Risk management: How to balance the risk of fatal accidents, property damage and social disruption in the planning of disaster risk reduction?

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Workshop on Risk Assessment and Acceptable Risk

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Overview

Icelandic Met Office

- Fatal accidents in natural disasters in Iceland
- Fatal accidents due to snow avalanches in Iceland
- Economical loss in natural disasters in Iceland
- Assessment of hazard/risk due to snow avalanches and landslides
- Protection measures
- The value of life
- Societal effect of natural disasters
  - Loss of lives
  - Direct economical loss
  - Disruption/indirect economic loss
- Acceptable risk
- The ALARP perspective

Natural disasters that need to be considered in Iceland

Icelandic Met Office

- Earthquakes
- Volcanic eruptions
- River floods
- Jökulhlaups (glacier outburst floods)
- Snow avalanches, ice avalanches
- Landslides (debris flows, rock avalanches, ...)
- Ocean floods, coastal erosion
- Tsunamis in lakes or in the ocean
- Crustal movements (e.g. GIA)
- Storms, snow storms, thunderstorms (lightnings)
- Sea ice
- Climate change (cool/warm periods, drought, anthropogenic climate change)
- Ocean acidification
- Soil erosion
- Forest fires
- ...

Fatal accidents in natural catastrophes in Iceland 1901−2016

Icelandic Met Office

Type of accident	Fatalities
Accidents at sea	thousands
Storms on land	hundreds
Avalanches	169
Landslides and rock falls	27
Volcanic eruptions	2
Earthquakes	1

Fatal snow avalance accidents in inhabited areas in Iceland in recent decades

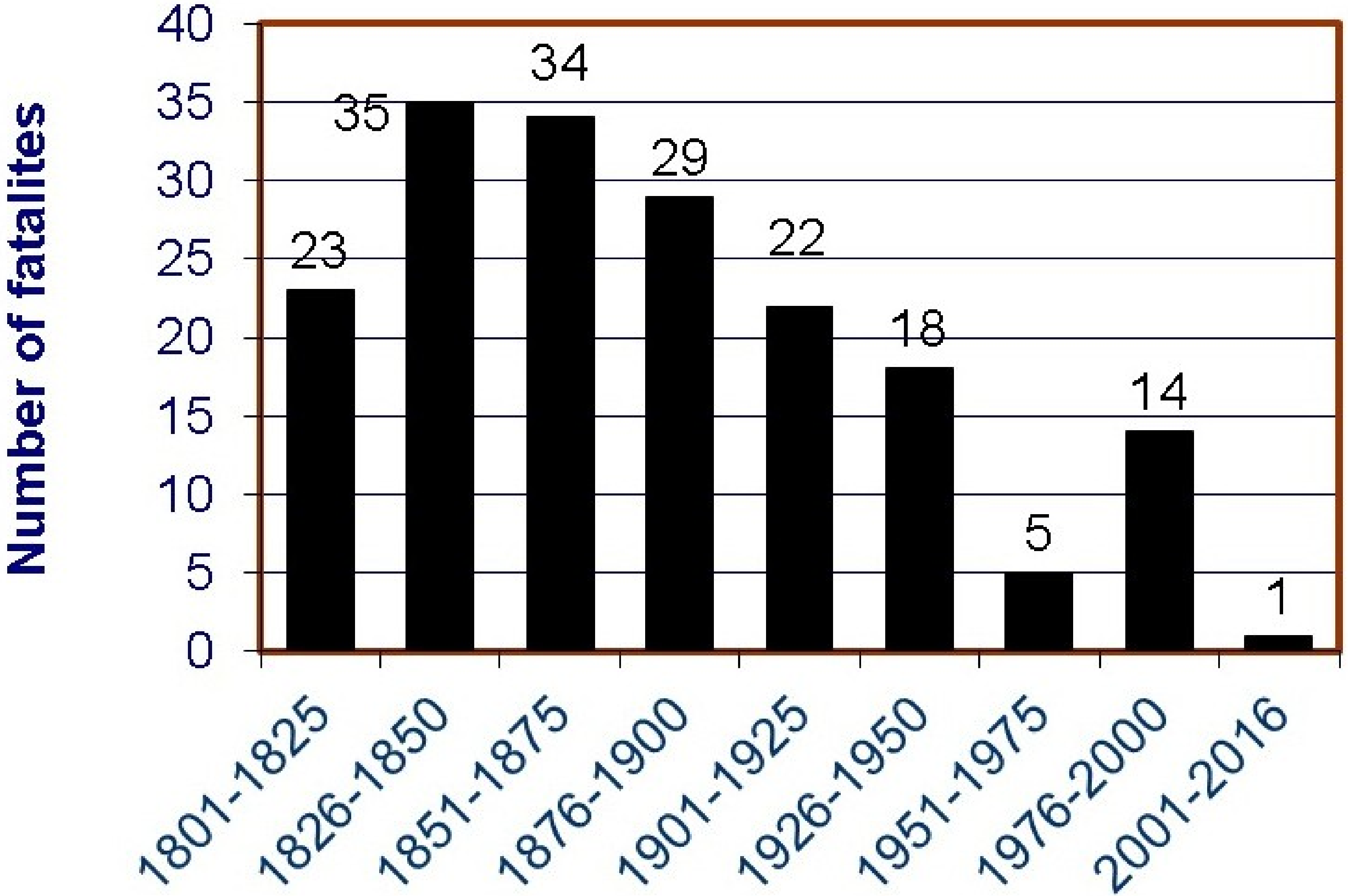
Icelandic Met Office

Date	Location	Fatalities
20.12.1974	Neskaupstaður	12
22.01.1983	Patreksfjörður	4
05.04.1994	Tungudalur, Skutulsfjörður	1
16.01.1995	Súðavík	14
18.01.1995	Grund, Reykhólahreppur	1
26.10.1995	Flateyri	20
13.01.2004	Bakki, Ólafsfirði	1
Total		**52**

