NVE

Jernbaneverket

Statens vegvesen

NIFS final report 2012 - 2016

The Natural Hazards program

Aunaas, Dolva, Humstad, Myrabø, Petkovic, Thakur, Viklund, Øvrelid & Øydvin

92
2016

RAPPORT

NIFS
NATURFARE
INFRASTRUKTUR - FLOM - SKRED

Rapport nr 92-2016
NIFS final report 2012 - 2016

Published by: Norwegian Water Resources and Energy Directorate

Editor: Bjørn Kristoffer Dolva

Authors: (JBV) S. Myrabø, M. Viklund, (NVE) K. Øvrelid, E.K.Øydvin, (SVV) G. Petkovic, T. Humstad, K. Aunaas, V. Thakur, (NIFS) B. K. Dolva

Print: NVEs hustrykkeri
Number printed: 100
Cover photo: Infrastructure challanged by quick clay slide (NPRA, 2015)
ISBN 978-82-410-1546-5
ISSN 1501-2832

Abstract: This final report gives a broad overview of the NIFS program. The R&D program was set up as a joint initiative between the Norwegian National Rail Administration (NNRA), the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Public Roads Administration (NPRA). These agencies have faced major common challenges, and a good collaboration is both cost-effective and competence-building for the organisations. The programme was carried out during the period 2012–2016.

Key words: avalanche, flood, hazard mapping, implementation, land use planning, monitoring and forcasting, preparedness, quick clay, safety measures, slide

Norwegian Water Resources and Energy Directorate
Middelthunsgate 29
P.O. Box 5091 Majorstua
N 0301 OSLO
Norway

Telephone: 22 95 95 95
Fax: 22 95 90 00
E-mail: nve@nve.no
Internet: www.nve.no

December 2016

Foreword

The NIFS programme was set up as a joint initiative between the Norwegian National Rail Administration (NNRA), the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Public Roads Administration (NPRA). The agencies have faced major common challenges, and a good collaboration is both cost-effective and competence-building for the organisations. The programme was carried out in the period 2012–2016.

The aim of NIFS has been to develop good, effective and forward-looking solutions for handling different natural hazards and contributing to enhanced civil protection. Through the R&D programme, various issues relating to floods and landslides/avalanches have been reported and documented. The results are of value to exercising the agencies' social mandate. Responsibility for implementation of the results and concrete recommendations rests with the respective agencies.

The agencies' steering group was composed as follows:

- Anne Britt Leifseth, Director of NVE's Landslide/Avalanche and Watercourses Department.
- Marit Brandtsegg, Director of the Directorate of Public Road's Traffic Safety, Environment and Technology Department under the Norwegian Public Roads Administration.
- Brede Nermoen (2013–2015), Acting Technology Director/Project Director, Norwegian National Rail Administration and Sverre Kjenne (2012–2013), Technology Director, Norwegian National Rail Administration.

The chairmanship of the steering group has rotated between its members. Bjørn Kristoffer Dolva has been project manager and Marie Haakensen has been project secretary. Brigt Samdal (NVE), Roald Aabøe (Norwegian Public Roads Administration) and Ragnhild Wahl (Norwegian National Rail Administration) have been project managers at their respective agencies. More than 100 employees at the three agencies have contributed to the project as sub-project managers, sub-activity managers and technical experts.

In NIFS, collaboration was established with several external parties that made important contributions to the result. The most important contributors have been: Norwegian University of Science and Technology (NTNU), SINTEF, Multiconsult, Norwegian Geotechnical Institute (NGI), Geological Survey of Norway (NGU), Norwegian Meteorological Institute (MET), Chalmers University of Technology, Rambøll, Western Norway Research and Work Research Institute (AFI).

We should like to thank everyone who was involved in the project.

Director of NVE's Landslide/ Avalanche and Watercourses Department

Director of the Directorate of Public Road's Traffic Safety, Environment and Technology Department under the Norwegian Public Roads Administration

Acting Technology Director/ Project Director, Norwegian National Rail Administration

Table of contents

Summary

More frequent extreme weather events and maintenance backlogs combined with interventions in catchment areas are some of the main causes of flood and landslide/avalanche-related damage to infrastructure and buildings. This represents a hazard to civil protection and the traffic flow on railways and roads. The natural hazards, infrastructure, floods and landslides/avalanches programme, acronymised in Norwegian as NIFS, is a joint initiative of the Norwegian National Rail Administration, Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Public Roads Administration. The overall goal has been to contribute to a safer society with more robust infrastructure, safer homes, safer transport and reliable avalanche/landslide and flood warnings. Important objectives have been to generate new knowledge and develop good, effective and forward-looking solutions for handling different natural hazards through collaboration across agencies and areas of responsibility.

The programme (2012–2015) had a budget of NOK 42 million. The agencies contributed with roughly 30 internal full-time equivalents. The agencies faced major common challenges, and NIFS has contributed to a better clarification and understanding of roles, exchange of skills and competence-building.

Key outcomes of NIFS are:

NVE, the Norwegian Public Roads Administration and the Norwegian National Rail Administration all play key roles in the work to restrict the risk of damage to buildings and public infrastructure as a result of floods and landslides/avalanches. The three agencies also operate in a technical field in which many other parties are involved. Understanding roles, long-term planning and co-ordination of natural hazard assessments have been clear objectives of NIFS. There is a need for clarification at the local and regional level in connection with development projects and crisis management and handling of undesirable events. Good relationships between the agencies at a local and regional level ensure effective collaboration and interaction, better communication with users and a better reputation.

Before setting up the NIFS programme, the agencies identified a need for a discussion about attitudes and a requirement for harmonisation of **acceptance criteria** for risk levels. NIFS recommends that work be carried out on the coordination of acceptance criteria for risk through close co-operation with the Norwegian Building Authority (DiBK) on revision of the TEK 17 Technical Regulations.

Mapping of hazards and associated consequences provides a basis for risk assessments. This is a key part of the effort to reduce vulnerability to natural damage. The collaboration on mapping flood and landslide/avalanche hazards must continue. It is important to continue the work on standardisation, coordination of data and information-sharing about flood and landslide/avalanche events, and to ensure the inclusion of ground surveys in a common national database at the NGU and that these are made available to society at large.

The assessment of natural hazards is fundamental to **land use planning** and will become increasingly important as a result of climate change. There is a need to look more closely at the provisions of the Planning and Building Act and at how information on natural hazards is communicated and understood. Many of the challenges of land use planning relate to managing water and the consequences of floodwater. Management of natural catchment runoffs and surface water must be addressed in all planning phases, and overall management of catchment areas should be achieved through coll aboration between different authorities.

Safety measures against floods and landslides/avalanches include a broad range of measures. Closer collaboration on safety measures will provide a more robust infrastructure, lower the risk of recurring damage and enable overall planning of measures in the entire catchment area. This will result in fewer delays, improve the quality of structures and measures, reduce the risk of damage and pro-

vide a better basis for overall RAV analyses. For example, it is recommended that the agencies utilise new technology for modelling and that the overview of safety measures be systemised by introducing routines for monitoring and maintenance.

Floodwater causes major damage and has consequences for many people. It also represents a significant socio-economic cost. There is therefore a need for a comprehensive management of flood and surface water, in which the entire catchment area is seen in context. This is a challenge given the large number of parties involved and where the consequences are in many instances greater for those who are 'downstream' of the event than where the problem arises. Even relatively minor changes to drainage and runoff conditions can result in very extensive damage to nearby infrastructure. The NIFS project proposes a number of measures to improve future management.

Norway and a few other countries face a particular challenge regarding the presence of **quick clay**. Quick clay consists of clay particles deposited in saltwater and is therefore present below the marine limit. The salt stabilises and binds the clay minerals and when it is washed out the clay assumes a structure which, if disturbed, can become totally agitated and take on a liquid form. Quick clay landslides can be triggered by minor interventions and become very large, even in almost flat terrain. NIFS has improved the methods for mapping quick clay. This has been achieved by looking at conventional geotechnical probing methods combined with geoelectrical measurements, and developing these further. The NIFS programme has worked on coordinating and revising the guidelines and establishing an agreed practice for assessing the stability of quick clay areas. It is recommended that a number of the results be incorporated into guidelines and regulations.

Because of the climatic and topographical conditions in Norway, complete protection of infrastructure against floods and landslides/avalanches is considered an impossible task. **Monitoring and forecasting** of natural hazards is therefore important in order to increase predictability and make it possible to reduce risk. Coordination of equipment and services for monitoring stability has been tested across the agencies. This has resulted in better utilisation of expertise, equipment and instruments across the agencies as well as shorter response times and better quality of service when rapid response is required. In practice, the basis for such a permanent collaboration has already been established through NIFS. Anticipated future access to radar satellite data in conjunction with other technological developments will improve the suitability of methods for identifying terrain deformations and monitoring infrastructure. NIFS recommends further investment in the use of radar satellite data through a broad collaboration on access to data and methodology development.

In the case of natural damage it is crucial for society to have a satisfactory level of **preparedness** in place and be rigged to handle the situation. Effective collaboration between the agencies requires access to sufficient information and good communication between the parties involved. The NIFS programme has formulated a proposal for common terminology lists in order to establish a shared platform and understanding. The glossaries concern landslide/avalanche types, emergency preparedness and response, mapping and safety measures. Mutual knowledge of plans and emergency response organisations ensure mutual understanding between the parties. NIFS has carried out exercises based on quick clay landslides and rockslides. A common field manual has been developed that covers the most common types of flood and landslide/avalanche events in Norway and includes both minor events with limited impact and major multi-agency events.

Good management of flood and landslide/avalanche risk requires a high level of knowledge and expertise. NIFS has delivered results and developed knowledge that form the basis for better management of natural hazards and provide guidance for further research in selected areas. Several fundamental studies have been conducted of methodologies for monitoring and forecasting, landslide/avalanche triggering and propagation mechanisms, quick clay mapping and quick clay properties. Further research into these topics is recommended.

Considerable **information and knowledge dissemination** to many target groups was carried out during the programme period. This included educational films for schools, recruitment initiatives aimed at students, scientific and popular science articles, industry seminars and internal professional workshops/seminars. All results, including 120 specialist reports, have been made available on the programme's website. This has resulted in increased knowledge and awareness of natural hazards, cause and effect relationships, and the need for documentation and verifiability. An example of this is heightened landslide/avalanche expertise in the consultancy sector that agencies, municipalities and developers commission to map landslide/avalanche hazards and carry out landslide/avalanche studies.

Many of the results from NIFS are ready for **implementation**, but specific projects and measures have also been highlighted that require further work. Many topics in the field of natural hazard management deserve attention and follow-up in the years ahead. The agencies can handle some of the topics individually, but others require coordination.

The recommendations from NIFS can be summarised into the following main points:

- The management of natural hazards should be further coordinated at all administrative levels
- The agencies' emergency response organisations should be further coordinated
- An overall methodology for assessing social consequences should be further developed
- Socio-economic analyses should be carried out of weather events that result in damage
- Joint collection, systemisation and storage of data relevant to natural hazard assessment should continue
- Risk and vulnerability analyses should include all water in the entire catchment area
- Consideration of drainage paths and flood problems should be included in all planning phases
- Repair measures should be made more robust to withstand climate impacts
- The regulatory framework for stability assessments in quick clay areas should be harmonised
- Multi-agency R&D work associated with floods and landslides/avalanches should be strengthened.

There is a need for continued formalised collaboration with broader participation than the three NIFS agencies. NVE has a coordinating responsibility for establishing and managing this. The collaboration will be based on a project-style approach and include all relevant parties.

Figur 1: The flood in Trysil in 2014 caused only limited damage due to flood protection.. Photo: Snøball as.

Figur 2: Challenges brought by natural hazards require cooperation. Photo: Norfilm 2012

1 Background to the NIFS programme

1.1 Situation description

Norway faces significant challenges associated with floods and landslides/avalanches. This is attributable to its topography, a mixed climate with wide temperature variations and challenging ground conditions such as the presence of quick clay. Extreme weather, heavy rainfalls, lack of maintenance and intervention in catchment areas are among the reasons we experience flood and landslide/avalanche-related events that cause damage to infrastructure and buildings. Such events also represent a danger to life and health. An overview of all extreme weather events in Norway over the last 20 years is shown in ANNEX 2. Knowledge of climate change suggests a future climate that will be 3–4 degrees warmer and that precipitation will increase by 5–30 per cent compared with the reference period 1979–2008 /1/. Increased precipitation increases the risk of floods and, in some places, also the risk of landslides/avalanches. To reduce the vulnerability of society to climate change, we need to adapt and build adequate robustness into the infrastructure. With regard to floods and landslides/avalanches, the increase in the frequency and intensity of short-term precipitation (~1 hour) is particularly significant.

The cost to society of floods and landslides/avalanches is significant, and in many cases the indirect cost is greater than the direct cost of measures to deal with the actual event and subsequent repairs. It is therefore important to develop tools for assessing both the total socio-economic cost and for prioritising between different solutions, e.g. prevention versus re-building. There is no reliable estimate of the total cost to society of natural hazard events, although insurance payments can provide an indication of cost trends. Payments made by insurance companies in Norway between 1980 and 2014 /2/ are shown in Figure 1.

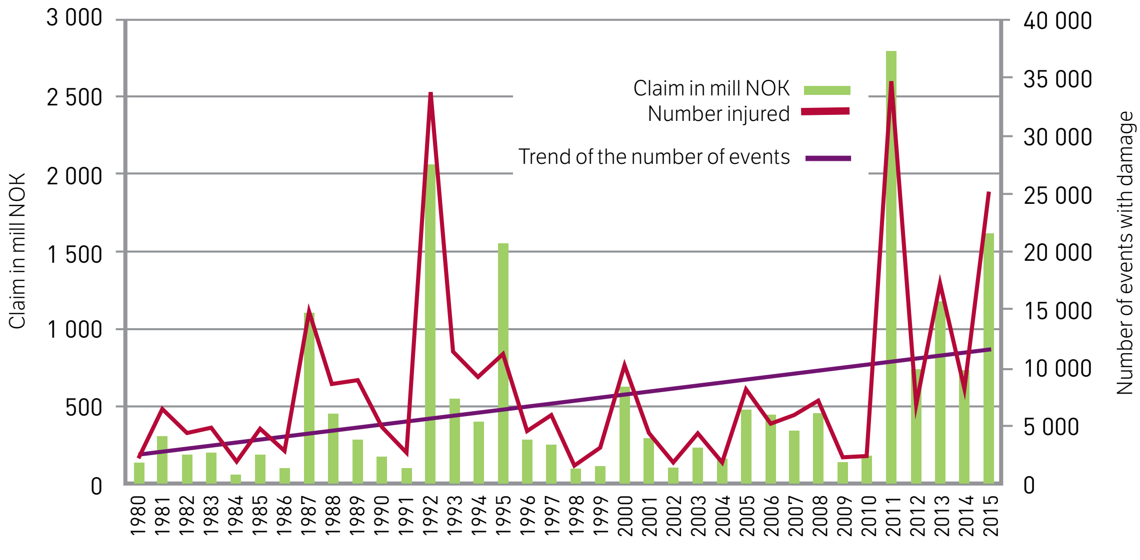


Figure 1 Claim statistics Finance Norway / 2/. The unbroken red curve shows the number of claims, the green bars show total payments, and the violet line shows the trend for the number of events.

The figure shows the total number of claims cases and insurance payments in NOK million made by insurance companies in Norway (Finance Norway). The figure does not provide a picture of the total extent of damage and the financial consequences since the figures do not include events and costs associated with public infrastructure. By comparison, the cost of the flood event in Gudbrandsdalen in 2013 is estimated to have been over NOK 1 billion /3/. The number of claims shows an increasing trend, and Finance Norway believes this is primarily due to the increasing number of natural damage events attributable to climate change together with increasing maintenance backlogs.

Land modification and intervention in all or parts of the catchment area can result in a heightened risk of floods and landslides/avalanches that impact both buildings and infrastructure. Unclear divisions of responsibility and a lack of collaboration between public and private sector organisations regarding catchment areas and catchment runoffs present challenges in relation to achieving a more uniform approach to reducing risks associated with floods and landslides/avalanches.

There is a significant backlog in infrastructure maintenance. Where the backlog is linked to a lack of drainage and flood management, the infrastructure will be particularly vulnerable to increased precipitation. The backlog increases the scope of damage; roads and railways which in principle should be capable of withstanding the impact of water, collapse under the impact of heavy precipitation. In many locations the drainage system is undersized and occasionally wrongly sited in terms of handling flood peaks. Urbanisation has further increased the problem of drainage. Necessary remedial modifications are costly, but the cost of not implementing the necessary remedial measures will in many cases be even greater/4/.

Natural hazard events such as the extreme weather Dagmar (2011) and the quick clay landslides in Kattmarka (2009) and Lyngen (2010), the rockfall at Oppdølsstranda (2008), the avalanche at Sunndal (2010) and the flood in Gudbrandsdalen (2011) demonstrated the need for better coordination, coordination of the regulatory framework, communication, competence development, research and dissemination of knowledge. This was the basis for establishing an R&D programme for floods and landslides/avalanches in Norway (NIFS) involving the three agencies NVE, the Norwegian Public Roads Administration and the Norwegian National Rail Administration.

1.2 Framework for work on floods and landslides/avalanches

1.2.1 Steering documents

Several white papers contain guidelines for the agencies' work. The following are most relevant to NIFS:

- Report to the Storting No 15 (2011–2012) 'How to live with the danger of floods and landslides/avalanches' /5/
- Report to the Storting No 29 (2011–2012) 'Civil protection' /6/
- Report to the Storting No 33 (2012-2013) 'Climate change adaptation in Norway' /137/

The **Planning and Building** Act from 2009 imposes requirements on municipalities, in particular regarding the preparation of RAV analyses and assessment of all risk and vulnerability factors of significance to whether an area of land is suitable for development, before permission is granted for land use and construction of buildings and infrastructure.

The **Regulations on technical requirements for building works (TEK10)** provide framework conditions for managing natural hazards in Norway. TEK10 supplements the Planning and Building Act's rules on processing building applications, quality assurance and control, on inspection, on approval of undertakings for the right to accept responsibility under the Planning and Building Act and on sanctions if the regulations are not complied with.

The Act relating to municipal preparedness duty, civil protection measures and civil defence (Civil Protection Act) requires that local governments assume responsibility for assessing which undesirable events could occur, the likelihood of these events occurring and what the potential consequences could be (Section 14 Risk and vulnerability analysis). Based on the risk and vulnerability analysis, the local authority shall prepare an emergency response plan, with an overview of which measures have been drawn up to handle undesirable events (Section 15 Municipal preparedness plan). It is the local authority's responsibility to protect its inhabitants' lives and health in the event of a crisis.

1.2.2 Division of responsibility and responsible parties

The central government has overall responsibility and issues guidelines in white papers, mandate letters etc. Sector responsibility is vested in several ministries. In this review we have emphasised the Ministry of Petroleum and Energy, the Ministry of Transport and Communications, the Ministry of Justice and Public Security, the Ministry of Local Government and Modernisation and the Ministry of Climate and Environment as the most important ministries. The ministries work at an overall strategic level, and when managing natural hazards the primary responsibility will be to issue clear guidelines for division of responsibility and prioritisation by the respective agencies.

Many parties are responsible for preventing landslides and flood damage. First and foremost, every citizen and land owner is responsible for their own safety. This can take the form of general precautions in connection with the use of one's own property, when passing through terrain and during other activity in areas that could be exposed to floods or landslides/avalanches. This also entails responsibility for activity or measures on own land/property and possible impacts of such activity on other land/property.

In addition to the three NIFS agencies, the following are among the many operational organisations that manage natural hazards:

- The Norwegian Directorate for Civil Protection and Emergency Planning (DSB)
- The Meteorological Institute (met.no)
- Geological Survey of Norway (NGU)
- The Norwegian Agricultural Agency
- The Norwegian Building Authority (DiBK)
- The Police
- County Governors
- County authorities
- Municipal authorities

This illustrates that managing natural hazards is complicated and demanding in terms of resources, and entails a great need for coordination between various entities and administrative levels.

1.2.3 The agencies' roles

NVE, the Norwegian Public Roads Administration and the Norwegian National Rail Administration all play key roles in the work to limit the risk of floods and landslides/avalanches resulting in damage to buildings and public infrastructure. The three agencies also operate in a field that involves many other parties.

NVE reports to the Norwegian Ministry of Petroleum and Energy. NVE's mandate is to ensure a uniform and environmentally-friendly administration of Norway's water resources, promote efficient energy markets and cost-effective energy systems, and contribute to efficient energy use. The directorate plays a key role in national flood preparedness planning and has overall responsibility for maintaining the national power supply. NVE is engaged in research and development in its field and is the national centre of excellence for hydrology in Norway. NVE has technical coordination responsibility for the state's administrative tasks related to flood damage and landslide/avalanche accidents. In accordance with Report to the Storting No 15 / 5/, NVE is alco charged with assisting municipalities and society at large in their effort to manage challenges associated with floods and landslides/avalanches through hazard mapping, land use planning, implementation of safety measures, monitoring and forecasting, assistance during events, and research and dissemination of knowledge/information. At directorate level, NVE is charged with the technical coordinating role in enacting national policy related to flood and landslide/avalanche prevention. As competent authority at the national level, NVE shall be a a unifying player in the field of flood and landslide/avalanche prevention.

The Norwegian National Rail Administration is the state's technical agency for railway operations. Its tasks are to offer train companies in Norway a safe and effective transport system through planning, developing, operating and maintaining the national rail network including stations and terminals. The Norwegian National Rail Administration is also responsible for the day-to-day management of rail traffic and for traffic information to passengers prior to their journey. As specified in Report to the Storting No 15 / 5/, the Norwegian National Rail Administration, as the competent sectoral authority, is responsible for preventing and managing flood and avalanche risk within its sector. The importance of the work on floods and landslides/avalanches in relation to these tasks was emphasised in the revised national budget for 2012, in which the Norwegian National Rail Administration was allocated an extra appropriation of NOK 200 million for repairs and safety measures in connection with floods, landslides/avalanches and fire. Civil protection and emergency response shall be an integral part of the Norwegian National Rail Administration's activities related to operation and maintenance, and planning and development of new infrastructure, among other things.

The Norwegian Public Roads Administration is responsible for planning, construction, operation and maintenance of the national road and county road networks and for supervision of vehicles and road users. The agency also draws up provisions and guidelines for road design, road traffic, traffic training and vehicles. The agency is responsible for national highway ferry services. These functions require the agency to play an important role in planning related to the handling of floods and avalanches. As specified in Report to the Storting No 15 /5/ the Norwegian Public Roads Administration, as the competent sectoral authority, is responsible for preventing and managing flood and avalanche risk within its sector. The Norwegian Public Roads Administration is required to take the risk of such events into account in its risk assessments, and to prepare strategies for managing such risks related to operation and maintenance of and investment in the road network. Civil protection and preparedness shall be an integral part of the Norwegian Public Roads Administration's work on operation, maintenance and development projects, among other things.

Figure 2 Common challenges for NVE, the Norwegian National Rail Administration and the Norwegian Public Roads Administration. Landslide in Soknedal, March 2012. Photo from 'Adressa'.

2 The NIFS programme

The programme was set up as a joint initiative between the Norwegian National Rail Administration, the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Public Roads Administration. The agencies have faced major common challenges, and a good collaboration is both cost-effective and competence-building for the organisations. The programme was carried out in the period 2012–2015 /55/, /73/, /97/.

The aim of NIFS has been to develop good, effective and forward-looking solutions for handling different natural hazards and to contribute to attaining the overall goal of a safer society with a more robust infrastructure, safer buildings, safer transport and reliable avalanche and flood warnings.

These goals were to be achieved through collaboration across agencies and areas of responsibility and by utilising new knowledge and new solutions. The following performance indicators were established to describe the desired future situation:

- Better safety for citizens based on an infrastructure that is better equipped to cope with the damaging impact of natural forces, both now and in a future characterised by increased intensity and frequency of natural damage as a consequence of climate change
- Optimum use of financial and technical resources for solving common challenges associated with natural hazards
- Better safety, greater robustness and improved regularity in land-based transport
- Step-by-step preparedness in order to be better prepared for natural hazards
- Better collaboration between agencies in crisis situations

The programme was divided into 7 technical sub-projects:

- Sub-project 1 Natural damage strategy
- Sub-project 2 Preparedness and crisis management
- Sub-project 3 Mapping, data coordination and RAV analyses
- Sub-project 4 Monitoring and forecasting
- Sub-project 5 Managing floods and floodwater
- Sub-project 6 Quick clay
- Sub-project 7 Landslide/avalanche and flood protection

NIFS included all specialised topics of relevance to floods and landslides/avalanches. However, the programme did not explore the details of urban water management and flooding in large watercourses. For these issues, reference is made to the Surface Water Committee's report 'Surface water in cities and densely populated areas – a problem and a resource' / 10/. NIFS has elected to concentrate on floods in small watercourses and floodwater. This is because it is precisely floodwater that often causes damage. It was considered important to increase our knowledge of both theoretical and practical management of the risks.

Climate change adaptation and coordination with flanking projects was important for all the sub-projects, and data coordination has been an overreaching part of all the sub-projects. All sub-projects had a core staff of specialists from each of the agencies, and management of the sub-projects was divided between the agencies. R&D activities were performed by in-house specialists from the agencies in collaboration with other public agencies, universities, colleges, research institutes and consultants.

NIFS has been organised with a steering group, project manager and project management group. All groups have representation from all three participating agencies. The agencies have jointly financed a full-time project manager.

The budget for the programme has been NOK 42 million, and the agencies have also contributed with an estimated 30 in-house full-time equivalents. Most of the budget was spent on assistance from consultants, research institutes and universities and colleges. The programme has financed one postdoc and several PhD scholarships, as well as provided financial support for summer jobs, bachelor and master theses.

The programme has used a dedicated communication plan to disseminate the outcomes /8/.

NIFS has focused on wide-reaching and varied dissemination of results from the project. The results from NIFS have been presented through reports, international and national conference articles, seminars and workshops, guest lectures, internal and external courses, industry seminars, media coverage (film, radio, TV, newspapers, publications) and through the project's and agencies' web portals. A breakdown of the various publications from NIFS is shown in Figure 3. A more detailed overview of the channels of information dissemination from NIFS is provided in Chapter 5.

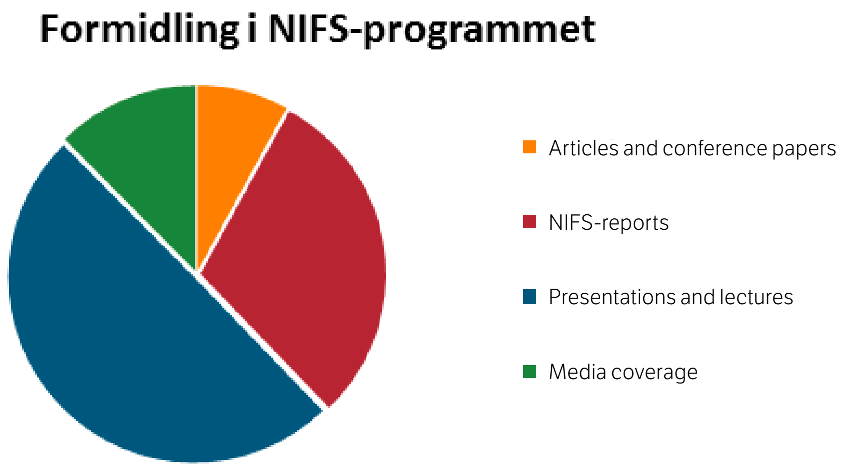


Figure 3 Illustration of information dissemination in NIFS.

The NIFS programme has generated factual knowledge and a basis for decision-making, which have resulted in recommendations. It has not been the mandate of the NIFS programme to implement any of these recommendations. The results have to some extent already been implemented by the agencies and other relevant organisations. Further implementation will be up to the relevant agencies and authorities.

3 Results and recommendations

The presentation of results and recommended measures from NIFS is based on the following structure, primarily taken from the thematic structure in Report No 15 to the Storting /5/:

- Responsibility and role division
- Risks and socio-economics
- Mapping of hazards and risks
- Land use planning
- Safety measures
- Managing floods and floodwater
- Safety in quick clay areas
- Monitoring and forecasting
- Preparedness and crisis management
- Research, education and communication

For a more detailed description of the individual sub-projects, organisation, completed tasks with results and recommendations, reference is made to the relevant specialist reports (see Chapter 6.3) and the joint summary report that was published in spring 2016.

3.1 Responsibility and role division

A large number of public and private sector parties are involved in the work to prevent and manage floods and landslides/avalanches. Thus, NIFS has had a clear objective to improve the understanding of roles, long-term planning, coordination of natural hazard assessments and coordination of technical terminology. Common terminology lists have been drawn up for natural hazards covering types of landslides/avalanches, mapping and safety measures /17/.

3.1.1 Overall coordination

The responsibility for responding to floods and landslides/avalanches is divided between several ministries. There are also numerous suppliers of data in this field. This creates a significant need for coordination, harmonised governing guidelines, prioritisations within the budgetary framework and agreements on binding collaborations. In the NIFS programme we have found that parties are generally aware of each other and acknowledge the division of roles, but also that there are overlaps in the understanding of roles along with shortcomings in coordination. Through NIFS, role division between the three agencies has been clarified. As a follow-up to NIFS, it is proposed that a collaborative arena is established between all parties who have responsibility in the field of floods and landslides/avalanches. As the national flood and landslide/avalanche authority, the NVE will assume day-to-day responsibility for this collaborative arena. This is described in Chapter 4. Within such an arena, any ambiguities regarding roles and responsibilities between the agencies that require clarification can be highlighted, and knowledge from daily operations and particular events can be shared. According to the experience of the NIFS collaboration, interaction in such an arena will also have intrinsic value.

Concerning division of responsibility at the ministerial level, NIFS proposes that the ministries are clearer and more coordinated in their mandate letters to subordinate agencies. The budgetary consequences of this must be clarified.

Good collaboration between the three agencies in NIFS is strongly desired by the agencies themselves. Through NIFS, however, we have experienced that even with a concrete development programme with a binding financial framework and dedicated resources, we encounter institutional barriers. This applies to diverging administrative and budgetary procedures, regulations that obstruct the flow of resources between the agencies, data systems that do not 'talk to each other' and different use of terminology. There are also requirements for reporting results whereby achieved common goals receive less attention than the deliveries from each individual agency. NIFS has experienced these barriers and would like to point out that, as a step towards making public sector administration more effective, the formal regulations on collaboration between the agencies must be simplified.

It is apparent from the NIFS experience that responsibility for collaboration between the agencies cannot rest with individuals but must be institutionalised. Such collaboration must become part of day-to-day operations and of the most effective way of solving interfacing tasks in partnership with other agencies/parties. Through NIFS we have also found that research and development work that is closely associated with day-to-day operations and takes place with support from established expert environments outside the agencies themselves, has a beneficial effect and provide a good basis for developing common work practices.

The NIFS agencies have to a lesser extent been concerned about communicating results upwards to their own and other ministries. This should be addressed once the programme has been concluded in order to also realise potential effects at this level.

3.1.2 Roles and coordination between the agencies

A review of relevant steering documents has been performed to assess any lack of clarity in role division and role understanding concerning the management of natural hazards /7/. While the NIFS agencies' general roles related to natural hazard management are clear /12/, there is a need for clarification at the local and regional level in connection with development projects, crisis management and undesirable events. We have noted that good relationships between the agencies at a local and regional level ensures effective collaboration and interaction, better communication with users and a better reputation. /12/.

NIFS has highlighted the need for unambiguous exchange of information and understanding of natural hazards through clarification at the overall planning level in connection with the planning and implementation of development projects. The division of responsibility for assessing the impacts of new interventions and developments must be clearly defined. It also means assigning clear responsibilities for assessing the impacts of interventions in existing infrastructure, i.e. inspection of the entire catchment area – including upstream of railways, roads and inhabited areas. This means that an agency responsible for implementing a measure must also be obliged to inform other agencies and relevant parties regarding planned safety measures.

3.1.3 Land use

Land use, and particularly coordinated assessment of the entire catchment area, is a key factor for reducing the damage to infrastructure resulting from floods and landslides/avalanches. NIFS has shown that in many cases damage occurs that is related to interventions or factors that are external in relation to the actual infrastructure, such as changes in vegetation or drainage conditions related to forestry, or levelling of agricultural land, Figure 4. Pilot projects were carried out in Gudbrandsdalen in which several parties in a catchment area analysed, proposed and implemented measures for managing runoff. The results demonstrate that the parties achieved a better overall understanding of this type of collaboration, and provided new cost-effective solutions for reducing risk. A report is currently being prepared on our experience of the pilot projects.

NIFS has shown that there is a need for better clarification of roles associated with the management of floods and surface water, particularly as regards the division of responsibility between central and local government agencies /7/. The NIFS agencies share the Surface Water Committee's problem description /10/.

