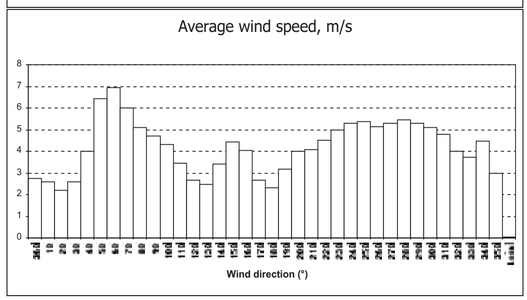


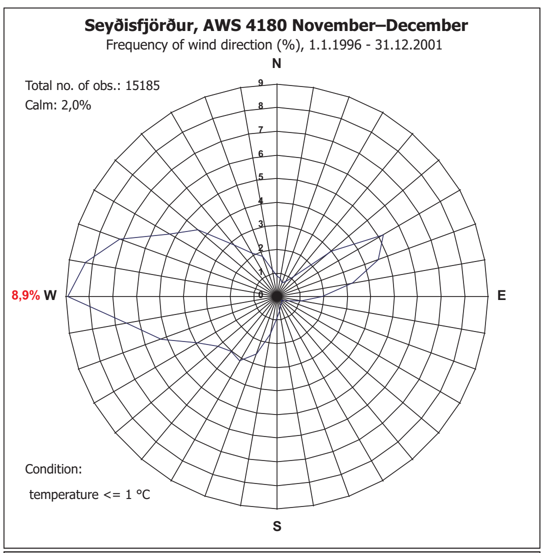


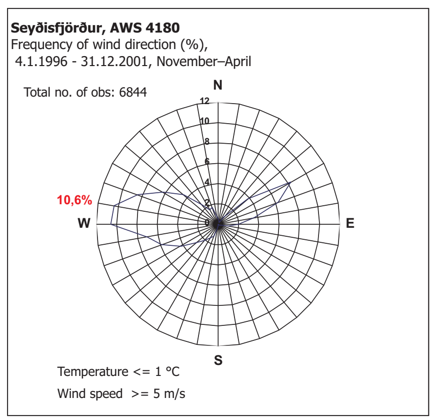

Seyðisfjörður, AWS 4180
Frequency of wind direction (%), 1.1.1996 - 31.12.2001.
Total no. of obs.: 52641
Calm: 2,2%
N
E
S
W
6,3%

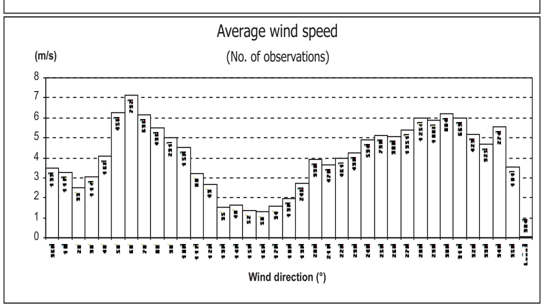

Seyðisfjörður, AWS 4180, November–April
Frequency of wind direction (%), 1.1.1996 - 31.12.2001
Total no. of obs.: 34961
Calm: 1,8%
N
E
S
W
7,2%

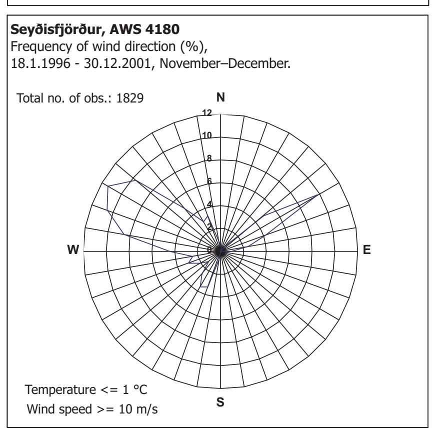

Average wind speed, m/s
Wind direction (°)