Rescue workers, Flateyri, 26.10.1995

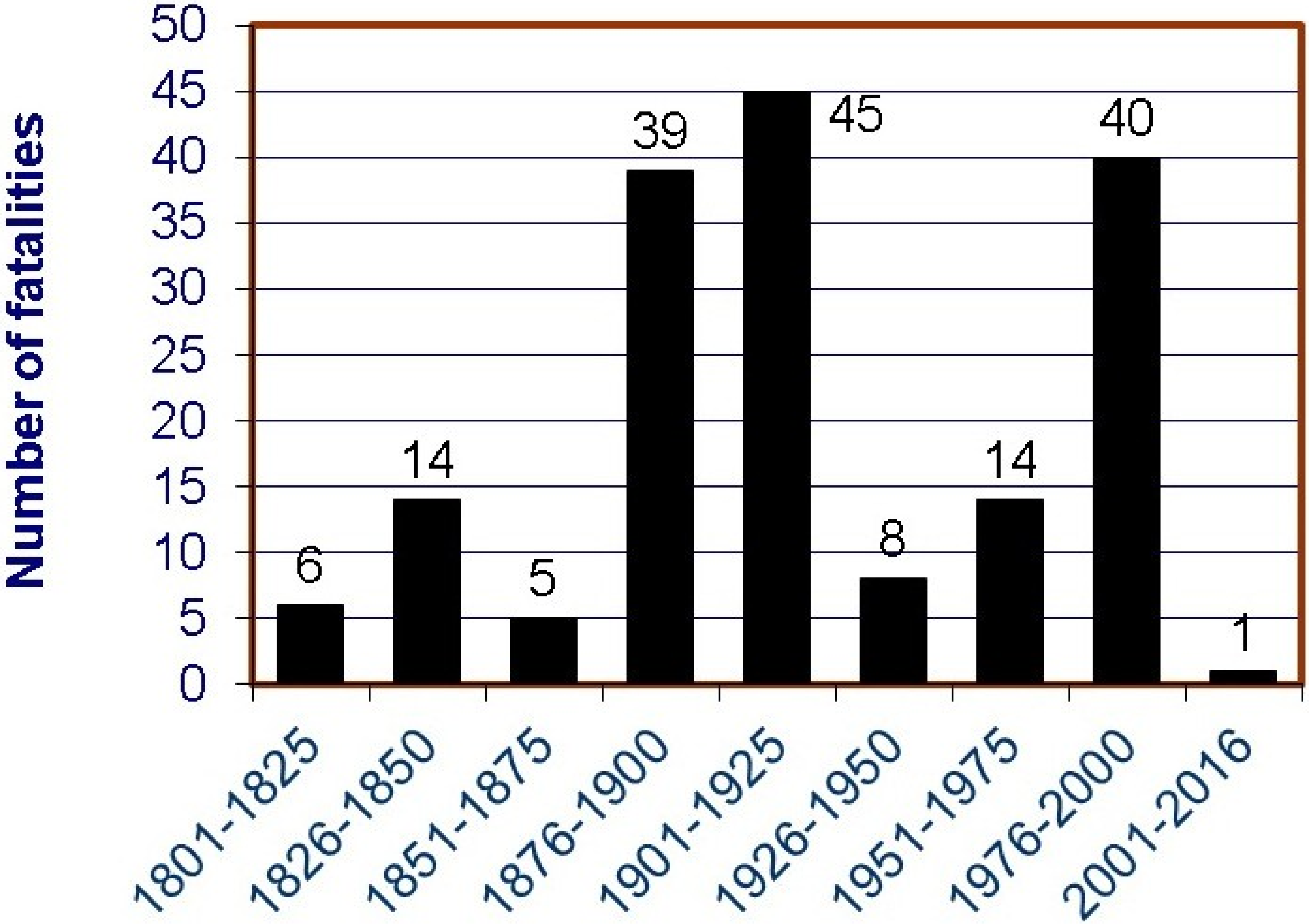
Fatal snow avalance accidents outside of inhabited areas in Iceland in the period 1801−2000

Icelandic Met Office



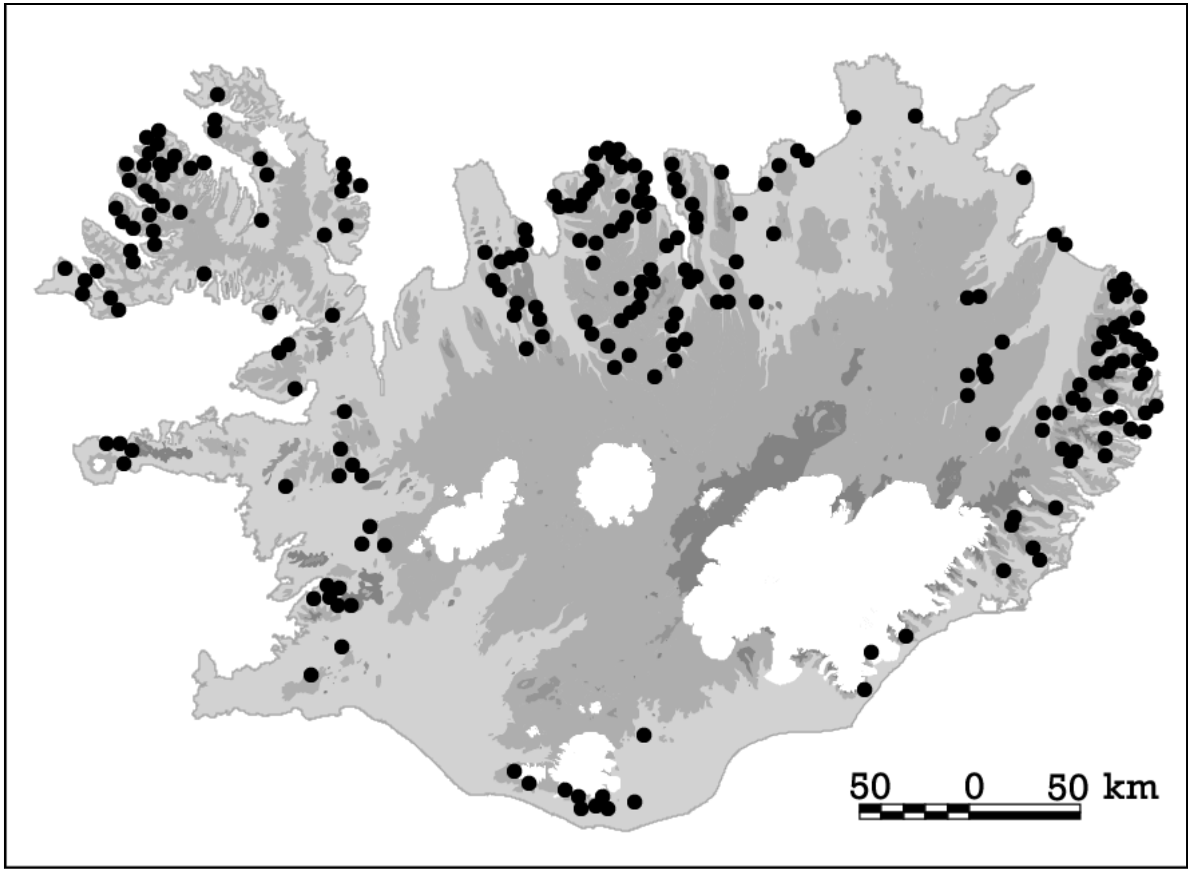
Fatal snow avalance accidents in inhabited areas in Iceland in the period 1801–2000