NIFS has demonstrated a need for making private individuals accountable for measures that they implement that can result in problems for neighbouring infrastructure. An example of this is forestry. Tree felling and driving through steep catchments can cause increased runoff and channelling of water which, in turn, increases flood and landslide/avalanche hazards. NIFS recommends that in areas of flood and landslide/avalanche hazards, consideration should be given to introducing provisions on protection forests with a duty to report felling upstream of infrastructure and buildings. An alternative option could be to use caution zones in forested areas in municipal land use planning. NIFS has established a dialogue with the Norwegian Agricultural Agency concerning forestry and has analysed consequences for buildings and infrastructure. From summer 2015, consideration of flood and landslide/avalanche hazards in connection with applications to construct forest roads has been increased in the Regulations on Planning and Approval of Agricultural Roads (lovdata.no). The regulations were amended on the recommendation of the NIFS programme. Applicants are now obliged to document whether such hazards are present and describe what measures must be implemented to limit the risk. The Norwegian National Rail Administration and the Norwegian Public Roads Administration now act as consultative bodies if the interventions are upstream of railways or roads /126/.

Figure 4 Floodwater in Fåvang running towards River Gudbrandsdalslågen in May 2013. Photo: Steinar Myrabø, 2012.

Because the construction of new forest roads has declined considerably in recent decades, the challenges associated with maintenance of ditches and culverts on existing forest roads have probably increased. NIFS proposes to extend environmental certification of forests to include natural hazards. We can then envisage that the forest owners' checklist will include inspection of ditches and culverts. In dialogue with the Norwegian Agriculture Agency, work is continuing on the concept that environmental certification – to which all forest owners subscribe – can also include preventive measures against natural hazards. A closer collaboration with the Norwegian Agriculture Agency can result in less damage to buildings, roads and railways caused by careless forestry. This also forms part of the overall responsibility of local governments in connection with RAV analyses /23/.

NIFS has cooperated with the forestry training centre at Honne (http://www.skogkurs.no/) and the project group for the Regional plan for River Gudbrandsdalslågen and tributaries /118/ to develop better procedures for assessing the consequences for runoff conditions in connection with the construction of forest roads. Based on this cooperation, courses have now been prepared for those who construct forest roads as well as for the municipal case officers who are to approve them. This is also described in more detail in 3.4.2. The project has reached its final phase, and a separate report will be prepared.

3.1.4 Responsibility and role division in emergency response work

NIFS has conducted emergency drills with the focus on collaboration and crisis management. This has provided valuable knowledge about collaboration between the NIFS agencies and other parties. It has been specifically ascertained that the roles and responsibilities of the NVE and the County Governor are not adequately communicated to the other parties involved. An overall understanding of roles improves communication and reduces the risk of misunderstandings during crisis management /13/, /14/, /15/.

Recommended measures – responsibility and role division

- Coordination by the ministries of their efforts to manage natural hazards in such a way as to ensure that the agencies and expert environments that contribute to the knowledge base also receive the necessary resources
- Involvement of the Norwegian Agricultural Agency in the collaboration with the NIFS agencies when assessing risks associated with construction, inspection and maintenance of forest roads
    - Revision of the guidelines 'Forest roads and landslide/avalanche hazards' to include forestry activities and natural hazards on a more general level
- Extending environmental certification of forests to include natural hazards
- Good relationship-building at the local level
    - For major projects involving all three agencies, a plan should be drawn up in which roles and division of responsibility are specified, among other things with reference to overriding governing documents and clarification of how these should be understood
    - At all levels of administration the division of responsibility in connection with potential undesirable events should be reviewed, to facilitate the handling of such events when they occur.
    - The roles of the NVE and the County Governor in crisis and emergency situations must be specified and communicated more clearly, particularly in relation to other parties involved in handling floods and landslides/avalanches.
- Establishment of formalised collaboration, with clarification of responsibility across the entire value chain all the way to the land owners, in the planning of physical interventions and in agreements on operation and maintenance.

3.2 Acceptable risks and socio-economics

Before setting up the NIFS programme, the agencies identified a need for discussing attitudes and harmonisation of acceptance criteria for risk levels. Differences and uncertainties were also identified concerning the basis for conducting RAV analyses and for assessing the socio-economics of projects. In Norwegian Official Report (NOU) 2015:16, the Surface Water Committee highlighted the legal aspects associated with responsibility and urban water /10/. Similar focus has not been placed on responsibility for runoffs from natural catchments.

On several occasions, Finance Norway has highlighted the need for a more uniform approach to socio-economic assessments of natural hazards. There have been calls for cost/benefit analyses of damage prevention compared to the cost of repairing the damage after the event. The need to establish a national risk and damage database that can provide a significantly better basis for making such analyses has also been highlighted. Finance Norway has also highlighted the need for greater involvement from the local government sector in contributing to the prevention of natural hazards (Skadedatasem2012).

3.2.1 Risk level

The harmonisation of risk acceptance criteria is completely dependent on contact with other public agencies. NIFS has been in dialogue with the Norwegian Building Authority, which is responsible for overall safety requirements in the Regulations on technical requirements for building works /16/. The NIFS agencies should make it a goal to contribute to the preparation of Regulations on technical requirements for building works TEK17. Regarding the harmonisation of the basis and methodology for RAV analyses, NIFS has prioritised looking at the planning phase. See Chapter 3.3.3.

A study has been conducted of risk acceptance criteria. As part of this a theme day was organised where different approaches to risk assessment and acceptance criteria were highlighted. In addition to the NIFS agencies, the Directorate of Civil Protection and Emergency Planning, the Norwegian

Geotechnical Institute, the Norwegian Building Authority and NGU also participated. The theme day was followed up with a study of risk acceptance criteria for floods and landslides/avalanches. The study shows that, in the main, the criteria coincide, but some disparities were identified that entailed a need for better coordination. In 2014 the Norwegian National Rail Administration established its own acceptance criteria for assessing landslide/avalanche events on roads, as the safety requirements in TEK10 are not aimed at roads and moving traffic. These criteria should be evaluated after a period of use and considered for coordination with the other agencies. It has also been identified that the Norwegian National Rail Administration and the Norwegian Public Roads Administration use different recurrence intervals as criteria for designing drainage systems. This should, as far as possible, be coordinated for all infrastructure /18/. When defining risk categories, the risk of floods, floods in watercourses and flood problems in tributaries and small streams should be seen in context.

3.2.2 Socio-economics

It has been an aim for NIFS to conduct socio-economic analyses of natural hazard events. We have experienced challenges in procuring source data for these types of analyses. Life, health and environmental hazards, climate impacts and financial assessments are key factors in the analyses. NIFS has reviewed some projects and found variations in the extent to which cost/benefit analyses are used as a basis for the prioritisation, if at all. Socio-economic analyses of the extreme weather 'Frida' have shown the potential cost-benefits of preventive measures /28/.

In conjunction with the Norwegian Association of Local and Regional Authorities (KS), NIFS has conducted a study of the costs and utility value of prevention versus rebuilding of municipally-owned infrastructure following natural damage. One general observation was that local authorities to a much lesser extent than central government authorities feel that they have the financial framework and incentives in place for investing in preventive measures after natural damage events have impacted public infrastructure. They often elect to only restore the infrastructure to the condition it was in before the natural damage occurred. A simplified method of assessing the cost of prevention versus the cost of rebuilding was developed /19/.

Example of socio-economic assessment

The flood in Gudbrandsdalen on 22 May 2013 led to the closure of the Dovre Line until 17 June. Several buildings and roads were flooded and damaged. The review of the consequences resulting from the closure and repair of the railway provides a good illustration of the complexity of such assessments /3/. The total estimated socio-economic cost of the consequences of the flood and shutdown of the railway line was at least NOK 1.1 billion. The socio-economic costs were broken down between four different factors as illustrated in Tabell 1. The cost of the inconvenience caused by closed roads was not calculated.

Table 1 Summary of the socio-economic costs of the flood event on the Dovre Line in 2013 (in 2013 kroner) / 3/.

Item	Description	Amount (mill. NOK 2013)
1	Socio-economic costs – railway sector	> 380.7
2	Reconstruction costs – road sector	> 165.0
3	Payments for reconstruction from insurance companies	410.0
4	Reconstruction costs – municipalities (costs not included in items 1 to 3)	> 136.7
	Total (based on obtained/estimated information)	> 1,092.4

The socio-economic costs for the railway alone amounted to NOK 380.7 million, and it is evident from the background material that railway reconstruction costs amounted to NOK 176 million – in other words, less than half of the total costs. Cost elements and a relative cost breakdown for 2013 are shown in Figure 5.

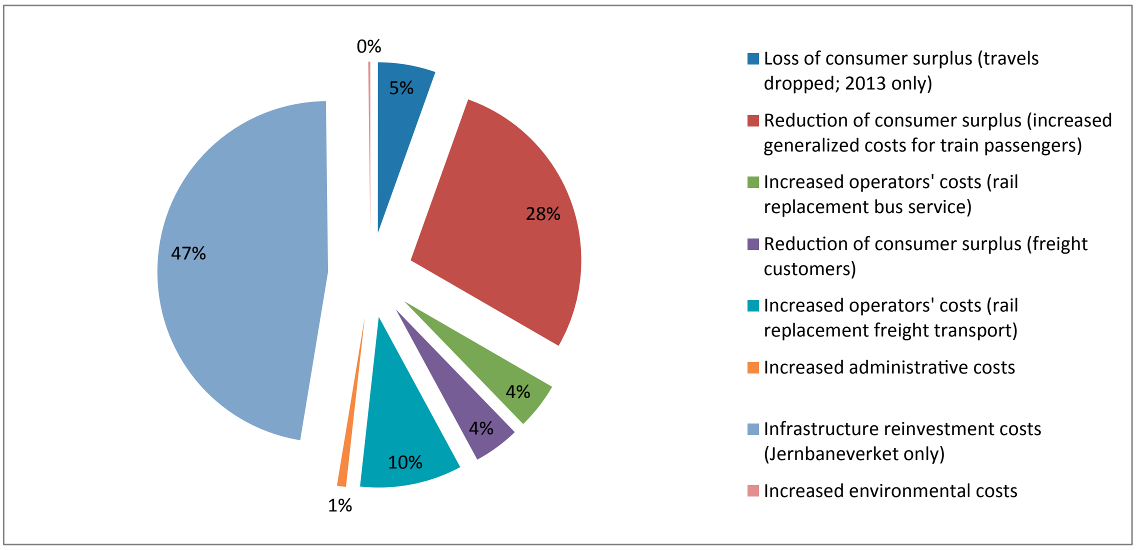


Figure 5 Breakdown of socio-economic costs by item for 2013 – railway (in per cent) (/3/).

NIFS has shown that there are insufficient source data for carrying out overall cost/benefit analyses of the various measures. Damage data are not easily accessible as no publicly accessible database is available for other than insurance claims. Data on damage to public infrastructure must therefore be collected in each individual case, as has been done in NIFS, for example. As a rule, such analyses are therefore not carried out and, if they are, considerable uncertainty is attached to the results. More source data are essential to being able to carry out better cost-benefit analyses, which are important in order to achieve an optimal decision-making basis.

Recommended measures – acceptable risks and socio-economics

- Socio-economic analyses of weather events that cause damage should be carried out routinely
- A common database should be established for weather-related events in which all infrastructure owners and the insurance industry store data on events and associated costs relating to repair/rebuilding
- Efforts should be made to establish overall risk acceptance criteria for flood and landslide/avalanche hazards
- NIFS recommends that work continues on the coordination of risk acceptance criteria
- It is recommended that close contact be maintained between the NIFS agencies and the Norwegian Building Authority in connection with the preparation of TEK17

3.3 Mapping of hazards and risks

Mapping of hazards and associated consequences provides a basis for risk assessments. This is a key part of the work to reduce vulnerability with regard to natural damage. Responsibility for hazard and risk mapping is divided between different parties and different methods are to some extent used for collecting and evaluating such data. There is also a need for better access to collected data and presentation of mapping results. Major challenges already exist regarding inadequate infrastructure robustness against damage from floods and landslides/avalanches. The effect of climate change will exacerbate these challenges.

3.3.1 Mapping methods

NIFS has developed methods of hazard mapping and presenting the results. This work showed how important it is to facilitate uniform methods of collection and registration of data. This makes it easier to share and use third-party data and reduces the risk of misinterpretation / 20/.

The methodology for mapping flood hazards along big watercourses is suitably addressed by the NVE, and the agencies are therefore prioritising the effort to improve methods and competence-building for mapping landslide/avalanche hazards and flood hazards in small catchments. The method for mapping the quick clay landslide hazards is described in Chapter 3.7.

The work has revealed that there are differences in the extent and level of detail to which the agencies map landslide/avalanche hazards in steep catchments. 'Landslides/avalanches in steep catchments' refers to avalanches, slush flows, rock falls, debris slides and debris flows. The NVE maps landslide/avalanche hazards in steep catchments in accordance with the safety levels in TEK10 (1/100, 1/1,000 and 1/5,000) / 125/. Areas are mapped in order to increase knowledge of exposed buildings which, in turn, provides a basis for landslide/avalanche prevention work. The Norwegian National Rail Administration and the Norwegian Public Roads Administration use maps from the NVE but have different acceptance criteria for landslides/avalanches in steep catchments. The main purpose is risk mapping for protecting those places along the road and rail infrastructure that are most critically exposed to landslide/avalanche hazards.

The agencies have coordinated their hazard mapping. This particularly applies to the use of source data, analysis and modelling tools, as well as mutual understanding and competence-building for implementation using verifiable methods. There still remain topics that should be coordinated. There is a particular need to achieve better collaboration concerning use of climate data, how forests are to be included in hazard mapping and as risk-reducing measures, and how simulations of landslide/avalanche events can be improved.

Much of the basis for mapping flood and landslide/avalanche hazards is based on historical data collected in separate databases. Based on a statistical analyses, it is possible to predict the frequency of flood and landslide/avalanche events of a certain size. The databases are often incomplete, however, and climate change and modifications to the landscape through man-made intervention mean that historical data cannot necessarily be used to assess future flood and landslide/avalanche scenarios. This applies to types of events and where they are likely to occur as well as to their size and frequency. For landslides/avalanches in steep catchments common analysis tooks and approaches to climate analyses other than a general description of the climate in a given area. In order to provide better basis for analysis, climate analyses must be conducted as a basis for predicting extreme precipitation values and specific recurrence intervals. A method and simple guidelines have been developed for calculating precipitation values for selected recurrence intervals to be used in landslide/avalanche hazard mapping and research. This method of climate analysis has already been used in all new landslide/avalanche risk mapping prepared by NVE, including for research in connection with the design of landslide/avalanche protection, and is described in detail in the revised guidelines /124/ and associated guidelines on 'Protection from landslides/avalanches in steep catchments. Mapping landslide/avalanche hazards in connection with land use planning and building applications' /113/.

3.3.2 Source data and data coordination

Necessary source data and facilitation of data coordination and data sharing are essential in flood and landslide/avalanche prevention work. NIFS has dedicated a great deal of time to developing a common understanding and better knowledge of different flood landslide/avalanche-relevant data, collection routines, standardisation of joint formats, quality assurance and storage, and to making available and presenting data for use by the agencies themselves and society at large.

All the agencies are involved in the work associated with terminology standardisation, and collection, storage and sharing of information. NIFS has been a collaborative arena for the start-up of the standardisation work by the three agencies and in relation to the Norwegian Mapping Authority /15/, /17/, /21/. Examples of source data in the form of measurements and registration:

- Measurement data/measuring stations that log hydrology and climate data
- Flood and landslide/avalanche events
- Data on damage caused by floods and landslides/avalanches
- Data on safety measures
- Data on drainage and related infrastructure
- Geotechnical data
- Geological data
- Data on forests and vegetation
- Detailed elevation data / terrain model (laser scanning, bathymetric modelling etc.)
- Satellite and radar data

There is extensive historical information concerning damage and weather data. In recent years the agencies have prepared several experience reports and guidelines. These are kept in different locations, however, and there is a need to collate and systemise the data in order to estimate the true extent of damage and to provide a basis for better cost/benefit analyses of measures. NIFS has reviewed and evaluated a great deal of this background material, and it provides a good starting point for a database of weather-related events in which all infrastructure owners and the insurance industry store data on weather-related events, including damage and causes, reconstruction/restoration costs and estimated prevention costs for each damage site. This will provide a good basis for a comprehensive presentation of source data and for preparing common guidelines on preventive measures.

NIFS has worked on the collection, systemisation and storage of available data. Examples of this include the collection of laser scanning data/detailed elevation data, registration of flood and landslide/avalanche events in small catchments, ground surveys in general and for quick clay in particular, setting up multiple measuring stations for temperature and precipitation. This work is very important for the purpose of identifying the true level of risk and enabling comparisons and evaluations to be made between different events with the involvement of private and public sector parties.

NVE has established its own technical solution for registering landslide/avalanche event data (landslide/avalanche registration) in which data are transferred directly to the National Landslide/Avalanche Database.Through NIFS, a joint system for registration of information has been prepared from landslide/avalanche events collated in a landslide/avalanche database (National Landslide/Avalanche Database, NSDB) that can be viewed on Skrednett. It is recommended that natural hazard-related observations and events be registered in the field via a mobile app (RegObs). Both registration of new events and further documentation of such events, registered in RegObs, can be carried out via the portal skredregistering.

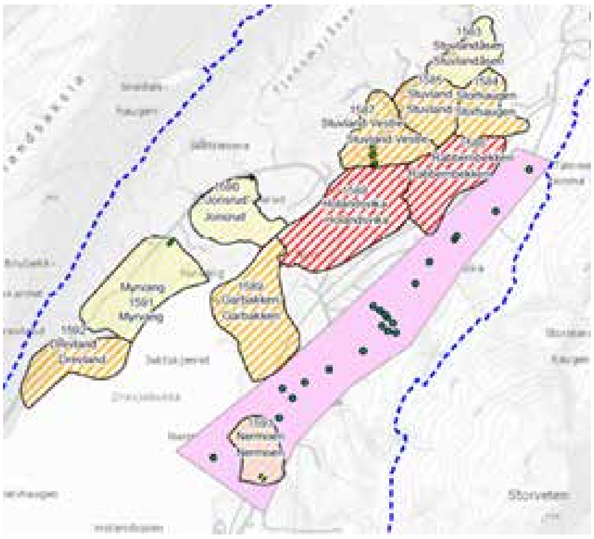
The Norwegian Public Roads Administration 's system for electronic reporting and follow-up of tasks related to operation and maintenance contracts (ELRAPP) forms part of the data flow for forecasting. At present, landslide/avalanche events are transferred manually via monthly extraction of data from the National Road Databank (NVDB) and spreadsheets from the Norwegian National Rail Administration /117/, /118/. Arrangements have been made so that the National Landslide/Avalanche Database can be used as a joint database, both for entering data from roads and railways and for automatic extraction of event data by the Norwegian National Rail Administration and the Norwegian Public Roads Administration, if desired.

Data on landslide/avalanche events is currently reported by the different agencies based on their own needs for an overview of landslide/avalanche problems. Records from the Norwegian National Rail Administration and the Norwegian Public Roads Administration are transferred to the National Landslide/Avalanche Database and shown together with other registered landslides/avalanches. The characteristics of these landslides/avalanches are not coordinated, however, and there is a need to continue the collaboration between the agencies in order to achieve more uniform and faster reporting, and to create systems for quality labelling of data and removal of duplicate data.

The authorities are now in the process of establishing a new national elevation model, which will provide a much better basis for the agencies' work. The Norwegian Mapping Authority manages the work, and it is assumed there will be a co-funding model whereby the Norwegian National Rail Administration, NVE and the Norwegian Public Roads Administration, among others, contribute financially. The national elevation model is based on laser scanning data with 2 points per m2 as standard, but with image matching (aerial photos based on sequential aerial photography) of many mountainous areas. This also includes laser scanning with 5 points per m2 in selected areas – assuming this can be financed by the parties that have reported a need for it. This kind of improved mapping will enable better modelling of different natural hazards – relating to landslides/avalanches and floods.

Quick clay data from old archives made available online

Background: Landslide/avalanche events have made the need to communicate/share ground survey data in a simple way more pressing. Old geotechnical reports are scanned in order to extract reports where there is evidence of quick clay. NVE and the Norwegian National Rail Administration have entered into a collaboration on supplementing the quick clay zone map at skrednett.no with data from the Norwegian Public Roads Administration. The Norwegian Public Roads Administration's historical data are displayed as 'Quick clay areas' on the map. These are not complete 'quick clay zones', like the zones shown on previous quick clay zone maps, but areas that represent the extent of the ground survey that forms the basis of the technical report.



Example: Old and new data on quick clay zones as displayed on Skrednett. Shaded zones are current quick clay zones. The quick clay area based on data from the Norwegian Public Roads Administration is shown in pink and with indication of the drill points in which ground surveys have shown evidence of quick clay. The blue dotted line is the marine limit.

To save both time and public resources, the Norwegian Public Roads Administration will complete and publish completed quick clay studies via Skrednett when quick clay is encountered in future planning and construction projects. A collaboration agreement has been established with NVE – as a template for other public and private sector parties to follow.

Reference

- NIFS (2016-041) Pilot study on coordinated use of 'known quick clay data'

Feedback suggests that the coordination of data between the agencies has been very well received and has made consultants and other users more aware of quick clay and other landslide/avalanche hazards.

Data coordination is profitable and also good management!

Background: Standardisation, data coordination and sharing of information are crucial to good collaboration and utilisation of common resources. Registering events and mapping natural hazard challenges for the purpose of information sharing ensures that everyone has access to optimal information. Uniform access to information ensures better quality of measures and services.

Example of report on collaboration and coordination.

References:

- NIFS (2013-1) Roles in the national work to manage natural hazards /7/
- NIFS (2014-63) Working separately or as a team? A study on coordination of flood and landslide/avalanche data between three collaborating agencies /21/
- Vista analysis (03/2015): Benefits and costs of national databases. Method development and testing of a national database of ground surveys /114/

Collaboration and coordination save resources, give better results and contribute to better civil protection.

It is of great importance that the mapping of hazards, consequences and thereby risk on the basis of historical flood and landslide/avalanche data is coordinated and in a consistent format. This will provide a good basis for establishing hazard and risk assessments in the form of hazard zone maps. The agencies manage a high volume of data, although there are significant variations in which data are collected and the quality of such data/104/.

Simpler sharing of map data provides a better overview of which maps and options exist. This saves a great deal of time and resources on searching for map data, especially for those who do not use such data on a day-to-day basis.

Quality-assurance of existing data and systemisation of the collection of new flood and landslide/avalanche data have been central themes in the NIFS programme throughout. Comparisons have been made of various sources of flood and landslide/avalanche data and these have been uniformly described by all the agencies /21/, /104/. These comparisons have provided increased awareness of the need for flood and landslide/avalanche data, for useful map access solutions in and across the agencies, and for making flood and landslide/avalanche data available to society at large. The benefits are found in quicker access and more accurate data (localisation and dating, and correct classification), the option of adding information as events are being observed, registered and analysed, and less chance of duplication of event data.

The agencies, in collaboration with the Norwegian Geotechnical Institute (NGU), have been working on developing an exchange platform for sharing information on ground surveys through a national database for ground surveys (NADAG). NADAG is operated and developed by the NGU, and aims to make all public ground surveys accessible, so that updated information on hazard areas and ground conditions will be accessible to all developers and planners, as well as to all agencies in emergency situations. Ground surveys financed by the NIFS agencies are regarded as public data. All agencies should strive to establish a contractual basis that includes a handover obligation to NADAG when ground surveys are carried out by public sector parties. The NIFS programme regards it as very important that this database as far as possible includes all available/relevant material associated with ground conditions. NIFS therefore recommends the introduction of an obligation on the part of all developers to submit such information to NADAG.

More emphasis must be placed on the mapping of flood and landslide/avalanche hazards in connection with streams and floodwater resulting from human intervention in natural drainage paths, including floodways, culverts and damage points (with a description of cause). This will make it easier to identify vulnerable points that should be subject to measures and focused on in emergency situations.

NIFS has made a significant contribution to achieving better data coordination between the agencies. Important questions that must be clarified in this ongoing collaboration are:

- Ownership of datasets when these are shared/mirrored between the systems. This concerns, for example, the manner in which data from landslide/avalanche and flood events from the Norwegian Public Roads Administration's database 'National Road Databank' (NVDB) and the Norwegian National Rail Administration's 'BaneData' are to be stored and displayed in the National Landslide/Avalanche Database.
- Improved data flow from the Norwegian Public Roads Administration's road traffic control centres and the Norwegian National Rail Administration's weather officers concerning closed roads/railways caused by floods, landslides/avalanches and other natural hazards (e.g. for publication at xgeo.no)

Shared data generates shared benefits – National Database for ground surveys – (NADAG)

Example of ground surveys as displayed in NADAG.

Background:
Report to the Storting No 15 (of 30 March 2012) emphasises the importance of making ground survey data available. The Geological Survey of Norway (NGU) together with NIFS has developed a National Database for ground surveys (NADAG) as a tool for more effective collection and use of ground survey data.

Calculations performed by Vista Analyse /114/ show that the cost of developing and running NADAG is around NOK 2.5 million per year. The anticipated (uncertain estimate) socioeconomic benefits are around NOK 16 million per year.

References:
- NIFS (2013-23): National Database for ground surveys – NADAG – feasibility studies /62/.
- Link to database: NADAG.

Collaboration and coordination or data are profitable.

3.3.3 Risk and vulnerability analyses

Risk and vulnerability analyses (RAV) are a key tool for assessing risk and vulnerability (including to floods and landslides/avalanches) for both existing and new infrastructure. There are major variations in the scope and quality of the RAV analyses that are conducted, however. Knowledge of the purpose of RAV analyses and how they should be used is also lacking. This gives rise to uncertainty in the procurement of such analysis services, both as regards requirements specification and assessment of the results. In certain contexts it would appear that this task has primarily been undertaken so as to be able to 'tick' the box for 'RAV analyses have been performed'.

The report 'RAV analyses in land use planning', /23/ which provides recommendations on the requirements for RAV analyses, demonstrates that there is a need to map the processes for RAV analyses in the three agencies more closely and to see these in light of the agencies' acceptance criteria. The agencies should be driving forces for gaining a uniform understanding of what is required of RAV analyses. Work should also be directed towards improving the understanding between the agencies of what constitutes an adequate level of research and documentation, based on the applicable acceptance criteria.

The NIFS programme has concluded that the transport agencies should primarily organise the RAV analysis work during the planning phases for adaptation at the municipal and county levels, as the latter represent the decision-making authorities /23/.

RAV analyses must be seen in a broader context

Background:
The transport agencies should organise the RAV analysis work for adaptation by the decision-making authorities at the municipal and county levels. There must be close co-operation between the transport agencies and municipal/county authorities in the implementation of the planning work. Keywords include the role of municipal authorities, the importance of the catchment area, the need for mapping vulnerable areas and for carrying out 'multi-disciplinary' RAV analyses. Participants in RAV analyses must be qualified to consider natural hazards and, as a minimum, be capable of assessing whether special expertise is required and able to procure necessary assistance where expertise is lacking. NIFS recommends further efforts to achieve uniform (if not identical) implementation and reporting (presentation) of RAV analyses.

Consistent RAV analyses should get everyone involved!

References:
- DSB 2014 Veileder til helhetlig risiko- og sårbarhetsanalyse i kommunen ('Guidelines for overall risk and vulnerability analysis in local government') (ISBN 978-82-7768-344-7) /115/.
- NIFS (2015-62): RAV analyses in land use planning /23/.

RAV analyses must be performed together and from an overall perspective.

3.3.4 Communicating hazards and risks

There are particular challenges associated with disseminating the results of mapping hazards and risks. It is of great benefit for the general public to be properly aware of hazards and risks, while we must also ensure that we do not spread unnecessary fear. At the same time, the publication of such results can have significant financial consequences, for example, for valuation of land.

Separate hazard zone maps have been prepared for different natural hazard events, including flood risk, quick clay, landslides/avalanches in steep catchments (avalanches, slush flows, rock falls, debris slides/flows and rockslides) Much work remains, and climate change is making this work more extensive. Public sector funding does not cover present day needs, so that all contributions to improving efficiency and performing mapping assignments are of great importance. During the programme period, NIFS organised four industry seminars for landslide/avalanche risk mapping to enhance skills and contribute to increasing capacity. The presentations from the seminars are available on the NVE website and on natural hazards.

NVE is responsible for the web portal skrednett which is used to provide an overview and links to relevant information, guidance material on mapping landslide/avalanche hazards, land use planning, safety measurs, forecasting and preparedness, for use in landslide/avalanche prevention work.

Recommended measures – mapping of hazards and risks

- Continued collaboration on mapping flood and landslide/avalanche hazards
- Continued work on standardisation, data collection and sharing of information about flood and landslide/avalanche events
  - Data from flood and landslide/avalanche events should be made accessible
  - Quality assurance of the National Landslide/Avalanche Database and improvement of registration solutions
  - All map information must be made available via web portals
- Establishment of routines to ensure that both historical and future data are submitted to NADAG
  - A contractual basis should be established that ensures a handover obligation to NADAG when ground surveys are carried out by public sector parties.
  - Establishment of routines for exchange of ground survey data via NADAG between all parties in the industry
- Further development of the collaboration on skrednett
- Preparation of adequate map data and a national elevation model with sufficient resolution, for the whole of Norway.
- Continued efforts to achieve overall implementation and reporting (presentation) of RAV analyses.
- Method for climate analyses for calculating extreme precipitation values used in landslide/avalanche risk assessments and studies

3.4 Land use planning

Assessing natural hazards must be a fundamental element of land use planning, particularly related to climate change. The pressure on land, urbanisation and environmental considerations means that there are many issues other than natural hazards that must also be emphasised in connection with land use planning. The focus on the impacts of climate change, however, is about to alter this picture. Assessment of flood and landslide/avalanche hazards is now required as an integral part of land use planning, although in practice it has been demonstrated that there are still major challenges associated with a lack of relevant professional skills. Experience from multiple flood and landslide/avalanche events, which have damaged road and rail infrastructure, shows that they are often triggered by building and construction projects. In these cases, the projects have either not been considered by the local authorities, or the events have been triggered by factors that have not been considered by the local authorities in their case processing.

Figure 6 Water finds new paths during a summer downpour in July 2014 at Bæla in Lillehammer.
Photo: Steinar Myrabø, 2014.

3.4.1 Municipal planning and case processing

In many cases, landscape intervention can increase the risk and consequences of flood and landslides/avalanches. It is generally the case that various types of landscape interventions are carried out close to public rail tracks, roads and buildings without possible flood and landslide/avalanche hazards being adequately assessed. This is attributable to a lack of understanding of which regulations actually apply, but is also partially attributable to unclear or too liberal regulations. For example, there is no application requirement for smaller embankments or ground levelling up to a height of 3 metres from the original level in sparsely developed areas (Section 4-1 Building Application Regulations). It should also be noted that, while other general formulations in the regulations provide a basis for assessing whether an application is required for a development project, such a specific limit could be perceived as a 'safe' embankment height. In quick layer areas an embankment of this height could be sufficient to trigger a landslide/avalanche.

Consequently, there is a need to look more closely at the provisions of the Planning and Building Act and how information on natural hazards is disseminated and understood. This particularly applies to measures in connection with the cultivation of new land, construction of forest roads and implementation of drainage measures in agriculture and forestry. /126/. It must be ensured that the municipalities submit relevant forest road development cases to the Norwegian National Rail Administration and the Norwegian Public Roads Administration.

3.4.2 An example of water management

Many of the challenges of land use planning relate to managing water as a natural hazard and the consequences of floodwater. Managing water, both in the form of runoff from the natural catchments and flood management, must therefore be included in all planning phases and the entire catchment area should be seen from an overall perspective.

NIFS has participated in the work of the project group for 'Regional plan for River Gudbrandsdalslågen and tributaries' in Oppland, and our experience of the collaboration that was established has been good. The work continues/118/ and includes:

Watercourse model for Lågen. NVE will be contributing with the development of a hydraulic model for parts of River Gudbrandsdalslågen and an impact analysis of the effect on flood risk of selected measures. The work is ongoing and will be completed in 2016/2017.

Study of sediment sources. In summer 2015, NVE conducted an extensive inspection of River Gudbrandsdalslågen and tributaries in order to map which of them carry the greatest volume of sediment. The results of this inspection will be used to identify what type of measures are required and where they should be implemented to reduce sediment transport.

Relevant measures in tributaries. Based on NVE's work with sediment sources, rivers that carry large volumes of sediment have been studied more closely and the need for measures has been considered.

Floodway maps for Oppland County. The project group is looking at the various tools that are available for planning flood and landslide/avalanche protection in small catchments. Use of models based on digital terrain models together with experience from NIFS are being considered in particular. The goal is to identify the most relevant tools and enable local authorities and other agencies to use these in their future land use planning as well as in planning flood and landslide/avalanche protection in small catchments. The County Governor in Oppland, the Norwegian Mapping Authority and the Norwegian National Rail Administration are now in the process of developing floodway maps for the whole of Oppland and Hedmark counties.

Arrangements will also made to offer municipalities training in the form of courses in how to utilise this tool.

