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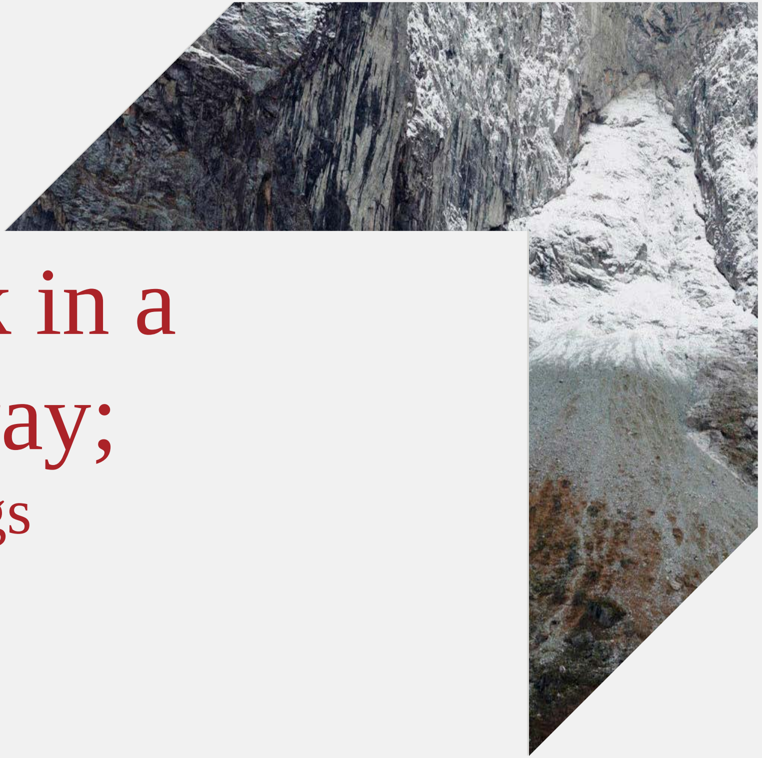


Natural hazards and risk in a changing climate, Norway;

Focus on infrastructure and buildings

Anders Solheim
Director, Natural Hazards, NGI (Norw. Geotechnical Institute)
Adj. professor, Dept. of geosciences, Univ. of Oslo

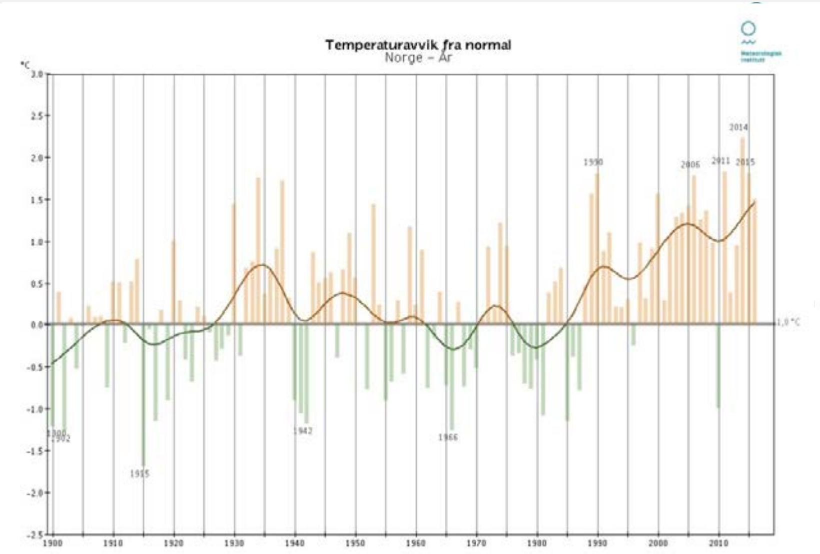
Riga, 28. April, 2017

Cotents

- Climate related natural hazards in Norway
- About risk
- Norwegian regulations
- Adaptation
  - Mapping and mitigation
- Important research

Natural hazards in Norway (and other places)

- Debris slides, debris flows, and landslides in sensitive clays (‘Quick clay’)
- Snow avalanches – Dry, wet and slushflows
- Rock slides and rock fall
- Tsunamis triggered by landslides
- Flooding, Storms and storm surge,
- Extreme temperatures



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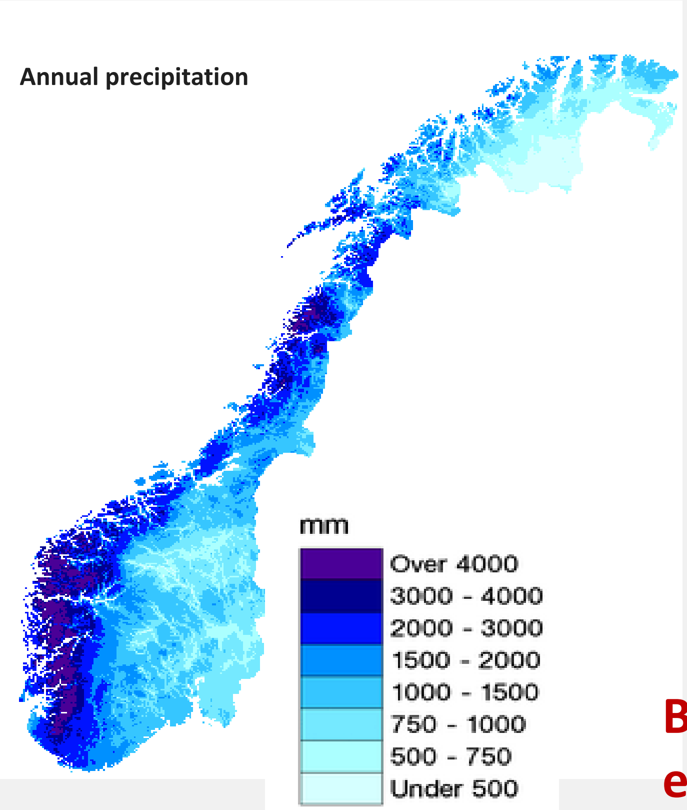
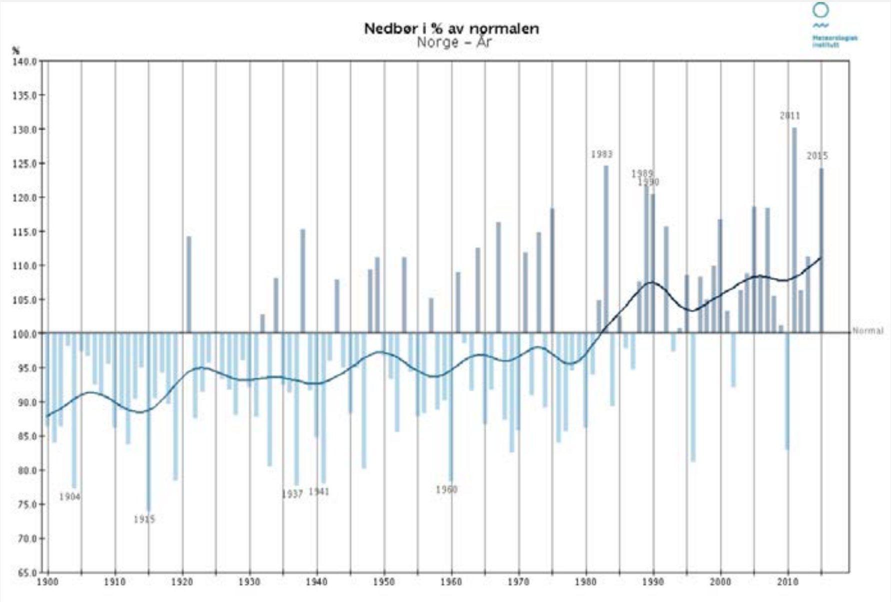
Most are climate related!

Precipitation pattern in Norway





Annual precipitation in Norway, 1900-2013
(% of ”normal” (1961-1990))

Both precipitation with long duration and short, extreme events can be critical.
<u>Today’s climate is already problematic</u>.