Icelandic Met Office



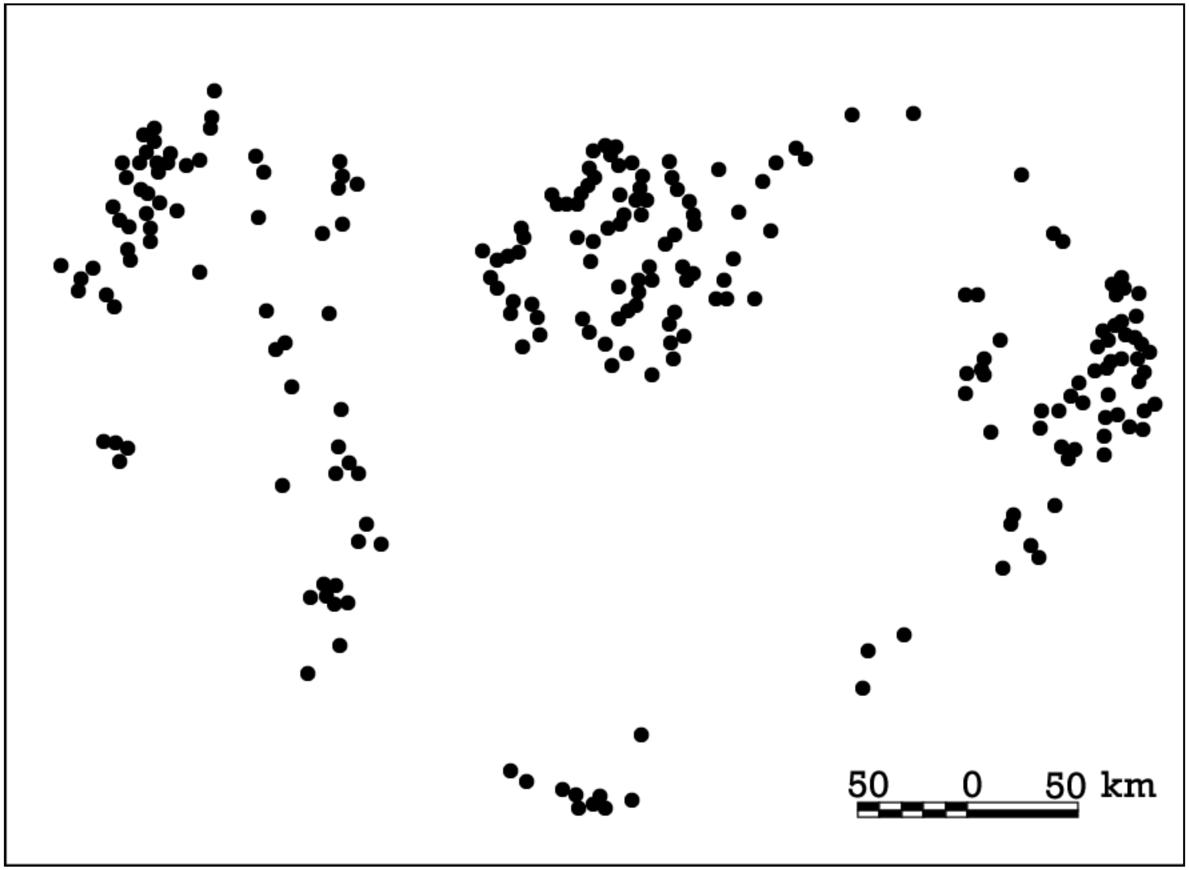
Accidents and damages due to avalanches and landslides

Icelandic Met Office



Based on Ólafur Jónsson, 1957,
and Helgi Björnsson, 1980

Accidents and damages due to avalanches and landslides



Based on Ólafur Jónsson, 1957,
and Helgi Björnsson, 1980

Economical loss due to some (large) natural disasters in Iceland

Icelandic Met Office

Data	Area	Event	Fatal-ities	Damage (million kr.)	Proportion of GDP
1973	Vestmannaeyjar	eruption	1	≈37000	60‰
20.12.1974	Neskaupstaður	avalanche	12	≈2275	3−4‰
09.01.1990	South/West Iceland	ocean flood	0	490	<1‰
03.02.1991	SouthWest Iceland	weather	0	3130	3‰
15.01.1995	Súðavík	avalanche	14	1310	1−2‰
26.10.1995	Flateyri	avalanche	20	1620	1−2‰
06.11.1996	Skeiðarársandur	jökulhlaup	0	2460	2‰
17.06.2000, 21.06.2000	South Iceland	earthquakes	0	6650	4‰
29.05.2008	South Iceland	earthquake	0	13870	8‰
Total, 1990−2015				**29530**	

Price level, Nov. 2016

General risk model for snow avalanche risk assessment in Iceland

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Risk is in general a function of

- **Hazard** (intensity/frequency): the frequency of an event with given intensity (magnitude) at a given point (time and space dependent)
- **Exposure**: The probability of an object or person being exposed to the hazard
- **Vulnerability**: The potential damage to a structure or injury to persons

Acceptable risk and hazard zoning

Icelandic Met Office

- Formal adoption of acceptable risk in terms of the probability of death due to avalanches and landslides for residences in towns and villages (0.2×10^{-4} per year)
- No account is taken of economic loss nor emergency response (evacuations)
- Hazard maps – risk lines denoting (“local”) acceptable risk and upslope areas with increasing risk

	Lower limit	Upper limit
– Zone **A**	0.3×10^{-4}	1.0×10^{-4}
– Zone **B**	1.0×10^{-4}	3.0×10^{-4}
– Zone **C**	3.0×10^{-4}	---

Exposure

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The probability of being there when an avalanche hits a residential or industrial building

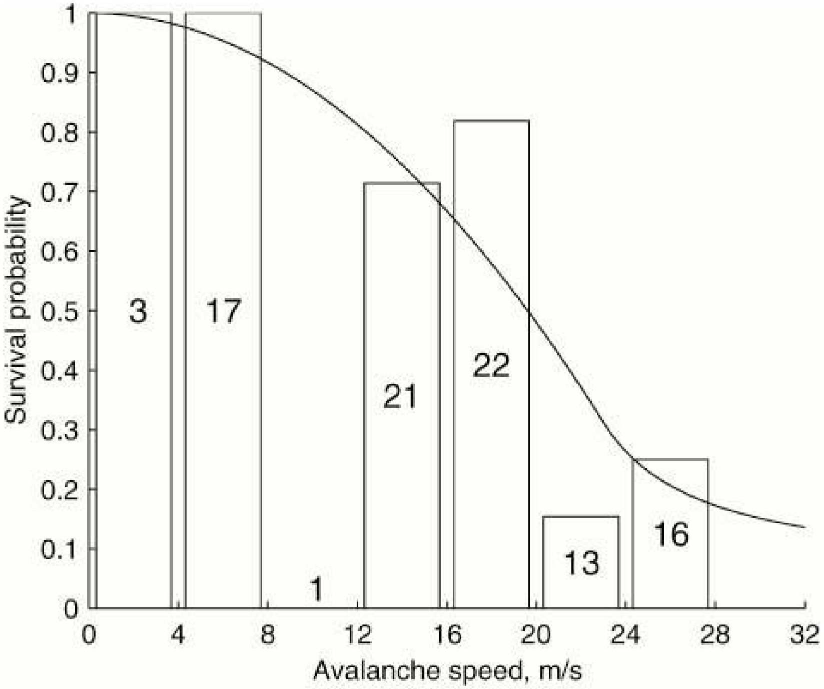
- Depends on type of building
- Average values are used
  - 75% for residential buildings
  - 40% for industrial buildings
  - other estimates where needed

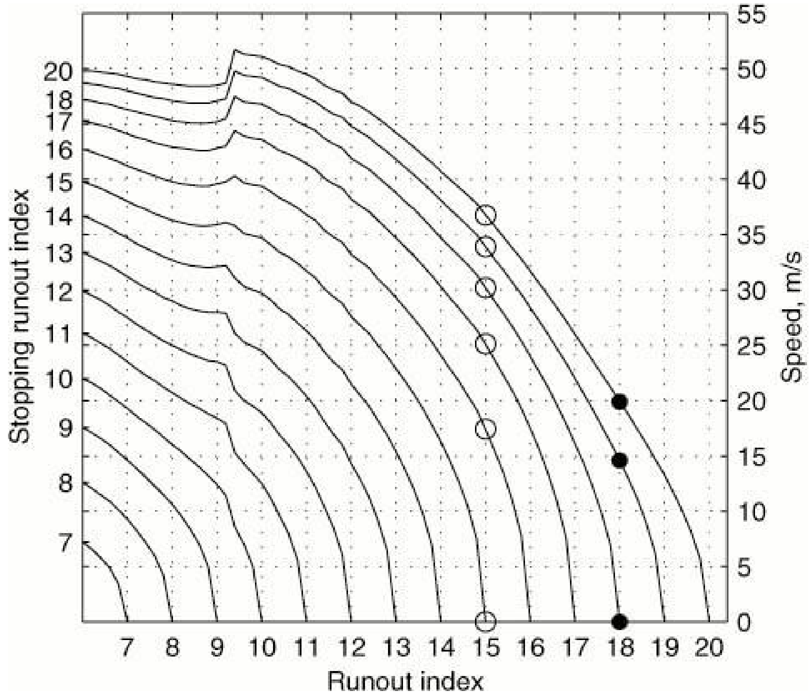
Vulnerability

The probability of being killed given that an avalanche hits your house

- Depends on size and speed of the avalanche
- Data from the avalanches at Súðavík and Flateyri are used
  - Speed of the avalanche back is calculated by the PCM snow avalanche model
  - Data fitted to a model where P(death) = f(speed)