Damage registration. Local police stations are responsible for registering insurance events in connection with natural damage compensation (the Natural Perils Pool). This task is now being transferred to a digital map database. The Norwegian National Rail Administration has developed a separate form for registering damage events.

Skills-enhancing measures. The work on the Regional Plan for the Lågen watercourse revealed a need for competence-raising measures for target groups such as municipal authorities, contractors, land owners, the Norwegian National Rail Administration, the Norwegian Public Roads Administration and the consultancy sector on issues such as 'Roads' (planning, case processing, construction and maintenance), 'Measures in watercourses' (planning and implementation), and 'Felling' (planning and implementation). Two specific course programmes have been prepared and initiated in collaboration with the Forestry Extension Institute (Forestry courses). The topics are 'The forest owners' "road map" to better forest roads' and 'Processing of road plans – with focus on climate change adaptation'.

The results are documented and communicated on an ongoing basis by Oppland County (Regional plan for River Gudbrandsdalslågen and tributaries).

Work on the regional plan for River Gudbrandsdalslågen can be used as a basis for a collaboration model to achieve an overall approach to protection from natural hazards in connection with watercourses. Communication in the planning phase

NIFS has concluded that conscious effort is required to improve communication and collaboration between the agencies and with other relevant projects, developers and land owners with regard to interventions with potential consequences for neighbours/others:

- Information obligation in connection with the planning and implementation of projects, including clarification at the overall planning level in order to avoid objections. In other words, unambiguous clarification of responsibilities in order to assess the consequences of new interventions and developments

- Clearer responsibility for assessing the consequences of interventions in existing infrastructure, i.e. inspection of the entire catchment area – including upstream of railways, roads and buildings
- An obligation to inform the two other agencies of planned safety measures Conscious efforts are needed to achieve better communication between the agencies regarding all types of relevant interventions
- Inquiries to and dialogue with all problem owners regarding coordinated planning of measures in the entire catchment area

NVE organised two rounds of 17 and 13 regional professional workshops, respectively, on floods and landslides/avalanches, as well as land use planning seminars in its five regions, during the periods 2010–12 and 2014–15 /136/. The experience was very positive. During the final round there were 86 participants from outside the NVE, including 40 from the Norwegian Public Roads Administration and 10 from the Norwegian National Rail Administration. This work must be followed up and expanded on.

Recommended measures – land use planning

- The possibility of introducing more stringent regulations for developments in the vicinity of railways and roads should be investigated.
- Better contact and collaboration concerning agricultural and forestry activities with regard to natural hazards
  - It must be ensured that the municipalities submit relevant forest road development cases to the Norwegian National Rail Administration and the Norwegian Public Roads Administration
- Drainage paths and floodways must be considered at the start of the planning process (at the municipal master plan level) and followed up in more detail during all planning phases from construction plans to inspection of project execution.
- Evaluation of the work on the 'Regional Plan for the Lågen Watercourse' with the goal of establishing a practice for preparing management plans for the entire catchment area that also include assessment of natural hazards
- Communication between all agencies in connection with planning and implementation of land use planning for specific projects must be strengthened

3.5 Safety measures

Flood and landslide/avalanche protection includes a broad range of safety measures, ranging from the prevention of floods and landslides/avalanches (erosion protection, retention, energy dissipation, sediment management, drainage, vegetation and optimal operation and maintenance of same) to reducing the damage caused by events (flood walls, avalanche/landslide protection). Safety measures will largely be planned and implemented by the individual agency, municipality or private party. Safety measures can, however, have significant consequences for nearby properties and installations. It would be advantageous to have better communication between the agencies regarding all types of relevant interventions, including:

- Project planning and implementation
- Measures related to existing infrastructure
- Information obligation regarding all planned safety measures

Closer collaboration on safety measures will result in a more robust infrastructure and lower the risk of recurring damage, and enable overall planning of measures for the entire catchment area, which will benefit the economy as a whole. The outcomes will be fewer delays, better quality of structures and measures, reduced risk of damage and a better basis for overall RAV analyses.

3.5.1 Analysis of damage potential of landslides/avalanches

Important considerations in connection with preventive measures are the size of the exposed area and the damage potential of different types of landslides/avalanches. Numerical modelling tools are an important aid in assessing relevant areas and safety measures. The use of numerical models can also increase our understanding of landslide/avalanche dynamics, provide a better basis for assessing potential damage areas, and optimise safety measures.

An assessment has been carried of how the most commonly used empirical and numerical simulation models calculate known flood and landslide/avalanche events in Norway. Numerical models are complex and require a good understanding of landslide/avalanche dynamics and how various input parameters affect the result. This is described in more detail in our reports and discussed in student theses undertaken in partnership with the programme /27/, /105/, /120/, /121/.

NIFS recommends that the agencies and the agencies' advisers should utilise simulation tools to a greater extent for assessing runout distance, landslide/avalanche propagation (dynamics) and landslide/avalanche speed when planning safety measures. Multiple models should be used (both empirical and numerical) to support the results. Thorough knowledge of the models is a prerequisite for being able to utilise them and will provide better and safer forecasts for landslide/avalanche runout and speeds. The agencies must invest more in skills development of specialists who work with simulation models through joint courses and industry workshops/seminars.

3.5.2 Choice of measures

There are extensive empirical data for assessing the effects of various safety measures. However, only some of the data have been systemised and evaluated with regard to type of damage, impact and costs. Hence, there is a need for a better overview of implemented safety measures for use in the analysis of events or when planning and assessing new measures. NIFS has particularly focused on putting in place an overview of reliable measures that work well and that can be used as 'templates'. Inspections have shown examples of how a lack of planning has resulted in measures that were not fit for purpose. There is also evidence that several safety measures have not been operated and serviced to a satisfactory level to uphold their safety effect. There are also examples of multiple parties requiring measures in the same area, whilbut a lack of knowledge of each other's plans result in sub-optimal solutions in terms of both location and design of measures. The programme has shed light on different safety measures, relevant areas of use and assumptions and experience in several NIFS reports /20/, /21/ /24/, /25/, /26/, /51/, /54/, /111/, /112/, /113/. Reports are currently being prepared on our experience of the pilot project catchments.

There is a need for the agencies to register implemented safety measures in a uniform way to facilitate information exchange and coordination. NIFS has created a list of what objects and properties landslide/avalanche safety measures should include (product specification). This has been reported to the Norwegian Mapping Authority, which coordinates the work to establish a coordinated reference system ('SOSI standard') for landslide/avalanche protection structures using a joint product specification.

Registering and sharing data on avalanche/landslide protection structures is important in order to benefit from past experiences and establish a best practice. A clear goal is to improve the quality of implemented safety measures.

A higher degree of systematic planning and implementation of safety measures will provide more correct design and location in the terrain. A common understanding of terms and definitions will facilitate sharing of data and lead to fewer misunderstandings stemming from different use of terminology. Relevant terminology is provided in NIFS report 2015-90 /17/. A complete overview of implemented safety measures is needed for use in connection with events or in planning/assessing new measures. This work has started, and work is under way on a solution for registration in both the National Road Databank at the Norwegian Public Roads Administration and in Banedata at the Norwegian National Rail Administration.

Vegetation has a significant potential for reducing the risk associated with landslides/avalanches and floods. Correspondingly, vegetational changes and clear-felling have potentially great consequences in the form of increased risk of floods and landslides/avalanches occurring and greater consequences for people, buildings and infrastructure.

NIFS has looked at the effect of forests as a landslide/avalanche mitigation measure in steep catchments. The results will be used to assess the effectiveness of forests in landslide/avalanche prevention work (hazard mapping, land use planning, safety measures) /105/. The study has shown that birch forests have a clear mitigating effect in avalanche trigger zones, while spruce forests have a mitigating effect on rockfalls in trigger zones and runout areas. Forests are often decisive for whether an avalanche can be triggered at all and for whether its size and runout can threaten buildings and infrastructure. NIFS has contributed with field validation of indications from previous Norwegian research, by attempting to trigger avalanches on steep slopes with various densities of birch forest. The results show that even small deciduous trees such as mountain birch with twigs and undergrowth reduce the possibility of triggering an avalanche and of fracture propagation. This particularly applies to snow conditions in which persistent weak layers represent an avalanche problem, as is often the case in a cold, dry climate. The results are presented in NVE report 2015:73 and have already been implemented in NVE's work and communicated to the consultancy sector.

3.5.3 Upgrading and maintenance of safety measures

The extent to which existing infrastructure is rebuilt after exposure to natural damage is considerable, and, when rebuilding, it is therefore important to ensure that the need to reduce the risk of new damage occurring is also addressed. Rebuilding must be planned so that the repairs do not merely restore the infrastructure to its original standard but also increases its robustness to withstand similar events. This means that an assessment must be made of the infrastructure's robustness in relation to future climate change. This is partially ensured in that the regulations on rebuilding and repairs to existing structures now also includes a requirement for robustness to withstand climate change. NIFS recommends establishing a fixed practice of cost/benefit analyses of different solutions. It should have the clear goal of ensuring appropriate technical quality and a higher degree of robustness /9/, /10/, /11/, /12/, /19/, /108/.

In particular, NIFS has highlighted the need for good routines regarding frequent inspection and maintenance to prevent damage occurring. There is a need to invest more in operation and maintenance. This applies to simple methods such as cleaning culverts, which, in turn, is important for reducing the risk of damage to infrastructure. By using more advanced methods of status monitoring and forecasting (e.g. level sensors with text message alerts in vulnerable streams), the need for manual inspection can be reduced and use of resources can be targeted.

Recommended measures – safety measures

- A practice of mutual information exchange (information obligation) should be established with collaboration across projects, property boundaries and infrastructure in connection with the planning and implementation of safety measures.
- The agencies and the agencies' advisers should start using modelling tools (empirical and numerical) for assessing the runout distance, propagation (width) and speed of landslides/avalanches.
    - The agencies should look further at the input parameters used in numerical simulation models for landslide/avalanche analyses to see how these affect the simulated results compared with observed landslides/avalanches
- Rebuilding after events must be made more climate robust. Cost/benefit analyses must be performed as a basis for assessing different solutions
- Collaboration on providing a systematic overview of safety measures (measures report) must be continued
    - Presentation of safety measures with evaluation of suitability and effect in a joint database
    - Continued collaboration between agencies and municipalities on creating a shared overview of good and bad measures and use of the experience in the selection and implementation of safety measures against floods and landslides/avalanches
    - Establishment of fixed routines for monitoring and maintenance of safety measures in connection with infrastructure
- NIFS recommends adjusting the criteria for assessing the landslide/avalanche prevention effect of forests.

3.6 Managing floods and floodwater

Floodwater causes great damage and has consequences for many people. It also represents a significant socio-economic cost. There is therefore a need for a comprehensive management of flood and surface water, in which the entire catchment area is seen in context. This is a challenge given the large number of parties involved and where the consequences are in many instances greater for those who are 'downstream' of the event than where the problem arises. Even relatively minor changes to drainage and runoff conditions can result in very extensive damage to nearby infrastructure.

On 6 August 2012, the extreme weather 'Frida' brought around 70–130 mm of precipitation to a narrow zone through Buskerud County with the highest intensity in Nedre Eiker. The high volume of precipitation caused a flood with a recurrence interval of 50 years or higher in parts of Buskerud County. NIFS has examined six areas in which flooding resulted in damage to buildings, roads and railways. These are areas near Krekling, Darbu, Burud, Skotselv and Åmot, all of which are situated outside the area with the greatest precipitation intensity, and the Krokstadelva river, situated in the area with the highest intensity. The photos in Figure 7 and Figure 8 illustrate how floodwater can have major consequences in the form of material damage and danger to life and health.

Figure 7 Floodwater running through a property at Burud. Photo: Steinar Myrabø, 2012.

Figure 8 Large volumes of floodwater accumulated behind the railway embankment at Burud, creating such enormous pressure that the embankment collapsed. Photo Steinar Myrabø, 2012.

The analyses conclude that it is important to look at the catchment area as a whole when attempting to identify the cause of the damage. Cleaning and maintenance of drainage paths is very important to prevent floodwater and reduce the extent of damage during flood events. Socio-economic analyses have shown that there are great benefits in preventive measures, and in order to implement effective measures, relevant specialist knowledge is essential. /28/.

3.6.1 Terrain runoff

Runoff calculations, assessments of causes of events and measures in the field, as well as assessment of plans with regard to flood problems, require good hydrological and hydraulic expertise. Several major transport and urbanisation projects suffer from the consequences of too little focus on drainage and flood issues. This can lead to irreparable and long-term damage. The NIFS programme has presented a proposal for changing areas of responsibility in connection with consultation rounds on the Building Application Regulations in the Norwegian Building and Planning Act. By promoting hydrology and hydraulics as separate areas of responsibility, they will receive greater focus in building and construction projects and these disciplines will have to be addressed in all major projects on an equal footing with other areas of responsibility. One precondition for adequate flood and surface water management by the agencies, is good ordering skills and the correct technical expertise. This will improve the quality of analyses and assessments and lead to better and more correct solutions. Thes will result in greater safety and robustness against flood and landslide/avalanche damage.

3.6.2 Floodways

A floodway is a path, natural or constructed, that leads floodwater to a recipient. Floodway maps are an important preparedness measure for preventing damage associated with flooding and surface water. Floodway maps (on both the regional and local scale) should be prepared that can be used as precautionary maps and to assess whether the drainage measures of different owners have been adequately designed.

Overall watercourse management plans are an important tool for managing the challenges surrounding floods and floodwater. NIFS recommends that the agencies closely follow and participate in the development and implementation of the 'Regional Plan for the Lågen Watercourse and Tributaries' and build on the experiences acquired from it.

The different agencies each possess data relating to floods, surface water and drainage. However, the data are partially in different formats, there is variation in which data are registered, and the data vary in quality. It will be of great value to achieve a total overview of registered events and for the data to be coordinated and comparable. At present, information about drainage measures is available in separate databases of the Norwegian National Rail Administration and the Norwegian Public Roads Administration. Provision must be made for better access to data for drainage measures between the various parties. This is crucial to different kinds of analysis, such as assessing where the water is being drained to and identifying vulnerable areas. Our reports on the events in Notodden in 2011, after 'Frida' in 2012 and in Gudbrandsdalen in 2011–2013, illustrate this very well /28/, /112/, /127/.

3.6.3 Drainage plans

Closed drainage paths and other interventions should be registered uniformly and in accordance with a common template. In collaboration with the Regional Plan for Lågen Watercourse, NIFS has drawn up a list of the most important parameters that should be registered for culverts (water throughflows) and has made a proposal for the coordinated reference system ('SOSI standard')). All municipalities in Gudbrandsdalen can now register culverts in their municipality (own and others) and enter them in the National Road Databank (NVDB). The Norwegian National Rail Administration and the Norwegian Public Roads Administration have established their own lists of culverts with the most important information: geometry, capacity, repairs carried out, etc. It is important to develop and maintain this list, and there is a need to quality-assure and link data from the various databases.

Drainage plans should be made at a municipal planning level with mapping of all drainage paths, including those that are closed, as well as all interventions and measures such as culverts, sills, dams, grates, sand traps, etc. (including the most important parameters). Drainage plans at a municipal planning level will provide a good overview of natural drainage paths and floodways, resulting in a better basis for taking account of drainage and flooding in various analyses and in planning at different levels. In conjunction with event data, this will enable different parties to more easily identify vulnerable areas in which measures can be implemented, thereby saving much time and resources. This practice should form the basis for all development and planning work intended to reduce the risk of flood and landslide/avalanche problems, including climate change adaptation.

3.6.4 Source data for flood calculations

Knowledge from NIFS and other projects we have collaborated on shows that there are insufficient source data available for use in analyses and as a basis for decisions regarding flood and landslide/avalanche problems. In particular there is a considerable lack of measuring stations for runoffs in small catchments. This can be illustrated by the fact that there are no measuring stations in the entire Gudbrandsdalen area. It takes many years to obtain statistically reliable data, so a good national network is urgently needed along similar lines to short-term data for precipitation. A better developed network of measuring stations will provide a better basis for design calculations as well as for issuing landslide/avalanche and flood warnings.

Together with its partners, the NIFS programme conducted extensive work on source data for precipitation, water flows and better calculation methods and made this generally available /59/, /74/, /75/, /76/, /78/, /82/, /94/, /103/, /125/.

Additional reports and results will become available in 2016 and will be implemented on an ongoing basis in the agencies' guidelines and regulations.

Flood calculations in small runoff catchments

Background:

NVE has previously issued guidelines on flood calculations that elaborate on the provisions in the Regulations on safety in waterway systems and describe the relevant prerequisites and methods for carrying out flood calculations for dams in accordance with the requirements. The latest version was issued in 2011: Guidelines for flood calculations.

There has long been a need and a demand for flood formulae and guidelines that focus on flood calculations in small catchments. Intense, local cloudbursts have a rapid impact without any possibility for early warning, with an attendant danger to life and health. With new source data from the Norwegian Meteorological Institute, NIFS has created comprehensive new guidelines for flood calculations in small unregulated catchments, largly on the basis of the results from NIFS's activities and reports.

Reference:
- NIFS (2015-07) Guidelines for flood calculations in small, unregulated catchments /125/.
- NIFS (2015-13) National formulae or flood calculations in small, unregulated catchments /103/
- NIFS (2015-86) Comparison of methods of flood calculations in minor, unregulated catchments /107/.

Better flood calculations in small catchments are vital for local flood management.

3.6.5 Guidelines for drainage

NIFS has prepared a report that forms the basis of guidelines for the drainage of roads and rail tracks. The report will be coordinated with existing road standards and the Norwegian National Rail Administration's technical regulations, and provides complementary descriptions of the requirements stipulated in these. The report includes hydrological and hydraulic calculations and provides recommendations for the planning of drainage systems.

It recommends that hydrological assessments be adapted to the properties of the catchment area, including future land use and climate change extrapolations. Uncertainty in calculations should be described and managed by use of safety factors. Hydraulic calculations should take into account both flow conditions and sediment transport, so that the drainage system is adapted as far as possible to the local conditions during a flood. Uncertainty associated with design should be managed by use of safety factors, to be chosen based on the consequences of overloading the drainage system. The planning of drainage systems must take into account existing and future land use in terms of both roads and railway tracks as well as third-party waterways. It is recommended that all waterways be seen as part of a whole, in which both upstream and downstream areas can be affected by water flows, erosion and sediment transport. Water management should also be included as part of an overall RAV analysis of natural hazards and should be considered in conjunction with avalanche/landslide-technical assessments along watercourses. The report provides recommendations on levels of detail in the different planning phases and recommends analysis methods and sources of information during the planning process. The guidelines on drainage are currently being published.

Guidelines on drainage

Background:
Management and use of water is regulated through a number of acts and regulations. Within the agencies, floodwater management and drainage of roads and rail tracks are currently covered by the Norwegian National Rail Administration's standards and the Norwegian National Rail Administration's technical regulations. The standards contain dimensioning and design requirements for individual drainage elements. However, they provide little background on how the individual values have been determined, and the standards are hardly suitable as training material.

NIFS has drawn up guidelines on the drainage of roads and rail tracks. Emphasis has been placed on presenting practical experience and advice, so that the guidelines will also be of benefit to those who have a more practical approach to the material. Emphasis has also been placed on the need for all infrastructure owners to collaborate on the development of the drainage systems. The guidelines will also be useful for educational purposes.

Water flows that road and rail-track drainage systems must be capable of handling

Reference:
- NIFS (2016-028) Drainage of roads and rail tracks /140/

The book provides an overall presentation with advice on the design and dimensioning of surface water and drainage systems, particularly for roads and rail tracks. It will also be of use for protecting other infrastructure.

Recommended measures – managing water and floodwater

- Drawing up drainage plans on a municipal level with an overview of drainage paths and implemented measures
- Establishing hydrology and hydraulics as separate areas of responsibility in relevant development projects
- Updates to and follow-up by specialist agency teams of standards and technical guidelines
- Establishing routines for verification and approval of hydrological and hydraulic calculations when designing drainage measures
- Establishing a fixed practice for registration of drainage measures
    - Continuing work in the trial municipalities and extension of this work to cover the whole of Norway
    - The Norwegian National Rail Administration and the Norwegian Public Roads Administration should verify data for their respective culverts and register the most important parameters
- Establishing a common database for road and rail-track points that are vulnerable to floods and surface water
- Work on the creation of more and better floodway maps on a local and regional scale must be strengthened
- Making all data on drainage measures available in a map solution for mutual use by the Norwegian National Rail Administration and the Norwegian Public Roads Administration, so that it is possible to visualise all drainage measures in a given area.
- Establishing more runoff stations in small catchments. This must be carried out in close collaboration with all agencies.

3.7 Safety in quick clay areas

Norway, faces a particular challenge regarding the presence of quick clay and use of these areas, as do several other countries (Canada, Sweden). Quick clay consists of clay particles deposited in salt-water and is therefore present below the marine limit. The salt stabilises and binds the clay minerals and when it is washed out the clay assumes a structure which, if disturbed, can become totally agitated and take on a liquid form. Quick clay landslides can be triggered by minor interventions and become very large, even in almost flat terrain. In Norway many people live in areas where there is a potential for quick clay landslides, and history has shown many dramatic events with and without the loss of human life. The Rissa landslide in 1978 in which around 6 million m3 of soil flowed out, is an example of how extensive such a landslide can be. One person died in the landslide. A total of 15 farms, two residential properties, a cabin and a village hall were completely or partially damaged. The extent of the landslide is shown in Figure 9.

Figure 9 Photo from the Rissa landslide (1978). Photo: Scanpix.

Any developments in quick clay areas must take particular account of landslide risk. This is addressed in regulations and guidelines, including the Norwegian Building Authority's (DiBK) guidelines on technical requirements for building works /16/, NVE's quick clay guidelines /29/, the Norwegian Public Roads Administration's manual V220 /30/, the Norwegian National Rail Administration's technical regulations, /31/ and Eurocode 7 /32/. These documents provide guidelines on safe design and construction in each respective sector and, prior to NIFS, were partially overlapping and contradictory. Under the NIFS programme, there has been particul focus on improving our understanding of quick clay as a material, on harmonisation of regulations, and on coordination of practice relating to design and construction in quick clay areas. Landscape interventions and landslide/avalanche risk assessments are described in detail in 3.4.1. Increasing the public's understanding of the potential hazards associated with excavation and infill work represents a general challenge. The plan for the programme work is described in detail in the report 'A national initiative on safety in quick clay areas' /53/.

3.7.1 Mapping quick clay

Mapping quick clay areas: localisation, propagation, layering and material properties are a key to risk assessment of quick clay areas at risk of collapse and the consequences of potential landslides. Based on the Rissa landslide, a programme has been implemented for regional mapping of quick clay areas. Quick clay areas with a potential landslide risk are being mapped on a regional level and, as of 2015, more than 1,000 quick clay zones have been mapped. These zones are classified by degree of hazard, consequence class and risk class. The results of this work are available as regional hazard maps (kartlegging/kvikkleireskred/).

NVE and the Norwegian Public Roads Administration have collaborated to improve the quick clay map in Skrednett. The Norwegian Public Roads Administration's historical data are shown as 'quick clay areas' on the map, while on new road projects the agency will prepare quick clay zones in accordance with the quick clay guidelines. Maps of a large number of quick clay areas are being made easily accessible to the public. Easy access to information makes it simpler to take account of landslide/avalanche hazards in land use planning and in building application cases.

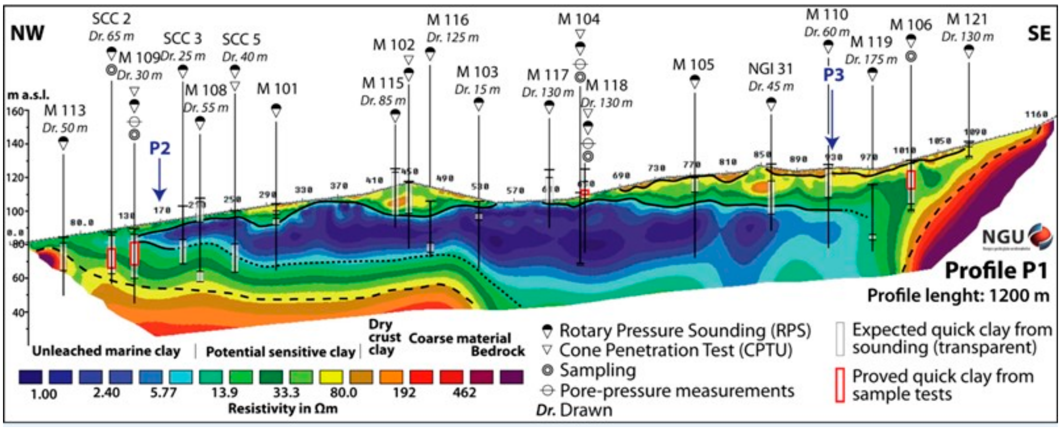
Figur 13: The quick clay in Lyngseidet in September 2010 caused vast damage of infrastructure and housing.
Photo: NPRA 2010

On the trail of quick clay

Background:
NIFS has been engaged in many activities related to improvement of methods for detecting quick clay. This has been done by looking at conventional geotechnical probing methods, combined with geoelectrical measurements, and developing these further.

Recommended detection procedures include conventional geotechnical probing methods, CPTU, vane shear testing and sampling with laboratory tests, downhole resistivity measurements (R-CPTU), electrical resistivity tomography (ERT) and airborne electromagnetic measurements (AEM). Results show that both previous and new methods must be used sensibly and leave room for misinterpretation in certain cases.

The project has resulted in a collaboration across geotechnics and geophysics, and it has looked at new methods, possible combinations of methods and the potential for further development. Combined use of geophysical and geotechnical measurement methods makes each technical field stronger and will be the recommended strategy in larger projects.



Example of combining ERT with traditional probing methods

References:
- NIFS (2012-46) Detection of quick clay using different probing methods /33/.
- NIFS (2013-42) Input to the national ground drilling database (NGD) /69/.
- NIFS (2014-47) Detection of brittle fracture material using R-CPTU /88/.
- NIFS (2015-81) Interpretation of active undrained shear strength from vane shear tests /34/.
- NIFS (2015-79) Extended interpretation basis for vane shear tests. Results from the preliminary study at the Norwegian University of Science and Technology /106/.
- NIFS (2015-101) Detection of quick clay using R-CPTU and electric vane borer. Results from field study /109/.
- NIFS (2015-126) Detection of brittle fracture material – final report /122/.

The work has raised competence in the industry and provided a basis for new guidelines from the Norwegian Geotechnical Society for detecting quick clay.

The NIFS programme has included a separate activity for the assessment of ground survey methods that can be used for detecting quick clay, and how these methods should be used. The work is carried out in partnership with the Norwegian Geotechnical Society and will result in common guidelines for necessary scope and type of ground surveys. The programme has focused on highlighting sources of error in current methods and experience. The programme has also improved existing field survey interpretation models /33/, /68/, /88/, /109/, /122/.

Vane shear testing is a simple and cost-effective method of determining the shear strength of clay in the field. Discussions surrounding the quality of the results as well as easier access to more advanced probing such as CPTU have resulted in a reduced range of use. NIFS has conducted a study that shows it is possible to establish a correlation between the shear strength of quick clay determined by vane shear tests in the field and traditional laboratory tests /33/, /34/, /68/, /106/, /109/. Further work is recommended to improve the quality of vane shear tests and to establish more source data in the form of a single database of results.

3.7.2 Guidelines for stability assessments

Stability calculations in areas containing quick clay can be a challenge and have often been the subject of much discussion in the geotechnical community. This applies to both geotechnical structures such as embankments and cuttings and also to natural slopes. Previously, stability assessments have been largely limited to assessing local stability, but there is now also a requirement for assessing what is defined as area stability in a wider area around the construction site.

It is very important for the agencies to clarify the distinction between local and area stability as this provides guidelines for which regulations to use. At present, there are some differences in practice within the industry. This is sometimes manifested in situations where what should have been area stability issues are treated as local stability issues. This has resulted in the planned measures being very extensive and have in several cases led to huge additional costs or brought a development project to a halt (kvikkleire-stopper-veg).

In collaboration with key players in the geotechnical community in Norway, the NIFS programme has worked on coordinating and revising guidelines and establishing a basis for an agreed practice for assessing the stability of quick clay areas /60/, /84/, /85/, /93/.

The NIFS programme has defined a distinction between local stability and area stability, which has been incorporated in the NVE's quick clay guidelines /29/. The distinction creates a natural transition between the agencies' regulatory frameworks. The NIFS programme has also established a calculation methodology for defining the boundary between local and area stability. This makes it possible for the construction client to differentiate between safety levels with regard to necessary local safety and the robustness of the measure in question. Calculation tools used in stability calculations do not possess the functionality to automatically identify the boundary in accordance with the proposed calculation methodology. The incorporation of calculation algorithms that automatically identify the boundary between local and area stability will simplify the method further /35/, /72/, /129/.

Another issue associated with guidelines for stability calculations is how the stability of natural and existing slopes should be assessed. The current practice is to assess these in the same way as slopes on which planned developments impose an additional ground load. NIFS has organised gatherings with important players in the industry to arrive at an agreed recommendation on how natural slopes should be assessed. The recommendation opens up for calculating natural slopes using drained shear strength parameters, subject to a minimum safety requirement based on undrained parameters to ensure a certain degree of robustness. A requirement is also included for a certain number of ground surveys and an overview of seasonal variations in pore pressure. In practice, the proposed changes will in many cases reduce the need for safety measures, which will also reduce costs. The proposal is described in a separate report /133/.

3.7.3 Trigger factors and propagation of quick clay landslides

Quick clay landslides can be triggered by apparently insignificant factors such as minor excavations, embankment works or erosion from rivers or streams in clay terrain. Disturbed quick clay and overlying soil can move up to several kilometres under unfavourable topographical conditions. The current practice for assessing the extent of trigger zones, runout areas and trigger factors for quick clay landslides is experience-based, and these methods have not been updated with information on landslides since the 1980s. The NIFS programme has looked more closely at and prepared an overview of known quick clay landslides as a basis for further analysis /61/, /65/, /66/, /67/, /71/.

A practical and more accurate method of estimating trigger zones and runout areas for quick clay is being prepared under the auspices of NIFS. The methods is intended for use on both an overall and on the detailed planning level. The method applies to quick clay landslides that do not run out to the sea and is based on available literature and experience-based knowledge /132/. The NIFS programme recommends that empirical correlations for landslide runouts to the sea are prepared, along with any assessments of secondary effects such as flood waves. Consideration should also be given to whether degree of hazard and impact assessments should differentiate between trigger zones and runout areas. NIFS has also supported research work to identify relevant parameters that can be used to prepare a numerical calculation model for calculating runout areas for quick clay landslides. The research found several uncertainties and weaknesses that must be dealt with before a complete calculation programme can be launched /89/, /90/, /91/, /92/. The research is being continued in Geofuture II, a research project supported by the Research Council of Norway.

The landslide at Nord-Statland gave the NIFS agencies an opportunity to test a closer collaboration through joint evaluation of the landslide and its causes. /101/. Studies of the event have provided much learning and experience and have identified issues associated with vibrations as a potential trigger factor for quick clay landslides. Against the background of this experience, studies have been conducted that have lead to new understanding of how vibrations from, for example, compacting work, could be one of many triggering factors of quick clay landslides. The results of these studies provide a basis for a new assessment methodology and revision of the applicable regulatory framework. The recommended principles for assessing landslide hazard on slopes of loose material as a consequence of vibrations from construction work have been summarised in a separate report /134/.

3.7.4 Stability calculations in quick clay areas

The geotechnical community agrees that choosing the correct material properties for quick clay (e.g. shear strength has an important impact on the calculated certainty of stability analyses. Assessing these properties has been an important task for the agencies in which the choice of shear strength, whether conservative or non-– conservative, can have great financial (and societal) consequences in many projects. In collaboration with key parties in the geotechnical community, the NIFS programme has established a common practice for assessing shear strength profiles and anisotropy factors in clay. The results of these studies have been summarised in separate reports /57/, /58/, /77/, /98/.

The programme has looked more closely at a probabilistic approach/analysis of ground surveys /56/. NIFS has part-financed a doctoral thesis that has examined the use of probabilistic methods of stability assessments in quick clay areas /36/. The work shows that an increased scope and better quality of ground surveys increase the reliability of a stability analyses. Probabilistic analyses will be able to help quantify any uncertainties in a stability analysis. It will therefore be a good tool for reducing such uncertainties by highlighting which variables are most important for the overall fracture probability. Probabilistic analyses as a tool for assessing safety in connection with developments in quick clay areas should be given priority in future. When addressing this topic further, trigger factors, both natural and man-made, must be included in an overall assessment of fracture probability.

3.7.5 Quick clay landslides in the shore zone

Very many quick clay landslides can be related to major or minor interventions in the shore zone. There is often little knowledge of ongoing processes and few data about the subsea terrain, as underwater mapping (bathymetry) is costly . Thus, regional quick clay mapping has barely been concerned with shore zone conditions.