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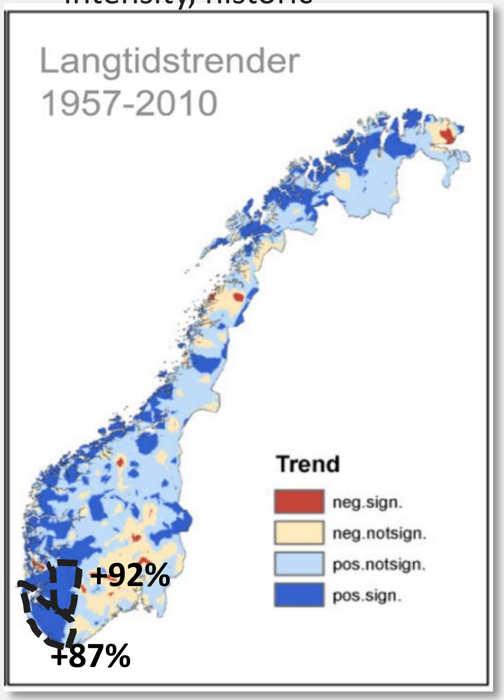
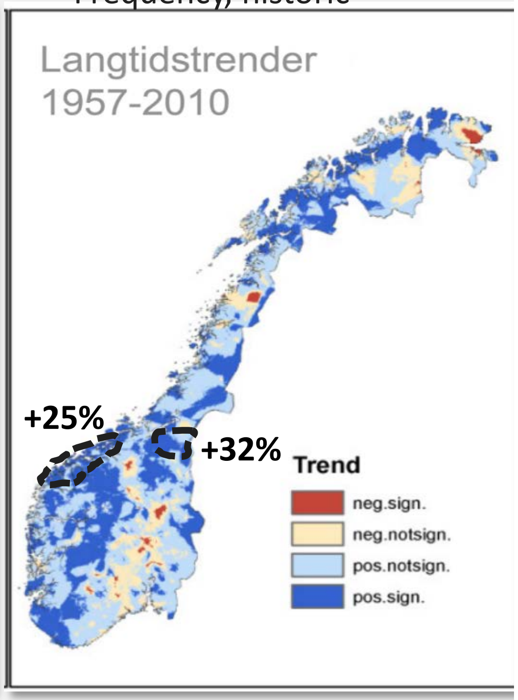
Regional precipitation trends in Norway

Intensity, historic



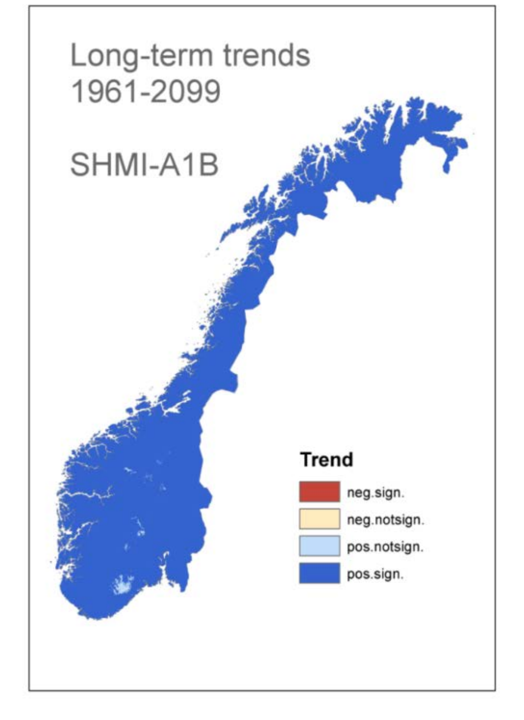
Yearly maximum 10 days precipitation

Frequency, historic



Days with >10mm «moderate to strong»

Frequency, historic + future



Days with >10mm «moderate to strong»

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Meteorologisk institutt

http://www.ngi.no/en/prosjektnett/infrarisk

Soil landslides and debris flows – major threat to the built environment,

Almost always triggered by prolonged and/or intense precipitation, and snow melt, but often assisted by human activity!

- Directly linked to weather and climate
- Ca. 125 fatalities last 150 years
- Economic loss from:
  - Damage to buildings and critical infrastructure
  - Closed roads, railroads, etc.

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..as well as to the transport infrastructure.

Flooding in village Kvam, 2011 and 2013

- Rebuilt after 2011, and hit again in 2013!
- Homes built on flood and debris flow fans are common in Norway!

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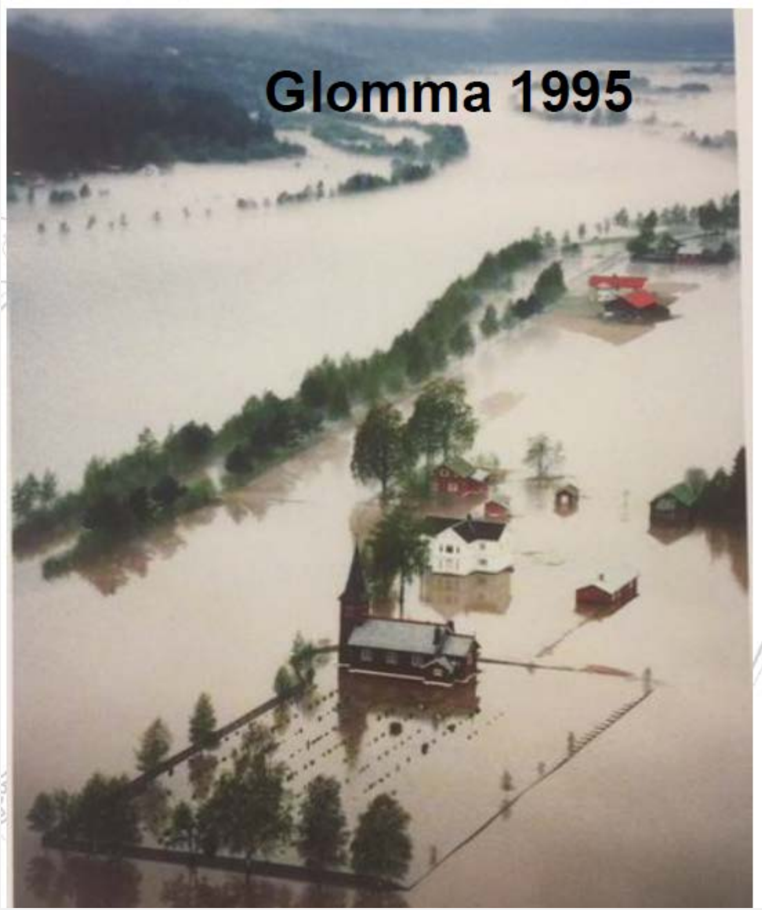
Flooding in large rivers

Situations we may see more often and not only during spring and fall.



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Flash flood, caused by heavy rain and blocked culvert

Notodden train station,
July 2011

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Quick clay: From firm clay to a ‘soup’

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Thakur and Degago (2012)

Recent quick clay slides, with large consequences!

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Rock fall – the most frequent geohazard in Norway

Budalen, Vestvågøy, July 2014

Rock fall triggered soil slide

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Rock fall to large rock slides – huge consequences

- Tsunamis from large rockslides into fjords or lakes – a major threat!
- 3 major accidents in 20th. Century, 174 deaths.

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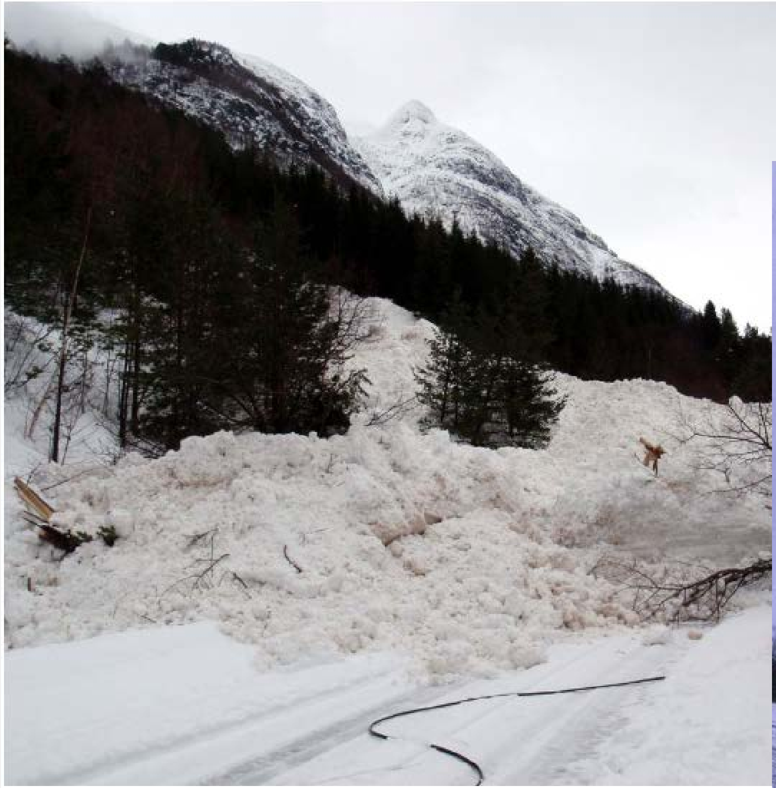
Snow avalanches – major problem for roads…..