Survival propability





The Icelandic snow avalanche risk model

$$\text{Risk at } r = F_{13} \int_{r}^{\infty} f(t)\, d(v_r(t))\, dt$$

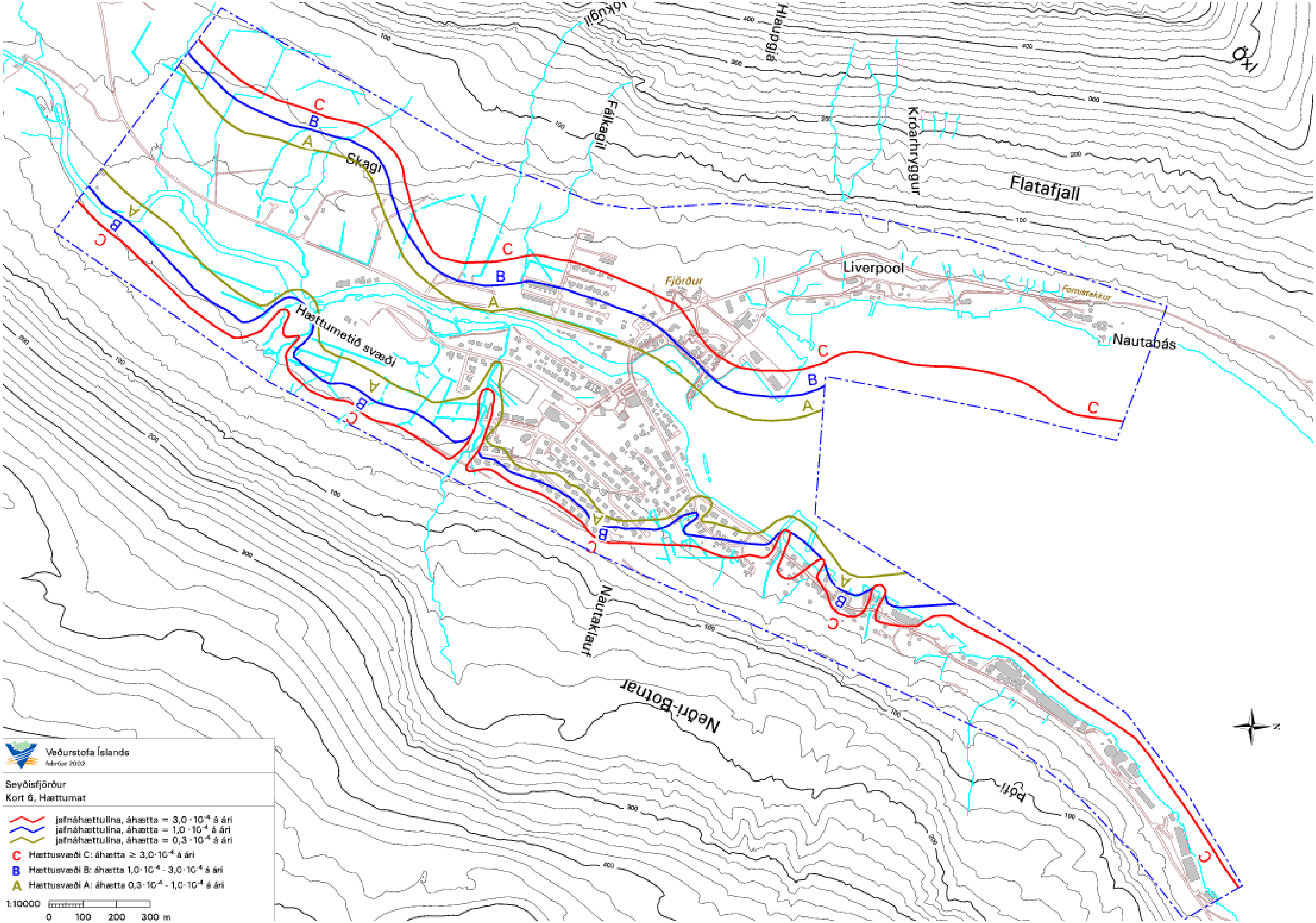
F_{13}: basis frequency

$f(t)$: probability density of runout (indices)

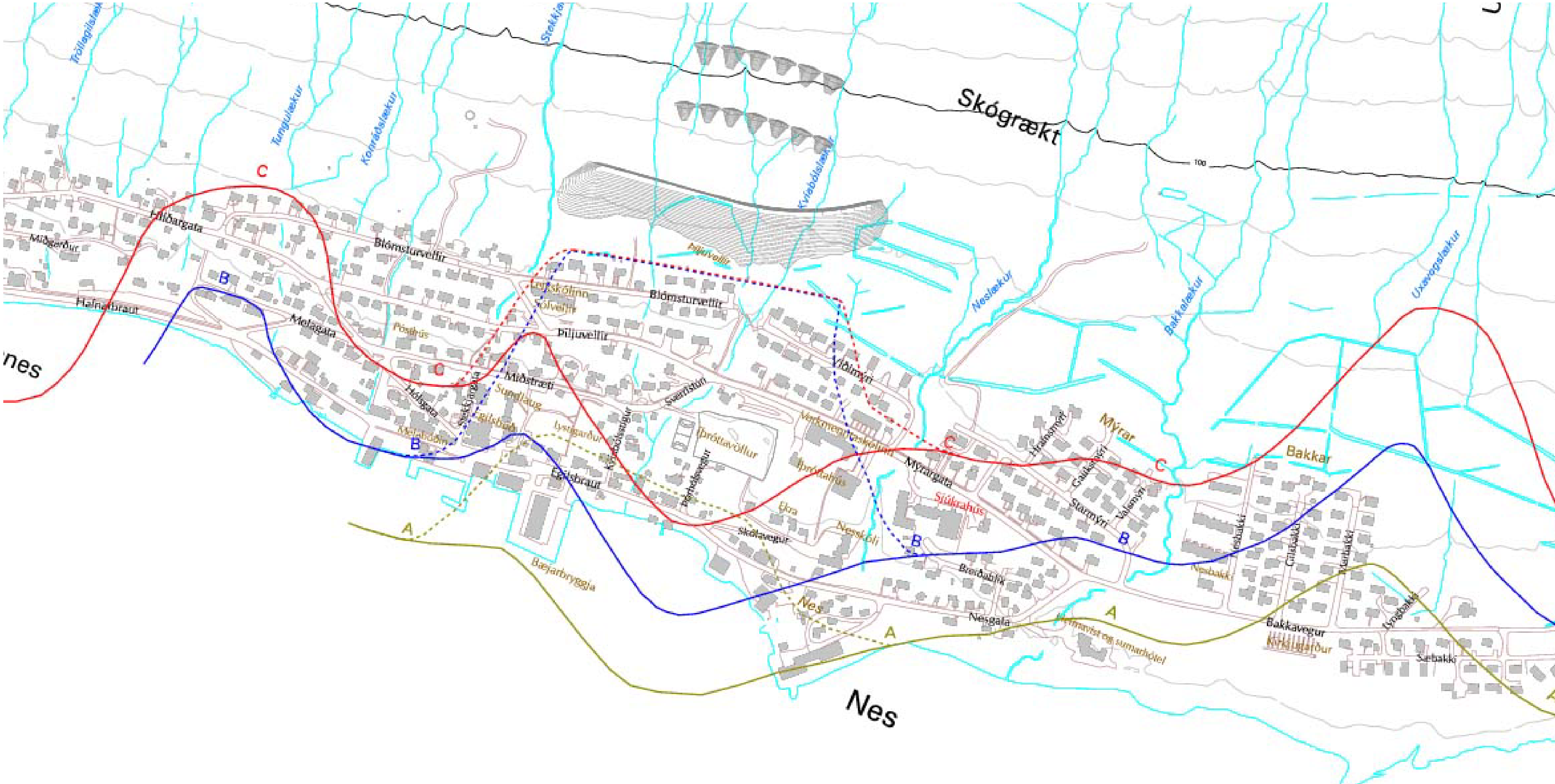
$v_r(t)$: speed of an avalanche with runout r at t