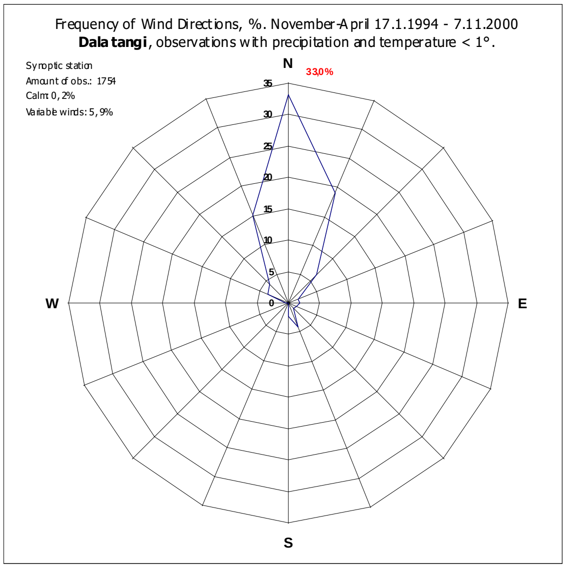

Average wind speed, m/s
Wind direction (°)

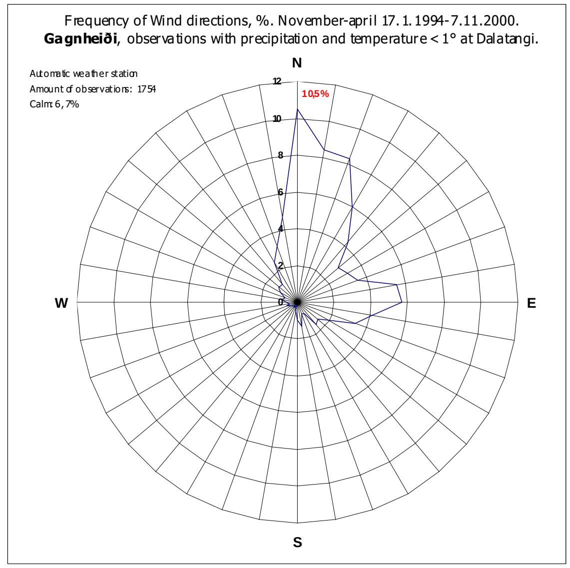

Seyðisfjörður, AWS 4180 November–December
Frequency of wind direction (%), 1.1.1996 - 31.12.2001
Total no. of obs.: 15185
Calm: 2,0%
N
E
S
W
8,9%
Condition:
temperature <= 1 °C

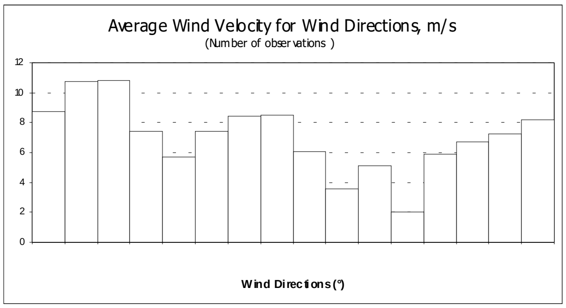

Seyðisfjörður, AWS 4180
Frequency of wind direction (%),
4.1.1996 - 31.12.2001, November–April
Total no. of obs: 6844
N
E
S
W
10,6%
Temperature <= 1 °C
Wind speed >= 5 m/s

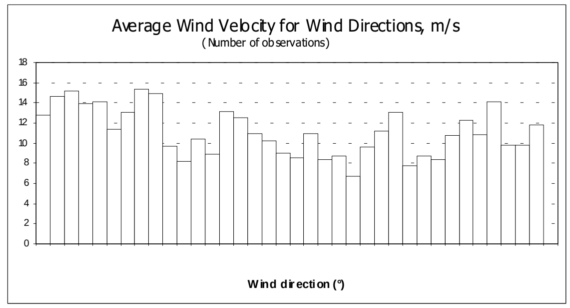

Average wind speed
(No. of observations)
(m/s)
Wind direction (°)