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…as well as for the railroads,

- Derailing between Bergen and Oslo 2007 because of avalanche blocking the rails
- One measure is warning and reduced speed when hazard is high

Expected future changes

Debris slides / flows

- Most of Norway will experience more days with strong / extreme precipitation, and hence increased frequency of landslides.

Flooding

- Frequency of floods will increase and be distributed more evenly in time (other than the typical spring –and autumn floods).

Landslides in sensitive clay (Quick clay slides)

- Most quick clay slides in recent 50-60 years are triggered by human activity.
- Probability of naturally triggered quick clay slides may increase due to increased erosion from flooding in rivers and streams.

Rock fall and rock slides

- Increase in number of days with strong precipitation may lead to increased frequency of rock fall.
- More frequent freeze – thaw episodes also increase the rock fall hazard.

Snow avalanches:

- Increased frequency of snow avalanches due to more precipitation.
- There are also indications of more days with strong wind, which also may increase the avalanche hazard.
- But! Increased temperatures lead to higher snow line and also higher tree line, both decreasing the hazard for the built infrastructure.

Quantification of Risk (from an engineer's viewpoint)

Risk = f(Hazard, Consequences)

or Risk = f(H, V, (E), U)

- **H** **=** Hazard (temporal probability of a threat)
- **V** **=** Vulnerability of element(s) at risk,
- (**E** **=** Exposure of element(s) at risk)
- **U** **=** Utility (or value) of element(s) at risk

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Quantification means quantifying all these elements of risk

Risk Assessment and Risk Management

What can cause harm?	→	**Danger** identification
How often can the event(s) occur (frequency/ magnitude)?	→	**Hazard** assessment
What is at risk?	→	**Elements at risk** identification
What is the potential for damage?	→	**Vulnerability** assessment
What is the probability of damage?	→	**Risk** estimation
What is the significance of the estimated risk?	→	**Risk evaluation** (acceptable/tolerable risk)
What should be done?	→	**Decision-making** on risk treatment (mitigation)

Risk Assessment

Risk Management

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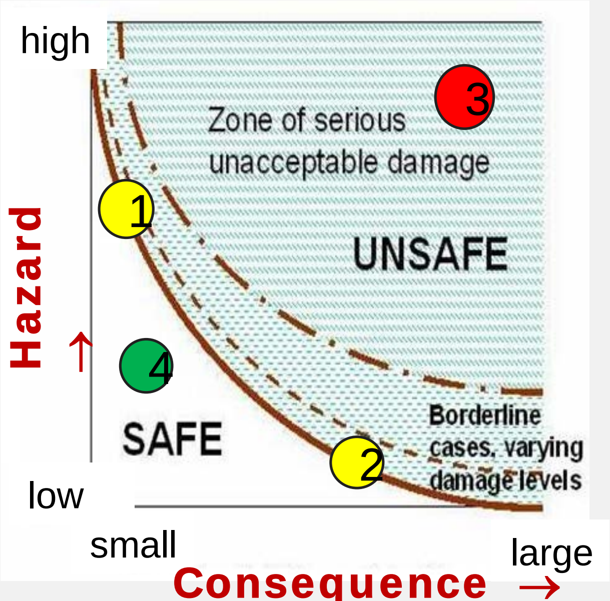
Modern risk-related challenges faced by geoscientists

- Acceptable risk concept
- Dealing with the risk posed by extreme events
- Multi-hazard, multi-risk and cascading events
- Holistic, transdisciplinary risk assessment and management
- Emerging issues:
  - Urbanisation
  - Climate change



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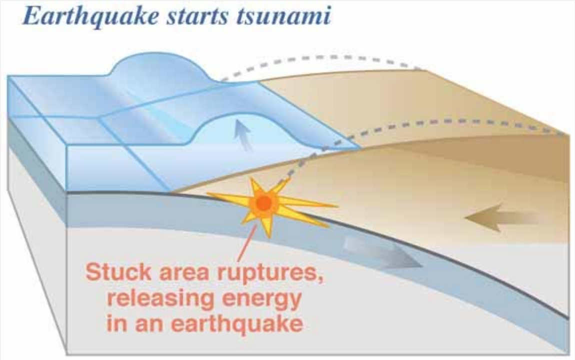
Risk acceptance

Challenge: Multi-hazards, multi-risks, dynamic vulnerability, cascading events

- Example: Great East Japan (Tohoku) Earthquake and Tsunami of 11th March 2011

Earthquake → Tsunami → Nuclear accident



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Risk reduction = adaptation

Risk = Hazard (probability) x consequences

(or Risk = H · V · (E) · U)

- Mapping
  - National, Regional or detailed mapping
  - Unsafe and safe areas
- Awareness
  - Knowledge and awareness
  - Monitoring and Early warning
  - Evacuation and rescue plans
- Measures
  - Physical mitigation measures (barriers, nets, etc..)
  - Non-physical measures; road closures, reduced speed on railway, etc.
  - **Proper land use planning and safe location of critical infrastructure.**

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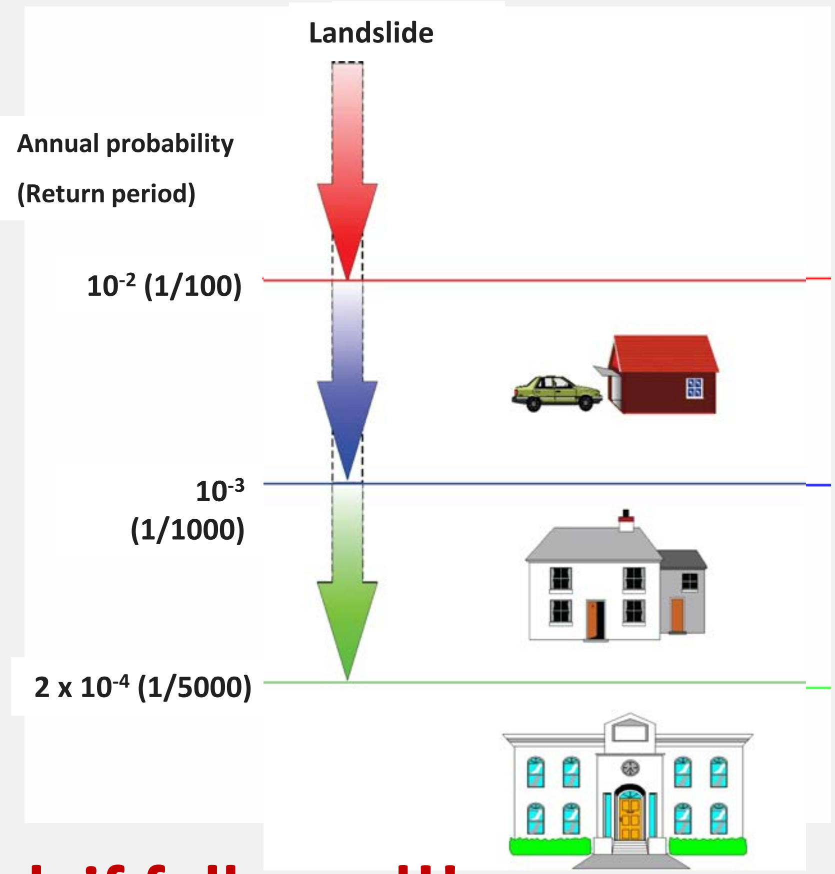
The Norwegian Planning and Building Act

- Definition of acceptable hazard for different types of buildings
- Based on annual probability (recurrence interval)
- Only for new buildings.