$d(v)$: probability of being killed if an avalanche with speed v hits the house

Acceptable risk 0.2·10–4 corresponds to aval. freq. (risk/exposure/vulnerability) 1:7000–1:3000 per year



Hazard zoning for Seyðisfjörður, eastern Iceland



Hazard zoning for part of Neskaupstaður, eastern Iceland

Cost of avalanche protection measures and relocation of settlements since 1995

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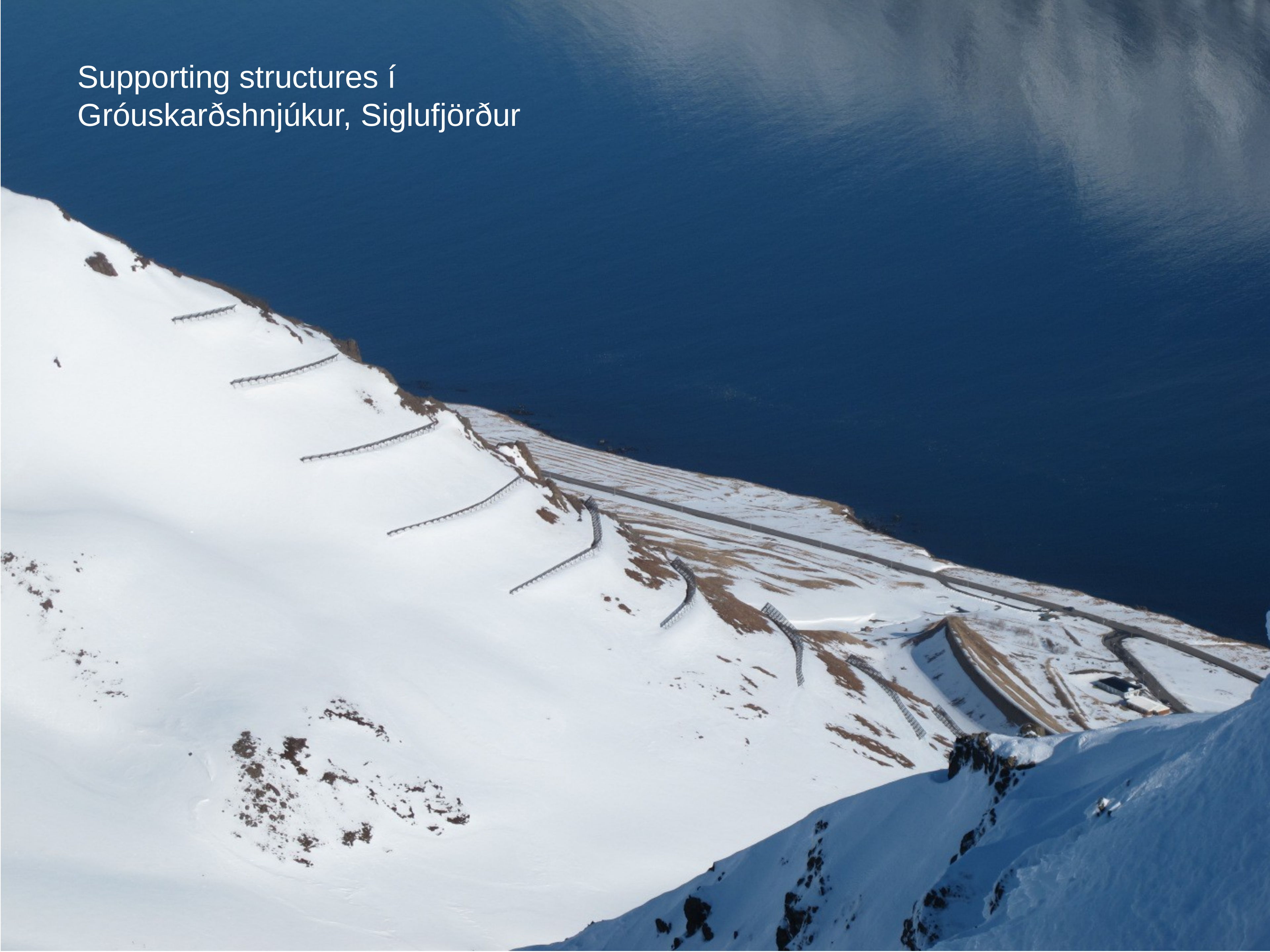
Staður	Measure	Year	Cost (million kr)
Súðavík	Relocation	1996	1753
Hnífsdalur	Relocation	1996	487
Flateyri	Deflecting dam	1997	957
Siglufjörður	Defl. dams, Strengsgil, Jörundarskál	1998	763
Neskaupstaður	Dams, mounds, supp. struct, Drangagil	2001	1189
Ísafjörður	Wedge, Funi	2002	71
Ísafjörður	Deflecting dam, Seljalandsmúli	2004	946
Siglufjörður	Supp. struct, Gróuskarðshnjúkur	2004	184
Seyðisfjörður	Catching and deflecting dams, Brún	2005	588
Siglufjörður	Catching dams	2007	1262
Bíldudalur	Deflecting dam, Búðargil	2009	335
Ólafsvík	Supp. struct., dams by river path	2009	403
Ólafsfjörður	Deflecting dam, Hornbrekka	2010	278
Bolungarvík	Catching dams	2011	1612
Neskaupstaður	Supporting structures, Tröllagil	2012	1074
Neskaupstaður	Dams, mounds, Tröllagil	2014	1739
Ísafjörður	Catching dam, below Kubbi	2013	427
Patreksfjörður	Catching dam by Klif	2014	326
Búðir við Fáskr.fj.	Measures by Nýjabæjarlækur	2014	104
Siglufjörður	supp. struct. in Hafnarhyrna, to 2015	2015	1023
Ísafjörður	Catching dam below Gleiðarhjalli	2015	714
Other	Various preparations	1995−2005	423
Total			**16655**