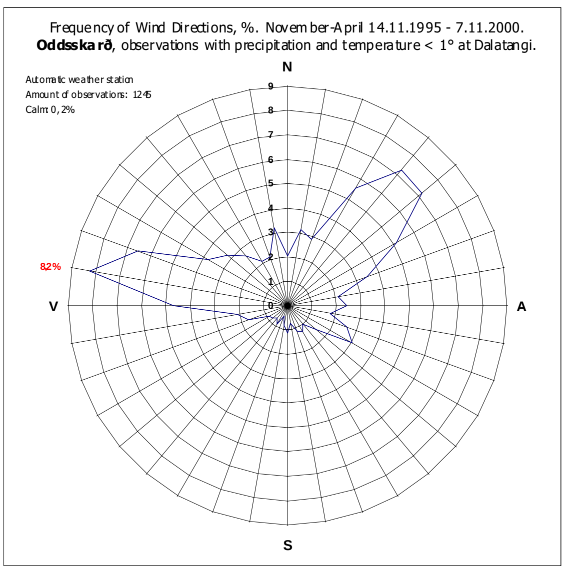

Seyðisfjörður, AWS 4180
Frequency of wind direction (%),
18.1.1996 - 30.12.2001, November–December.
Total no. of obs.: 1829
N
E
S
W
Temperature <= 1 °C
Wind speed >= 10 m/s

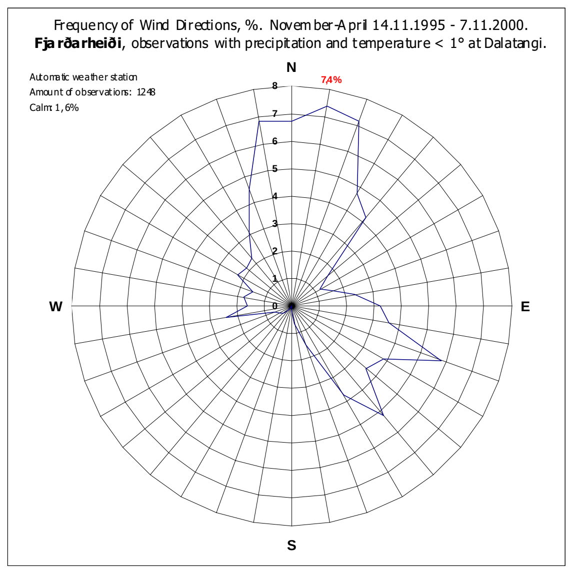

Frequency of Wind Directions, %. November-April 17.1.1994 - 7.11.2000
Dalatangi, observations with precipitation and temperature < 1°.
Synoptic station
Amount of obs.: 1754
Calm: 0,2%
Variable winds: 5,9%
33,0%
N
E
S
W

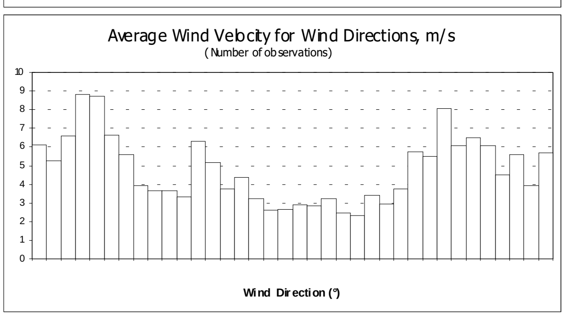

Frequency of Wind directions, %. November-april 17.1.1994-7.11.2000.
Gagnheiði, observations with precipitation and temperature < 1° at Dalatangi.
Automatic weather station
Amount of observations: 1754
Calm: 6,7%
10,5%
N
E
S
W

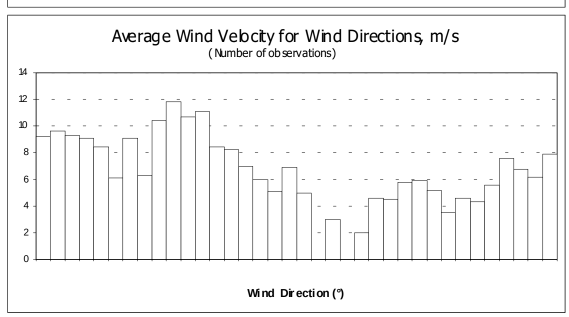

Average Wind Velocity for Wind Directions, m/s
(Number of observations)
Wind Directions (°)


Average Wind Velocity for Wind Directions, m/s
(Number of observations)
Wind direction (°)