Equivalent for flood hazard

Safety class, flood	Consequence	Largest annual probility
F1	Small	1/20
F2	Medium	1/200
F3	Large	1/1000

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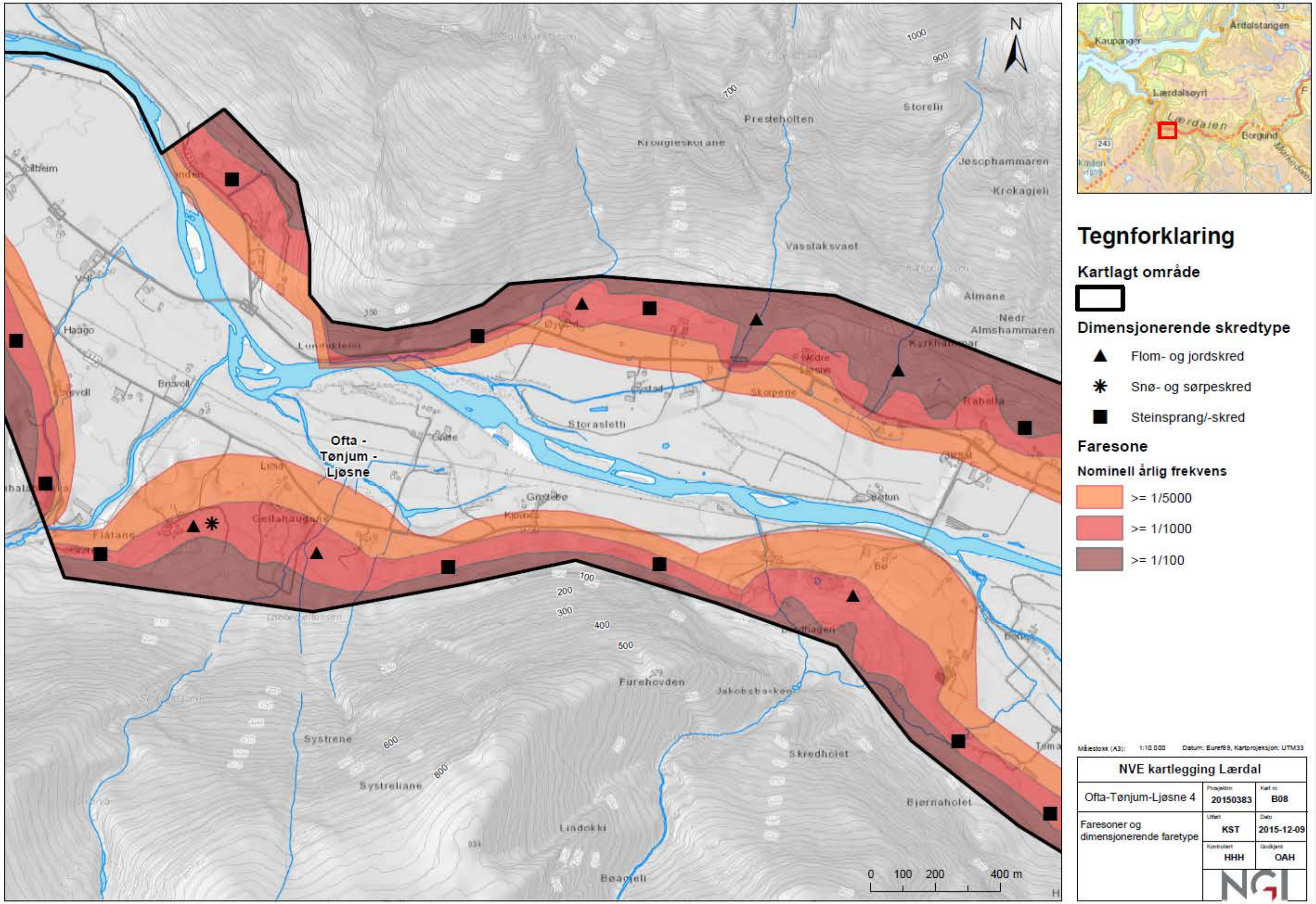
The PBA is a very good tool, if followed!!

Mapping of landslide and snow avalanche hazard, Lærdal, Norway.



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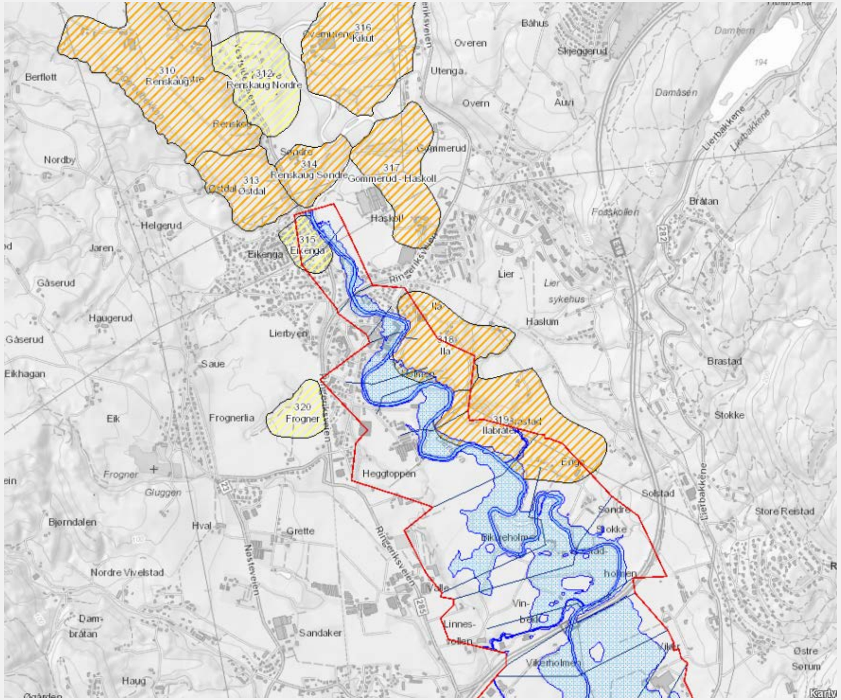
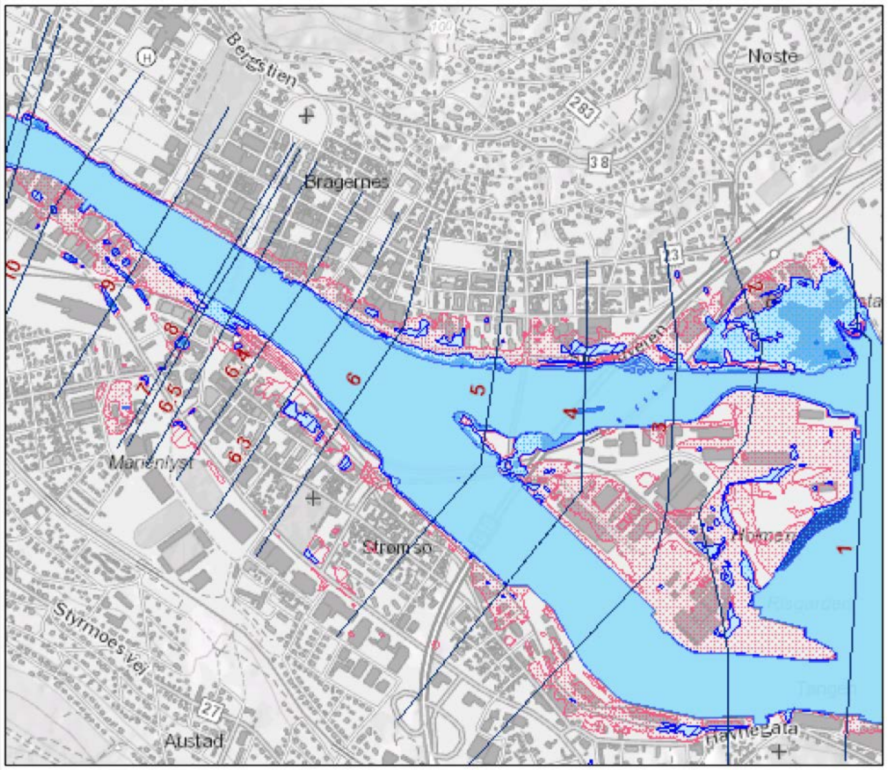
Mapping flood and quick clay hazard

Quick clay hazard and 200 year flood



200 year flood zone now, and in 2100, Drammen City



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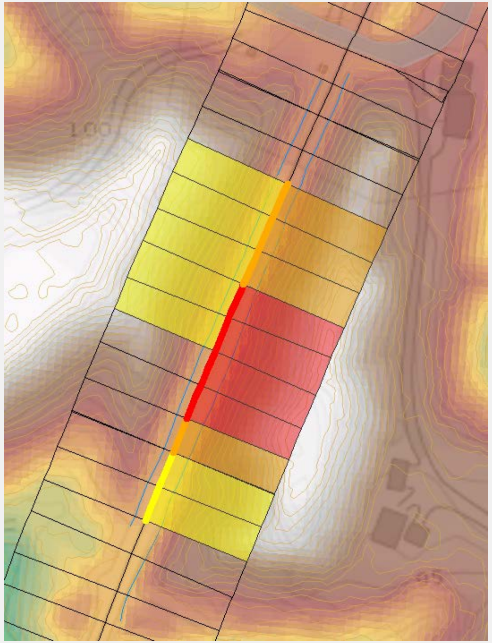
Railroads (and other linear infrastructure)

- Railways of Norway
  - 4219 km
  - Norwegian National Railroad Administration
  - **Much of the railroad network is 50-100years old!**

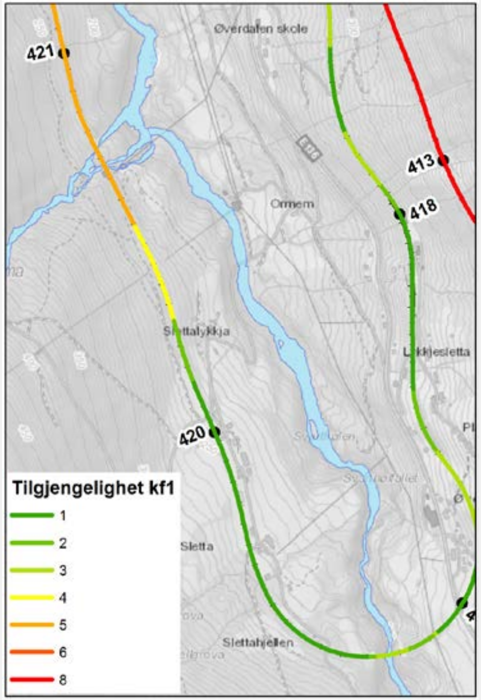
- Challenging environment
  - Flooding
  - Landslide
  - Avalanche
  - Rock fall

Risk mapping along the railroad; ‘the NGI method’

Combines a series of parameters for hazard and consequence and provides maps for each km. The GIS analyses is followed up by field work at the hotspots.