Price level Dec. 2015


Supporting structures í
Gróuskarðshnjúkur, Siglufjörður

Deflecting dams at Flateyri, photo: Oddur Sigurðsson

“Value” of life

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Society is saving lives all the time at considerable (but limited) cost

- ICE-SAR spent ~10000 man-hours 18−20 November 2016 to save the life of a patarmigan hunter in eastern Iceland, several such search efforts are carried out for each life saved (“equivalent” value is **several 100 millj. IKR per saved life**)
- Some cancer and heart/liver transplant patients receive treatment at the cost of **several 100 millj. IKR but not much more**

“Willingness to pay”, example from the Icelandic road network

- There are 197 single-lane bridges with total length ca. 9400 m on roads with 90 km/h max. speed in the Icelandic road network, there-off 39 bridge of length ca. 4000 m in total are located on the main ring road around Iceland
- Fatal accidents on single-lane bridges in Iceland are few and far between. One person was killed in an accident on a single-lane bridge in the period 2011−2015 and four were seriously injured
- Replacing all 39 bridges on the ring road is estimated to cost **13.2 billion IKR**, Icelandic politicians/society seem willing to do this in the next 10−20 years
- If we adopt a ~50 year time window for the useful functioning of a bridge, these numbers indicate that replacing all single-lane bridges on the ring road will save ~10 lives and prevent ~40 serious accidents over a 50 year time period, perhaps equivalent to **~23 fatalities** if we count ~3 serious accidents as one fatality

“Value”of life

The answer to the *Ultimate Question of Life, the Universe, and Everything* is, as we all know,

42

In a similar spirit the value of life, according to the previous slide, is

~500 million IKR or

~4 million Euros

If the already built and planned protection measures for snow avalanches and landslides reduce the death toll by an order of magnitude over their technical lifetime, the saved lives will come at a cost of several hundred million IKR each

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Price level, Nov. 2016

What about other natural distasters than snow avalanches and landslides in settlements?

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They are different

- Economical considerations dominate
- Acceptable risk must be primarily based on monetary considerations although risk to life is also important
- Planning of settlements is of prime importance but risk to tourists aviation, communication lines, and general functioning of the society must also be considered
- Evacuation and other emergency response to after natural disasters occur is also a critical element of general risk management

Issues to be considered regarding risk to life

- Societal risk
- Voluntary/involuntary risk
- Personal control and experience
- Short or far-reaching consequences
- The utility of the activity in question

Risk management – Quantitative approach to an unquantifiable problem

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Risk analysis requires quantitative measure of loss or benefit

- This may be *lives lost*,
- *Economic losses*, or
- *Equivalent economic losses* when all losses including lives, societal disruption, emotional disturbances, ... have been converted to monetary values (“monetized”)

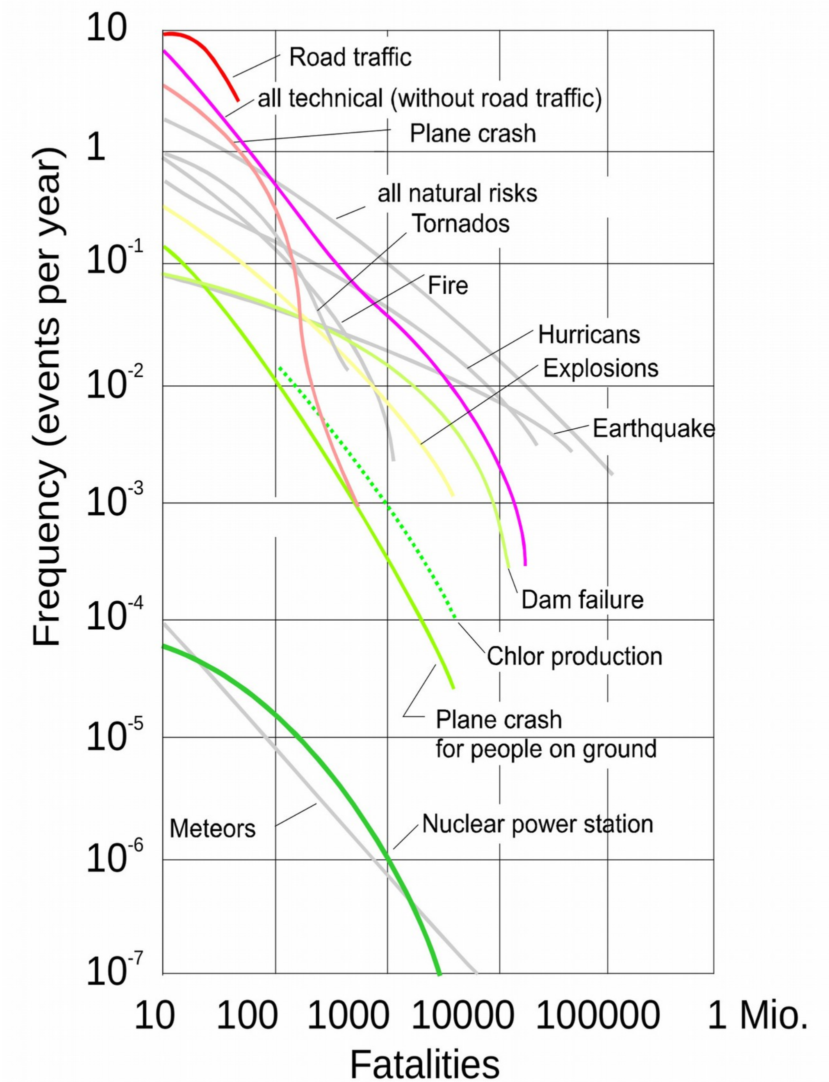
Benefit–cost analysis

- Protective measures and other efforts to reduce risk can be evaluated and prioritized based on their effect to minimize loss or maximize benefit

Very often uncertainty obscures both types of analyses

- Uncertainty about the hazard (return period, intensity, vulnerability) may one or several orders of magnitue
- Uncertainty about losses or the arbitrariness of the unavoidable assumptions also runs in the orders of magnitude
- There is also uncertainty about the effectiveness of protective efforts