One objective of the agencies has been to examine whether any special shore zone issues should be taken into account when mapping and classifying landslide risk. This is because several events have indicated that the degree of hazard may have been underestimated, particularly as a consequence of inadequate knowledge about topographical and morphological conditions. Degree of hazard assessments and delineation of quick clay zones are conducted using the same methods as previously (on land), but it is important to also examine the subsea topography and ground conditions separately. This includes seabed topography (including location of shore slope) and ground surveys that can detect any landslide-prone loose material along the seaboard /37/, /38/, /79/, /81/.

3.7.6 Stabilising quick clay areas

NIFS is funding research into salt infiltration in the form of a doctoral thesis at the Norwegian University of Science and Technology. New surveys have been conducted in a test field established at Ulvensplitten in Oslo in 1972, with a mixture of salt in quick clay. The results of the survey from the old test field show a considerable increase in the strength of the quick clay from salt infiltration, and there is also a continuing stabilising effect even after a prolonged period.

A new test field was also established at Dragvoll in Trondheim in 2014 to examine how salt spreads in clay deposits. The results of the experiments are expected to be ready in 2016.

The results from these studies could contribute to a better understanding of infiltration mechanisms in Norwegian clay as a potentially cost-effective method in long-term safety work in areas with low safety levels /63/.

The programme has looked more closely at various forms of stabilisation of sensitive clays both in Norway and abroad /64/, /100/. More detailed investigations into how quick clay reconsolidates itself after a landslide event have also been carried out /70/. The material properties of quick clay have been studied in detail both in the field and in the laboratory /95/, /96/, /98/, /99/.

3.7.7 Further work

NIFS has conducted research to get a better understanding of issues associated with quick clay and landslide/avalanche hazards that have led to concrete results and recommended measures. In some cases a need has been identified to conduct further research into many of the topics. This particularly applies to:

- Detection of quick clay
- Probabilistic analysis as a tool for assessing landslide/avalanche hazards
- Model for estimating historical and future pore pressure (climate impact) in natural slopes.
- Vibrations from construction activities as trigger factors for landslides/avalanches
- Development of a method for numerical modelling of runout areas
- Further development of methods for stabilising quick clay
- Further development of our understanding of the fundamental material properties of quick clay
    - Reconsolidation of quick clay following a landslide
    - Effect of storage time and sample disturbances
    - Interpretation of vane shear tests
- Method for assessing runout areas on an empirical basis extended to include landslides with runouts to the sea
- Assessment of degree of hazard and consequences in quick clay runout areas

The NIFS programme has established an international collaboration with other countries that face similar challenges associated with quick clay (primarily Sweden and Canada). The NIFS programme has been an initiator and main contributor in establishing and implementing the 1st International Workshop on Landslides in Sensitive Clays (Quebec) IWLSC2013. A considerable part of the quick clay work in the NIFS programme will be published in connection with the 2nd International Workshop on Landslides in Sensitive Clays (Trondheim) IWLSC2017.

Recommended measures – safety in quick clay areas

- Incorporation of the results of NIFS in relevant guidelines and regulations:
  - Distinguishing between local stability and area stability
  - Procedures for mapping and determining degree of hazard in shore zones containing quick clay
  - Criteria for using effective stress analyses in stability assessments of natural and existing slopes
  - Agreed principles for choice of shear strength properties of clay
  - Agreed recommendation on using anisotropic displacement parameters (ADP) in stability calculations
  - Methodology for assessing landslide/avalanche risk resulting from vibrations from construction activities
  - Procedures for sampling and interpretation of block test data
- An algorithm has been developed for locating the boundary between local stability and area stability for use in geotechnical planning tools.
- Recommended method for calculating trigger zones and runout areas tested in relevant projects under the auspices of the agencies, and further development based on experience before full implementation in NVE's quick clay guidelines.
- Probabilistic analyses as a tool for assessing safety in connection with developments in quick clay areas should be considered as a future focus area
- Methods for stabilising quick clay should be tested in relevant projects
- Effect of storage time on clay samples should be taken into account when planning and conducting ground surveys
- In future revisions of the agencies' regulations and guidelines, particular attention should be paid to landslide/avalanche issues in shore zones.

3.8 Monitoring and forecasting

Climatic and topographical conditions in Norway mean that full protection of infrastructure against floods and landslides/avalanches is considered an impossible task. Monitoring and forecasting natural hazards is an important priority area in order to increase the predictability of hazardous events. This can improve information about the potential hazard, thereby reducing the risk to life and health. Experience of instrumentation in landslide/avalanche-prone areas show precisely that increased knowledge of landslide/avalanche runout paths obtained by means of instrumentation provide a better basis for assessing the damage potential and need for safety measures such as closure and evacuation. This is well illustrated through measurements of the stability of the area around Mount Mannen in Rauma municipality in 2014 and 2015 (Red danger level for the Veslemannen massif). The results of the monitoring programme for landslide movements in 'Veslemannen' / 39/ are directly used in evacuation plans when communicating with the general public. Also, similar observations have been made through sub-projects in a number of other areas. An example of this is laser scanning of areas that pose a potential landslide/avalanche risk / 22/, /131/.

Forecasting and monitoring activities were largely overlapping with current activities in the operational landslide/avalanche forecasting system that the same agencies collaborated on alongside NIFS. Multiple activities were therefore guided and financed by the landslide/avalanche forecasting services, while NIFS only handled smaller R&D activities associated with these. The weighting between NIFS and the landslide/avalanche forecasting services is outlined in Figure 10.

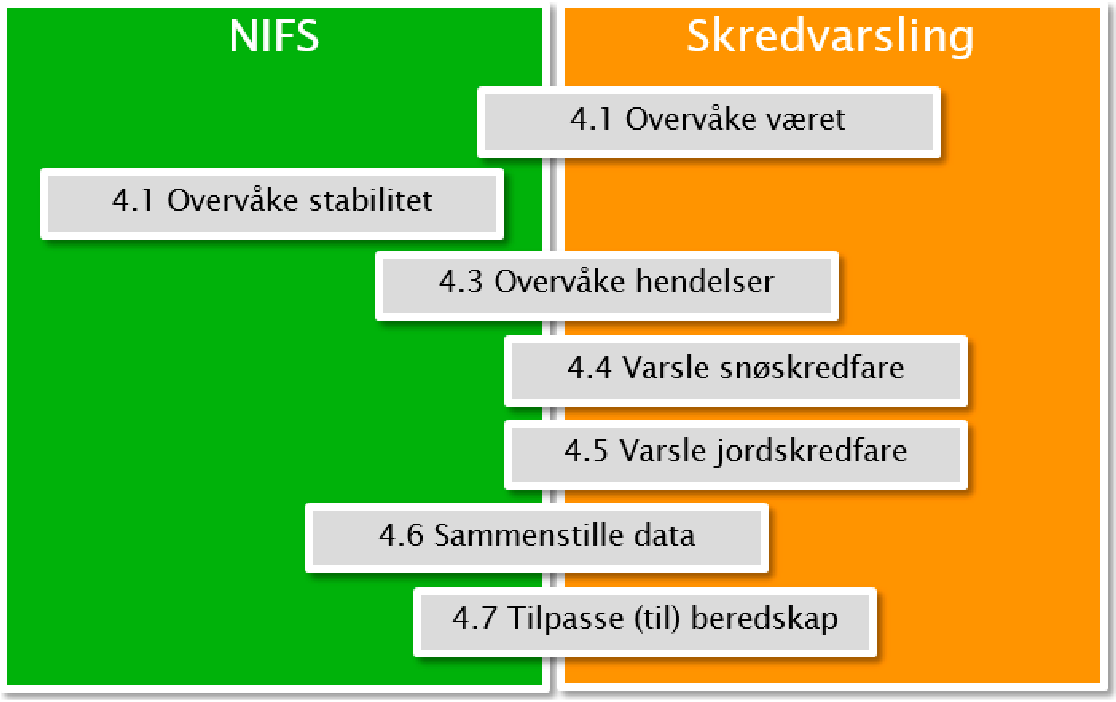


Figure 10 The figure outlines how activities in the sub-project for forecasting and monitoring were distributed between NIFS and the operational landslide/avalanche forecasting services.

Only projects within the topic of stability monitoring were entirely financed and managed by NIFS, whereas in respect of the other activities, NIFS contributed with R&D assignments and documentation of activities that were primarily financed and managed by the landslide/avalanche forecasting services.

3.8.1 Monitoring stability

In NIFS the coordination of equipment and services for monitoring stability has been tested across the agencies through collaboration on the specific projects that have been initiated. We have seen that this coordination has provided better utilisation of expertise, equipment and instruments across the agencies, as well as faster response times and better quality when there has been a need for rapid response to events. It will obviously be beneficial to take take this kind of coordination further. In practice, the basis for such a permanent collaboration has already been established through NIFS.

The methods for stability monitoring that have been tested in NIFS have primarily concerned instrumentation in and adjacent to defined slide paths or remote sensing of larger landslide/avalanche areas. The instrumentation used has included geophones, tremor measurements, ///guide shoes (skids?) and various snow profile measurements. Laser scanning, radar, time lapse photography and terrestrial photogrammetry and aerial photogrammetry using drones and helicopters are examples of optical and electro-magnetic remote-sensing techniques, while infrared measuring of avalanche activity is an example of acoustic remote sensing techniques. All these methods have been tested in this sub-project.

These projects are presented in detail in the final report from the sub-project, which is currently being prepared. Several of them are also discussed in a 7-page article in the publication Teknisk Ukeblad, see facsimile in Figure 11.

Figure 11 Facsimile of Teknisk Ukeblad no. 5/2015 about different instrumentation and remote sensing techniques used to monitor stability and landslide/avalanche movements.

The testing of the various measurement methods has in itself provided better knowledge about the technology behind the methods, but it has also contributed to a better overview of the possibilities and limitations within the different areas of application. A summary of the areas of application is given in Tabell 2.

Table 2 Summary of measurement methods assessed by NIFS and classified into the most relevant areas of application.

Areas of application	Measurement method tested and assessed in NIFS
Real-time forecasting of landslides/avalanches Measurements in specific slide paths of landslide/avalanche mass movements or of resulting ground vibrations. May be used in automatic forecasting by means of, for examlpe, traffic lights.	- Doppler radar for avalanche paths - Geophones in avalanche paths
Forewarning of imminent landslides/avalanches Measurements of trigger zone properties for specific avalanche paths. Can be used as a basis for local and/or regional forecasting.	- Snow profile measurements in trigger zones - ///Guide shoes (skids?) under wet snow cover (slab avalanches) - Ground-based InSAR-radar for slab avalanches - Time lapse sequence of trigger zones
Identifying general landslide/avalanche activity Measurements of general landslide/avalanche activity and indications of landslides/avalanches that have occurred in landslide/avalanche-prone areas.	- Infra-red measurements (avalanches) - Tremor measurements (rockfalls)
Identifying terrain deformation Mapping landslide/avalanche-prone areas, documentation of developments in areas of suspected landslide/avalanche risk and detecting the risk of new landslides/avalanches following an event.	- Ground-based InSAR (terrain surface) - Satellite-based InSAR (terrain surface) - Ground-based laser scanning (terrain surface) - Terrestrial photogrammetry and aerial photogrammetry using drones and helicopters (terrain surface)

Recommendations regarding implementation and further development of monitoring methods are described in detail in the summary report from the NIFS sub-project, which is currently being prepared. Several of the projects have also been documented in reports from a number of suppliers.

Interferometric Synthetic Aperture Radar (InSAR) is a satellite-based radar technology that enables mapping and monitoring of terrain deformations. The multiple-use potential of satellite-based InSAR radars and relevant R&D assignments have been documented in a feasibility study in which the Norwegian Public Roads Administration, the Norwegian National Rail Administration and NVE participated together with the Norwegian Geotechnical Institute and the Norwegian Space Centre /123/.

Through NIFS, the Northern Research Institute has mapped the possibilities and limitations of using InSAR technology for more than just rockslides (rockslides along roads). This has improved the agencies' knowledge of the possibilities and limitations of using InSAR technology from radar satellites. The greatest benefit of InSAR is that it can be used in areas that are difficult to access and can provide an overall picture of an area as opposed to other methods that primarily provide point information. The actual methodology is well developed, but there are still some limitations on utilisation of this method in very steep terrain and in areas of dense vegetation or snow cover. InSAR is primarily suited to long-term monitoring (deformations over months or years) but not for monitoring rapid deformations that must be reported immediately.

Anticipated future access to radio satellite data in conjunction with technological developments will enhance the suitability of the method for identifying terrain deformations and monitoring infrastructure. NIFS recommends further investment in the use of radar satellite data through inter-agency collaboration and coordination with other parties on access to data and method development. This will improve the quality of deformation mapping and provide utility value to all parties /40/.

NIFS has mapped the status and potential for using drones when there is a risk of flooding and landslides/avalanches. An industry seminar was organised in January 2015 and camera drones were tested for photo and video recordings for both R&D projects and for operational use. On behalf of NIFS, SINTEF has conducted an assessment of empirical experience and the potential for using drone technology in the field of natural hazards and infrastructure relevant to the agencies. The report proposes a number of areas in which drone technology could potentially be used by the agencies – in the natural hazards area as well as for infrastructure inspection /41/. In NIFS, photogrammetry has been conducted for terrain modelling and landslide/avalanche risk assessments at 'Veslemannen' and county road Fv 63 at Trollstigen /39/, /40/.

Figur 16: NIFS reports 2015/100 "Veslemann (rock-fall), autumn 2014: Monitoring and preparedness" and 2015/122 "Satelite-based radar interferometry (InSAR) for natural hazards, landslides and infrasructure" show the large scope of the NIFS-programme .

Terrain model from drones for analysis of rockfall risk

Background:
The companies TerraTec and Bygg Control carried out photography from drones in 2014 and 2015 to generate photogrammetric terrain models that could be compared in order to detect any changes/deformations in the terrain (county road Fv 63 Trollstigen, Rauma Municipality, Møre og Romsdal County).

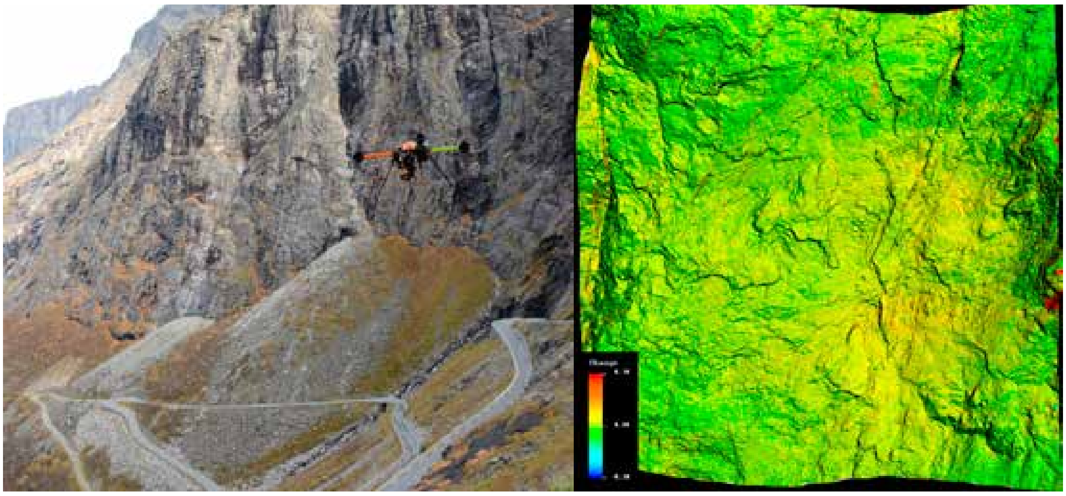


Figure: Drone at Trollstigen (on left) and terrain model in which terrain changes are visualised.

A comparison between two photogrammetric terrain models from photos taken one year apart with a drone has been tested at Trollstigen. The objective was to locate any deformations and rockfalls in the mountainside by comparing the terrain models. The terrain analysis has detected changes in the terrain that have also been verified from the photos. The accuracy of the terrain model is better than 5 cm for the entire measurement area. This has been control-measured using fixed points and laser scanning.

The project has detected changes in the terrain. This method will be a supplement/alternative to other methods that can identify deformations across an area, such as laser scanning and ground-based radar.

Reference:
NIFS (2015-114): Deformation analysis of steep mountainsides using drone-based photogrammetry /110/.

There should be closer collaboration between the agencies in connection with acute events and testing of monitoring methods. A fixed annual (regular) inter-agency seminar/workshop for exchange of knowledge and expertise on landslide/avalanche instrumentation should be established.

3.8.2 Data collection and presentation

Through the landslide/avalanche forecasting services and NIFS, a collaboration has been established between the agencies for the collection of event data, and an assessment has been conducted of the need for and objectives of event registration by the agencies. In the work on monitoring and forecasting in NIFS, the following data sources have been most relevant:

- Weather observations
- Hydrological observations
- Landslide/avalanche activity and hazard signs

During the period 2012–2015, the agencies jointly established 43 weather stations in areas and at altitudes that were previously poorly represented. Of these weather stations, 14 are so-called plateau stations and 29 are summit stations. The plateau stations are located in wind-protected areas and are equipped with rain gauges, thermometers and snow depth sensors. The summit stations are located on wind-exposed summits and therefore measure only wind and temperature. The aim of this initiative is to take into account the agencies' common needs, make data sets openly accessible, contribute to better interpolation of grid data in map services such as senorge.no and xgeo.no and, of course, better forecasting services. The work has been coordinated by a group comprising specialists from the NVE, Norwegian Public Roads Administration, Norwegian National Rail Administration and the Norwegian Meteorological Institute. The work has been financed by NVE and the Norwegian Public Roads Administration, while the Norwegian Meteorological Institute has contributed one full-time equivalent in case processing and assumed responsibility for operating the new stations. At the same time, the Norwegian National Rail Administration has built its own stations and reported and coordinated the information with the group. The Norwegian Public Roads Administration has also equipped its existing stations with sensors that are useful to the forecasting services and which increasingly use alternative energy sources such as fuel cells in areas with no access to electricity.

During the period 2013–2105, NVE expanded its hydrological station network to better meet the need for landslide forecasting, adding approximately. 20 groundwater stations and 9 new water level stations in small catchments. Several of the groundwater and water level stations have been established in collaboration with the Norwegian National Rail Administration. NVE has conducted a review of the Norwegian hydrological station network and looked at future requirements, including those associated with landslide/avalanche forecasting /135/. The report is based on input from both internal and external users (including the Norwegian Public Roads Administration and the Noregian National Rail Administration) and is intended as a work tool for operation and maintenance of the Norwegian hydrological station network up to 2020.

There are still many mountain areas in Norway with few weather stations, particularly outside the avalanche warning regions. Thus, it will be important to continue to develop the station network. Uptime requirements and accepted service intervals differ between the agencies. Service and maintenance routines must be improved, and common maitenance system and uptime requirements should be established as soon as possible. The uptime requirements should be governed by the station's area of application. An upgrade and expansion of weather stations will provide better background data for forecasting, improve the quality of weather data in xGeo/seNorge, and weather models will be better at reflecting local differences.

Weather data are administered by the Norwegian Meteorological Institute (MET). MET's quality assurance of weather data is vital to ensure good data quality, which forms the basis of assessing the likelihood of events occurring. Several measurement values from the Norwegian Public Roads Administration, for example, are not sufficiently quality-assured. NVE continues to administer weather data from its water flow stations itself, without this being quality-assured by MET. Management and quality assurance of all weather data at MET provides better and more uniform data quality and facilitates the distribution of weather data to other parties /42/, /43/.

NIFS proposes that the agencies continue a method of working whereby the agencies meet frequently in order to coordinate the development and operation of publicly owned weather stations.

Under the NIFS programme, a PhD candidate has examined measuring and modelling techniques to investigate the content and movement of water in layered snow. The object of the paper was to assess properties in snow with a high water content. Field tests have been conducted using a georadar specially developed for the Norwegian Defence Research Establishment (FFI). The preliminary field tests show promising results and can be used to map layering, water content and water transport in snow.

The results are used to improve a numerical model for water transport in snow and could be used as a basis for assessing stability in wet snow. The work has been presented at conferences (ISSW) , and also forms part of the study programmes at the University of Oslo.

Logging of landslide/avalanche activity and signs of landslide/avalanche hazatrds was improved during the period by further developing the regObs (NVE) and ELRAPP R13 (Norwegian Public Roads Administration) systems. RegObs is an application for professional and voluntary reporting of hazard signs and assessments. NVE has developed this tool in collaboration with the Norwegian Public Roads Administration, amongst others. In the same period the Norwegian Public Roads Administration developed new reporting forms in its ELRAPP system. A form called 'R13 Natural hazard' is now used across large parts of Norway to report natural hazards and preparedness/emergency response measures. The requirement for using this form has gradually been introduced in operating contracts. In 2013, 631 forms were submitted. The corresponding figure for 2015 was 1,690 forms. ELRAPP has been partially integrated with regObs, so that certain data are transferred in real time to NVE's landslide/avalanche forecasting systems.

NIFS proposes that the collaboration on data exchange for landslide/avalanche activity and hazard signs be continued through the collaboration on landslide/avalanche forecasting.

Weather and event data of relevance to landslide/avalanche forecasting are primarily presented on the following platforms:

- eKlima.no (for the general public)
- halo.met.no (for forecasters/emergency response personnel and other professional agencies)
- xGeo.no (for forecasters/emergency response personnel and the general public)
- Varsom.no/regObs.no/seNorge.no (for the general public)
- ELRAPP (web and app) (for operating contractors at the Norwegian Public Roads Administration)

The agencies' forecasters, avalanche/landslide-technical advisers and emergency response personnel can use xgeo.no to obtain a quick overview of weather conditions and events. Since autumn 2015, operational contractors have been able to access each other's observations and assessments via the ELRAPP app.

NIFS proposes continued joint development of these systems in the future. There is therefore a need for continued allocation of resources to the IT segment, among other things to ensure further development and stability in regObs and ELRAPP. In respect of xgeo.no, it would be beneficial to work more on user-friendliness, smarter ways of displaying data and improving stability.

3.8.3 Forecasting

The forecasting services for avalanches/landslides (incl. slush slides and debris slides/flows) have been further developed in parallel with the NIFS programme by the same three agencies in collaboration with the Norwegian Meteorological Institute. The landslide/avalanche forecasting service is operated by NVE and is available to the general public via the web portal varsom. The service has been well received by the NIFS agencies, local authorities and the public at large. It is used as a support tool for closing and opening roads and railways and in connection with the evacuation of inhabited areas. The landslide/avalanche forecasting service makes use of the tools and data sets described in the previous section. Work is also continuing on development of the web-based warning tool.

Further development of a common landslide/avalanche warning service

Background:
Alongside the NIFS programme, the agencies' landslide/avalanche forecasting service has been further developed. This development has been extensively documented in NIFS reports (see references below). The service has been very well received by the NIFS agencies and local authorities and is used as a support tool for closing roads and railways, and fin connection with evacuations. Collaboration on the development and operation of landslide/avalanche forecasting continues and the landslide/avalanche warning service is being transformed into a permanent service.

Relevant NIFS reports associated with monitoring and forecasting

References:
- NIFS (2013-31): Monitoring in the event of acute landslide/avalanche events – Report from exercises in Sunndalsøra with ÅTB and NGU /22/.
- NIFS (2013-65): The avalanche warning service – Evaluation of the 2013 winter season/44/.
- NIFS (2014-37): Preliminary regionalisation and susceptibility analysis for landslide early warning purposes in Norway /83/.
- NIFS (2014-43): Threshold studies for triggering of landslides Norway /86/.
- NIFS (2014-44) Regional warning of landslide hazards: Analysis of historical debris slides/flows and slush slides in Gudbrandsdalen and Ottadalen /49/.
- NIFS (2014-79): The avalanche warning service – Evaluation of the 2014 winter season/45/.
- NIFS (2014-80): Norwegian Avalanche Warning Service Programme Review /46/.
- NIFS (2014-90): Regional warnings of landslide hazards: Analysis of historical debris slides/flows and slush slides in Troms county /50/.
- NIFS (2015-66): Avalanche warning using the nearest neighbour method. Test of the Canadian nearest neighbour model on avalanche data from Senja /47/.
- NIFS (2015-78): The avalanche warning service. Evaluation of the 2015 winter season/48/.

The first phase of the collaboration on landslide/avalanche forecasting has adopted funding as a priority area for the period 2013–2017. The collaboration should also continue after that period. The Norwegian National Rail Administration and the Norwegian Public Roads Administration have made allowances for this in their input to the National transport plan (NTP) 2018–2027, and the agencies have indicated that funding should be close to the current level.

The forecasting work can be made more effective through further development of forecasting tools in which weather packages and reporting of other relevant data will be generated automatically. This will mean less manual work.

Avalanche warnings
The quality of avalanche warnings will be better with a quality system that describes and evaluates the accuracy and effect of the warnings. There should be better robustness for the observer corps. At present, the system is vulnerable if an observer is ill, for example. For the avalanche warning service, coordination and improvements could potentially reduce the number of staff needed for the actual task of forecasting and issuing warnings. This could lead to lower costs in the long term but is dependent on investments in IT and significant improvement of current forecasting tools.

The quality of the observation work can be improved through further development and coordination of course packages. A separate reporting system should be established for accidents and events /27/, /44/, /45/, /46/, /47/, /48/, /54/, /105/.

3.8.4 Landslide warnings

Debris flow/slide warning services are being gradually coordinated with shared tools and joint distribution, routines and evaluation meetings in order to achieve the best possible synergy between the two services. The challenges include access to personnel, implementation of new monitoring rotas with shorter days and fewer personnel on duty, operational safety and decision-making support and forecasting tools. Work on simplifying forecasting routines and increasing coordination with the MET weather forecasting service has started. Remaining work includes completion of a joint subscription solution for natural hazard warnings, via text messages and email, better coordinated presentation on varsom, yr and TV meteorologists. There is a need to strengthen communication with regional and local authorities and municipal authorities in particular in order for the landslide warning service to be better known and understood. There is also a need to strengthen the mutual exchange of data and knowledge between the agencies (NVE, NNRA, NPRA), especially with regard to evaluating the accuracy of the forecasting services and as a basis for adjusting existing threshold values and improving the service. Work on a combined hydrometeorological landslide/avalanche index and precautionary maps (NGU-NGI) must continue so as to provide local emergency response parties with tools in the form of support maps on varsom. Joint NVE-MET R&D activities have already resulted in improved grid data (Xgeo) on observations and forecasts. Focus should be placed on implementing a three-hour resolution as input for hydrological models and drawing up threshold values for shorter time resolutions for different regions, different landslide/avalanche types, for both local and regional warnings. There is much international interest in the Norwegian model, which uses hydrology (synergy with flood warnings) for the operational national warning service for landslide hazards at the regional level, and inter-agency collaboration with free data sharing between MET, NVE, the Norwegian Public Roads Administration and the Norwegian National Rail Administration. In October 2016, NVE will organise an international workshop on operational landslide warnings in an attempt to establish an international network.

Reports concerning forecasting/warnings and studies of landslides /49/, /50/, / 83/, /86/, /120/, /121/.

Recommended measures – forecasting and monitoring

- Agency collaboration on landslide/avalanche forecasting should continue and be further developed
- The Norwegian National Rail Administration should be more involved than it currently is
- NIFS also proposes that the agencies continue a method of working whereby the agencies meet frequently in order to coordinate the development and operation of publicly owned weather stations
- NIFS proposes that the collaboration on data exchange for landslide/avalanche activity and risk signs be continued through the collaboration on regObs and ELRAP landslide/avalanche warnings.
- Forecasting tools for landslide/avalanche forecasters should be further developed with a view to achieving fewer manual operations. This represents a vital time factor that could be crucial to covering larger parts of Norway.
- Further work should be carried out to develop reliable landslide/avalanche indices and automatic hazard maps
- Staffing of forecasting groups and observer networks should be less vulnerable to unexpected absence (e.g. sickness absence) and management of prolonged crisis situations.

3.9 Preparedness and crisis management

In the case of natural damage it is crucial for society to have a satisfactory level of emergency preparedness in place and be rigged to handle the situation. Effective coordination between the agencies requires access to sufficient information and good communication between the parties.

3.9.1 Terminology

Terminology is used differently across the agencies in connection with managing crises and events. Terminology usage also differs across the other agencies and parties involved in the management of landslide/avalanche and flood events. For example, 'tactical level' does not mean the same thing in the police as it does in the Norwegian National Rail Administration. Based on evaluations and reports, however, this is not considered to be a problem in practice. These differences are manageable as long as the respective parties are aware of them.

The fact that the parties use different terminology in their emergency response plans and in certain cases use different definitions of the same term is a source of miscommunication and of diverging understanding of critical situations requiring immediate joint action and effective communication. Shared terminology provides better understanding and easier and more precise communication, thereby reducing the risk of misunderstandings arising in crisis management. Efforts should be made to establish common terminology usage for crisis/emergency response at the Norwegian National Rail Administration, NVE, the Norwegian Public Roads Administration, and a distinction should be made between activities associated with preparedness and crisis management. Consistent terminology usage will clarify the differences in work before the event (emergency preparedness) and during the event (crisis management). This is not easy to change, however, as it often involves well-established terms. What is most important is that the parties involved are aware of the differences and are familiar with each other's emergency response organisation. It is therefore recommended to implement training in interaction between regional and central management.

The NIFS programme has formulated a proposal for common terminology lists in order to establish a shared platform and understanding /17/. The lists concern landslide/avalanche types, emergency preparedness and response, mapping and safety measures.

3.9.2 Emergency response plans on an operational level

During the NIFS period the Norwegian Public Roads Administration has created a new emergency response template for all natural hazards /13/. This includes a significant link to the new warning services (varsom.no) and emergency response tools (xgeo.no, RegObs). It may be relevant for other parties to do the same. The work on emergency response plans within the agencies and sharing of same with the relevant collaborating parties (local authorities, County Governor, emergency services) should continue.

Practice makes perfect – exercises and evaluations

Background:
Exercises focusing on potential quick clay landslides in Trondheim and rockslides from Veslemannen in Rauma Municipality in Møre og Romsdal County. Our work has shown that there is a significant need for exercises/workshops for the various parties involved in managing landslide/avalanche and flood events. The parties were sometimes uncertain as to who had responsibility for what during an event. There were several practical tasks where there was uncertainty surrounding who should perform the task. It was stressed that there was a great need for seminars of this type, and it was concluded that the form of seminar was educational for all parties. The way in which the work was conducted and the exercise form have been developed in a way that enables very cost-effective implementation in the form of internally organised day seminars.

An example is the National Risk Picture 2014 (Directorate of Civil Protection and Emergency Planning) and a report from NIFS.

References:
- NIFS (2014-64): Sub-report 1- Emergency response plans and crisis management /13/.
- NIFS (2014-76): Sub-report 2 - Crisis support tools CIM – Recommendations /14/.
- NIFS (2015-110): 'Veslemannen' autumn 2014 – monitoring and emergency response /39/.
- NIFS (2015-105): Sub-report 3 - Information exchange during exercises and events /15/.
- NIFS (2016-04): Summary: Preparedness and crisis management /128/.

Exercises involving all parties provide closer contact between decision-makers and practising agencies/parties and ensure better plans and better emergency preparedness.

Coordination of emergency response plans provides a better local overview of potential natural hazards and associated emergency preparedness information, better coordination in crisis situations and a better basis for and utilisation of RAV analyses.

3.9.3 Emergency response plans on tactical and strategic levels

The three agencies all have step-by-step preparedness that involves stepwise escalation of an emergency situation depending on its nature. At present, varying steps and colour codes are used by the agencies and, to some extent, also within the agencies. This can seem confusing and can hamper uniform communication. There are some different approaches to and assessments of events in the three agencies, which could result in one and the same event having a different 'colour' at one and the same time. This is only natural as the agencies have different tasks and will be differently affected by an event. A common meaning of the colour codes will give the other agencies an indication of how events affect the respective agencies /128/.

It is therefore recommended that the agencies describe their step-by-step preparedness using the same colour codes as society at large: yellow – orange – red

3.9.4 Information and communication

Good preparedness and crisis management depend on good information and communication. This means mutual information between the agencies, information obligation and collaboration across projects, properties and infrastructure owners /15/.

One of the prerequisites for collaboration is access to identical and quality-assured information, for example, about an event or crisis. The framework and prerequisites must be clarified in advance. It is recommended that clear guidelines be prepared for collaboration between the agencies and for information exchange between the agencies and between agencies and municipal authorities. Fixed contact points for information exchange should be established.

Information sharing across the agencies should occur based on the recipient's need for information, and this should be defined as part of the emergency response plan. In principle, it is recommended that only situational reports be shared. Routines for coordination of external information should be prepared and implemented in the plans. They should contain an overview of contact points and contact persons at the respective agencies.

The work with NIFS has shown that there is a significant need for exercises/workshops for the various parties involved in managing landslide/avalanche and flood events. The parties were sometimes uncertain as to who had responsibility for what during an event. There were several practical tasks where there was uncertainty surrounding who should perform the task. The need for these types of seminars has been deemed significant, and it was concluded that this type of seminar was educational for all parties. The NIFS programme has created a template for implementation of workshop/desktop exercises at a regional level. It is recommended that such exercises be carried out in all counties using the same model that is used in Trondheim and Molde to establish contact points between parties and facilitate better collaboration, and that local and regional parties become aware of their respective roles.