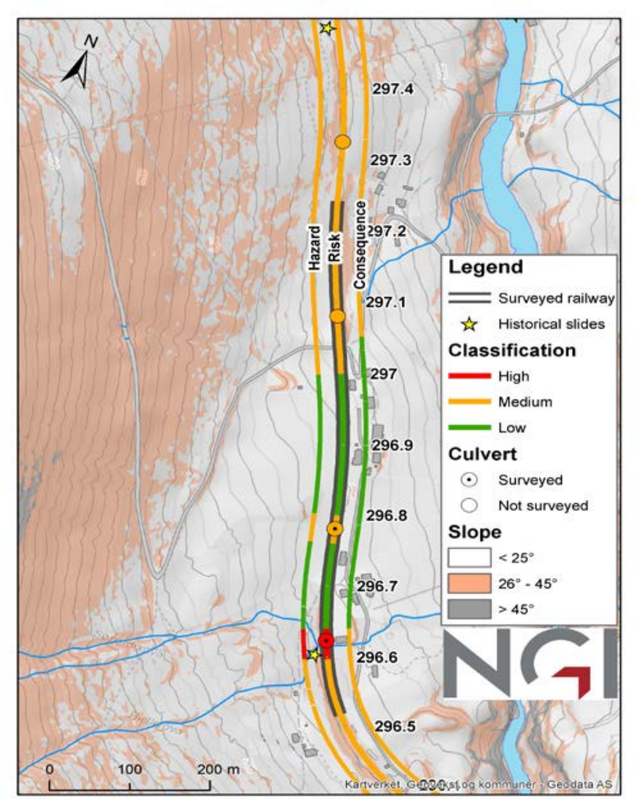


Landslide hazard



Accessibility (vulnerability)

Result, risk assessment



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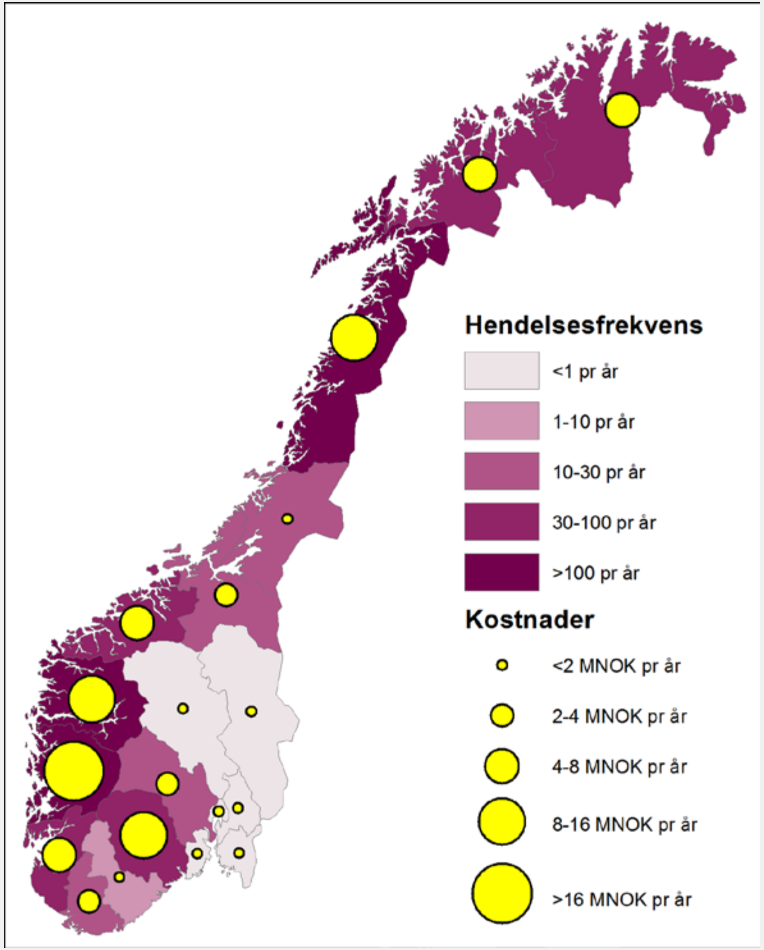
Annual road closures caused by natural hazards, Norway

- All types of landslides and snow avalanches for the entire road network.
- Based on registered events in the period 2000 – 2010
- Largest cost related to delays and detours
- Most likely underestimated costs
- Joint planning for road and railroad development important.



http://www.ngi.no/en/prosjektnett/infrarisk

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°CICERO Senter for klimaforskning

The 'SafeLand Project':

Living with landslide risk in Europe: Assessment, effects of global change, and risk management strategies.

http://esdac.jrc.ec.europa.eu/projects/safeland

- EC Call 2008 – Prediction of triggering and risk assessment for landslides (in a global change perspective)
- 27 partners from 12 countries
- More than 25 End-users from 11 countries
- Coordinated by NGI/ICG (Norway)
- Total funding € 8.6 mill
- Project duration: 1 May 2009 – 1 May 2012