Frequency of Wind Directions, %. November-April 14.11.1995 - 7.11.2000.
Oddsskarð, observations with precipitation and temperature < 1° at Dalatangi.
Automatic weather station
Amount of observations: 1245
Calm: 0,2%
8,2%
N
A
S
V

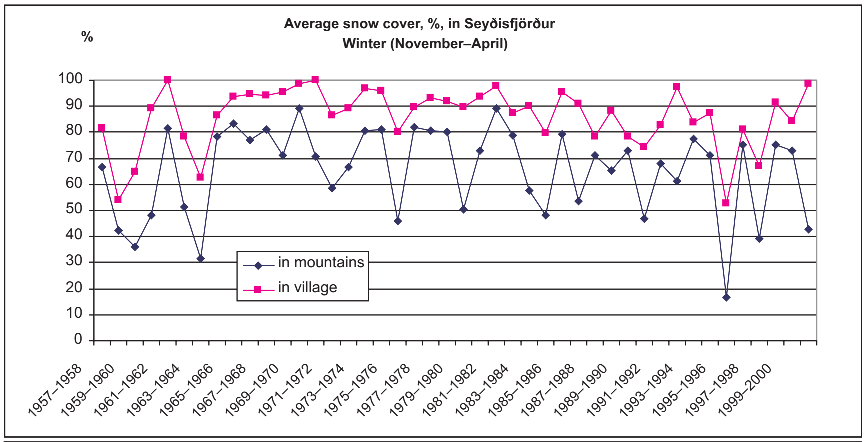

Frequency of Wind Directions, %. November-April 14.11.1995 - 7.11.2000.
Fjarðarheiði, observations with precipitation and temperature < 1° at Dalatangi.
Automatic weather station
Amount of observations: 1248
Calm: 1,6%
7,4%
N
E
S
W

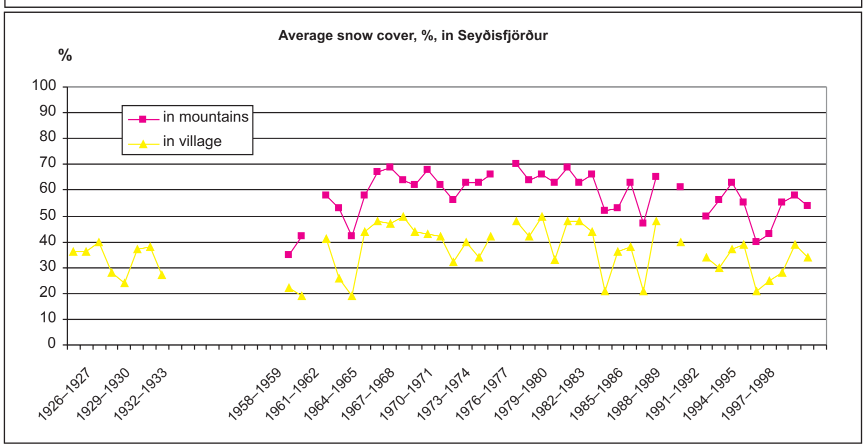

Average Wind Velocity for Wind Directions, m/s
(Number of observations)
Wind Direction (°)


Average Wind Velocity for Wind Directions, m/s
(Number of observations)
Wind Direction (°)

C.1 Snow cover in Seyðisfjörður

	Average snowdepth, cm							Maximum measured snowdepth, cm						
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1993/1994			39	70	68	72				53	128	91	89	
1994/1995			24							34		65	122	
1995/1996					27		41				4	28	6	41
1996/1997	26	29	54	71	31	45	27	29	41	70	105	47	61	28
1997/1998				17	20	47					20	39	54	
1998/1999		12	50	67	55	65	59		15	54	88	64	79	74
1999/2000			50	64	75	135	35			66	94	127	156	46
2000/2001			28	89	0	35	53			36	105		62	62