3.9.5 Crisis support tools

In NIFS, CIM is considered a crisis support tool. Experience shows that CIM is an accurate and powerful tool, providing there is active use and adequate resources for continuous training and exercises. CIM is a tool that can contribute to better preparedness and crisis management. However, CIM remains one of several tool available to management to support its work. CIM must therefore be adapted to the organisation – not the other way around.

It is recommended that the agencies' emergency response plans be reviewed and updated before CIM is introduced. CIM can then be implemented based on these plans. All agencies must take responsibility for ensuring that necessary resources are allocated to implementation and training in the use of CIM as a crisis management tool /14/.

Implementation of CIM must be based on a clear system ownership, necessary resources and a clear plan for organisation, management and operation. Experienced users of CIM emphasise the importance of having a clear system ownership and sufficient resources to operate CIM on an ongoing basis. This is critical in order to succeed in the long term.

The Norwegian Public Roads Administration's model for implementation and training with CIM has proved successful. During the project period CIM has also been adopted by NVE and the Norwegian National Rail Administration. Operation and maintenance of CIM should be introduced as an integral part of each agency's emergency response organisation and as a part of an overall system for crisis management. If an organisation is to succeed with CIM, the tool must be integrated in emergency response plans and exercises, and must be updated in accordance with these.

3.9.6 Field manual for flood and landslide/avalanche events

Through NIFS a separate field manual for flood and landslide/avalanche events has been developed to support specialists so that they can make the correct decisions /102/.

Use of the field manual provides better safety routines for personnel in the field during events. It simplifies the coordination of resources and enables more effective response work during events, which results in higher and more even quality in the assessment of measures. The decision-making basis is better, and quicker decisions provide better information about the anticipated closure time for the infrastructure. The agencies must follow up how the field manual is used during events (particularly with regard to risk assessments) and hold a seminar in order to share experience of the use of the field manual /51/. It is recommended that NVE assumes responsibility for any future revisions in collaboration with the Norwegian Public Roads Administration and the Norwegian National Rail Administration.

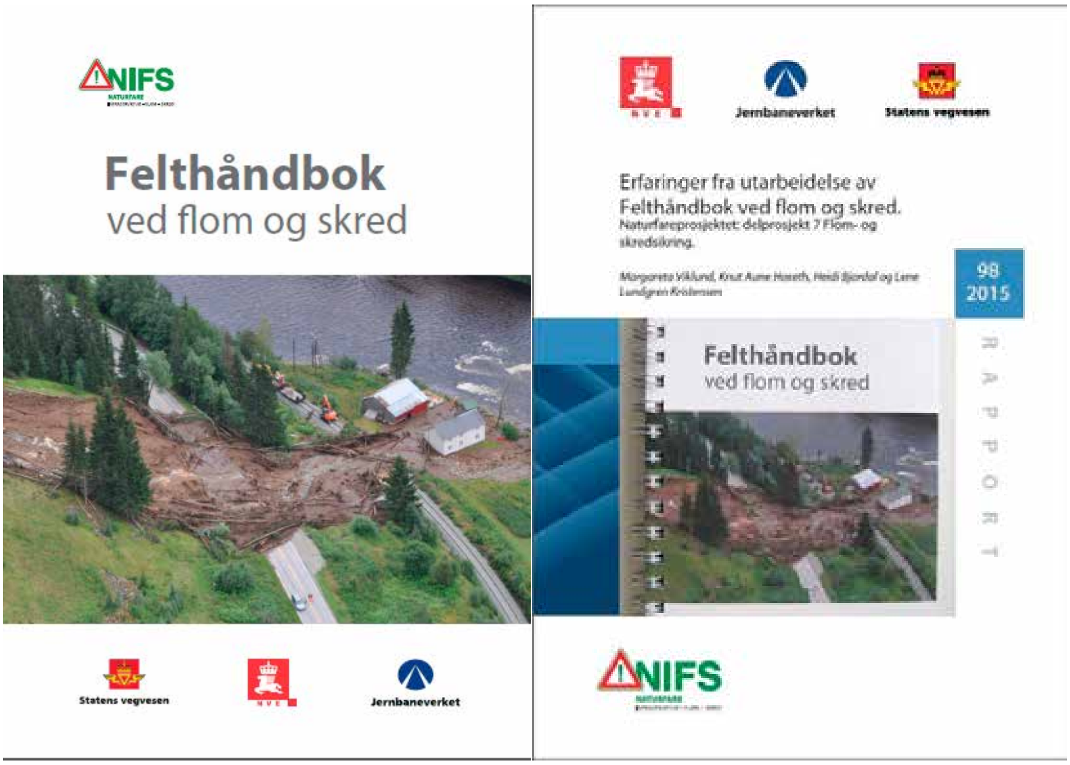
Figur 17: The Swedish Civil Contingencies Agency published in 201–2013 a manual for field work in landslide zones. It provided the basis for the field manual developed in NIFS. .

When a crisis looms – field manual for managing flood and landslide/avalanche events

Background:
NIFS has developed a field manual to support specialists in their follow-up of flood and landslide/avalanche events. The manual covers the most common types of flood and landslide/avalanche events in Norway and covers both minor events with limited consequences and major multi-agency events. As well as containing technical chapters describing the various event types, the field manual also contains separate chapters on safety work, communication during events and a breakdown of responsibility and roles.

The objective of the field manual is to contribute to better safety routines for specialists who follow up events in the field and to ensure more coordinated technical assessments by and between the agencies.

The project recommends that the agencies follow up and evaluate how the field manual is used during events, e.g. by holding a seminar at which specialists can share their experience of using the manual. Such an evaluation should particularly focus on the risk assessment templates and how these are understood and used.



For example, the field manual for floods and landslide/avalanches and experience report from its preparation

References:
- Field manual for floods and landslide/avalanches (ISBN 978-82-7704-145-2) /102/.
- NIFS (2015/98): Experience of the preparation of the field manual for floods and landslide/avalanches /51/.

With this tool at hand, personnel will work more safely and achieve a better decision-making basis, and it will improve collaboration and efficiency.

Recommended measures – preparedness and crisis management

- The agencies' plans for preparedness and crisis management should be coordinated.
  - The three agencies should agree on a common terminology for preparedness/emergency response and crises, and common terms for describing various levels of preparedness and crisis.
  - Instructions must be drawn up for sharing information in a crisis situation.
  - Common routines must be prepared for coordination of external information during crises and emergencies.
  - Training in collaboration must be provided for regional and central management.
- NIFS recommends coordinated use of common definitions of technical terms describing natural hazards in accordance with lists drawn up by NIFS.
- The agencies' emergency response plans should be based on the same design levels as in society at large: yellow – orange – red.
- The 'Field manual for floods and landslide/avalanches should be used by the agencies and other parties performing work for the agencies in all flood and landslide/avalanche events

3.10 Research, education, skills development and communication

Optimal management of flood and landslide/avalanche risk requires a high level of knowledge and expertise. Skills development among own employees and across the industry generally is an important measure for improving the quality of planned safety measures. Thus, emphasis must be placed on research, education and communication of results. It is also important that the general public, as recipients and users of information who often represent the 'first line' in connection with monitoring and forecasting, are well informed about flood and landslide/avalanche risk. The 'nearest neighbour method' is such a tool /47/. Thus, communication of knowledge to the general public through schools, media, public meetings and web portals is important as a risk-reducing measure.

3.10.1 Research

NIFS has created a good basis for further research on selected topics related to floods and landslides/avalanches. Through NIFS, several fundamental studies have been undertaken into methodologies for forecasting and monitoring, landslide/avalanche triggering and propagation mechanisms, quick clay mapping and quick clay properties. It is important that research on these topics continue.

Efforts should be made to establish good collaborative arenas for R&D between public sector parties, the Research Council of Norway, universities, research institutions and private sector parties. Separate research programmes have been established both nationally and internationally, and it is natural to include further research activities in such collaboration projects. All agencies in the NIFS programme participate in the Centre for Research-based Innovation 'Klima 2050' (klima2050), in which other parties from academia, business and industry and other public sector agencies also participate. It is important to ensure that risk economics, socio-economics and the need for collaboration between the various institutions are clearly addressed through the work in Klima2050.

3.10.2 Education and skills development

Training concerning natural hazards must start early, and this requires more knowledge about natural hazards for school children. This will provide increased awareness among young people as well as increased interest and thereby better recruitment to the expert environments. NIFS has made several films for schools: about floods, landslides/avalanches and quick clay. Each of these films has been divided into three topics: nature and hazard signs, essential knowledge and protection from natural hazards.

NIFS has made two short films aimed at young people at upper secondary school level. The topics are floods and landslides/avalanches, and the objective is to make a fresh contribution to the 'Geosciences' subject at the upper secondary school level. The films have been developed around three topics: nature and hazard signs, knowledge that is essential for managing natural hazards, and concrete ways of protecting oneself from these hazards. For many years the Norwegian Centre for Science Education has been using films to communicate knowledge of natural science. We have therefore consulted the Norwegian Centre for Science Education on how the contribution from NIFS could be designed. The school films on floods and landslides/avalanches have used new footage as well as some clips from previous school films about floods and landslides/avalanches.

Expertise, training and communication – Geomobil1

Background:
Quick clay landslides are a national challenge, and basic training in quick clay landslides is crucial. The Norwegian Public Roads Administration has developed a mobile laboratory that is used for teaching parts of the Geotechnics study programme at Ålesund University College. In connection with the quick clay landslides at Mofjellbekken (Skjeggestad bridge - E18 highway in Vestfold County), Geomobil1 was mobilised and on site within 24 hours in order to start mapping ground conditions.

Kjerneboring: Ved det mobile geotekniske laboratoriet (GeoMobilen) til Statens vegvesen får studentene ved Bachelor i ingeniørfag, Bygg, ved Høgskolen i Ålesund innblikk i metoder for å bedømme faren for skred og dårlig fundamentering. Fra venstre: Laborant Anniken Setalid og studentene Lars Lange, Endre Kobbeltvedt, Thomas Kløften og Kristina Lausund.

– Skred krever kunnskap

– Det er avgjørende at byggingeniører også på høgskolenivå har solid kunnskap i geoteknikk.

Source: The Sunnmørsposten newspaper, 30 October 2014

There is a significant need for new specialists with expertise in natural hazards at the Bachelor, MSc and PhD levels. Natural hazards must form an integral part of an interdisciplinary approach to land use planning for engineering, architectural, agriculture and forestry education. Volda University College, with its departments of media studies and social studies, is planning a new master module from autumn 2016 focusing on public participation in training municipal planning and communications staff, particularly regarding the risks that can threaten a local community. This was initiated in collaboration between NVE and the university college to strengthen the part of the training that concerns natural hazards forecasting.

Enhancing the skills of the agencies and the industry as a whole and knowledge sharing constitute good resource use and provide better utilisation of allocated funding. There is little specialist expertise at several management levels and a considerable need for both basic and upper secondary training in the field in both the public and private sectors. Each agency has drawn up several useful reports and guidelines that the agencies' specialists should be familiar with. Examples include the Norwegian Public Roads Administration's recently revised guidelines on protection from avalanches and debris flows, and the report on planning and designing drainage measures that is being prepared as part of the NIFS programme.

Resources are limited, however, in terms of both time and funding for courses and continuing education. E-learning is an efficient way of training with reduced time use and costs with regard to travel and accommodation. A conscious effort must therefore be made to develop both e-learning modules and continuing/further education in surface water management, floods and landslides/avalanches. NIFS recommends that all employees in the agencies be informed of courses, seminars and meetings, either via websites or by sending emails to designated and dedicated expert environments. In some cases, it can also be expedient to collaborate on planning when the topic concerns several of the agencies' areas of responsibility.

The NIFS programme recommends continuing investment in specialised skills development. This is important in order to achieve the right quality in landslide/avalanche and flood prevention work, both within the agencies and among external executing parties. We recommend that the agencies ensure that expertise is maintained in areas of responsibility in the flood and landslide/avalanche field, and take active part in industry seminars etc. as appropriate /21/, (Presentations-from-NVE-event).

Education, skills development and dissemination of knowledge

Background:

The State depends on qualified and motivated staff to be able to offer high-quality services to the population and business and industry. In order to be an attractive, competitive and quality-conscious employer, the State must – both centrally and through its agencies – make provisions for staff to develop their skills and careers. The individual agency should utilise the opportunity to become a 'learning organisation', among other things by offering learning-intensive jobs, systematic knowledge sharing and by offering training and continuing and further education. (Personnel manual for civil servant (SPH: 1.7 The State's skills development policy)

NIFS has contributed with skills development in the agencies and in the industry and knowledge sharing that contributes to good resource use and better utilisation of allocated funding. There is little specialist expertise at several administrative levels and a considerable need for both basic and further training in the field in both the public and private sectors.

Illustration of dissemination of knowledge and joint learning

References:
Two ongoing doctoral studies, One postdoctoral project, more than xx master and bachelor theses at universities, xx articles for journals and conferences, approximately 120 reports, internal and external courses, seminars, workshops and more than 250 lectures/presentations have been produced under the auspices of the NIFS programme.

Knowledge forms the basis for correct choices and solutions

NVE has implemented and assessed the need for new regional seminars for municipal authorities in which land use planning and use of maps/GIS tools in the field of natural hazards will be the main topics. This is a natural future area of collaboration with other public agencies, consultants and other partners. This will provide better quality and broader participation in seminars and courses concerning natural hazards.

3.10.3 Communication

Better public participation and more competent municipal planners will make local communities more robust in relation to natural hazards and enhance trust between citizens and the authorities. This also creates awareness of the agencies' sectoral responsibility as civic developers. Public participation is very important in managing flood and landslide/avalanche risks. It concerns:

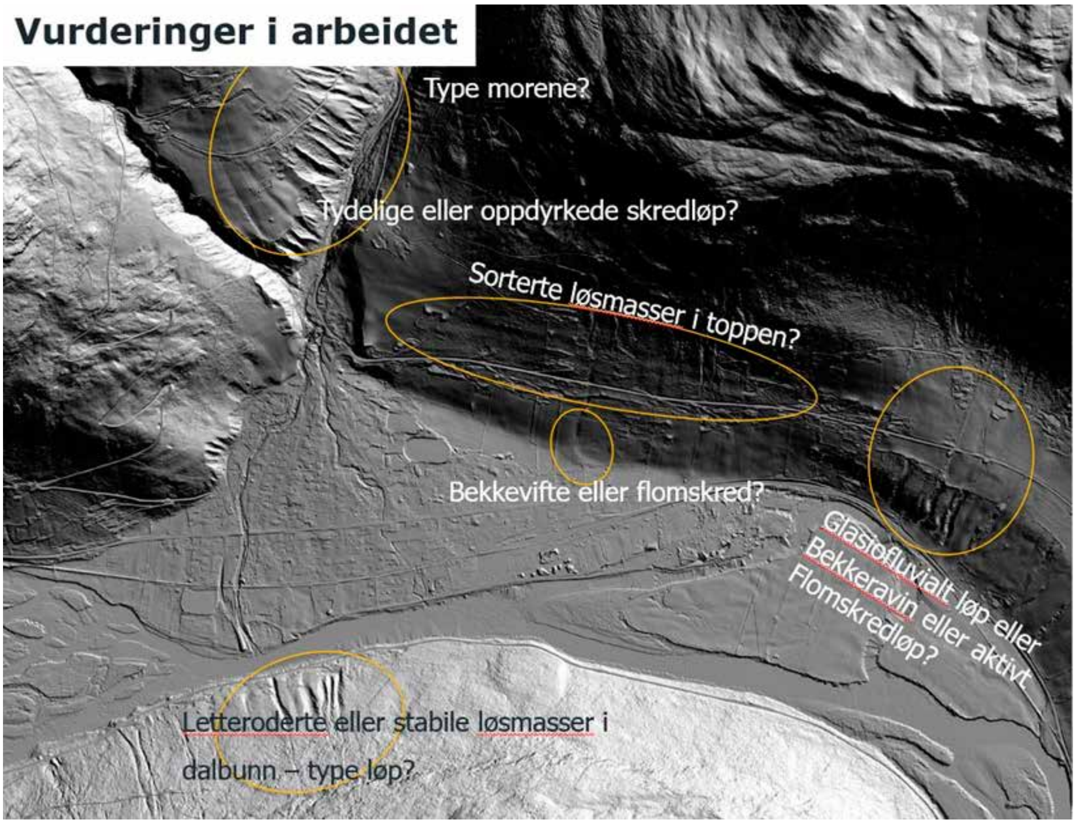
- Preparation and prevention of risk
- Risk management before an event
- Risk management during and after an event

Public meetings have been used as an arena for informing the general public about flood and landslide/avalanche risk, monitoring and preventive measures. Results from surveys in the NIFS programme show that the youngest age groups (18–39) represent a challenge as they depend less on specialist knowledge and believe that public meetings provide less useful information than the oldest age group (62–72 years) does. The organisation of public meetings can be improved so as to create more participation by local residents. The recommendation primarily concerns preventive work, although close cooperation with local residents is also important during and after an event /52/.

Several industry seminars on landslide/avalanche hazards for the consultancy sector have already been held under the auspices of NIFS. Industry seminars are important; they have been a good arena for providing information and receiving feedback about what should be prioritised. There is a great interest in industry seminars and the possibility of sharing knowledge between companies. The result is heightened awareness in the expert landslide/avalanche environment of quality, and the need for documentation and verifiability of discretionary assessments. The outcome is greater landslide/avalanche expertise in the consultancy sector that is commissioned to map landslide/avalanche hazards and conduct landslide/avalanche studies of steep catchments for agencies, local authorities and developers. The result for the agencies is a greater common understanding of quality and verifiability throughout the sector.

Industry seminars for landslide/avalanche mapping

Background:
In the programme period 2012–2015 many training measures have been implemented across the agencies. NVE has conducted special courses and seminars addressing land use planning – with the primary target group being local authorities, and natural hazard mapping – with the target group being consultants and service providers. Industry seminars (4) on mapping landslide/avalanche hazards in steep catchments, like the ones that were held in 2014–2015, are important. The seminars increase the professional expertise of all parties that carry out and use hazard mapping and risk studies. The seminars have been a good arena for providing information and receiving feedback about what is important.



Example of interpretation of debris challenges for landslide/avalanche mapping (Lena Rubensdotter, NGU-2015).

Reference:
News items and presentations at www.nve.no

A mutual understanding of quality will raise awareness among landslide/avalanche experts of the need for documentation and verifiability of discretionary assessments.

A survey has been carried out of today's users and the use they make of our databases and websites /21/ with in-depth interviews with users of landslide/avalanche and flood data. The results show a wide range of uses and skills and different perceptions of how the term 'data coordination' is interpreted. It was found that there is a clear need for better standardisation of data.

A survey has also been conducted internally across the agencies regarding knowledge of flood and landslide/avalanche data, which generated a total of 279 responses from the 3 agencies. The report is being prepared. The questions were:

- 'Which data sources do you use? What do you use the data for?'
- To what extent do the agencies manage to reach relevant users with their relevant flood and landslide/avalanche data – natural hazard data?

The results show a potential in several expert environments within the organisations for reaping great benefits from providing better training and adapted tools for use of flood and landslide/avalanche data. The survey also showed there was little awareness of the availability of relevant flood and landslide/avalanche data that could be important for organisations other than the expert environments that work directly with natural hazard data. A priority skills development initiative would therefore be to highlight where flood and landslide/avalanche data can be found and how it can be used in preventive work. The agencies administer great volumes of relevant natural hazard data. Which information is available, and in what way and how it can be best used, must be made easily accessible. The use of social media and new information channels provides faster and more effective communication, including during a crisis.

Recommended measures for research, education, skills development and communication

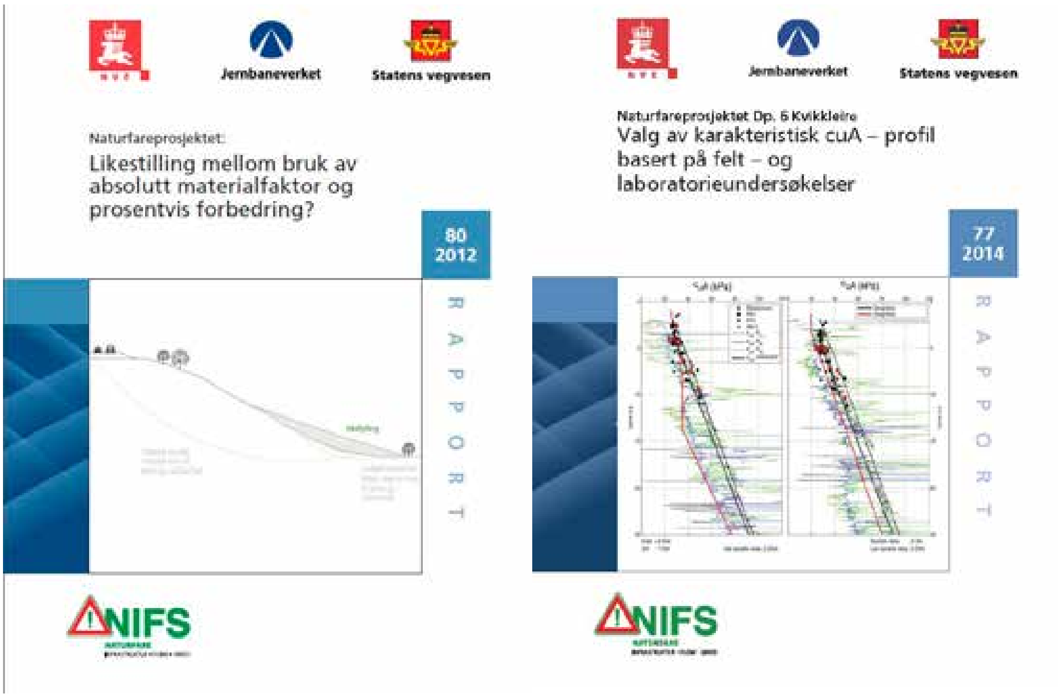
- The capacity for research and education in natural hazards must be increased.
  - Research should be continued through industry collaboration.
- There should be a comprehensive education programme on natural hazards and land use planning.
  - Knowledge of natural hazards should to a greater extent be incorporated into upper secondary school education, among other things by using the school films that NIFS has developed in partnership with the Norwegian Centre for Science Education.
  - Closer collaboration between the NIFS agencies and university colleges to contribute to professional quality in education.
- Investment in targeted professional skills development in floods and landslides/avalanches.
  - The agencies should collaborate on organising courses on floods and landslides/avalanches.
  - Industry seminars organised by NIFS on different topics associated with mapping should continue and be expanded to include topics relating to planning and implementation of safety measures.
  - E-learning modules and continuing and further education courses should be developed for surface water management, floods and landslides/avalanches.
- Good participation by local residents should be ensured in connection with
  - preparation and prevention of risk
  - Risk management following a forecast event: before, during and after the event
- The agencies, in collaboration with local authorities, should establish dialogue with and support local communities threatened by natural hazards before the events occurs.
- Through presentations and websites the agencies should actively inform about which information and which natural hazard data are available, and about how to make optimum use of such information.

The NIFS programme has many examples that demonstrate how cooperation and collaboration give results. This can be illustrated by reference to the results achieved and associated with the development of regulations and improved guidelines.

Coordination and joint development of regulations and guidelines

Background:
Several guidelines and standards are currently used for developments in quick clay areas. NIFS has made provision for the development and harmonisation of the regulations for planning, engineering and construction in quick clay areas.

Coordinated and improved regulations offer major socio-economic benefits. In the case of one specific project, county road 91 Breivikeidet Bridge–Hov in Troms County, proposals were submitted for two alternative development solutions depending on which regulatory framework was applicable. The proposal for a new regulatory framework would entail fewer safety measures and cut costs by NOK 18–28 million. This corresponded to approximately 6–9% of the total project costs, estimated at NOK 320 million.



Examples of reports on the development of regulatory frameworks and guidelines

References:
- NIFS (2012-80): ???Correspondence between use of absolute material factor and percentage improvement /60/.
- NGI 20130424-01-TN: Supplementary assessment – scope of safety measures in accordance with the NVE guidelines Technical memo
- NIFS (2014-14): An agreed recommendation for using anisotropic factors when planning in a Norwegian clay environment /77/.
- NIFS (2014-77): Selection of characteristic CuA profile based on field and laboratory tests /98/.
- NIFS (2014-59): Correspondence between use of absolute material factor and percentage improvement. Use of stress changes to define local landslides/avalanches and large area landslides/avalanches /93/.
- NIFS (2014-XXX): Safety philosophy for assessment of area stability on natural slopes on an effective stress basis (under preparation).

The harmonisation and development of a regulatory framework has a major socio-economic consequences.

Good communication and a general understanding of complex issues require that expert environments, as far as possible, find common ground and reach a common understanding. The NIFS programme has achieved this.

Study of the causes of landslide/avalanche events – with extensive technical evidence.

Background:
Report to the Storting No 15 (2012) assigned NVE the task of establishing programmes for such studies. NIFS contributed with a thorough study of the event in Nord-Statland and by ensuring that the study group was broadly composed. We would like the agencies and the expert environments to achieve a general level of experience associated with such cooperation by establishing good work processes and ensuring that the work is broadly anchored in the Norwegian expert environments. The work resulted in the report on the landslide-induced tsunami on 29 January 2014 at Nord-Statland. The mandate, working method and reporting were continued in the investigation into the landslide by the Mofjellbekken bridges on 2 February 2015. The landslide event in August 2015 on the E6 highway in Sørkjosen in Troms County was similarly investigated.

Good examples of joint technical investigations of landslides.

Reference:
- Letter from NVE of 22 July 2013 (with attached memo of 25 June 2013).
- NVE (2014-93): Landslide at Nord-Statland. Investigation of technical causality /101/.
- NVE (2015-53): The landslide by the Mofjellbekken bridges (Skjeggestad landslide). Investigation of technical causality.

Such professional collaboration has yielded good results with regard to the individual events, while also providing the parties involved and the expert environments with skills development and new learning.

Figur 18: Landslide at Bogelia in Vaksdal municipality imposed challenges on both road and railway.
Photo: Julie Bjørlien, 2015

4 The road ahead

4.1 National strategy for management of floods and landslides/avalanches

Report to the Storting No. 15 (2011–2012) stated that NVE and other public sector parties together must draw up a national strategy for coordination and collaboration on management of flood and landslide/avalanche risk /5/. The strategy must specify areas of collaboration and identify measures to improve interaction between the parties. The respective parties must contribute in their own areas of responsibility and cooperate on solving tasks where this is appropriate. Through a national strategy for floods and landslides/avalanches and related projects, the parties shall achieve the following:

- better resource utilisation
- better quality of service
- greater understanding across areas of responsibility
- better and easier access to information

NIFS has created a good basis for a national strategy. Many of the results from NIFS will be ready for implementation by the agencies, but specific projects and measures have also been highlighted that require further work. These are addressed on a point-by-point basis in Chapter 3. NVE, the Norwegian Public Roads Administration and the Norwegian National Rail Administration are now planning for a fixed structure to be established from 2016 to follow up a national strategy. Other parties will be included, in accordance with Report to the Storting No 15 (2011–2012) /5/.

4.2 Organisation of the work

Apart from NVE, the Norwegian Public Roads Administration and the Norwegian National Rail Administration, relevant public sector parties include:

- The Norwegian Building Authority
- The Norwegian Directorate for Civil Protection and Emergency Planning
- The Norwegian National Rail Administration
- The Norwegian Mapping Authority
- The Norwegian Agricultural Agency
- The Norwegian Meteorological Institute
- The Norwegian Environment Agency
- The Geological Survey of Norway
- The National Police Directorate
- The Norwegian Public Roads Administration

Other parties:

- Academic and research environments
- The Norwegian Association of Local and Regional Authorities
- Other special interest organisations

NVE will have primary responsibility for the work, but there are plans for a steering group and secretariat to see to the day-to-day management of the collaboration. The steering group will consist of the key parties. NVE will be responsible for the secretariat, which will preferably be recruited from the agencies that serve on the steering group.

NVE and the Directorate of Civil Protection and Emergency Planning are engaged in a dialogue about coordinating the work on a national strategy for floods and landslides/avalanches with a revitalisation of 'Collaboration area nature'. The mandate was originally defined in 2011 and revised in 2012.

'Collaboration area nature is a forum for collaboration on preventive and vulnerability-reducing work in connection with natural events. This includes both sudden, dramatic events and more prolonged, gradual changes that in the long term could impact society's vulnerability, including climate change'. Further development of the collaboration is seen in connection with the follow-up of the 'Sendai Framework for Disaster Risk Reduction 2015-2030' from the UN World Conference on Disaster Risk Reduction, in Sendai, Japan 14–18 March 2015. In Norway it is primarily the same parties that are relevant, and thematically there are also significant overlaps. The aim will be to simplify the coordination of activities and rationalise the administration.

A separate steering group has been established for flood and landslide/avalanche warning services between NVE, the Norwegian Meteorological Institute, the Norwegian Public Roads Administration and the Norwegian National Rail Administration. It has been proposed that this be included in the structure for the national strategy.

For the implementation of projects under the national strategy, year-on-year agreements must be entered into on the distribution of costs.

4.3 Content

Based on recommendations from NIFS described above, some main topics have been identified that are regarded as being particularly relevant as input to the national strategy. This is not an exhaustive list but a basis for further work on defining projects for 2016 and beyond. There are many topics in the field of natural hazard management that deserve attention and future follow-up. Some of the topics can be handled by the agencies individually. The present selection emphasises topics in which collaboration across sectors is regarded as being especially beneficial or challenges that are strategic in the sense that they require clarification on an overall level.

4.3.1 Uniform management of catchments

NIFS has demonstrated in various ways how important it is to see catchments in context when flood damage is to be prevented.

In Gudbrandsdalen work is under way on a management plan for River Gudbrandsdalslågen. This could be a way of ensuring that catchments are seen in context. There is a need to evaluate this planning work before continuing the work on a greater scale. The management plan for River Gudbrandsdalslågen will be completed in 2016.

Better coordination within catchments is regarded as having the potential for major benefits in the prevention of damage. It has therefore been argued that this should be a main focus area in the national strategy.

A follow-up project should have the following goals:

- Analyses associated with floods and floodwater should view the entire catchment area in context
- Risk-reducing measures being assessed and analysed should include both those being implemented based on plans in accordance with the Norwegian Building and Planning Act and minor measures that are implemented without being processed under this legislation
- The administration should make provisions for assessing both upstream and downstream conditions in connection with the planning and implementation of measures.
- Further development of the concept of overall plans that include both major and small catchments.

4.3.2 Data coordination

This heading has a very wide scope. We are talking about an entire value chain from establishing source data in the form of measurements and registrations to the presentation of results from analyses that use measurement data, models and expert assessments. Throughout this entire chain, coordination will be an issue in the form of standardisation of formats, establishment of routines for procurement, quality assurance, storage, sharing and presentation. Data coordination can also entail collaboration to ensure uniform use of tools and models for forecasting, hazard mapping, protection, etc.

Proposals include more measuring stations for precipitation and runoff, better coverage of detailed elevation data, improving the collection of geotechnical data, and better coordination of quality assurance and storage of data. Considerable work has been carried out via NIFS on ensuring registration of events and on data sharing. Concrete recommendations have been issued regarding strengthening the source data, data sharing and data presentation. Some keywords from the previous recommendations:

- Better measurements
    - Monitoring (continuous measurements): Climate, hydrology, satellite measurements
- Better registration of events
    - Registration of flood and landslide/avalanche events
    - Registration of damage, including costs, as a consequence of landslide/avalanche events
- Better overview of measures
    - Overview of vulnerable objects (culverts, etc.)
    - Overview of critical infrastructure and damage levels
    - Overview of protective measures
- Collaboration on hazard mapping
    - Common tools for quick clay mapping
    - Use of climate data, forest data etc. for mapping landslide/avalanche hazards in steep catchments
    - Improved data flow and access to source data (measurements, registrations)

Improving the collection of source data and coordination and sharing of data are regarded as having the potential for major benefits in the prevention of damage. This should be a priority area in the national strategy.

4.3.3 Socio-economics

There is a demand for better source data for socio-economic analyses relating to natural hazards and for analyses to be increasingly conducted both before and after events. The aim is to improve the basis for prioritisation of measures and document the benefits of implemented measures. The analyses should include both direct damage to buildings and infrastructure and indirect costs, for example as a consequence of traffic disruption in the infrastructure.

A follow-up project should ensure:

- Standardisation of damage registration formats across all sectors (insurance, municipal and state-owned infrastructure, etc.)
- Establishing a common solution for collation and presentation of damage data from different sources
- Establishing a procedure for damage registration in the relevant agencies that defines who is to register what and when
- Implementation of pilot projects for socio-economic analyses that include indirect costs to society.