Societal risk
F-N curves



Proske, 2008

Societal risk

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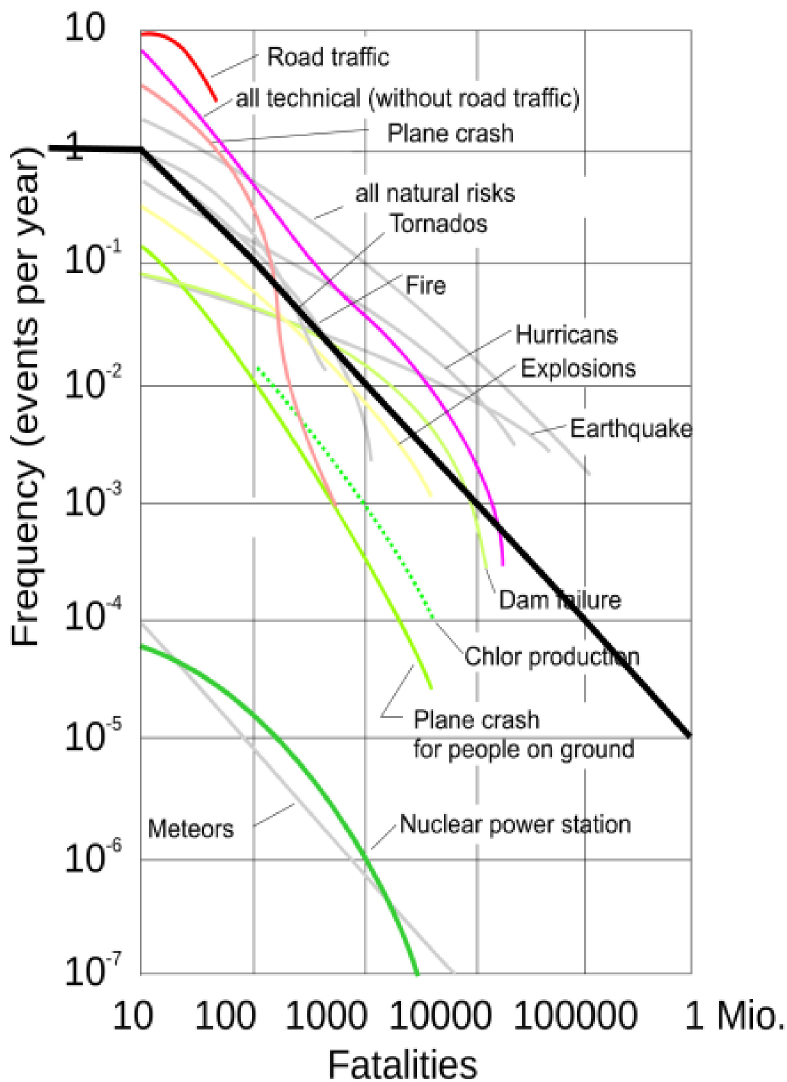

Proske, 2008
with suggested
“acceptable” risk

Ocean floods in Siglufjörður

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Ocean floods in Siglufjörður

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The town of Siglufjörður is treatened by snow avalanches and debris flows from the mountain and ocean floods and storm surges from the sea

- The floods are already a problem for part of the town
- There is substantial subsidence of the ground, particularly after the construction of large buildings or infrastructure but also generally
- There is a continuous rise in the neighbouring sea level that is forecast to continue for the foreseeable future

An analysis of the increasing flood risk by a local engineer (Þorsteinn Jóhannesson, 2010) concluded

- Buildings have to be repared at a substantial cost compared with their value if they are flooded beyond the ground level
- The present value of future costs of repairs renders a building essential worth-less if it is located where the return period of floods of this magnitude is ~15 years
- It is possible to strengthen flood protection dams and install powerful pumps to protect the area
- It may also be possible to plan for a long term raise of the ground level in this area but many concrete buildings can then not be used in the long term
- The most effective adaptation strategy is probably a combination of many types of efforts

Landslide-induced tsunami in Lake Askja in July 2014

Icelandic Met Office

Landslide-induced tsunami in Lake Askja in July 2014

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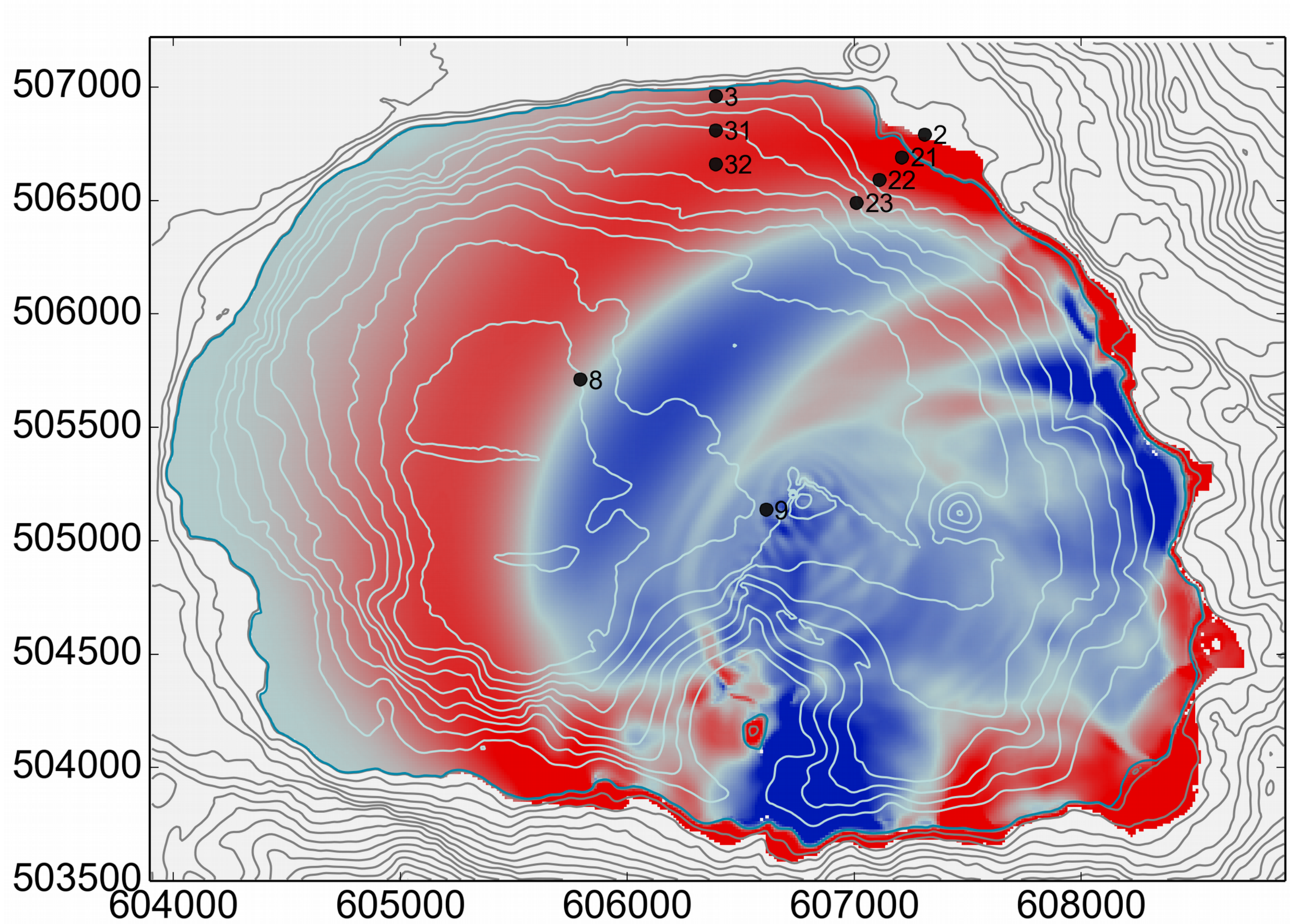