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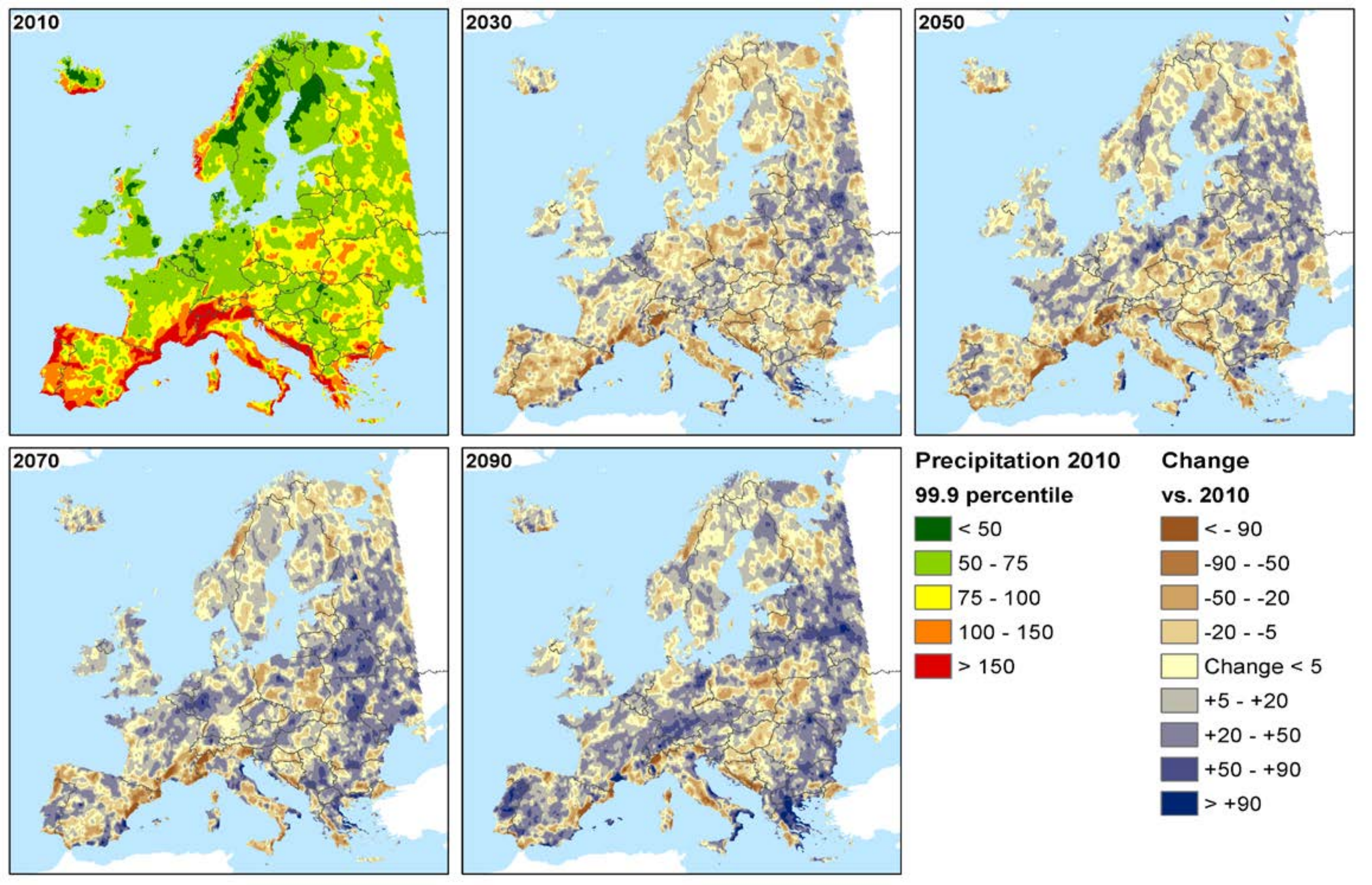
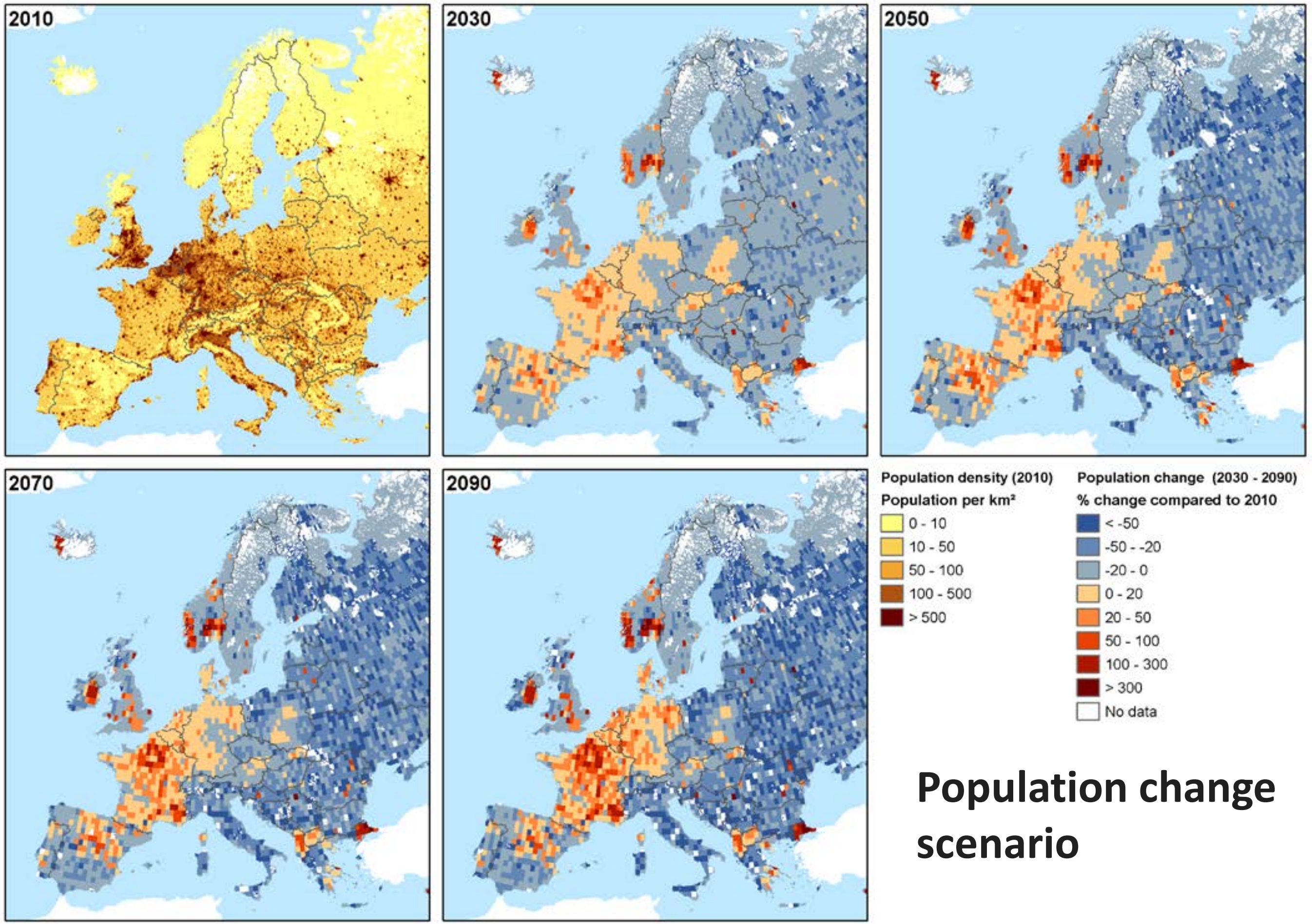
Main SafeLand research topics

- The effect of climate change and human activity on landslide frequency
- Forecast landslide hazard and detect high-risk zones
- Quantify triggering mechanisms and model run-out
- Develop a generic QRA framework for improved risk management
- Develop guidelines for use of remote sensing techniques, monitoring and early warning systems
- Develop decision-support tools to choose an appropriate set of mitigation and prevention measures