4.3.4 Follow-up after events

Two topics have been identified that are of particular relevance to the national strategy:

- How to achieve prevention in connection with repairs following damage?
  In many cases there is a good opportunity to improve safety in connection with repairs following damage. An important question is the extent to which upgrading should be governed by regulations or left up to the individual party. In this connection, there is also the question of who should cover the costs and whether the compensation schemes associated with insurance and the Norwegian National Fund for Natural Damage Assistance can provide financial support for preventive measures. The question of liability in this context can be complex, see 5.3.1.
- How should technical surveys and evaluations be conducted following an event?
  Investigations into the technical causes of landslides/avalanches have been tested through NIFS: Several types of reporting and evaluation are carried out following an event. It would be relevant to look more closely at these schemes and see whether they can be better coordinated.

4.3.5 Skills development

NIFS has strongly emphasised the positive experience of collaboration on skills development tasks across the agencies and through extensive use of own employees. The good collaboration that has been established should be continued. This can happen in one of several ways. One way would be to establish permanent groups for coordination of regulations and practice relating to selected topics. There has also been positive experience of organising industry seminars that include private sector parties to discuss technical challenges, for example related to mapping. Some of these types of activities should be continued under the national strategy through joint development of courses and industry seminars.

Good study programmes at university level are an important measure for skills development. There must also be more focus on knowledge of natural hazards in upper secondary school education. This will help raise interest in natural hazards and improve recruitment to relevant professions.

Knowledge among local residents and infrastructure users is important to ensure good management of natural hazards. Specialist seminars on land use planning in flood and landslide/avalanche-prone areas, held in 2012–13 and 2014–15 in NVE's five regions have only provided positive experiences. This work must be followed up and developed further.

In areas with known natural hazards it is particularly important that accurate information is available to local residents and infrastructure users. It is equally important, however, to improve the involvement of the general public and achieve good communication between specialists and local residents. More two-way communication must be a goal for the future management of natural hazards.

4.3.6 National forum for flood and landslide/avalanche prevention

There are plans for an annual conference/seminar: 'National forum for flood and landslide/avalanche prevention'. This will be an arena for presenting the results of our work and how we work across the sectors. The ambition is for this to be an important meeting place and arena for knowledge transfer on a national level. It will not in any way exclude participation by municipal and regional players, although other arenas will be specifically.

5 Reports and publications

'Now this is not the end. *It is not even the beginning of the end. But it is, perhaps, the end of the beginning'* (Churchill, 1942).

The NIFS R&D programme has been completed and provides an overview of deliveries in the various communication channels we have used during the process. The overview refers to published material and implemented measures. In many ways this is no more than a presentation of the status to date, as there are both material and plans for comprehensive publication of additional reports, articles and implementation across the agencies.

5.1 Journal & conference papers

Amundsen, Helene A.; Emdal, Arnfinn; Sandven, Rolf; Thakur,Vikas 2015: On engineering characterization of a low plastic sensitive soft clay. GeoQuebec2015 - Challenges from North to South.

Amundsen, Helene A.; Thakur, Vikas; Emdal, Arnfinn 2015: Comparison of Two Sample Quality Assessment Methods Applied to Oedometer Test Results. Proceedings of the 6th International Symposium on Deformation Characteristics of Geomaterials

Dolva, B.K., Petkovic, G., Øvrelid, K., Øydvin, E.K., Dahle, H., Myrabø, S., Thakur, V., Viklund, M.: NIFS R&D program with focus on results to date and expectations for the project period 2012-2015, Geoteknikkdagen, Oslo, 2013

Dolva, B.K. et al. «Interdepartemental research programme on natural hazards, infrastructure, floods and slides (NIFS)«, Natural disasters and societal safety. Joint symposium DNVA – NTVA, s. 51-81, Oslo April 28 2015, s. 51-81

EGU2015-11282: Dahl M-P., Colleuille H., Boje S., Sund M., Krøgli I., Devoli G. 2015. Operational early warning of shallow landslides in Norway: Evaluation of landslide forecasts and associated challenges. Geophysical Research Abstracts. Vol. 17, EGU2015-11282, 2015. EGU General Assembly 2015

EGU2015-13384: Krøgli I., Fleig A., Glad P., Dahl M-P., Devoli G., Colleuille H. 2015. Experiences from coordinated national-level landslide and flood forecasting in Norway. Geophysical Research Abstracts Vol. 17, EGU2015-13384, 2015, EGU General Assembly 2015

EGU2015-15395: Devoli G., Krøgli I., Dahl M-P., Colleuille H., Boje S., Sund M. 2015. Geotechnical considerations in early warning of flooding and landslides: Case study from Norway. Geophysical Research Abstracts. Vol. 17, EGU2015-15395, 2015, EGU General Assembly 2015

ESRI 2015: Devoli G., Bell R., Fischer., Rubensdotter L., Stalsberg K., Cepeda J., Peereboom I., Juliussen H. 2015. Varsling av jordskredfare, hvordan brukes aktsomhetskartene. ESRI Konferanse, Oslo, 4-6 February 2015. Oslo, Norge. http://www.slideshare.net/GeodataAS/devoli-et-al-6-feb2015esri

Helle T. E., Nordal S, Aagaard P., Lied O.K. 2015a Long-term-effect of potassium chloride treatment on improving the soil behavior of highly sensitive clay – Ulvensplitten, Norway. Canadian geotechnical journal 2015.

Helle. T. E., Bryntesen R. N., Amundsen H. A., Emdal A, Nordal S, Aagaard P, 2015b Laboratory setup to evaluate the improvement of geotechnical properties from potassium chloride saturation of a quick clay from Dragvoll, Norway. GeoQuebec2015 - Challenges from North to South.

Helle T.E., Gjengedal I., Emdal A, Aagaard P., Høydal Ø.A., 2014 Potassium Chloride as Ground Improvement in Quick Clay Areas – A Preliminary Study. Landslides in Sensitive Clays - From Geosciences to Risk Management.

IAEG 2014: Devoli G., Kleivane I., Sund M., Orthe N-K., Ekker R., Johnsen E., Colleuille H. 2014. Landslide early warning system and web tools for real-time scenarios and for distribution of warning messages in Norway. Proceeding IAEG 2014, 15-19 September, Torino, Italy.

ICACMAG 2014: Thakur V., Degago S, Oset, F., Dolva B K. (2014). Identification of flow slide susceptible sensitive clay using the disintegration energy concept. 14th *International Conference on Advances in Computer Methods and Advances in Geomechanics*, Kyoto 1.

ISSMGE 2013: Thakur V., Degago S. A., Oset F., Dolva B. K. and Aabøe R. 2013. A new approach to assess the potential for flow slide in sensitive clays. Une nouvelle approche pour évaluer le potentiel de Coulée dans les argiles sensibles. International conference on soil mechanics and geotechnical engineering, ISSMGE, Paris, France, pp 2265-2269.

ISSW 2013: Barfod E., Müller K., Saloranta T., Andersen J., Orthe N. K., Wartianien A., Humstad T., Myrabø S., and Engeset R. 2013. The expert tool XGEO and its applications in the Norwegian Avalanche Forecasting Service. International Snow Science Workshop, Grenoble, 2013

ISSW 2014-P3.46: Kristensen L. L., Humstad T., Orset K. I., Bjordal H. (2014): Contingency plans for snow avalanches for improved road management in Norway. International Snow Science Workshop, Banff, 2013.

ISSW 2014: D'Amboise C., Müller K., Øyan M-J, Hamran S-E., Schuler T.V (2014). First results from a FMCW radar for snowpack monitoring. Proc. Int. Snow Science Workshop, Banff, pp 803-807.

Landslide forum 2014: Bell R., Cepeda J., Devoli G. (2014). Landslide susceptibility modeling at catchment level for improvement of the landslide early warning system in Norway. Proceedings 3rd World Landslide Forum 3, 2-6 June 2014, Beijing.

Landslide forum 2014: Boje S, Colleuille H, Cepeda J, Devoli G (2014). Landslide thresholds at regional scale for the early warning system in Norway. Proceedings 3rd World Landslide Forum 3, 2-6 June 2014, Beijing.

NGM 2012: Thakur V, Oset F, Degago S A, Berg P O, Aabøe R, Wiig T, Elisabeth E D, Lyche E, Sæter M B, Robsrud A (2012) «A critical appraisal on the definition of Brittle clays». Nordic Geotechnical Meeting. Copenhagen, May 2012.

NGM 2014: Thakur V, Oset F, Degago S A, Strand, S.A. Nyheim, T, Lyche E, Viklund M, Dolva B K (2014) «Estimation of retrogression and run-out distance of landslide debris». Norwegian Geotechnical Conference, Oslo, November, 2014.

Oset, F., Thakur, V., Aunaas, K., Dolva, B.K., Sæter, M. B., Robsrud, A., Viklund, M. , Nyheim, T., Lyche, E., and Jensen, O. A., 2013: Regulatory framework for road and railway construction on the soft sensitive clays of Norway. Advances in Natural and Technological Hazards Research by Springer.

PIARC TC1.3: Petkovic G, Humstad T & Dolva B. K. 2015. Analysis at nation level of vulnerability an adaptation measures in Norway. Proceedings, 2016

Thakur, V., Degago S, Oset, F., et al. 2014. Characterization of post-failure movements of landslides in soft sensitive clays. Natural Hazards book: Advances in Natural and Technological Hazards Research: 91–104.

Thakur, V., & Degago, S.A. 2013. Disintegration of sensitive clays. *Géotechnique Letters* 3(1): 20–25.

Thakur, V., Degago, S.A., Oset, F., Dolva, B.K. & Aabøe, R.: A new approach to assess the potential for flow slide in sensitive clays / Une nouvelle approche pour évaluer le potentiel de Coulée dans les argiles sensibles, at 18th ICSMGE in Paris, 2013

Thakur, V., & Degago, S.A. 2014. Quickness approach for assessment of flow slide potential. Inter. Journal SEAGS & AGSSEA 45(1): 85-94.

Thakur, V., Degago S, Oset, F., Dolva, B. K., Aabøe, R., Aunaas, K., Nyheim, T., Lyche, E., Jensen O. A. Viklund, M., Sæter, M. B., Robsrud, A., Nigguise, D. & L'Heureux J.S. 2014. Characterization of post-failure movements of landslides in soft sensitive clays. Natural Hazards book: Advances in Natural and Technological Hazards Research: 91-103.

Thakur V., Nigussie, D. & Degago S.A. 2014. A preliminary study of rheological models for run-out distance modelling of sensitive clay debris

Thakur, Vikas; Degago, Samson Abate 2015: Understanding the Disintegration of Sensitive Clays using Remolding Energy Concept. Proceedings of the 6th International Symposium on Deformation Characteristics of Geomaterials.

Thakur, Vikas; Degago, Samson Abate; Sandven, Rolf Birger; Gylland, Anders Samstad 2015: In-situ determination of remolding energy of soft sensitive clays. GeoQuebec2015 - Challenges from North to South.

In accordance with the plan, further results will be published at:

- Nordic geotechnicians meeting (NGM 2016) in Iceland (May 2016),
- The Via Nordica conference in Trondheim (June 2016),
- 2nd international workshop on landslides in sensitive clays (IWLSC2017) (Trondheim June 2017).

5.2 NIFS reports

Report	Title	Editor/Author	ISBN/ISSNN	Publishing status
2012-33	The Natural Hazards project (sub-project 6) Quick clay. A national initiative on safety in quick clay areas	Editor: Vikas Thakur; lecturers: Frode Oset, Arnfinn Emdal, Claes Alén, Maj Gøril G. Bæver-fjord, Einar Lyche, Hans Petter Jostad, Inger Lise Solberg, Vikas Thakur, Tonje E Helle	978-82-410-0821-4 1501-2832	NVE: October 2012, www.naturfare.no December 2012
2012-34	The Natural Hazards project (sub-project 6) Quick clay. Data report on quick clay landslide at Esp in Byneset in January 2012	Vikas Thakur (NPRA)	978-82-410-0822-1	NVE: October 2012, www.naturfare.no December 2012
2012-35	The Natural Hazards project (sub-project 4) Monitoring and forecasting Experiences from study trip to the Ministry of Transportation (British Columbia) and Canadian Avalanche Center	Tore Humstad, Eivind S Juvik and Gunne Håland (Norwegian Public Roads Administration)		NVE: October 2012, www.naturfare.no December 2012
2012-40	Programme plan 2012–2015 for agency programme 'Natural hazards – infrastructure, floods and landslides/avalanches (NIFS)	Editors: Bjørn Kristoffer Dolva and Marie Haakensen; Authors: Ragnhild Wahl et al.	978-82-410-0828-3 1501-2832	NVE: 1 November 2012, www.naturfare.no December 2012
2012-46	The Natural Hazards project (sub-project 6) Quick clay. Detection of quick clay using different probing methods	Rolf Sandven, Arne Vik & Sigbjørn Rønning (Multiconsult), and Erik Tørum, Stein Christensen & Anders Gylland (SINTEF)	978-82-410-0834-4	At Multicon-sult: 415559 of 2012:11:20 NVE: November 2012, www.naturfare.no December 2012
2012-73	The Natural Hazards project (sub-project 6) Quick clay. Probabilistic analysis of ground surveys in sensitive clay areas	Maj Gøril Bæverfjord & Erik Tørum (SINTEF), and Rolf Sandven & Arne Vik (Multiconsult)	978-82-410-0861-0	At SINTEF: SBF2012 A0310 of 2012:11:30 Published on www.naturfare.no
2012-74	The Natural Hazards project (sub-project 6) Quick clay. Percentage improvement of material factors in brittle fracture materials	Vikas Thakur & Frode Oset (NPRA), Erik Tørum (SINTEF) and Håvard Narjord (Multiconsult)	978-82-410-0862-7	At SINTEF: Memo 3C0970-2 rev.2 of 2012:11:30 Published on www.naturfare.no
2012-75	The Natural Hazards project (sub-project 6) Quick clay. Use of anisotropic displacement parameters in stability calcula-tions in brittle fracture materials	Odd Arne Fauskerud, Corneliu Athanasiu & Cristian Rekdal Havnegjerde (Multiconsult), and Erik Tørum, Stein Olav Christen-sen & Anders Gylland (Sintef)	978-82-410-0863-4	At Multiconsult 415559-RIG-RAP-002 of 2012: 11.30 Published on www.naturfare.no
2012-78	The Natural Hazards project (sub-project 5) Floods and floodwater. Extreme short-term precipitation in Eastern Norway from pluviometer and radar data	The Norwegian Meteorologi-cal Institute (MET): Karianne Ødemark, Eirik Førland, Jostein Mamen, Christoffer A Elo, Anita V Dyrrdal and Steinar Myrabø (Norwegian Public Roads Administration)	978-82-410-0866-5	At MET report 14/2012 of 2012: 12.17 NVE - January 2013, www.naturfare no - March 2013
2012-80	The Natural Hazards project (sub-project 6) Quick clay. Correspondence between use of absolute material factor and percentage improvement	Erik Tørum & Stein Christensen (SINTEF) and Håvard Narjord & Roar Skulbørstad (Multiconsult)	978-82-410-0860-3	At SINTEF: SBF 2012A0309 of 2012: 11.30 Published on www.naturfare.no

2013-01	The Natural Hazards project (sub-project 1) Natural damage strategy. Roles in the national work to manage natural hazards	Rambøll AS: Erlend Falch, Jonas Vevatne, Bård Vestøl Birkedal		At Rambøll January 2013. www.naturfare.no March 2013
2013-21	The Natural Hazards project (sub-project 6) Quick clay. Extent and runout distance of quick clay slides based on catalogue of landslide/avalanche events in Norway.	NGU: Jean-Sebastien L'Heureux and Inger-Lise Solberg	978-82-410-0889-4	Published by NVE / at NGU Report 2012.040 of 2012: 11.21
2013-22	The Natural Hazards project (sub-project 6) Quick clay. Preventive mapping of landslides along shore zones in Norway. Summary of experiences and recommendations	NGU: Louise Hansen, Jean-Sebastien L'Heureux, Inger-Lise Solberg and Oddvar Longva	978-82-410-0890-0	Published by NVE / at NGU Report 2012.046 of 2012: 11.28
2013-23	The Natural Hazards project (sub-project 6) Quick clay. National Database for ground surveys – NADAG – preliminary study	NGU: Inger-Lise Solberg, Per Ryghaug, Bo Nordahl, Hans de Beer, Louise Hansen and Jan Høst. Input from NVE, NPRA, NNRA, NGI and Oslo municipality	978-82-410-0891-7	Published by NVE / at NGU Report 2012.054 of 2012: 12.11
2013-26	The Natural Hazards project (sub-project 6) Quick clay. Assessment of mapping basis for quick clay in shore zones	NGI: Jean-Sebastien L'Heureux		At NGI: 20120754-01-R/ 1. December 2012 / Rev. no.: 0
2013-31	The Natural Hazards project (sub-project 6) Quick clay Monitoring of acute landslide/ avalanche events	Åknes/Tafjord Emergency response ICT and NGU: Lene Kristensen, Thierry Oppikofer, Tore Bergeng	978-82-410-0899-3	Åknes report 02 2013
2013-33	The Natural Hazards project (sub-project 6) Quick clay. Salt diffusion as ground reinforcement in quick clay	Tonje Eide Helle (NPRA)	978-82-410-0901-3	Published by NVE
2013-37	The Natural Hazards project (sub-project 6) Quick clay. Gentle installation methods for cement pilings and use of slurry	NGI: Astri Eggen	978-82-410-0906-8	Published by NGI: 20120746-1-R/ 20 December 2012 / Rev. no.: 0
2013-38	The Natural Hazards project (sub-project 6) Quick clay. Q-Bing – Runout model for quick clay slide: Characterisation of historical quick clay landslides and input parameters for Q BING	NGI: Jean-Sebastien L'Heureux (Norwegian report version of 2013-39)	978-82-410-0907-5	Published by NGI: 20120753-02-R / 27 November 2012 / Revision: 0
2013-39	The Natural Hazards project (sub-project 6) Quick clay. Q-Bing – Runout model for quick clay slide: Characterisation of historical quick clay landslides and input parameters for Q-Bing	NGI: Jean-Sebastien L'Heureux (English report version of 2013-38)	978-82-410-0908-2	Published by NGI: 20120753-02-R / 27 November 2012 / Revision: 0 English version of report 20120751-01 - R
2013-40	The Natural Hazards project (sub-project 6) Quick clay. Landslide at Døla in Vefsn. Study of material properties	NGI: Ragnar Moholdt	978-82-410-0909-9	Published by NGI: 20120853-01-TN / 28 November 2012 / Revision: 0
2013-41	The Natural Hazards project (sub-project 6) Quick clay. State of the art: Block tests	NGI: Kjell Kalsrud, Vidar Gjelsvik, Reidar Otter	978-82-410-0910-5	Published by NGI: 20120866-01-R / 27 December 2012 / Revision: 0

2013-42	The Natural Hazards project (sub-project 6) Quick clay. Input to the 'National ground drilling database (NGD)' – preliminary study	NGI: Eivind Magnus Paulsen	978-82-410-0911-2	Published by NGI: 20120867-01-TN
2013-43	The Natural Hazards project (sub-project 6) Quick clay. Strength increase of reconsolidated quick clay following a landslide	NGI: Ragnar Moholdt	978-82-410-0912-9	Published by NGI: 20120853-01-TN / 1 January 2013 / Revision: 1
2013-46	The Natural Hazards project (sub-project 6) Quick clay. NIFS-N1 Q-Bing – Runout model for quick clay slide: Back-analyses of runout for Norwegian quick-clay landslides	NGI: Dieter Issler, José Mauricio Cepeda, Byron Quan Luna and Vittoria Venditti (ICG/ Università di Bologna)	978-82-410-0917-4	Publishing at NGI: 20120753-01-R / 30 November 2012 / Revision: 0
2013-55	The Natural Hazards project (sub-project 6) Quick clay. Workshop on the use of anisotropy in stability assessments of brittle fracture materials	Sumary by Frode Oset, Norwegian Public Roads Administration, Directorate of Public Roads. The lectures are attached as appendices to the report.	978-82-410-0925-9	Published by NGI: 05 07 2013, www.naturfare.no 07 2013
2013-57	Programme plan 2012–2015 for the Government Agency Programme 'NATURAL HAZARDS – infrastructure for floods and slides (NIFS)'	Editors: Bjørn Kristoffer Dolva and Marie Haakensen. Authors: Ragnhild Wahl, Brigt Samdal, Roald Aabøe, Solveig Kosberg and Art Verhage	978-82-410-0931-0	Published by NGI: 09 2013, www.naturfare.no 08 2013
2013-60	The Natural Hazards project (sub-project 5) Floods and floodwater. Flood estimation in small catchments	Editor: Anne K. Fleig NVE / Authors: Anne K. Fleig, Donna Wilson (NVE)	978-82-410-0929-7 1501-2832	Published by NGI: 10 2013
2013-65	The Natural Hazards project (sub-project 4) Monitoring and forecasting. The avalanche warning service. Evaluation of the 2013 winter season	NVE: Editor: Solveig Kosberg / Authors: Karsten Muller, Solveig Kosberg, Emma Barfod, Birgit Katrine Rustad, Markus Landrø	978-82-410-0933-4	Published by NGI: 08 2013, www.naturfare.no 01 2014
2013-66	The Natural Hazards project (sub-project 5) Floods and floodwater. Water flow stations in Norway with catchments smaller than 50 km2	NVE: Seija Stenius	978-82-410-0937-2 1501-2832	Published by NGI: 09 2013, www.naturfare.no 10 2013
2014-03	The Natural Hazards project (sub-project 5) Floods and floodwater. Design short-term precipitation for Telemark County, Southern Norway and Western Norway	MET: Eirik Førland, Jostein Mamen, Karianne Ødemark, Hanne Heiberg and Steinar Myrabø (NNRA)	978-82-410-0950-1	Published by MET: report 28/2013, www.naturfare.no 10 2013
2014-04	The Natural Hazards project (sub-project 7) Landslide/ avalanche and flood protection Protective measures against floods and landslides/avalanches. Inspections in Troms and Finnmark counties in 2013	Editor: Knut Aune Hoseth (NVE)/ Authors: Knut Aune Hoseth (NVE), Lene Lundgren Kristensen (NPRA), Gunne Håland (NPRA).	978-82-410-0953-2	Published by NGI: 27 01 2014, www.naturfare.no 02 2014
2014-13	The Natural Hazards project (sub-project 5) Floods and floodwater. Characterisation of flood regimes. Sub-project. 5.1.5	NVE: Seija Stenius, Per Alve Glad, Donna Wilson	978-82-410-0961-7	Published by NGI: 01 2014, www.naturfare.no 02 2013

2014-14	The Natural Hazards project (sub-project 6) Quick clay. An agreed recommendation on using anisotropic factors in the design of Norwegian clays	Editor: Vikas Thakur (NPRA) with working group Frode Oset (NPRA), Margareta Viklund (NNRA), Stein-Are Strand (NVE), Vidar Gjelsvik (NGI), Stein Christensen (SINTEF) and Odd Arne Fauskerud (Multiconsult AS)	978-82-410-0962-4	Published by NGI: 01 2014, www.naturfare.no 04 2013
2014-22	The Natural Hazards project (sub-project 3.1) How to calculate extreme values for specific recurrence intervals. Manual for calculating return values of precipitation for different recurrence intervals (for non-statistics)	NVE: Galina Ragulina, Andrea Taurisano	978-82-410-0970-9 1501-2832	Published by NGI: 03 2014, www.naturfare.no 08 2013
2014-26	The Natural Hazards project (sub-project 1) Natural damage strategy. Comparison of risk acceptance criteria for landslides/avalanches and floods. Study for the Natural Hazards Programme (NIFS)	NGI: Unni M. K. Eidsvig	978-82-410-0962-4	Published by NGI: 20120800-01-R / 11 November 2014 / Revision: 1 Published by NGI: 05 2014, www.naturfare.no 05 2013
2014-27	The Natural Hazards project (sub-project 6) Quick clay. Landslide/avalanche mapping in shore zones – continuation	NGI: Jean-Sebastien L'Heureux	978-82-410-0974-7	Published by NGI: 20130701-01-R / 5 December 2013 / Revision: 0 Published by NGI: 05 2014, www.naturfare.no 06 2014
2014-28	The Natural Hazards project (sub-project 5) Floods and floodwater. 'Twig dams' in Slovakia. Small terraces made from local materials; experiences from study trip for possible use in Norway.	Editor: Bent C. Braskerud (NVE) co-authors (NIFS agencies): Knut A. Hoseth, Tone Israelsen, Torgeir Kval, Steinar Myrabø, Sven-Håkon Nordlien and Joar Skauge	978-82-410-0975-41501-2832	Published by NGI: 05 2014, www.naturfare.no 06 2014
2014-34	The Natural Hazards project (sub-project 6) Quick clay. Landslide/avalanche mapping in shore zones – a summary	Authors (NVE): Odd Are Jensen and Trude Nyheim	978-82-410-0974-6	Published by NVE: www.naturfare.no 10 2014
2014-35	The Natural Hazards project (sub-project 5) Floods and floodwater. Characterisation of flood regimes. Revision of report 13-2014	Author (NVE): Seija Stenius, Per Alve Glad, Donna Wilson	978-82-410-0937-2 1501-2832	Published by NGI: 03 2015 www.naturfare.no 10 2014
2014-37	The Natural Hazards project (sub-project 4) Monitoring and forecasting Preliminary regionalization and susceptibility analysis for landslide early warning purposes in Norway	Authors (NVE): Graziella Devoli, Mads-Petter Dahl	978-82-410-0985-3	Published by NGI: 05 2014, www.naturfare.no 09 2014
2014-39	The Natural Hazards project (sub-project 6) Quick clay. Effect of progressive fracture changes for development in quick clay areas: Sensitivity analysis based on data from ground surveys on the section of road between Sund and Bradden in Rissa.	Authors (NGI): Petter Fornes, Hans Petter Jostad	978-82-410-0988-4	at NGI 12 May 2014: 20092128 00 -6-R, www.naturfare.no June 2014

2014-40	The Natural Hazards project (sub-project 6) Quick clay. Effect of progressive fracture changes for development in quick clay areas: Sensitivity analysis-1	Authors (NGI) Petter Fornes/ Hans Petter Jostad wrote the foreword, front page and text (NGI report) (called report 3) may be published	978-82-410-0989-1	at NGI 12 May 2014: 20092128 00 -6-R, www.naturfare.no June 2014
2014-42	The Natural Hazards project (sub-project 5) Managing floods and floodwater. Design short-term precipitation for Møre & Romsdal, Trøndelag and North Norway.	Authors (MET): Erik Førland, Jostein Mamen, Karianne Ødemark, Hanne Hieberg and Steinar Myrabø (NNRA)	978-82-410-0991-4	At MET 20 March 2014 NVE April 2014 www.naturfare.no July 2014
2014-43	The Natural Hazards project (sub-project 4) Monitoring and forecasting. Threshold studies for triggering of landslides in Norway. Summary of hydrological threshold studies at NVE from 2009 to 2013	Authors (NVE): Søren Boje, Herve Colleuille, Graziella Devoli	978-82-410-0992-1 1501-2832	Published by NGI: 05 2014, www.naturfare.no 09 2014
2014-44	The Natural Hazards project (sub-project 4) Monitoring and forecasting. Regional warnings of landslide hazards: Analysis of historical debris slides/flows and slush slides in Gudbrandsdalen and Ottadalen	Nils Arne K. Walberg, Graziella Devoli	978-82-410-0993-81501-2832	Published by NGI: 05 2014, www.naturfare.no 09 2014
2014-46	The Natural Hazards project (sub-project 6) Quick clay. Feasibility study into the development of a national block test database	Author: Eivind Magnus Paulsen (NGI)	978-82-410-0995-2	NGI 1 December 2013: 20130760-01--R www.naturfare.no June 2014
2014-47	The Natural Hazards project (sub-project 6) Quick clay. Detection of brittle fracture material using R-CPTU	Authors (MC): Alberto Montafia, Rolf Sandven	978-82-410-0996-9	MC 6 December 2013: 415559-RIG-RAP-002rev00 www.naturfare.no
2014-54	The Natural Hazards project (sub-project 1) Natural damage strategy. Collaboration and coordination concerning natural hazards Mini study of the joint project E6 highway – The Dovre Line and the Follo Line	Authors (Rambøll AS): Erlend Falch, Marianne Holmesland and Jørgen Biørn.	978-82-410-1006-4	At Rambøll in June 2014. www.naturfare.no June 2014
2014-55	The Natural Hazards project (sub-project 6) Quick clay. Effect of progressive fracture changes for development in quick clay areas: A1 Numerical method of calculating undrained fractures in sensitive materials	Authors (NGI) Hans Petter Jostad/Gustav Grimstad	978-82-410-1107-1	NGI 12 May 2014: 20092128-00 -4-R, www.naturfare.no June 2014
2014-56	The Natural Hazards project (sub-project 6) Quick clay. Effect of progressive fracture changes for development in quick clay areas: A2 Back calculation of the Vestfossen landslide	Authors (NGI) Hans Petter Jostad/Gustav Grimstad	978-82-410-1008-8	NGI 01 June 2012: 20092128-00-5-R, www.naturfare.no August 2014
2014-57	The Natural Hazards project (sub-project 6) Quick clay. Safety in connection with development of quick clay areas. Effect of progressive fractures in ravines	Authors (NGI) Petter Fornes / Hans Petter Jostad	978-82-410-1009-5	NGI 12 May 2014: 20130275-01-R www.naturfare.no in June 2014 due to be published by NVE and on the website

2014-58	The Natural Hazards project (sub-project 6) Quick clay. Safety in connection with development of quick clay areas. Probability of fracture with percentage improvement	Authors (NGI): Petter Fornes, Hans Petter Jostad	978-82-410-1010-1	NGI 12 May 2014: 20130275-02-R www.naturfare.no in June 2014 currently being published by NVE and on the website
2014-59	The Natural Hazards project (sub-project 6) Quick clay. Correspondence between use of absolute material factor and percentage improvement – use of stress change to define local landslides/ avalanches and area landslides/ avalanches	Authors (SINTEF) Stein Olav Christensen, Anders Samstad Gylland	978-82-410-1011-8	SINTEF 21 Oct 2013: SBF2013A0274 www.naturfare.no in Nov. 2014.
2014-62	The Natural Hazards project (sub-project 5.1.6) Floods and flood-water. Regional formulae for index floods and frequency curves	Authors (NVE): Per Alve Glad, Trond Reitan and Seija Stenius	978-82-410-1014-9	Published by NVE June 2014 www.naturfare.no 9 2014
2014-63	The Natural Hazards project (sub-project 3.2) A study of coordination and sharing of flood and landslide/avalanche data for three collaborating agencies	(Work Research Institute): Knut Fossestøl and Eric Breit	978-82-410-1015-6	Published by the Work Research Institute (r2014:6) May 2014
2014-64	The Natural Hazards project (sub-project 2) Preparedness and crisis management Sub-report 1- Emergency response plans and crisis management	Authors: Bjørn Stuedal (own firm) Kari Øvrelid (NVE), Trond Sandum (NNRA), Hein Gabrielsen (NPRA)	978-82-410-1016-3	Published by NVE 5 May 2014 www.naturfare.no 31 July 2014
2014-67	The Natural Hazards project (sub-project 6) Quick clay. Effect of long-term storage on sample quality	Authors (NGI): Jean-Sebastien L'Heureux, Yunhee Kim, Tone Solem	978-82-410-1019-4	NGI: 1 Dec 2013: R20130672-01-R, www.naturfare.no Oct. 2014 Published by NVE October 2014
2014-68	The Natural Hazards project (sub-project 6) Quick clay. Effect of storage time on sample quality	Authors (NGI): Jean-Sebastien L'Heureux, Yunhee Kim (translated by Tone Solem)	978-82-410-1020-0	NGI: 1 Dec 2013: R20130672-01-R www.naturfare.no in June 2014 Published by NVE October 2014
2014-70	The Natural Hazards project: Status autumn 2014 Results and the road ahead	Authors: Project management (incl. sub-project managers)	978-82-410-1020-0	Published by NVE October 2014
2014-76	The Natural Hazards project (sub-project 2) Preparedness and crisis management Sub-report 2 - Emergency response plans and crisis management	Authors: Bjørn Stuedal (own firm) Kari Øvrelid (NVE), Trond Sandum (NNRA), Hein Gabrielsen (NPRA)	978-82-410-1027-9	Published by NVE ??.?? 2014 www.naturfare.no 10 2014
2014-77	Crisis support tools CIM – Recommendations	Authors: Frode Oset (NPRA), Margareta Viklund (NNRA), Odd Arne Fauskerud, (Multiconsult AS), Stein Christensen (SINTEF), Steinar Nordal (Norwegian University of Science and Technology) , Stein-Are Strand (NVE), Vidar Gjelsvik (NGI), Vikas Thakur (NPRA)	978-82-410-1028-6	Published by NVE 05 2015 www.naturfare.no 09 2015 -