C.2 Monthly accumulated precipitation in Seyðisfjörður, mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1936	195.1	108.9	186.4	43.3	85.3	46.8	48.4	79.3	155.3	49.5	89.7	38.4	**1106.0**
1937	299.3	234.4	42.9	83.1	110.1	20.5	82.9	70.8	256.2	83.7	71.0	122.6	**1478.0**
1938	161.6	69.2	63.4	12.3	29.5	65.4							
1957									77.9	88.0	108.2	89.9	
1958	169.6	82.2	82.4	67.1	37.1		21.0	81.3	134.9	210.1	57.6	286.9	**1270.0**
1959	74.0	120.6	191.3	66.8	59.7	80.0	50.9	103.2	54.1	131.6	468.7	350.4	**1751.0**
1960	136.0	205.0	117.1	104.6	66.5	32.2	161.0	6.1	26.5	72.4	467.8	368.6	**1764.0**
1961	259.4	106.2	71.7	200.2	108.8	84.2	26.5	104.1					
1962	150.0	46.8	105.5	102.9	37.9	221.0	43.2	60.9	152.5	255.9	74.4	90.7	**1341.7**
1963	2.3	104.8	226.1	239.4	104.5	125.6	72.8	37.6	42.1	133.2	125.5	67.7	**1281.6**
1964	31.7	124.8	112.8	61.7	251.9	122.3	39.4	111.6	84.2	12.9	73.4	118.2	**1144.9**
1965	151.6	9.0	74.4	87.5	128.0	146.8	31.6	52.1	41.5	59.3	116.6	124.1	**1022.5**
1966	171.2	139.9	111.8	97.8	73.2	77.5	44.5	86.9	137.3	103.1	59.7	154.1	**1257.0**
1967	220.4	231.7	138.4	58.2	173.1	38.9	81.9	16.6	44.3	258.2	81.9	88.4	**1432.0**
1968	90.0	134.5	118.7	31.7	27.7	79.5	33.7	72.5	168.2	281.6	339.8	97.8	**1475.7**
1969	360.1	69.7	55.6	45.4	17.0	79.2	111.4	56.2	30.8	109.8	169.9	226.4	**1331.5**
1970	408.4	230.4	88.3	54.6	63.8	7.9	148.2	49.6	148.5	265.3	162.2	81.4	**1708.6**
1971	184.8	110.3	165.9	131.6	128.3	39.1	59.3	120.5	82.4	123.1	107.2	126.0	**1378.5**
1972	378.2	188.6	222.2	171.5	154.2	222.9	52.5	42.4	95.0	189.9	204.4	515.0	**2436.8**
1973	188.6	119.0	60.9	174.2	42.2	26.0	32.0	76.3	131.2	112.2	115.2	134.4	**1212.2**
1974	444.7	443.9	216.0	49.0	86.5	124.4	94.0	190.4	317.6	90.9	207.4	230.1	**2494.9**
1975	330.8	67.4	83.8	107.4	23.2	25.1	108.5	19.0	118.3	76.1	134.2	52.5	**1146.3**
1976	91.0	145.9	323.8	69.9	150.9	73.5		7.3	12.6	469.1	258.6	115.3	
1977	360.0	109.8	176.3	222.0	36.8	21.1	118.7	47.3	56.1	422.6	148.9	111.2	**1830.8**
1978	305.6	194.9	444.6	10.7	16.2	52.6	172.1	70.9	101.7	94.6	170.8	298.2	**1932.9**
1979	133.8	123.3	49.2	73.9	131.1	23.2	42.5	40.8	133.9	147.1	177.9	253.5	**1330.2**
1980	100.8	98.5	107.8	40.9	49.2	134.4	53.0	37.4	132.4	187.5	71.0	96.6	**1109.5**
1981	71.2	149.6	232.1	44.3	41.2	52.3	58.9	101.4	344.2	263.0	297.4	183.6	**1839.2**
1982	181.9	250.1	143.8	35.4	97.3	8.6	54.4	133.2	165.4	408.5	153.6	171.9	**1804.1**
1983	140.0	79.6	116.9	130.3	115.0	58.6	33.2	33.4	106.0	427.8	134.3	123.3	**1498.4**
1984	269.9	143.2	89.7	52.2	10.7	38.3	23.0	37.8	262.6	154.6	259.8	228.2	**1570.0**
1985	64.8	46.7	106.0	166.6	99.2	28.1	112.0	241.1	71.3	68.4	123.8	256.4	**1384.4**
1986	322.9	16.8	237.5	166.5	204.2	23.8	40.8	23.1	48.4	78.7	264.5	325.1	**1752.3**
1987	55.0	169.6	160.3	45.2	11.0	77.3	106.0	25.6	384.2	175.5	114.8	110.3	**1434.8**
1988	224.2	155.2	68.4	129.3	94.8	11.5	195.2	256.6	259.3	95.5	90.2	71.3	**1651.5**
1989	154.0	250.3	261.6	124.8	106.1	63.9		237.2	214.8	134.8	70.2	150.9	
1990	355.0	304.1	151.0	57.4	9.2	44.0	52.5	53.2	150.8	276.7	139.8	115.4	**1709.1**
1991	228.8	149.5	421.0	111.0	78.8	4.1	40.6	31.0	103.2	305.2	223.2		
1992	43.9	195.5	181.6	109.0	77.1	29.1	65.1	201.0	236.2	129.4	269.3	193.2	**1730.4**
1993	269.5	46.7	91.1	159.2	114.1	124.8	68.9	41.8	21.2	34.4	166.0	326.7	**1464.4**
1994	415.9	193.8	146.6	66.6	44.0	123.6	30.4	168.8	57.5	79.5	182.6	214.4	**1723.7**
1995	236.5	139.7	197.9	66.2	63.0	99.9	36.8	30.0	43.5	524.0	50.5	53.2	**1541.2**
1996	147.6	186.3	54.8	134.5	26.7	114.8	30.6	56.0	111.8	345.4	116.0	156.8	**1481.3**
1997	143.6	194.2	108.0	41.5	21.0	86.3	59.1	124.4	145.4	198.4	211.0	166.2	**1499.1**
1998	414.8	117.0	113.2	74.5	25.7	37.7	36.7	25.8	255.6	153.9	312.3	333.8	**1901.0**
1999	337.2	80.9	183.4	106.4	83.1	63.1	20.7	28.4	337.0	176.6	47.2	120.8	**1584.8**
2000	136.6	241.2	145.4	63.5	18.7	27.6	11.6	49.4	148.9	239.4	336.3	197.5	**1616.1**
2001	212.1	163.9	194.4	133.3	64.0	41.1							
maximum	444.7	443.9	444.6	239.4	251.9	222.9	195.2	256.6	492.0	524.0	468.7	515.0	
minimum	2.3	9.0	42.9	10.7	9.2	4.1	11.6	6.1	12.6	12.9	47.2	38.4	
max 24 hr	110.8	140.6	114.8	78.2	86.7	108.5	107.6	108.0	137.9	128.6	132.2	135.3	