SafeLand - Climate change scenario for 21st century

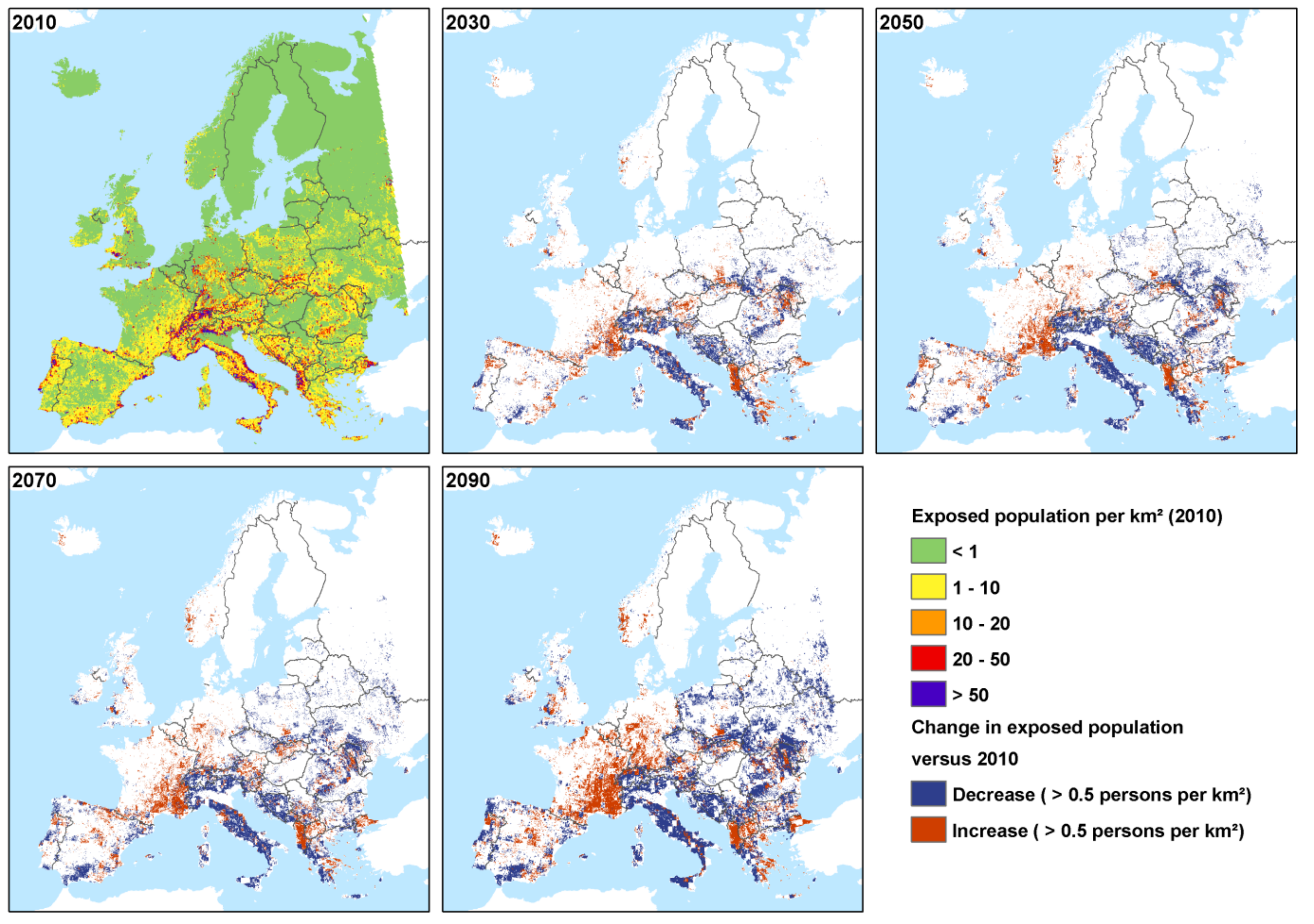


SafeLand – Demography scenario



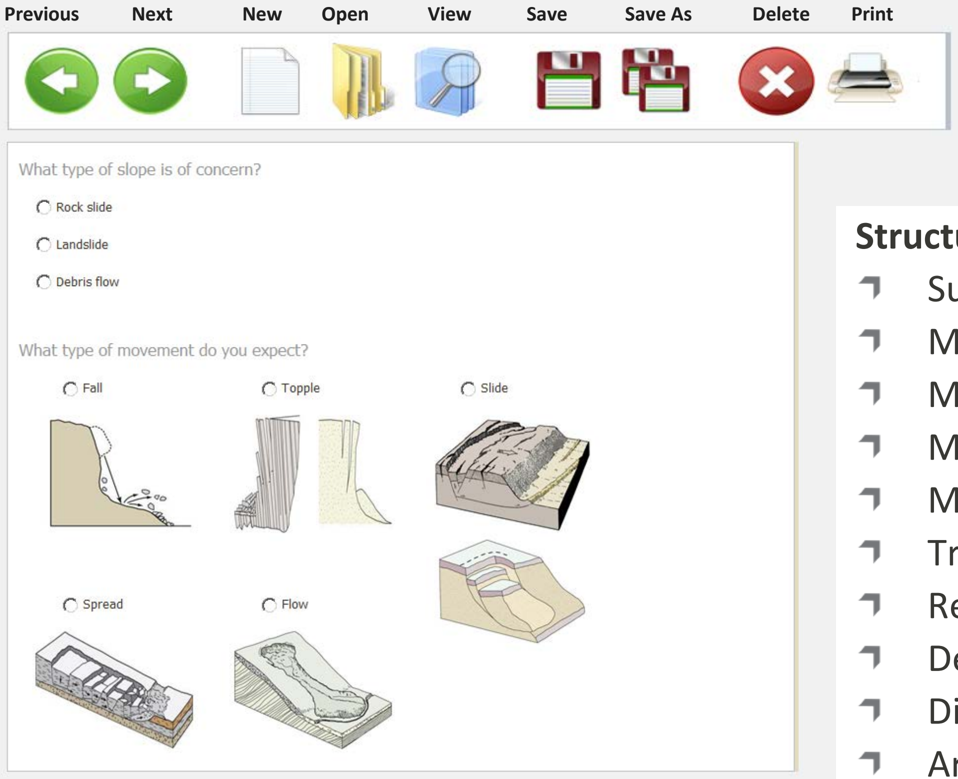
Population change scenario

SafeLand - Change in population exposed to landslides



SafeLand - Web based toolbox of mitigation measures

Example web page



Soon to be released on the web.

Structural measures included

- Surface erosion and surface erosion control
- Modifying slope geometry
- Modifying surface drainage
- Modifying groundwater regime – deep drainage
- Modifying mechanical characteristics of unstable mass
- Transfer of loads to more competent strata
- Retaining structures
- Deviating the path of landslide debris
- Dissipating the energy of debris flows
- Arresting/containing landslide debris or rockfall

Mitigation to protect important infrastructure.

Gudvangen

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Other structural measures

- At present, great focus on **green, nature based solutions,** also in major calls from EU-H2020 and the RCN

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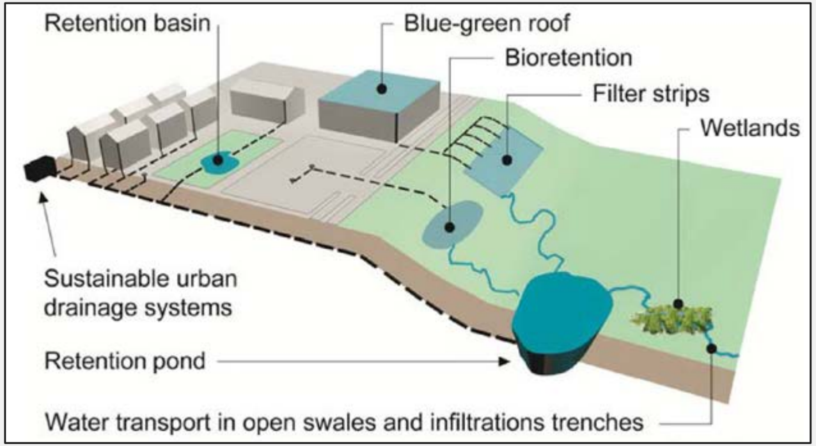
RCN: Center for Research Based Innovation (SFI): **'KLIMA2050'**

- Risk reduction through climate adaptation of buildings and infrastructure
- 20 Partners from research, public sector, and industry.
- 8 years; 2015-2023
- Total budget NOK 221 mill. (24 mill. EURO)

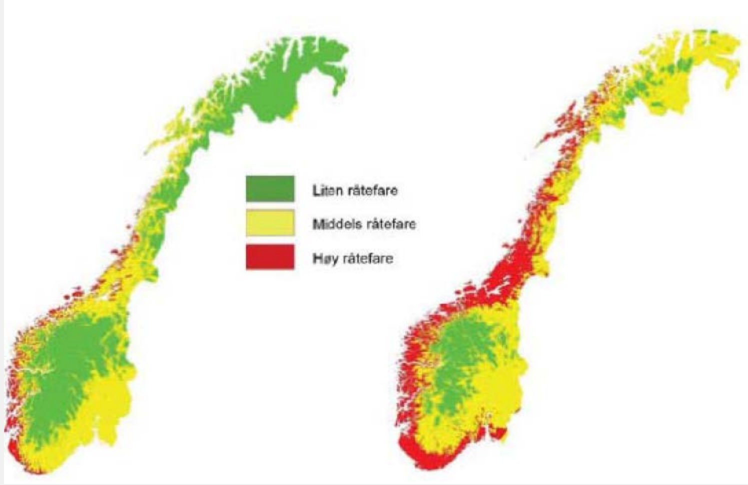
WP 1: Climate adaptation of buildings
WP2: Urban flooding
WP3: Water triggered landslides(NGI)
WP4: Management and decsision processes



NGI **www.klima2050.no**

KLIMA2050 – stormwater management and buildings

Wood rottening hazard



1961-1990 **2071-2100**

Much of the Norwegian building stock is wooden. Need to build smarter in the future.

WP3 Sub-work packages

- WP3.1 – Development of analytical and numerical codes
- WP3.2 - Environmentally sustainable methods for improving drainage and stabilizing soil and rock slopes
- WP3.3 - Protection of critical infrastructure (CI) from landslides
- WP3.4 - Early warning systems (EWS)
- WP3.5 – Management of landslide risk