2014-79	The Natural Hazards project (sub-project 6) Quick clay. Selection of characteristic CuA – profile based on field and laboratory tests (under revision!!!)	Authors (NVE): Emma Barfod	978-82-410-1030-5	Published by NVE Nov. 2014 www.naturfare.no 04 2014
2014-80	The Natural Hazards project (sub-project 4) Monitoring and forecasting. The avalanche warning service. Evaluation of the 2014 winter season	Authors (NVE): Grant Statham, Emma Barfod	978-82-410-1031-6	Published by NVE March 2015 www.naturfare.no ?? 2014
2014-87	The Natural Hazards project: Mapping the status and potential of drone-based technology. Applications relating to natural hazards and infrastructure	Authors (SINTEF ICT): Esten Ingar Grøtli, Aksel A Transeth, Anders Gylland, Petter Risholm, Ida Soon Brøther Bergh	978-82-410-1036-1	SINTEF ICT: 30.11.2014 A26527- Open publication at NVE ??.?? 2014 www.naturfare.no 12 2014
2014-88	The Natural Hazards project (sub-project 6) Quick clay. NGI's recommendations on requirements for the effect of brittle fracture behaviour	Author: (NGI) Petter Fornes	978-82-410-1037-8	NGI: 19 Nov. 2014: R20140075-01-R Published by NVE 12 2014 www.naturfare.no 12 2014
2014-90	The Natural Hazards project (sub-project 3.2) Mapping analysis of historical debris slides/flows and slush slides in Troms county	Author: (NVE) Graziela Devoli	978-82-410-1039-2	Published by NVE 19.03. 2015 www.naturfare.no 03 2015 -
2014-92	The Natural Hazards project (sub-project 6) Quick clay pre-study: Ground improvement for marginally stable slopes	Author: Minna Karstunen, Chalmers University of Technology	978-82-410-1041-5	Chalmers: November 2014 Published by NPRA ??.?? 2014 www.naturfare.no 12 2014
2014-93	The Natural Hazards project (sub-project 6) Quick clay. Landslide at Nord-Statland. Investigation of technical causalality (NVE report as news item for us)	Authors (NVE): Stein-Are Strand and Einar Lyche Co-authors: Ragnar Moholdt (NGI), Steinar Nordal (Norwegian University of Science and Technology), Vikas Thakur (NPRA), Frode Oset (NPRA), Margareta Viklund (NNRA)	978-82-410-1042-2	Published by NVE 12 2014 www.naturfare.no 12 2014
2015-00	The Natural Hazards project (sub-project 7) Landslide/avalanche and flood protection Field manual for floods and landslide/avalanches	Prepared by: Vivian Caragounis, Knut Aune Hoseth and Helge Leif Nordvik from NVE, Heidi Bjordal and Lene Lundgren Kristensen from NPRA and Margareta Viklund from NNRA, in collaboration with experts from the three agencies and the police.	978-82-7704-145-2	Launched on 23 March 2015. A description is published on www.naturfare.no 27 March 2015
2015-01	The Natural Hazards project (sub-project 3.1) Summary report. Review of landslide/avalanche hazard investigations prepared by consultants 2011–2014.	Authors (NVE) Galina Ragulina, Andrea Taurisano	978-82-410-1045-31501-2832	Published by NVE 01 2015 www.naturfare.no 01 2015
2015-07	The Natural Hazards project (sub-project 5) – Water gone astray. Guidelines for flood calculations in small, unregulated catchments	Editor: Seija Stenius, Per Alve Glad (NVE) Authors: Seija Stenius, Per Alve Glad, Thea Karoline Wang, Thomas Væringstad	1501-0678	Published by NVE 12 2015 www.naturfare.no 01 2016

2015-13	The Natural Hazards project (sub-project 5.1.6) Floods and floodwater. National formulae for flood calculations in small, unregulated catchments. Revision of report 62-2014	Authors (NVE): Per Alve Glad, Trond Reitan and Seija Stenius	9788241010606 15012832	Published by NVE in February 2015 www.naturfare.no 04. 2015
2015-61	The Natural Hazards project (sub-project 7) Landslide/avalanche and flood protection Study tour to Switzerland	Authors: (NPRA) Gunne Håland and Audun Langelid	978-82-410-1108-5	Published by NVE June 2015 www.naturfare.no 06.2015
2015-62	The Natural Hazards project (sub-project 3.3) RAV analyses in land use planning Recommendation on collaboration between the transport agencies	Authors: Lars Berggren (NNRA), Peer Sommer Erichson (NVE) and Jan Otto Larsen (NPRA/UNIS).	978-82-410-1109-2 1501-2832	Published by NVE June 2015 www.naturfare.no 06. 2015
2015-65	The Natural Hazards project (sub-project 3) – Mapping. Quality control, analysis and proposal for updating historical quick clay slides and other clay slides registered in the National Landslide/Avalanche Database (NSDB)	Editor: Inger-Lise Solberg (NGU) Authors: Ewa Solkalska (NPRA), Graziella Devoli (NVE), Inger-Lise Solberg (NGU), Louise Hansen (NGU) Vikas Thakur (Norwegian University of Science and Technology)	978-82-410-1112-2	Published by NVE 07 2015 www.naturfare.no 08 2015
2015-66	The Natural Hazards project (sub-project 4) Monitoring and forecasting. Avalanche warning using the nearest neighbour method. Test of the Canadian nearest neighbour model on landslide/avalanche data from Senja.	Editor: Eivind Juvik (NPRA) Authors: Eivind Juvik, Katharina Kahrs and Tore Humstad.	1501-28322 978-82-410-1113-9	Published by NVE 08 2015 www.naturfare.no 08 2015
2015-73	The Natural Hazards project (sub-project 3) – Mapping. Avalanches in birch forests – Trial test in Abisko	Editor (NVE): Emma Barfod	978-82-410-1114-6	Published by NGI 18 12 2014 (as 20130918-01-R) and at NVE 08 2015 www.naturfare.no 08.2015
2015-78	The Natural Hazards project (sub-project 4) Monitoring and forecasting. The avalanche warning service. Evaluation of the 2015 winter season	Authors: Karsten Müller, Solveig Kosberg, Emma Barfod, Birgit Katrine Rustad, Markus Landrø, Ragnar Ekker, Andreas Haslestad, Rune Engeset and Erik Johnsen	978-82-410-1125-2	Published by NVE Sept. 2015 www.naturfare.no 09 2015
2015-79		Author (Norwegian University of Science and Technology): Anders Samstad Gylland	1501-2832	Norwegian University of Science and Technology: 11.12.2014 Published by NVE 09 2015 www.naturfare.no 09 2015
2015-81	The Natural Hazards project (sub-project 6) Quick clay. Expanded interpretation basis for vane shear tests. Results from the preliminary project at the Norwegian University of Science and Technology	Author (Norwegian University of Science and Technology): Anders Samstad Gylland	978-82-410-1132-0	Published by NVE 09 2015 www.naturfare.no 09 2015
2015-86	The Natural Hazards project (sub-project 6) Quick clay. Interpretation of active undrained shear strength from vane shear tests	Editor: Seija Stenius	978-82-410-1137-5	Published by NVE 09 2015 www.naturfare.no 10 2015

2015-04	The Natural Hazards project (sub-project 5) – Water gone astray. Comparison of methods for flood calculations in small, unregulated catchments.	Authors: Seija Stenius, Per Alve Glad, Trond Reitan, Thea Caroline Wang, Anne Kristina Tvedalen, Petter Reinemo, Sølvi Amland.	978-82-428-0355-9	Published by Western Norway Research 06 2015 Norwegian Association of Local and Regional Authorities R&D 08 2015 www.naturfare.no 08.2015
2015-90	Foresight, hindsight or passivity? How do you assess the costs of prevention versus the costs of rebuilding physical infrastructure exposed to natural damage and climate change?	Carlo Aall (Western Norway Research), Marta Baltruszewicz (Western Norway Research), Kyrre Groven (Western Norway Research), Anders-Johan Almås (SINTEF) and Frode Vagstad (Vagstad Prosjektservice AS)	978-82-410-1141-2	Published by NVE 10 2015 www.naturfare.no 10 2015
2015-91	The Natural Hazards project (sub-project 7) Landslide/avalanche and flood protection. Registration of landslide/avalanche and flood protection measures at NVE, NPRA and NNRA.	Editor: Lene Lundgren Kristensen (NPRA) Authors: Lene Lundgren Kristensen, Jan Otto Larsen (NPRA), Aart Verhage, Odd Are Jensen, Graziella Devoli, Birgit Katrine Rustad (NVE) and Margareta Viklund (NNRA)	978-82-410-1142-9	Published by NVE 10 2015 www.naturfare.no 10 2015
2015-93	The Natural Hazards project (sub-project 5) – Water gone astray. Socio-economic costs of the Gudbrandsdalen floods of 2013	Editor: Heidi Bjordal (NPRA) Author(s): Marianne Myhre Odberg, Kristin Skei, Silje Skarsten, Lene Lunddgren Kristensen, Heidi Bjordal (NPRA) et al.	978-82-410-1145-0	Published by NVE 10 2015 www.naturfare.no 11 2015
2015-97	The Natural Hazards project (sub-project 5) Water gone astray Recommended method for flood calculations in small, unregulated catchments	Authors: Seija Stenius & Per Alve Glad (NVE)	978-82-410-1149-8	Published by NVE 11 2015 www.naturfare.no 11 2015
2015-98	The Natural Hazards project (sub-project 7) Landslide/avalanche and flood protection. Experiences of the field manual for floods and landslide/avalanches	Author(s): Margareta Viklund (NNRA), Knut Aune Hoseth (NVE), Heidi Bjordal (NPRA), Lene Lundgren Kristensen	978-82-410-1150-4	Published by NVE 11 2015 www.naturfare.no 11 2015
2015-100	The Natural Hazards project: Veslemannen autumn 2014 – Monitoring and preparedness	Author: Lars Harald Blikra and Kari Øvrelid (NVE)	978-82-410-1152-8	Published by NVE 11 2015 www.naturfare.no 11 2015
2015-101	The Natural Hazards project (sub-project 6) Quick clay. Detection of quick clay using R-CPTU and electric vane borer. Results from field study.	Editor: Hanne B. Ottesen (NPRA) and Ingrid Havnen (NVE) Authors: Rolf Sandven, Alberto Montafia (MC)	978-82-410-1153-5	Published by NVE 11 2015 www.naturfare.no 11 2015
2015-104	The Natural Hazards project (sub-project 6) Quick clay. Workshop on safety philosophy.	Editor: Margareta Viklund (NNRA) Authors: Frode Oset (NPRA), Hanne B. Ottesen (NPRA), Kristian Aunaas (NPRA), Einar Lyche (NVE), Stein-Are Strand (NVE), Trude Nyheim (NVE), Margareta Viklund (NNRA)	978-82-410-1156-6	Published by NVE 11 2015 www.naturfare.no 11 2015

2015-105	The Natural Hazards project (sub-project 2): Preparedness and crisis management. Information exchange during exercises and events.	Authors: Bjørn Stuedal (own firm) Kari Øvrelid (NVE), Trond Sandum (NNRA), Hein Gabrielsen (NPRA), Camilla Røhmne (NPRA), Olianne Eikenæs (NVE) and Roger Steen	978-82-410-1157-3	Published by NVE 12 2015 www.naturfare.no 12 2015
2015-106	The Natural Hazards project. Communication plan for the natural hazards, infrastructure, floods and landslides/avalanches R&D programme 2012–2016.	Editor: Marie Haakensen Authors: project management with contributions from communications staff Kjell Solem (NPRA), Dag Svinsås (NNRA) and Erik Due (NVE)	978-82-410-1158-0	Published internally in the programme in 2012, at NVE 12 2015 www.naturfare.no 12 2015
2015-107	The Natural Hazards project (sub-project 7) Landslide/avalanche and flood protection. Comparison of modelling tools for Norwegian avalanches.	Editor: Gunne Håland (NPRA) Author(s): Gunne Håland, Knut Inge Orset, Harald Norem and Martine H. Frekhaug (NPRA)	978-82-410-1159-7	Published by NVE 12 2015 www.naturfare.no 12 2015
2015-114	The Natural Hazards project (sub-project 4) Monitoring and forecasting. Deformation analysis of steep mountainside using drone-based photogrammetry.	Author: Leif Erik Blankeenberg, TerraTec AS and more.	978-82-410-1166-5	Published by NVE 12 2015 www.naturfare.no 12 2015
2015-115	The Natural Hazards project (sub-project 7) – Protective measures against floods and landslides/avalanches. Inspections in Hordaland and Sogn og Fjordane counties in May 2014.	Authors: Knut Aune Hoseth (NVE), Lene L. Kristensen, Gunne Håland (NPRA), Margareta Viklund (NNRA), Heidi Bjordal (NPRA)	978-82-410-1167-2	Published by NVE 12 2015 www.naturfare.no 12 2015
2015-120	The Natural Hazards project (sub-project 1) Natural damage strategy. – On the alert against natural hazards.	Editor (NVE): Sverre Kjetil Rød Authors: Sverre Kjetil Rød, Gordana Petkovic (NPRA), Knut Sørgaard (NVE), Odd Are Jensen (NVE), Aart Verhage (NVE), Hallvard Berg (NVE) and Per Lars Erik Viréhn.	978-82-410-1172-6	Published by NVE 12 2015 www.naturfare.no 12 2015
2015-122	The Natural Hazards project (sub-project 3) – Mapping. Satellite-based radar interferometry (InSAR) for natural hazards, landslides/avalanches and infrastructure.	Authors (NGU): Line Rouyet, Tom Rune Lauknes, Kjell-Arild Høgda	978-82-410-1174-0	Published by NVE 12 2015 www.naturfare.no 12 2015
2015-123	The Natural Hazards project: Sub-project 5.3: Flood and landslide/avalanche events in Gudbrandsdalen.	Editor (NNRA): Maria H. Olsen Authors: Maria H Olsen, Agathe A Hopland, Steinar Myrabø, Per Viréhn and Per A Glad (NVE).	978-82-410-1175-7	Published by NVE 12 2015 www.naturfare.no 12 2015
2015-124	The Natural Hazards project: Sub-project 5.3: Flood and landslide/avalanche events in Gudbrandsdalen.	The Natural Hazards project: Sub-project 5.3: Flood and landslide/avalanche events in Gudbrandsdalen. Editor (NNRA): Maria H. Olsen Authors: Maria H. Olsen, Agathe A. Hopland, Steinar Myrabø, Per Viréhn, Per A Glad (NVE), O E Almenningen and E Traae (NVE).	978-82-410-1176-4	Published by NVE 12 2015 www.naturfare.no 12 2015

2015-126	The Natural Hazards project (sub-project 6) Quick clay. Detection of brittle fracture material - Final report.	Editors: Hanne B Ottesen (NPRA), Ingrid Havnen (NVE), Mostafa Abokhalil (NNRA) Authors: Rolf Sandven, Alberto Montafia, Anders S Gylland, Kristoffer Kåsin, Andreas A Pfaffhuber, Michael Long	978-82-410-1178-8	Published by NVE 12 2015 www.naturfare.no 12 2015
2015-129	The Natural Hazards project (Sub-project 1) – Natural damage strategy – Forest and natural hazards.	Authors: Knut Sørgaard (NPRA), Art Verhage (NVE) Odd Are Jensen (NVE)	978-82-410-1181-8	Published by NVE 01 2016 www.naturfare.no 01 2016
2015-130	The Natural Hazards project (sub-project 5) – Water gone astray. Flood in Notodden on 24 July 2014.	Editor: Agathe Alsaker Hopland (NNRA) Authors: Maria Hetland Olsen (NNRA), Ole Erik Almenningen (NNRA), Steinar Myrabø (NNRA), Per L E Viréhn (NNRA), Eirik Traae (NVE)	978-82-410-1182-5	Published by NVE 01 2016 www.naturfare.no 01 2016
2015-134	The Natural Hazards project (sub-project 5) – Water gone astray. Design short-term precipitation.	Authors (MET): Eirik Førland, Jostein Mamen, Lars Grinde, Anita V Dyrrdal and Steinar Myrabø (NNRA)	978-82-410-1186-3	Published by NVE 01 2016 www.naturfare.no 01 2016
2016-04	The Natural Hazards project (sub-project 2) – Preparedness and crisis management. Summary: Preparedness and crisis management.	Authors: Bjørn Stuedal (own firm) Kari Øvrelid (NVE), Trond Sandum (NNRA), Camilla Røhme (NPRA), Hein Gabrielsen (NPRA), Olianne Eikenæs (NVE) and Roger Steen	978-82-410-1193-1	Published by NVE 01 2016 www.naturfare.no 01 2016
2016-08	The Natural Hazards project (sub-project 6) Quick clay. The boundary between local and area stability.	Editor: Frode Oset (NPRA) Authors: Kristian Aunaas, Frode Oset and Hanne Bratlie Ottesen (NPRA), Stein-Are Strand, Einar Lyche and Ingrid Havnen (NVE), Margareta Viklund and Mostafa Abokhakil (NNRA), Odd Arne Fauskerud (Multiconsult), Stein Christensen (SINTEF), Vidar Gjelsvik (NGI), Vikas Thakur (Norwegian University of Science and Technology)	978-82-410-1198-6	Published by NVE 02 2016 www.naturfare.no 02 2016
2016-12	The Natural Hazards project (sub-project 4) Monitoring and forecasting. Measurement of Stabrekkfonna in Sjåk Municipality using ground-based radar (InSAR).	Editor: Ingrid Skrede (NVE) and Tore Humstad (NPRA) Authors Ingrid Skrede (NVE) and Lene Lundgren Kristensen (NPRA)	978-82-410-1202-0	Published by NVE 02 2016 www.naturfare.no 02 2016
2016-13	The Natural Hazards project (sub-project 4) Monitoring and forecasting. Monitoring of landslides/avalanches and other slope processes using ground-based laser scanning.	Author(s): T. Oppikofer (NGU)	978-82-410-1203-7	Published by NGU 02 2016 Published by NVE 02 2016 www.naturfare.no 02.2016

2016-14	The Natural Hazards project (sub-project 6) – Quick clay. Method for assessing trigger and runout areas for large area landslides/avalanches.	Authors: Kristian Aunaas, Hanne Bratlie Ottesen, Frode Oset (NPRA) Trude Nyheim, Stein-Are Strand, Einar Lyche (NVE). Odd Arne Fauskerud (Multiconsult), Kjell Karlsrud , Jean-Sébastien L'Heureux, Vidar Gjelsvik (NGI), Vikas Thakur (Norwegian University of Science and Technology).	978-82-410-1204-4	Published by NVE 02 2016 www.naturfare.no 02 2016
2016-15	The Natural Hazards project (sub-project 6) Quick clay. Safety philosophy for assessment of area stability on natural slopes.	Editor: Einar Lyche (NVE) Authors: Stein-Are Strand (NVE), Frode Oset, Hanne Bratlie Ottesen (NPRA), Margareta Viklund (NNRA)	978-82-410-1205-1	Published by NVE 02 2016 www.naturfare.no 02 2016
2016-16	The Natural Hazards project (sub-project 6) Quick clay. Dynamic stresses and landslide/avalanche hazards	Authors: Jean-Sebastien L'Heureux, Jörgen Johansson (NGI)	978-82-410-1206-8	Published by NVE 02 2016 www.naturfare.no 02 2016
2016-026	The Natural Hazards project (sub-project 5) – Water gone astray Example of drainage measures in small catchments	Editor: Agathe Alsaker Hopland (NNRA) Authors: Agathe Alsaker Hopland (NNRA), Maria Hetland Olsen (NNRA), Steinar Myrabø (NNRA), Eirik Traae (NVE)	978-82-410-1217-4	Published by NVE 02 2016 www.naturfare.no 02 2016
2016-027	The Natural Hazards project (sub-project 6) - Quick clay Detection of brittle materials. Summary report with recommendations	Editor: Ingrid Havnen (NVE) and Hanne Ottesen (NPRA) Authors: Rolf Sandven, Alberto Montafia, Anders Gylland, Kristoffer Kåsin, Andreas A.	978-82-410-1218-1	Published by NVE 02 2016 www.naturfare.no 2 2016
2016-028	The Natural Hazards project (sub-project 5) – Water gone astray – Drainage manual Drainage of infrastructure	Editor: Harald Norem (NPRA) Authors: Harald Norem (NPRA) Kristine Flesjø (NPRA), Joakim Sellevold (NPRA)	978-82-410-1219-8	Published by NVE 03 2016 www.naturfare.no 03.2016
2016-039	The Natural Hazards project (sub-project 5) – Water gone astray. 3 pilot fields in Gudbrandsdalen Description of measures	Editor: Steinar Myrabø (NNRA) Authors: Maria Hetland Olsen (NNRA), Steinar Myrabø (NNRA) et al. ...	ISSN 1501-2832	Published by NVE 03 2016 www.naturfare.no 03.2016
2016-036	The Natural Hazards project October 2014 - flooding at the west coast of Norway	Authors: Halvor Dannevig, Kyrre Groven og Carlo Aall	978-82-428-0366-5	Published by NVE 03 2016 www.naturfare.no 03.2016
2016-041	The Natural Hazards project (sub-project 3) – Mapping Pilot study on coordinated use of 'known quick clay data'	Editor: Hanne B Ottesen (NPRA) Author(s): Eli K. Øydvin NVE, Hanne B Ottesen (NPRA) and more.	ISSN: 1501-2832	Published by NVE 03 2016 www.naturfare.no 03 2016

5.3 Student theses

The references below demonstrate that we have had an extensive collaboration with the Norwegian University of Science and Technology on master and student theses. This work should be expanded to include more educational institutions.

5.3.1 Master theses

Aavatsmark, Erik: Mapping of stability and hydrogeology in ravine landscape along the new railway line north of Eidsvoll station NMBU, 2014

Bjerre, Jesper: Development and evaluation of an effective stress-based model for soft clays, Norwegian University of Science and Technology, 2015

Cederström, Emil: Application of Probabilistic Methods in Slope Stability Calculations, Chalmers, 2014

Eide, Henrik Takle: On shear-wave velocity testing in clay, Norwegian University of Science and Technology, 2015

Faqiri, Khoshal: Hydraulic capacity of culverts under sediment transport - Multibarrel setup, Norwegian University of Science and Technology, 2014

Frekhaug, Martine Holm: An assessment of prediction tools for Norwegian debris flows, Norwegian University of Science and Technology, 2015

Gotvassli, Ida: Model testing of culvert designs, Norwegian University of Science and Technology, 2013

Grue, Ragnhild Håøy: Rheological parameters of Norwegian sensitive clays focusing on the Herschel–Bulkley model, Norwegian University of Science and Technology, 2015.

Helle, Cecilie Myklebust & Tzatzakis, Anonios N: Comparative study of laboratory tests from the E6 highway Klett, Norwegian University of Science and Technology, 2015

Hennig, Ida Marie: Floodway and precautionary mapping using GIS above the Brandrudsåa catchment area in Gudbrandsdalen, Norwegian University of Science and Technology, 2015

Hole, Lars Jørgen: Analysis of unstable road cutting at Svølgja on country road Fv 30, Norwegian University of Science and Technology, 2015

King, Jeremy Raymond: Undrained shear creep in quick clay: development of a triaxial device and evaluation of Esp, Byneset, as a potential research site, Norwegian University of Science and Technology, 2013

Kvalsvik, Miriam Natalie Lande: Experience of closed drainage systems and roads outside densely populated areas, Norwegian University of Science and Technology, 2015

Larsen, Eirik: Hydrologically correct elevation models, runoff and response times in Soknedal – a GIS study, Norwegian University of Science and Technology, 2015

Mathisen, Åsmund Ertshus: Repair of and problems with twig and log dams viewed from a geomorphological perspective, based on theories and observations from Soknedal, Norway, Norwegian University of Science and Technology, 2015

Nigussie, Daniel: Numerical modelling of run-out of sensitive clay slide debris, Norwegian University of Science and Technology, 2013

Olsen, Maria Hetland: The effect of human intervention in runoffs and material transport during a heavy precipitation event. Case studies from Gudbrandsdalen after the floods of 2013, Norwegian University of Science and Technology, 2014

Puakowski, Stanislaw: Interpretation methods of CPTU and RCPTU with special focus on soft soils. Assessment of classical approaches and data mining techniques, Norwegian University of Science and Technology, 2015

Putri, Masdiwati Minati: Hydraulic capacity of culverts under sediment transport, Norwegian University of Science and Technology, 2014

Rudolfsen, Kenneth Thomsen: Use of electrical resistivity tomography (ERT) to investigate variations in water content in the ground – a method test, Norwegian University of Science and Technology, 2015

Sletten, Joakim Ripman: On the earth pressure coefficient at rest during creep, Norwegian University of Science and Technology, 2015

Shresta, Suresh: Shear creep in sensitive clays, Norwegian University of Science and Technology, 2015

Syversen, Fredrikke S.G: A study of the mineralogical composition of sensitive Norwegian clays – from a geotechnical perspective, University of Oslo, 2013

Taiani, Bonaventura: Numerical analysis of field vane tests on soft clays, Norwegian University of Science and Technology, 2015

Terlaky, Fanni: Comparison of the hydraulic capacity of different culvert inlet designs under sediment transport conditions, Norwegian University of Science and Technology, 2015

Tilahun, Tesfaye Kerlos: The identification of quick clay layers from various sounding methods, Norwegian University of Science and Technology, 2013

Torpe, Guro Rosshaug: Development and evaluation of procedures for conducting undrained shear creep tests in quick clays, Norwegian University of Science and Technology, 2014

Ulvestad, Siri: Disturbance energy in sensitive clays. Norwegian University of Science and Technology, 2013

Venås, Martin: Monitoring and forecasting of slab avalanches at Stavbrekka in Skjåk, Norwegian University of Science and Technology, 2015

Viréhn, P L E: Water on Devious ways - A GIS Analysis, Norwegian University of Science and Technology, 2014

Xiang, Yu: Laboratory investigation of the pore pressure build-up in moving debris, Norwegian University of Science and Technology, 2015

Yifru, A. Assessment of Rheological Models for Run-out Distance Modelling of Sensitive Clay Slides, Focusing on Voellmy Rheology, Master thesis, Norwegian University of Science and Technology, 2014

5.3.2 Project/student theses

Austdal, Morten & Kolseth, Per Arne: Self-cleaning culvert inlets, Norwegian University of Science and Technology, 2014

Austefjord, Synnøve Wiger: The landslide in Sørkjosen on 10 May 2015, Norwegian University of

Science and Technology, 2016

Botnen, Lars Gudmund: Trigger and runout areas for slides in quick clay areas, Norwegian University of Science and Technology, 2015

Børstad, Simen Drogset, Solbjør, Jonny & Stengel, Vegard: A study of foundation engineering at Tresfjord bridge, Ålesund University College, 2014

Christiansen, L.F: Literature and model testing with dams as protective measures, p. 131, Norwegian University of Science and Technology, 2013

Frekhaug, Martine Holm: Run-out modelling of debris flows, Norwegian University of Science and Technology, 2014

Henriksen, Alexander B.: Planning of wood terracesas erosion and flood measures based on engineering-biological methods – example projects: Jotbekken and Minnesund station, NMBU, 2015

Hoel, Morten Nordheim, Hundal, Erlend, Kleppe, Anette Windingstad: What is brittle fracture material? Bachelor thesis, HiST. 2012

Laache, Emilie: Effective debris flow countermeasures. A literature review of debris flow countermeasures, Norwegian University of Science and Technology, 2015

Sherchan, Bigyan: Stability analysis of different Norwegian slides, Norwegian University of Science and Technology, 2015

Torpe, Guro Rosshaug: Evaluation of undrained shear creep tests in sensitive clays, Norwegian University of Science and Technology, 2013

Yang, Mingbo: Pore water pressure distribution in the shear zone of debris flow, Norwegian University of Science and Technology, 2015

Zamani, Navid, Mikkelsen, Martin, Abu Saeid, Jehad: Run-out distance in quick clay landslides. Bachelor thesis, HiST 2013

Øveraas, Astrid Thorvik: An introduction to quick clay and the use of resistivity as a geophysical measuring method, Norwegian University of Science and Technology, 2015

5.4 Film

During the programme period we initially collaborated with the company Norfilm, followed by Snøball. Both stills images and video-recordings/films of events have been produced, and two short films about floods and landslides/avalanches have been made with upper secondary schools as the target group. The films are available from www.naturfare.no.

Films and images have also been used during presentations and as contributions to internal and external courses, seminars and conferences.

The key points about the NIFS programme are also summarised in an information film, which describes the objective, working method, the different parts of the project and the road ahead.

5.5 Presentations and lectures

A significant number of lectures and presentations have been held at various types of internal conferences, seminars and meetings, including at: the Norwegian Academy of Science and Letters (DNVA), several ministries, directorates, Geoteknikkdagen (201–2014), the Research Council of Norway (NFR), the Norwegian Hydrological Council/Norwegian Water Association, the Norwegian Academy of Technological Sciences (NTVA), the Norwegian Geotechnical Society (NGF), the Association of Consulting Engineers (RIF), Teknologidagene (2012–2015), TEKNA courses, educational institutions. The list is not exhaustive and includes more than 200 presentations.

During the programme period, members of staff have made contributions to international conferences, including EGU 2015 (Vienna), IAEG 2014 (Turin), ICACMAG 2014 (Kyoto), ISSW 2013 (Grenoble), ISSW 2014 (Banff), IWCLS (Québec), Landslide forum 2014 (Beijing), NGM (Copenhagen), TRA (Paris) and TRB (Washington).

5.6 Media coverage

We have no complete overview of media coverage relating to the work carried out under the NIFS programme. However, we have noted that both the agencies and the results attract considerable media attention when natural events occur. The experience of a greater ability on the part of the three agencies and other administrative bodies to act as one in pursuance of the same goals is good.

During the programme period, NIFS has had many articles in professional journals, as well as radio, TV and newspaper coverage etc. Our communications strategy of highlighting the collaboration between the agencies as a basis for good results has worked, and the agencies as a brand appear to be even stronger than before. We have used the available opportunities to elucidate what we have considered relevant topics and also made ourselves available when approached during various events in order to bring the natural hazard message across.

6 Reference list

/ 1/ NCCS (2015):'Climate in Norway 2100. Knowledge base for climate change adaptation updated in 2015', NCCS report no. 2/2015.

/ 2/ Finance Norway (2015):'Statistics and key figures for damage insurance 2015'.

/ 3/ NIFS (2015-93):'Socio-economic costs of the Gudbrandsdal floods of 2013', NVE, October 2015.

/ 4/ NTP (2007):'The effects of climate change on the transport sector', National transport plan 2010–2019.

/ 5/ OED (2012):'How to live with the hazards – on floods and landslides/avalanches', Report to the Storting No 15, 30 March 2012.

/ 6/ JD (2012):'Civil protection', Report to the Storting No 29, 15 June 2012.

/ 7/ NIFS (2013-01):'Roles in the national work to manage natural hazards', Rambøll, January 2013.

/ 8/ NIFS (2015-106):' Communication plan for the natural hazards, infrastructure, floods and landslides/avalanches R&D programme 2012–2016. NVE, December 2015.

/ 9/ Norwegian Official Report (2010):' Adapting to a changing climate. Society's vulnerability and need to adapt to the consequences of climate change, 5 December 2010.

/ 10/ Norwegian Official Report (2015):'Storm water in cities and densely populated areas – A problem and a resource', 2 December 2015.

/ 11/ KMD (2013):'Climate change adaptation in Norway', Report to the Storting No 33, 7 May 2013.

/ 12/ NIFS (2014-54):'Collaboration and coordination concerning natural hazards. Mini study of the joint E6 project – The Dovre Line and the Follo Line', Rambøll, June 2014.

/ 13/ NIFS (2014-64):'Sub-report 1 - Emergency response plans and crisis management', NVE, 15 May 2014.

/ 14/ NIFS (2014-76):'Sub-report 2 - Crisis support tools CIM – Recommendations, NVE, 20 October 2014.

/ 15/ NIFS (2015-105): 'Sub-report 3 - Information exchange during exercises and events', NVE, December 2015.

/ 16/ Norwegian Building Authority' (2011):' Guidelines on technical requirements for building works'.

/ 17/ NIFS (2015-90):'Natural hazard terminology', NVE, October 2015.

/ 18/ NIFS (2014-26):'Comparison of risk acceptance criteria for landslides/avalanches and floods. Study for the Natural Hazards Programme (NIFS), NGI-20120800-01-R, 11 March 2014.

/ 19/ Western Norway Research (2015):'Foresight, hindsight or passivity? How do you assess the costs of prevention versus the costs of rebuilding physical infrastructure exposed to natural damage and climate change?', Western Norway Research report no. 4/2015, 1 June 2015

/ 20/ NIFS (2015-01):'Summary report. Review of landslide/avalanche risk investigations prepared by consultants from 2011–2014', NVE, January 2015.

/ 21/ NIFS (2014-63): 'Working separately or as a team? A study of coordination of flood and landslide/avalanche data for three collaborating agencies'. Work Research Institute report 2014:6.

/ 22/ NIFS (2013-31):'Åknes/Tafjord Emergency response ICT and NGU', Åknes report 02/2013, 26 April 2013.

/ 23/ NIFS (2015-62):' RAV analyses in land use planning', NVE, June 2015.

/ 24/ NIFS (2014-04):'Protective measures against floods and landslides/avalanches. Inspections in Troms and Finnmark counties in autumn 2013', NVE, 27 January 2014.