D Profile drawings

Drawing no.	Profile ID	Avalanche path
1	seha21aa	Skagi, south of Drottningarlækur
2	seha19aa	Skagi, near Langitangi
3	sebj33aa	Bjólfur, between Jókugil and Fálkagil
4	sebj36aa	Bjólfur, upper starting area, above Fjörður
5	sebj31aa	Bjólfur, upper starting area, through Kálfabotn and Hlaupgjá
6	sebj31ca	Bjólfur, Kálfabotn and Hlaupgjá
7	sebj41aa	Bjólfur, Liverpool
8	sebj44aa	Bjólfur, Flatafjall
9	sebj48aa	Bjólfur, Nautabás
10	sest09aa	Strandartindur, Strandargil
11	sest08bb	Strandartindur, Þófi
12	sest16aa	Strandartindur, south of Hæðarlækur
13	sest05ca	Strandartindur, Skuldarlækur
14	sest05bb	Strandartindur, between Skuldarlækur and Stöðvarlækur
15	sest11aa	Strandartindur, uppermost starting zone in Efri-Botnar
16	sebh02aa	Botnahlíð, south of Búðará
17	sebh10aa	Botnahlíð, between Nautaklauf and Dagmálalækur
18	sebh11aa	Botnahlíð, north of Dagmálalækur
19	segr14aa	Grákambur, south of the settlement
20	segr16aa	Grákambur, Hádegisá
21	segr18aa	Grákambur, south of Hádegisá