Landslide-induced tsunami in Lake Askja in July 2014

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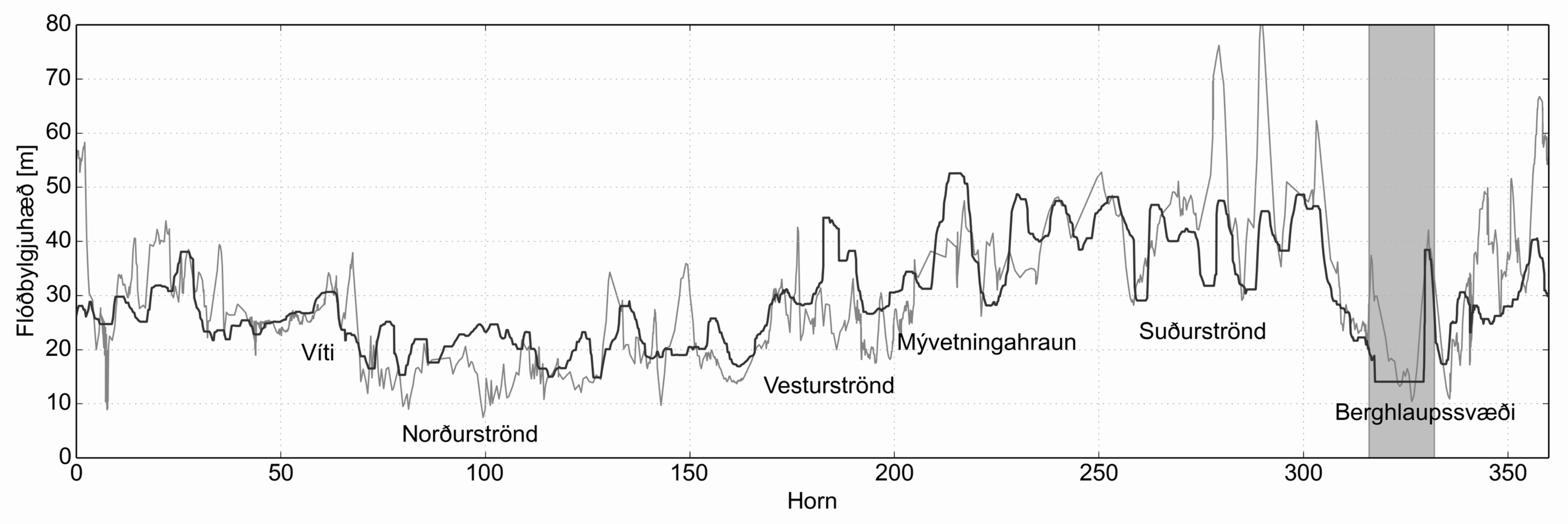

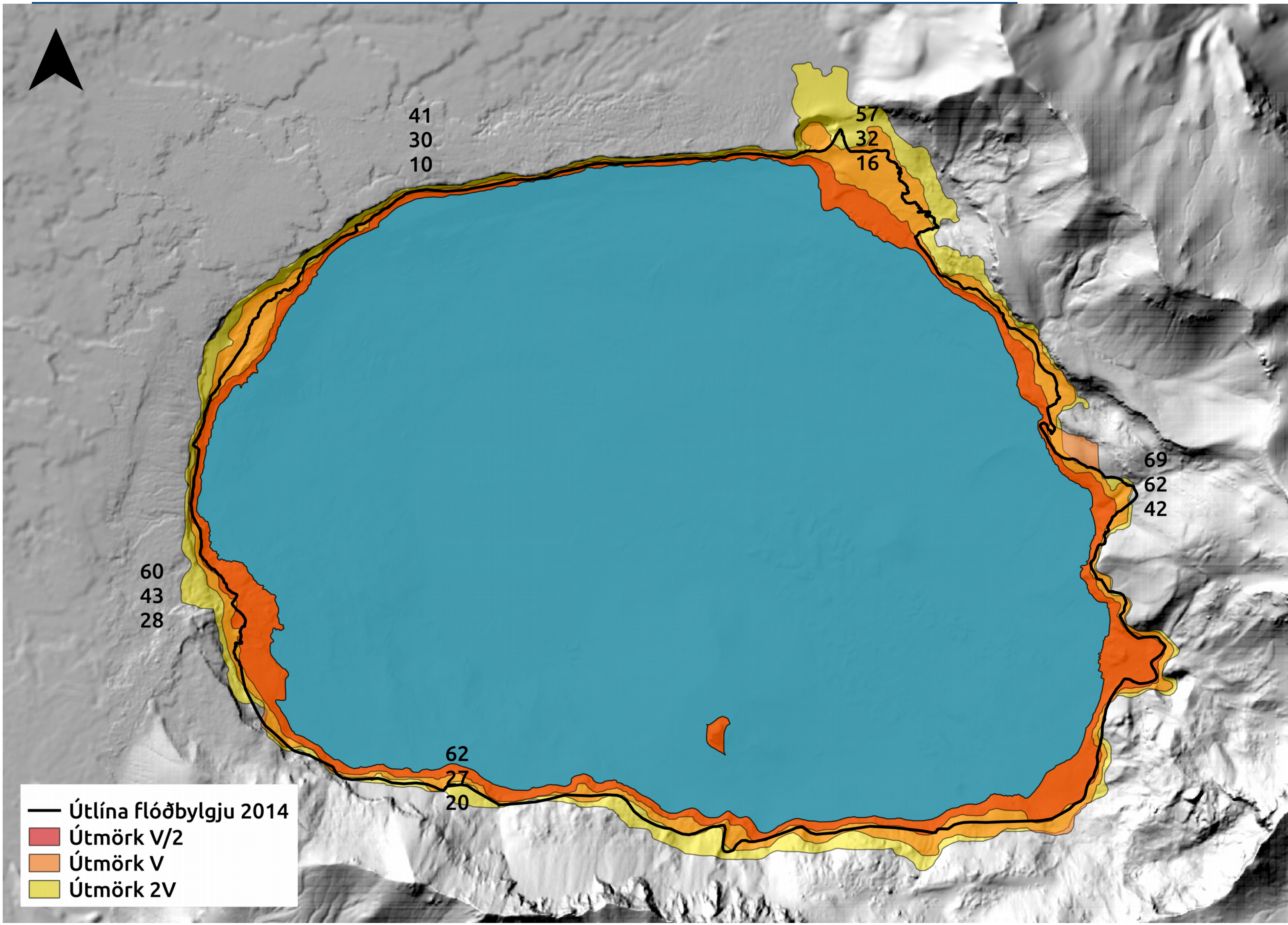
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Útlína flóðbylgju 2014
Útmörk V/2
Útmörk V
Útmörk 2V

Acceptable risk

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No definition of acceptable risk is valid for all situations

- ... but many will agree that *acceptable risk to life due to natural disasters* for each and every individial should be an order of magnitude lower than the risk due to other accidents and causes of death in society with some account taken of societal risks
- Appropriate *acceptable risk to material property* might be considered on the basis on the present value, with a suitably chosen interest rate, of required repairs or insurance compensations and other lossesthat are expected in the long term without protection measures or other actions to reduce risk
- The *acceptable risk to infrastructure*, such as power and communication facilities, is especially delicate as the indirect losses due to social disruption may be many time higher than the direct losses inflicted upon these systems, it is essential to take these indirect losses into account for proper risk management

The ALARP principle

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"… as low as reasonably practicable"

- We may not be able to quantify all the factors that determine hazards, vulnerability, protective measures, etc.
- … *but*, we can perhaps implement measures and make plans that are obviously useful where this is possible and adopt a wait-and-see approach where the uncertainty is very great
- There are several important compontents in an ALALP risk management approach
  - Long term planning of safe new settlements
  - Long term development of existing settlement aiming for improved safety
  - Proper difference between requirements to planned and exiting settlements
  - Improved resilience of power and communication systems
  - Sensible crowd management
  - Efficient emergency planning
  - Promotion of common sense at all levels dealing with risk

Common sense

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“Common sense is not so common”

Voltaire, Dictionnaire Philosophique (1764)

Common sense is not applied by default. For common sense to be used it must be consiously applied and actively promoted at all levels of societal planning