/ 25/ NIFS (2015-61):'Study tour to Switzerland', NVE, May 2015.

/ 26/ NIFS (2015-91):'Registration of landslide/avalanche and flood protection measures at NVE, the Norwegian Public Roads Administration and Norwegian National Rail Administration', October 2015.

/ 27/ NIFS (2015-107): 'Comparison of modelling tools for Norwegian avalanches', NVE, December 2015.

/ 28/ NIFS(2015-124):'The Frida flood and landslide event in Southern Norway in 2012', NVE December 2015.

/ 29/ *NVE (2014):' Protection against quick clay slides. Assessment of area stability in land use planning and development in areas with quick clay and other types of soil with brittle fracture properties', NVE, April 2014.*

/ 30/ *NPRA (2014):'Geotechnics in road building', NPRA, June 2014.*

/ 31/ *NNRA (2015):'Technical regulations', NNRA, 3 September 2015.*

/ 32/ *Norwegian Standard (2008):'Eurocode 7: Geotechnical design', NS-EN 1997-1:2004+NA:2008.*

/ 33/ *NIFS (2012-46):'Detection of quick clay using different probing methods', Multiconsult-415559-RIG-RAP-001, 21 November 2012.*

/ 34/ *NIFS (2015-81):'Interpretation of active undrained shear strength from vane shear tests', Norwegian University of Science and Technology , 8 December 2014.*

/ 35/ *NIFS (2015-104):'Workshop on safety philosophy', NVE, 2015.*

/ 36/ *Bæverfjord, M.G. (2015):'Reliability analysis using finite elements for geotechnical slope stability evaluations', PhD Norwegian University of Science and Technology , 2015:318, December 2015.*

/ 37/ *NIFS (2013-22):'Preventive mapping against landslides along shore zones in Norway. Summary of experiences and recommendations', NGU-2012.046, 28 November 2012.*

/ 38/ *NIFS (2013-26):'Assessment of mapping basis for quick clay in shore zones', NGI-20120754-01-R, 1 December 2012.*

/ 39/ *NIFS (2015-100):'Veslemannen autumn 2014 – Monitoring and emergency response', NVE, November 2015.*

/ 40/ *NIFS (2015-122):'Satellite-based radar interferometry for natural hazards, landslides/avalanches and infrastructure', NVE December 2015.*

/ 41/ *NIFS (2014-87):'Mapping the status and potential of drone-based technology. Application within natural hazards and infrastructure', SINTEF ICT- A26527, 30 November 2014.*

/ 42/ *NIFS (2014-03):"Design short-term precipitation for Telemark County, Southern Norway and Western Norway", MET-28/2013, 19 December 2013.*

/ 43/ *NIFS (2014-42):'Design short-term precipitation for Møre & Romsdal and Trøndelag counties and Northern Norway', MET-5/2014, 20 March 2014.*

/ 44/ *NIFS (2013-65):'The avalanche warning service. Evaluation of the 2013 winter season', NVE, August 2013.*

/ 45/ *NIFS (2014-79):'The avalanche warning service. Evaluation of the 2014 winter season', NVE, November 2014.*

/ 46/ *NIFS (2014-80):'Norwegian Avalanche Warning Service. Programme review', NVE, March 2015.*

/ 47/ *NIFS (2015-66):'Avalanche warning using the nearest neighbour method. Test of the Canadian nearest neighbour model on landslide/avalanche data from Senja, NVE, August 2015.*

/ 48/ *NIFS (2015-78):'The avalanche warning service. Evaluation of the 2015 winter season', NVE, September 2015.*

/ 49/ *NIFS (2014-44):'Regional warnings of landslide hazards: Analysis of historical debris slides/flows and slush slides in Gudbrandsdalen and Ottadalen, NVE, May 2014.*

/ 50/ *NIFS (2014-90):'Analysis of historical debris slides/flows and slush slides in Troms county', NVE, 19 March 2015.*

/ 51/ *NIFS (2015-98):' Experiences of the field manual for floods and landslide/avalanches, NVE, November 2015.*

/ 52/ *NIFS (2015-120):'On the alert against natural hazards', NVE, October 2015.*

/ 53/ *NIFS (2012-33):'A national initiative on safety in quick clay areas', NVE October 2012.*

/ 54/ *NIFS (2012-35):'Experiences from study trip to the Ministry of Transportation (British Columbia) and the Canadian Avalanche Center', NVE, October 2012.*

/ 55/ *NIFS (2012-40):'Programme plan 2012–2015 for agency programme 'Natural hazards – infrastructure, floods and landslides/avalanches (NIFS)', NVE, 1 November 2012.*

/ 56/ *NIFS (2012-73):'Probabilistic analysis of ground surveys in sensitive clay areas', SINTEF-SBF2012 A0310, 30 November 2012.*

/ 57/ *NIFS (2012-74):'Percentage improvement of material factors in brittle fracture materials', SINTEF Memo 3C0970-2 rev. 2, 30 November 2012.*

/ 58/ *NIFS (2012-75):'Use of anisotropic displacement parameters in stability calculations in brittle fracture materials', Multiconsult-415559-RIG-RAP 30 November 2012.*

/ 59/ *NIFS (2012-78):'Extreme short-term precipitation in Eastern Norway from pluviometer and radar data', MET-14/2012, Desember2012.*

/ 60/ *NIFS (2012-80):'Correspondence between use of absolute material factor and percentage improvement', SINTEF-SBF2012A0309, 30 November 2012.*

/ 61/ *NIFS (2013-21):'Extent and runout distance of quick clay slides based on catalogue of landslide/avalanche events in Norway', NGU-2012.040, 21 November2012.*

/ 62/ *NIFS (2013-23):'National Database for ground surveys – (NADAG) – preliminary study', NGU-2012.054, 9 April 2013.*

/ 63/ *NIFS (2013-33):'Salt diffusion as ground reinforcement in quick clay', NVE, 21 December 2012.*

/ 64/ *NIFS (2013-37):'Gentle installation methods for lime cement columns and use of slurry', NGI-20120746-1-R, 20 December 2012.*

/ 65/ *NIFS (2013-38):'Characterisation of historical quick clay landslides and input parameters for Q BING', NGI-20120753-02-R, 27 November 2012.*

/ 66/ *NIFS (2013-39):'Characterization of historical quick clay landslides and input parameters for Q-Bing', NGI-20120753-02-R, 17 January 2013.*

/ 67/ *NIFS (2013-40):'Landslide at Døla in Vefsn. Study of material properties', NGI-20120853-01-TN, 28 November 2012.*

/ 68/ *NIFS (2013-41):'State of the art: Block tests', NGI-20120866-01-R, 1 December 2012.*

/ 69/ *NIFS (2013-42):'Input to: National ground drilling database (NGD)' – preliminary study', NGI-20120867-01-TN, 22 October 2012.*

/ 70/ *NIFS (2013-43):'Increasing the strength of reconsolidated quick clay following a landslide', NGI-20120853-01-TN, 1 January 2013.*

/ 71/ *NIFS (2013-46):'Back-analyses of run-out for Norwegian quick-clay landslides', NGI-20120753-01-R, 30 November 2012.*

/ 72/ *NIFS (2013-55):'Workshop on the use of anisotropy in stability assessments in brittle fracture materials', NVE, 5 July 2013.*

/ 73/ *NIFS (2013-57):'Programme plan 2012-2015 for the Government Agency Programme: NATURAL HAZARDS – infrastructure for floods and slides (NIFS)", NVE, 1 November 2012.*

/ 74/ *NIFS (2013-60):'Flood estimation in small catchments', NVE, October 2013.*

/ 75/ *NIFS (2013-66):'Water flow stations in Norway with catchments smaller than 50 km', NVE, September 2013.*

/ 76/ *NIFS (2014-13):'Characterisation of flood regimes', NVE, January 2014.*

/ 77/ *NIFS (2014-14):'An agreed recommendation for using anisotropic factors in the design of Norwegian clays, NVE, January 2014.*

/ 78/ *NIFS (2014-22): 'How to calculate extreme values for specific recurrence intervals? Manual for calculating return values of precipitation for different recurrence intervals (for non-statistics)', NVE, March 2014.*

/ 79/ *NIFS (2014-27):'Landslide/avalanche mapping in shore zones – continuation', NGI-20130701-01-R, 5 December 2013.*

/ 80/ *NIFS (2014-28):'Twig dams in Slovakia. Small terraces made from local materials; experiences from study trip for possible use in Norway, NVE, May 2014.*

/ 81/ *NIFS (2014-34):'Landslide/avalanche mapping in shore zones – a summary', NVE, October 2014.*

/ 82/ *NIFS (2014-35):'Characterisation of flood regimes. Revision of report 13-2014', NVE, March 2014.*

/ 83/ *NIFS (2014-37):'Preliminary regionalisation and susceptibility analysis for landslide early warning purposes in Norway', NVE, May 2014.*

/ 84/ *NIFS (2014-39):'Effect of progressive fracture development for development in quick clay areas: Sensitivity analysis based on data from ground surveys on the section of road between Sund and Bradden in Rissa, NGI -20092128-00-6-R, 12 May 2014.*

/ 85/ *NIFS (2014-40):'Effect of progressive fracture changes for development of quick clay areas: Sensitivity analysis 1', NGI-20092128-00-6-R, 12 May 2014.*

/ 86/ *NIFS (2014-43):'Threshold studies for triggering of landslides in Norway. Summary of hydrological threshold studies at NVE from 2009 to 2013', NVE, May 2014.*

/ 87/ *NIFS (2014-46):'Feasibility study into the development of a national block test database', NGI-20130760-01—R, 1 December 2013.*

/ 88/ *NIFS (2014-47):'Detection of brittle fracture material using R-CPTU', Multiconsult-415559-RIG-RAP-002, 6 December 2013.*

/ 89/ *NIFS (2014-55):'Effect of progressive fracture changes for development of quick clay areas: A1 Numerical method of calculating undrained fractures in sensitive materials, NGI-20092128-00-4-R, 12 May 2014.*

/ 90/ *NIFS (2014-56):'Effect of progressive fracture changes for development of quick clay areas: A2 Back calculation of the Vestfossen landslide, NGI-20092128-00-5-R, 1. June 2012*

/ 91/ *NIFS (2014-57):'Safety in connection with development of quick clay areas. Effect of progressive fracture changes in ravines', NGI 20130275-01-R, 12 May 2014.*

/ 92/ *NIFS (2014-58):'Safety in connection with development of quick clay areas. Probability of fracture with percentage improvement', NGI-20130275-02-R, 12 May 2014.*

/ 93/ *NIFS (2014-59):'Correspondence between use of absolute material factor and percentage improvement – use of stress change to define local landslides/avalanches and area landslides/avalanches', SINTEF-SBF2013A0274, 21 October 2013.*

/ 94/ *NIFS (2014-62):'Regional formulae for index floods and frequency curves', NVE, June 2014.*

/ 95/ *NIFS (2014-67):'Effect of storage time on sample quality', NGI-R20130672-01-R, 1 December 2013.*

/ 96/ *NIFS (2014-68):'Effect of storage time on sample quality', NGI-R20130672-01-R, 1 December 2013.*

/ 97/ *NIFS (2014-70):'Status autumn 2014 Results and the road ahead, NVE, October 2014.*

/ 98/ *NIFS (2014-77):'Selection of characteristic CuA profile based on field and laboratory tests', NVE, 19 May 2015.*

/ 99/ *NIFS (2014-88):'NGI's recommendations for requirements for the effect of brittle fracture behaviour, NGI-R20140075-01-R, 19 November 2014.*

/ 100/ *NIFS (2014-92):'Pre-study: Ground improvement for marginally stable slopes', Chalmers, November 2014.*

/ 101/ *NIFS (2014-93):'Landslide at Nord-Statland. Investigation of technical causality', NVE, December 2014.*

/ 102/ *NIFS (2015-00):'Field manual for floods and landslide/avalanches', NVE, 27 March 2015.*

/ 103/ *NIFS (2015-13):'NIFS (2015-13) 'National formulae for flood calculations in small catchments . Revision of report 62-2014', NVE, February 2015.*

/ 104/ *NIFS (2015-65):'Quality control, analysis and proposal for updating historical quick clay slides and other clay slides registered in the National Landslide/Avalanche Database (NSDB)', NVE, July 2015.*

/ 105/ *NIFS (2015-73):'Avalanches in birch forests – Trial test in Abisko', NGI-20130918-01-R, 18 December 2014.*

/ 106/ *NIFS (2015-79): 'Extended interpretation basis for vane shear tests. Results from the preliminary project at the Norwegian University of Science and Technology', Norwegian University of Science and Technology , 11 December 2014.*

/ 107/ *NIFS (2015-86):'NIFS (2015-86) Comparison of methods of flood calculations in small, unregulated catchments', NVE, September 2015.*

/ 108/ *NIFS (2015-04X):'Foresight, hindsight or passivity? How do you assess the costs of prevention versus the costs of rebuilding physical infrastructure exposed to natural damage and climate change?', Western Norway Research 4/2015, June 2015.*

/ 109/ *NIFS (2015-101):' Detection of quick clay using R-CPTU and electric vane borer. Results from field study', Multiconsult-415559-RIG-RAP-003, 6.October 2015.*

/ 110/ *NIFS (2015-114):'Deformation analysis of steep mountainside using drone-based photogrammetry', NVE, December 2015.*

/ 111/ *NIFS (2015-115):'Inspections in Hordaland and Sogn og Fjordane counties in May 2014', NVE December 2015.*

/ 112/ NIFS(2015-123):'Flood and landslide events in Gudbrandsdalen', NVE December 2015.

/ 113/ NVE (2014-8): 'Protection from landslides/avalanches in steep catchments. Mapping landslide/avalanche hazards in connection with land use planning and building applications', NVE, May 2014.

/ 114/ Vista analysis (03/2015): 'Benefit and cost of national databases. Method development and testing of a national database of ground surveys'. Vista analysis May 2015.

/ 115/ Directorate of Civil Protection and Emergency Planning (DSB) (2014): 'Guidelines for overall risk and vulnerability analysis by local authorities' (ISBN 978-82-7768-344-7). DSB 2014

/ 116/ The Norwegian Public Roads Administration (2013) 'NVDB National Road Databank. Practical guidelines for using the National Road Databank in Norwegian municipalities', Directorate of Public Roads, January 2013.

/ 117/ The Norwegian Public Roads Administration (2013) 'NVDB- strategy 2014–2017. NVDB and the Geodata section'. Directorate of Public Roads, Road and Transport department, June 2013.

/ 118/ Oppland County Council 'Draft of plan programme. Regional plan for the River Gudbrandsdalslågen and tributaries'. Oppland County, December 2013.

/ 119/ Christiansen, L F (2013). 'Literature and model testing with dams as protective measures'. Department of Civil and Transport Engineering. Norwegian University of Science and Technology Trondheim, Norway. p. 131, 2013.

/ 120/ Frekhaug, M H 'Run-out modelling of debris flows', Norwegian University of Science and Technology 2014.

/ 121/ Frekhaug, M H: 'An assessment of prediction tools to Norwegian debris flows', Norwegian University of Science and Technology 2015.

/ 122/ NIFS (2015-126): 'Detection of brittle fracture material – Final report'. Multiconsult - 415559-RIG-RAP-004, Nov. 2015.

/ 123/ Norwegian Space Centre (NRS) (2014): 'Mapping and monitoring of landslide/avalanche hazards and infrastructure using radar satellites and InSAR methodology. Basis for a strategic plan for public sector use of interferometry in Norway'. NRS report 02/2014, March 2014.

/ 124/ NVE (2014-02): 'Flood and landslide/avalanche risk in land use planning'. Guidelines no 2 – 2011, NVE revised 22 May 2014.

/ 125/ NVE (2015-07): Guidelines for flood calculations in small, unregulated catchments'. Guidelines 7-2015, NVE December 2015.

/ 126/ NIFS (2015-129):'Forest and natural hazards'. NVE January 2016.

/ 127/ NIFS (2015-130):'Water gone astray. The flood in Notodden on 24 July 2014'. NVE January 2016.

/ 128/ NIFS (2016-04):'Summary: Preparedness and crisis management'. NVE January 2016.

/ 129/ NIFS (2016-08):' The boundary between local and area stability'. NVE February 2016.

/ 130/ NIFS (2016-12):' Measurement of Stabrekkfonna in Sjåk Municipality using ground-based radar (InSAR)', NVE February 2016.

/ 131/ NIFS (2016-13):'Monitoring of landslides/avalanches and other slope processes using ground-based laser scanning', NVE February 2016.

/ 132/ NIFS (2016-14):' Method for assessing trigger and runout areas for large area landslides/avalanches', NVE February 2016.

/ 133/ NIFS (2016-15):'Safety philosophy for assessment of area stability on natural slopes', NVE February 2016.

/ 134/ NIFS (2016-16):'Dynamic stresses and landslide/avalanche risk, NVE February 2016.

/ 135/ NVE (2013-48):' Norway's hydrological station network', NVE June 2013.

/ 136/ NVE (2016-6):' 30 specialist seminars from 2010–2015 on flood, landslide/avalanche, safety and watercourse management responsibility at NVE', NVE January 2016.

/ 137/ MD (2012): 'Climate change adaptation in Norway', May 2013.

/ 138/ NIFS (2016-26):'Example of drainage measures in small catchments, NVE February 2016.

/ 139/ NIFS (2016-27):' Detection of brittle materials. Summary report with recommendation', NVE February 2016.

Annex 1 - Contributors

Overview of key contributors to the NIFS programme

Sub-project 1 – Natural hazards strategy

The working group for SP 1 was chaired by Gordana Petkovic (NPRA).
The group was small, and NVE was represented by Aart Verhage, Hallvard Berg and Odd Are Jensen (as from 2013). Trond Børsting (up to and including 2014) has represented the Norwegian National Rail Administration and Knut Sørgaard (NVE until 2013), Kjetil Rød and Gordana Petkovic have represented the Norwegian Public Roads Administration.

Sub-project 2 – Preparedness and crisis management

All participants from the three agencies have practical knowledge and expertise from preparedness work at their respective agencies. A consultant assisted throughout the project period. The following participated throughout the process:

Regional Head Kari Øvrelid (NVE) chaired the working group and was supplemented by Trond Sandum (NNRA), Hein Gabrielsen (NPRA), Camilla Røhme (NPRA), Olianne Eikenes (NVE), Roger Steen (NVE) and Consultant Bjørn Henning Stuedal. The latter, from the company Stuedal Kommunikasjon, acted as technical secretary for the sub-project from 2012.

Sub-project 3 Land use, data coordination and RAV analyses

The core group of contact persons in sub-project 3 comprised: Eli K. Øydvin (NVE sub-project manager), Heidi Bjordal (NPRA) and Per Anton Fevang (NNRA).

The following specialists have taken part in the sub-project activities:

- 3.1 Mapping
  NVE: Andrea Taurisano (activity manager), Eli K Øydvin, Delia Kejo, Håvard Juliussen, Jaran Wasrud
  NPRA: Heidi Bjordal, Lene Kristensen, Hanne Bratlie Ottesen
  NNRA: Anders Wåla, Per Anton Fevang
- 3.2 Data coordination
  NNRA: Ellen Strandenæs (activity manager)
  NPRA: Heidi Bjordal
  NVE: Eli K. Øydvin, Håvard Juliussen
- 3.3 RAV analyses Plan
  NPRA: Jan Otto Larsen, Kristine Flesjø, (Arne Gussiås)
  NNRA: Lars Berggren
  NVE: Peer Sommer-Erichson, Grethe Helgås
- 3.4 Flood and landslide/avalanche events
  NVE: Håvard Juliussen (activity manager), Eli K. Øydvin, Søren Elkjær Kristensen, Nils Kristian Orthe and Odd Are Jensen
  NPRA: Heidi Bjordal, Knut Jetlund
  NNRA: Ellen Strandenæs, Per Anton Fevang
- Pilot – Tools for quick clay mapping (sub-project 3)
  NPRA: Hanne Ottesen, Kristian Aunaas, Roald Aabøe
  NVE: Ingrid Havnen, Eli K. Øydvin
  NNRA: Maria Hetland Olsen and Margareta Vikslund

Sub-project 4 – Monitoring and forecasting

The sub-project was led by Tore Humstad (NPRA) for most of the period. During two leaves of absence Rune Engeset (NVE) and Halgeir Dahle (NPRA) acted as stand-ins. The avalanche and landslide warning services were organised as separate projects affiliated to NIFS because of the close collaboration and professional affiliations between the agencies.

The following specialists were most actively involved in the sub-activities:

- 4.1 Weather monitoring
  NVE: Rune Engeset, Morten Due Nordahl
  NPRA: Knut Inge Orset (activity manager) Stine Mikalsen
  NNRA: Steinar Myrabø
  Norwegian Meteorological Institute: Cecilie Stenersen, Ragnar Brekkan
- 4.2 Monitoring stability
  NVE: Odd Are Jensen, Lene Kristensen, Ingrid Skrede
  NPRA: Halgeir Dahle (activity manager), Tore Humstad
- 4.3 Monitoring of landslide/avalanche events
  NVE: Nils Kristian Orthe
  NPRA: Tore Humstad (activity manager)
- 4.4 Warning of avalanche risk
  NVE: Rune Engeset (activity manager), Karsten Muller, Solveig Kosberg
  NPRA: Tore Humstad, Knut Inge Orset, Silje Haaland
  NNRA: Jeanette Gundersen
- 4.5 Warning of landslide hazards
  NVE: Hervé Colleuille (activity manager), Ingeborg Kleivane, Graziella Devoli
  NPRA: Tore Humstad
  NNRA: Steinar Myrabø
- 4.6 Collating data
  NVE: Emma Barfod
  NPRA: Tore Humstad (activity manager), Knut Inge Orset, Silje Haaland
- 4.7 Preparedness coordination
  NPRA: Tore Humstad (activity manager), Knut Inge Orset, Lene Lundgren Kristensen
  NNRA: (Jeanette Gundersen), Steinar Myrabø

Sub-project 5 – Flood and floodwater management

The sub-project was led by Steinar Myrabø (NNRA), assisted by Sverre Husebye (NVE) and Kristine Flesjå (NPRA).

The following participated from the agencies:

- 5.1 – Per Alve Glad, Seija Stenius, Thea Caroline Wang, Anne Fleig, Trond Reitan, Donna Wilson, Thomas Væringstad
- 5.2 – Joakim Sellevold, Steinar Myrabø, Bent Braskerud, Ole Erik Almenningen, Eirik Traae, Christoph Siedler, Per Viréhn, Tone Israelsen, Kristine Flesjø, Harald Norem and Monika R. Lund
- 5.3 – Maria H Olsen, Steinar Myrabø, Agathe A Hopland, Ole Erik Almenningen, Eirik Traae, Christoph Siedler, Per Viréhn.

Sub-project 6 – Quick clay

SP 6 was organised through a working group composed of members from the three NIFS agencies. The roles and the number of persons that have been part of the working group has varied during the project period. Members of SP 6 have been:

Sub-project manager Vikas Thakur (2012 up to and including 2014) (NPRA) Kristian Aunaas (2012 up to and including 2015, sub-project manager in 2015)

- NPRA: Hanne Ottesen (2015), Frode Oset (from 2012 up to and including 2015) and Tonje Eide Helle (2012)
- NNRA: Margareta Viklund (from 2012 up to and including 2015), Mostafa Abokhalil (from 2014 up to and including 2015), May-Britt Sæther (from 2012 up to and including 2014), Arnulf Robsrud (from 2012 up to and including 2014)
- NVE: Stein-Are Strand (from 2012 up to and including 2015), Trude Nyheim (from 2012 up to and including 2015), Ingrid Havnen (from 2013 up to and including 2015), Einar Lyche (from 2012 up to and including 2015),Odd Are Jensen (from 2012 up to and including 2014) and Ellen E D Haugen (2012 up to and including 2013)

Sub-project 7 – Landslide/avalanche and flood protection

The project had a core group of participants who worked on multiple assignments. The sub-project was led by the Norwegian National Rail Administration, initially represented by May-Britt Sæter, then Pål Buskum and finally Margareta Viklund.

Other participants from the Norwegian National Rail Administration included Tone Israelsen, Silje Skarsten and Kristin Skei. Knut Aune Hoseth, Odd Arne Mikkelsen and Marianne Odberg participated from NVE, while Lene Kristensen, Heidi Bjordal and Gunne Håland have participated from the Norwegian Public Roads Administration. In addition, several other experts from the agencies participated in various activities.

For the work on the field manual, Vivian Caragounis was appointed project manager and the work was followed up by a working group.

Øystein Dolmen, popular Norwegian artist and comedian;

> *Success if often something you can see. Like the top of an iceberg. The party is short compared to the work lying behind, just like most of the iceberg lies under water. But the path to success has truely also been a party, thanks to the ingenious collaborators and a creative community, which I was so unbelievably lucky to be a part of.*
>
> *This is where I find the biggest of all pleasures: to be allowed to be a part of something bigger. To come along. To be one of the many who can take pleasure in the success we have achieved together.*
>
> *Now, that is something to be grateful for.*
>
> *Few things last forever. One day the iceberg will melt and dissolve in the infinite sea, become a part of the infinity that absorbs all and everything.*
> *The balance exercise of the Universe. Which we rehearsed. Together.*

The NIFS-experience can also be described in this way.

Annex 2 – Extreme weather

All extreme weather events in Norway since the first was named in October 1995

Agnar	12.10.1995: Nordmøre, Trøndelag: Violent storm.
Bera	11.11.1995: Troms and Western Finnmark: Storm. Risk of avalanche and difficult driving conditions.
Dag	31.1.1996: Eastern Finnmark: Violent storm in coastal and fjord regions.
Erika	28.2.1996: Trøndelag: Storm, violent storm of short duration.
Frode	12.10.1996: Nordland, Troms and Western Finnmark: Storm or violent storm.
Gerd	28.10.1996: Lindesnes to the Oslofjord including land areas: Storm.
Hauk	14.1.1997: Spitsbergen: Up to violent storm.
Idun	31.1.1997: Nordland, Troms and Finnmark: Storm in Nordland and Troms. Storm followed by violent storm in Finnmark.
Joar	6.2.1997: Vestfjorden, Ofoten: High water level. Nordfjord, Møre og Romsdal, Trøndelag: Violent storm, high water level.
Kari	17.2.1997: Rogaland, Hordaland, Sogn og Fjordane, Trøndelag: Storm and some violent storm.
Leif	16.11.1997: Spitsbergen: Some violent storm.
Mari	9.11.1998: Inner Sør-Trøndelag: Storm.
Njål	26.11.1999: Støtt to Narvik: Storm surge.
Olrun	28.11.1999: Hordaland, Sogn og Fjordane, Trøndelag: Storm to violent storm.
Peter	24.12.1999: Agder, Telemark, Vestfold, Østfold: Strong gale or storm.
Reidun	28.1.2000: Lindesnes – Swedish border: Storm surge.
Sølve	27.3.2000: Eastern Finnmark: Storm.
Tora	28.10.2000: Agder: Storm. Heavy precipitation and high water level.
Ulf	15.1.2001: Troms and Finnmark: Storm.
Valdis	15.12.2001: Finnmark: Violent storm.
Yrjan	17.12.2002: Vesterålen, Troms, Finnmark: Storm or violent storm.
Agda	14.1.2003: Møre og Romsdal, Sør-Trøndelag south of the Trondheimsfjord: Storm and violent storm.
Bengt	28.10.2003: Tromsø to Vardø: Storm surge.
Clara	3.12.2003: Salten to Western Finnmark: Storm.
Dyre	6.12.2003: Møre og Romsdal, Trøndelag: Storm.
Edda	10.12.2000: Nord-Helgeland to Southern Troms: Storm and violent storm.
Finn	21.12.2004: Nordmøre to Vesterålen: Storm, followed by violent storm.
Gudrun	8.1.2005: Southern Rogaland: Violent storm. From Agder to the Swedish border: Strong gale to storm. Egersund to the Swedish border: Storm surge.
Hårek	10.1.2005: Nord-Trøndelag to Lofoten: Storm and violent storm, storm surge.
Inga	11.1.2005: Egersund to Kristiansund: Storm surge. Small to violent storm.
Jostein	August 2005: Warning withdrawn, the storm is weakening.
Kristin	14.9.2005: Hordaland and parts of Sogn og Fjordane: Extreme precipitation.
Loke	14.11.2005: Rogaland, Hordaland and Sogn og Fjordane: Extreme precipitation.
Mona	11.12.2005: Helgeland, Saltfjellet, Salten and Lofoten: Storm and heavy precipitation.
Narve	18.1.2006: Namdalen, Nordland, Troms, coastal and fjord regions in Western Finnmark: Violent storm and storm.
Oda	4.12.2006: Stavanger–Stad: Storm surge.
Per	13.1.2007: Rogaland, Hordaland and Sogn: Violent storm in coastal areas.
Rita	19.12.2007: Northern Troms, Eastern Finnmark and coastal and fjord regions in Western Finnmark: Storm to violent storm.
Sondre	25.1.2008: Sognefjorden to Kristiansund: Storm and storm surge.
Tuva	31.1.2008: Farsund to the Swedish border: Storm.

Ulrik 25.10.2008: Nordfjord, Møre og Romsdal, Trøndelag, Saltfjellet and Helgeland: Violent storm.
Vera 20.11.2008: North of the Trondheimsfjord: Violent storm.
Yngve 31.12.2008: Northern Helgeland, Saltfjellet, Salten and Lofoten: Violent storm.
Ask 26.1.2010: Nordland, Troms and Finnmark: Storm and violent storm.
Berit 25.11.2011: Møre og Romsdal to Finnmark: Storm surge.
Cato 25.12.2011: Nordland, Troms and Western Finnmark: Storm surge.
Dagmar 25.12.2011: Nordfjord, Møre og Romsdal, Trøndelag: Violent storm, wind gusts of hurricane force. Finnmark: Extremely high water level.
Emil 3.1.2012: Rogaland and Vest-Agder: Storm, wind gusts of hurricane force
Frida 6.8.2012: Vest-Agder: Violent storm, wind gusts of hurricane force.
Geir 21.6.2013: Aust-Agder and Vest-Agder, Telemark, Buskerud and Oppland: Heavy precipitation over a short period, 50–90 mm locally.
Hilde 16.11.2013: Sør-Trøndelag, Nord-Trøndelag and Helgeland: Violent storm and 13–15 metre high waves hitting the coast.
Ivar 12.12.2013: Møre og Romsdal and Trøndelag: Short-term westerly and north-westerly violent storm and hurricane force winds. Gusts up to 45 metres per second.
Jorun 8.3.2014: Finnmark: Violent storm, wind gusts of 40 metres per second, heavy precipitation.
Kyrre 12.3.2014: Trøndelag and Nordland: Extremely heavy precipitation 60–100 mm.
Lena 9.8.2014: Hordaland, Sogn og Fjordane: Southerly storm and violent storm, wind gusts of up to 25–30 metres per second.
Mons 30.12.2014: Nordland: Local heavy precipitation, up to 100 mm. Mild weather and heavy precipitation that caused flooding and major landslide/avalanche hazards.
Nina 10.1.2015: Sogn og Fjordane to Østfold: Hurricane force wind in Western Norway with gusts of up to 46 metres per second, violent storm in the mountains. Full storm in Østfold. Heavy precipitation in Western Norway, which fell as snow inland and in the mountains.
Ole 7.2.2015: Trøndelag, Nordland and Troms, and mountain areas in Southern Norway: Storm in Trøndelag, violent storm and hurricane force winds in Nordland and Troms. Full storm, hurricane force winds in individual locations in mountain areas in Southern Norway. Gusts of up to 52.9 metres per second were registered in Nordland. Storm surge and waves of up to 25 metres.
Petra 17.9.2015: Agder, Telemark, Vestfold and Buskerud. Heavy precipitation over several days filled rivers and lakes, and flooding occurred when a new trajectory of heavy heavy precipitation arrived from the south.
Roar 1.10.2015: Trøndelag and Helgeland. Heavy precipitation over several days produced a 50-year flood. Wind forces up to violent storm from Stad to Bodø.
Synne 5.12.2015: Rogaland in particular, but also Vest-Agder and Hordaland, received heavy precipitation that caused floods and slides/avalanches.
Tor 29.1.2016: Extreme weather Tor affected both Eastern and Western Norway. Forecast on Tuesday 28 January 2016. Friday's (29/1) storm hit a larger area than the meteorologists first thought. Tor may create hurricane force winds along the coast, extreme wind gusts far inland and individual waves of 20 metres.

If the forecasts hold, the storms Friday afternoon and evening may represent a danger to life and assets in as many as eight of Norway's counties. Extreme weather over such a large area is a rare event.

'This is a major low pressure system and a big storm. It may be somewhat similar to Dagmar, except that it will strike further south,' says government meteorologist Geir Ottar Fagerlid, emphasising that the forecasts may still change.

Sources: met.no , nrk.no , tv2.no and yr.no

Norges
vassdrags- og
energidirektorat

NVE

Norges vassdrags- og energidirektorat

Middelthunsgate 29
Postboks 5091 Majorstuen
0301 Oslo

Telefon: 09575
Internett: www.nve.no