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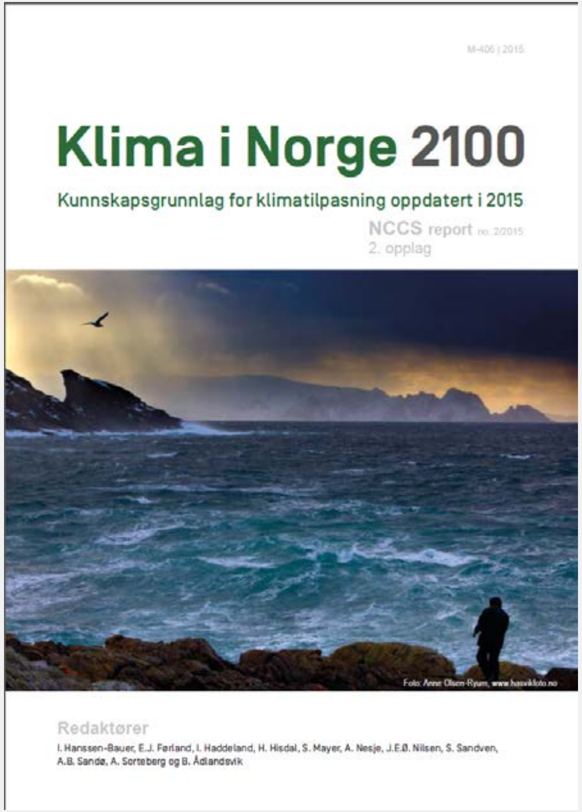
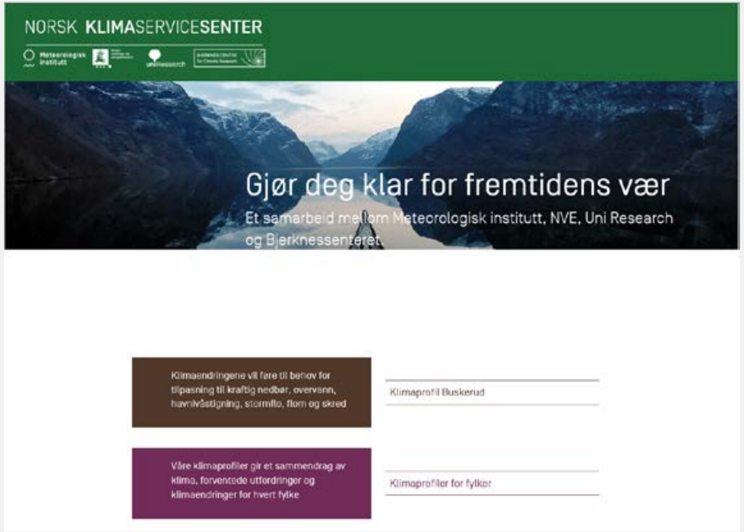
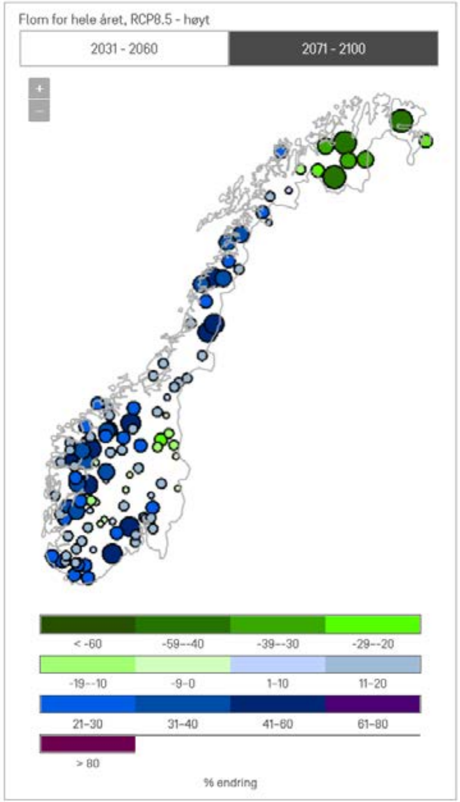
Important tools for local and regional authorities





Climate profiles for each county and for ‘your location’, based on current knowledge.

Flood hazard, 2071-2100



Important tools for regional and local planners

Klimaprofil Sør-Trøndelag

Jan.2016

Forventa klimaendringer fram til år 2100

Klimafaktorer: Hoved-årsak	Klimafaktorer: Klimarelatert hendelse	Hendelser - detaljer	Forventede endringer i klima Klimaprofil Sør-Trøndelag 2016
Økt nedbør	Ekstrem nedbør	Oversvømmelse/overvann	Økt sannsynlighet
	Flom	Regnflom	Økt sannsynlighet
		Snøsmelteflom	Uendret/ mindre sannsynlighet
		Isgang	Mulig økt sannsynlighet
	Skred fra fjell	Steinskred	Usikkert
		Fjellskred	Usikker
	Skred i løsmasser	Jordskred	Økt sannsynlighet
		Kvikkleire-skred	Usikkert
	Skred i snø	Løssnø/flak	Mulig økt sannsynlighet
		Sørpe	Økt sannsynlighet
Økt vind	Sterke vinder		Usikkert
	Stormflo		Økt sannsynlighet
Varmere klima	Økt lokal temperatur		Inngår ikke i Klimaprofil-16
	Tørke		
	Havstigning		

Klimaprofil for 9 fylker ferdig:

Finnmark – Troms - Nordland
N.- S. Trøndelag
Sogn- og Fjordane - Hordaland

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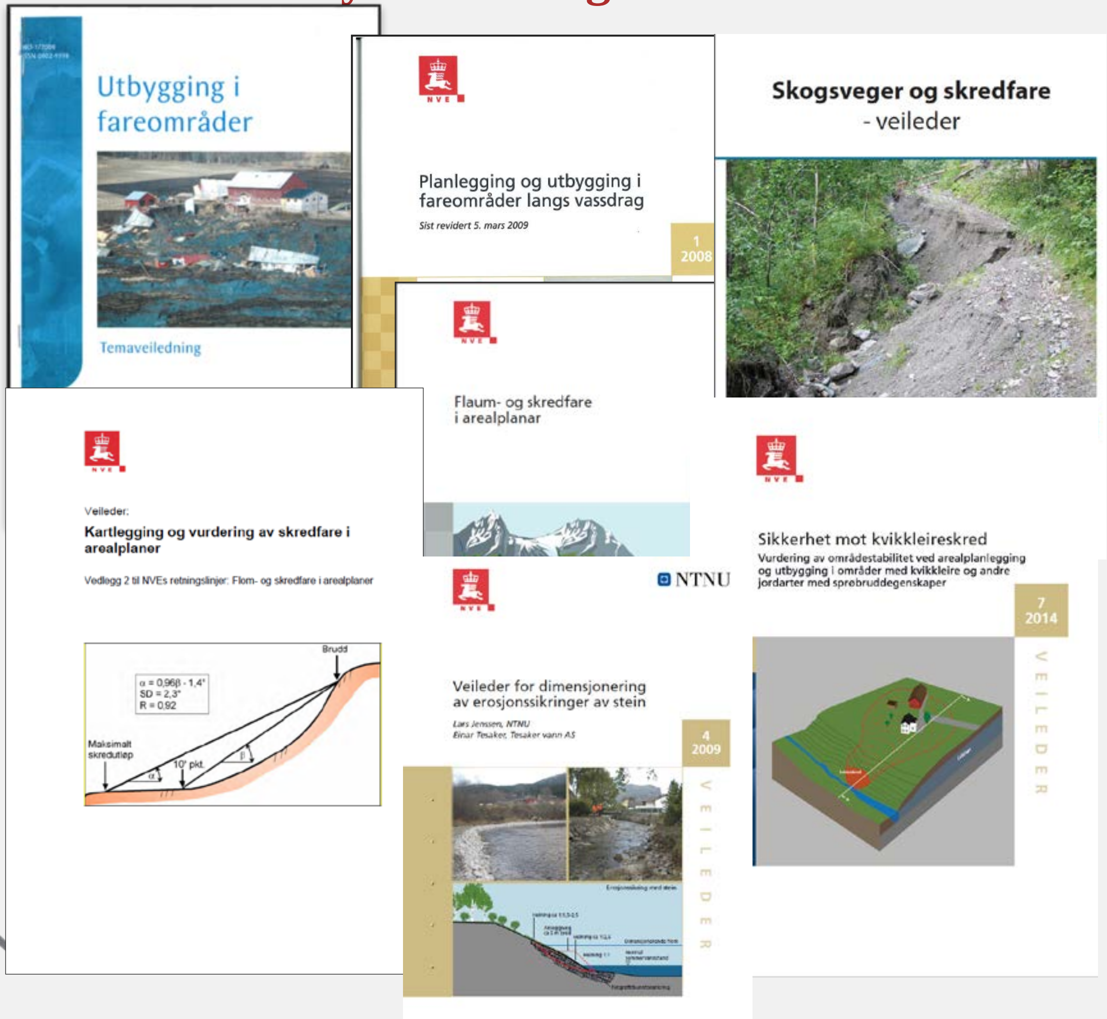
Publicly available guidelines and recommendations



<u>Advice to municipalities:</u>

- Follow the guidelines
- Use expert advice through through the entire process of land use planning.
- Assess larger areas and the possbility for multiple problems (multi-hazards).
- Regular control of all measures.

Some take-home messages

- Norway is a steep country, with lots of weather, and natural hazards will always be present.
- Climate change leads to more frequent landslides and floods.
- Risk can be reduced, but not eliminated!
- Best adaptation measure is proper land use planning and building techniques, with 'climate effect added' on most dimensions.
- If current rules, regulations, guidelines are followed, we have come quite far.
- Research is crucial, with active stakeholder involvement as a very important factor.
- Still, the 'mitigation business' faces prosperous times!

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THANK YOU!