ANALYSIS AT THE NATION LEVEL OF VULNERABILITY AND ADAPTATION MEASURES IN NORWAY

G. PETKOVIC, T. HUMSTAD & B.K. DOLVA
Norwegian Public Roads Administration, Oslo, Norway
GORDANA.PETKOVIC@VEGVESEN.NO

ABSTRACT

This paper aims at presenting how the Norwegian Public Roads Administration has been working on adaptation to climate change. The focus is on categories of general importance, so that it may be comparable with the work or needs of other road agencies.

The authors look back at the process up to now and recognise the most important parts of the framework for adaptation to climate change. Both the national and the NPRA's own framework for adaptation to climate change are described and discussed.

Finally, measures for adaptation of the road network to climate change are outlined: for new roads, existing roads, for better preparedness and for improving the knowledgebase for adaptation.

1. INTRODUCTION

The Norwegian Public Roads Administration has a long tradition of operating roads in difficult weather and managing a road network in a challenging climate. During the last 10 or 20 years, we have become more and more aware of storms, adverse weather, heavy rainfall, sudden changes of temperature and snow melting, causing floods and landslides.

A few recent examples, see Figure 1: Gudbrandsdalen in central Norway, experienced two major floods only two years apart, in 2011 and 2013. Properties, roads and railways suffered severe damage, and the society has been coping with the consequences ever since. The fact that there had not been enough time to implement some of the protection measures planned after the first flood before the second flood hit gave a new perspective on the vulnerability of the society.
In October 2014, a severe flood hit the western coast of Norway, causing vast damage to the municipalities, both settlements and infrastructure. The costs of repair are estimated at € 20 million for municipal protections measures only. In addition, approximately € 40 million will be paid by insurance companies for damage to more than 1000 private properties.

The aim of this paper is to present how the Norwegian Public Roads Administration went about assessing the impact of climate change on the road network and deciding on adaptation measures. The focus is on categories of general importance, so that it may be comparable with the work or needs of other road agencies.

The work involves a large number of people, both colleagues at the NPRA and our collaboration partners, especially the Norwegian National Rail Administration and the Norwegian Water Resources and Energy Directorate. The authors wish to acknowledge all their contributions.

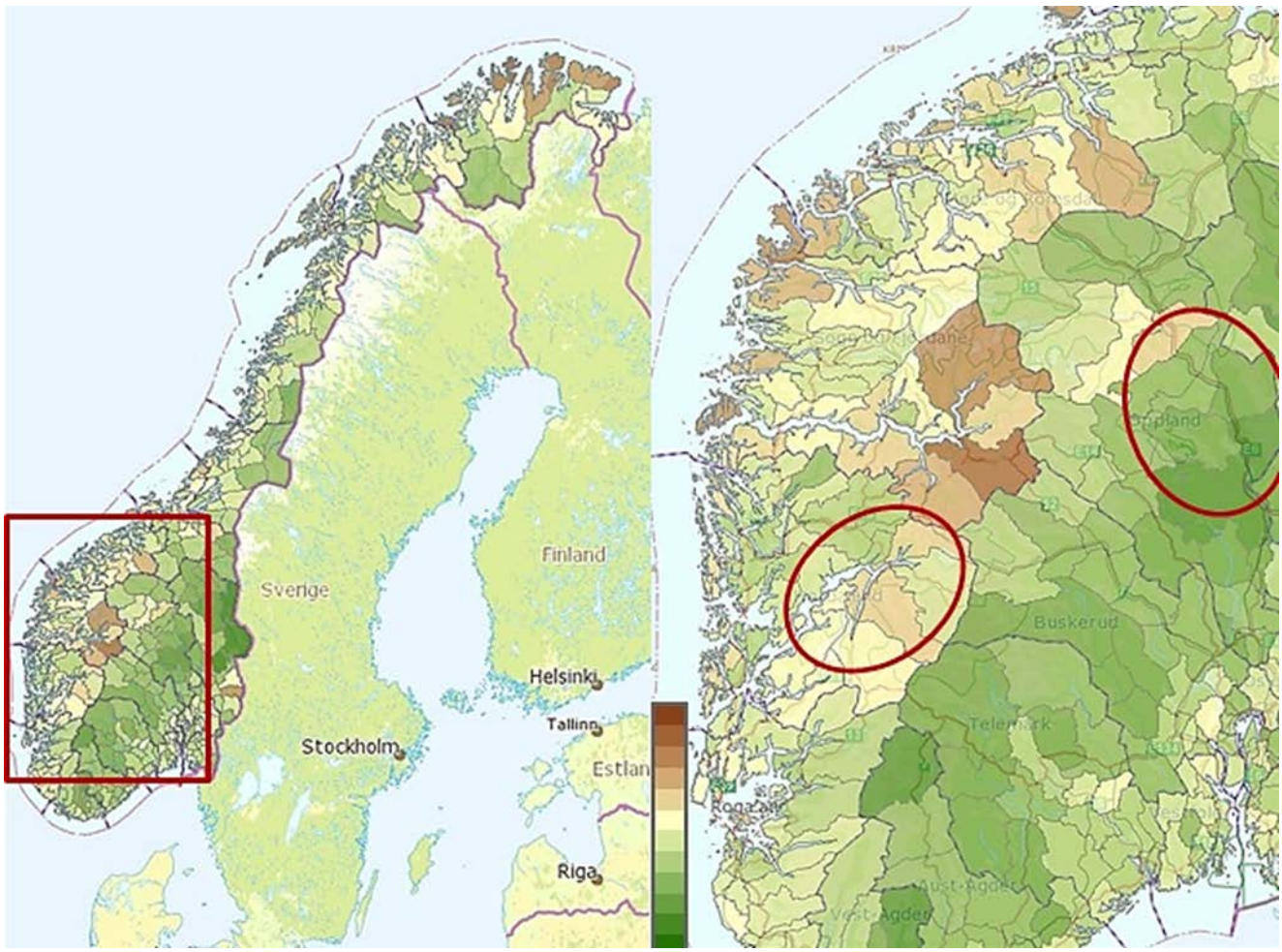

Figure 1 - Map of Norway from www.environment.no, with coloured indications of vulnerability, social and physical, from low (green) to high (brown).

2. MAIN CHALLENGES FOR NORWEGIAN ROAD NETWORK

2.1. Climate in Norway

Compared to other regions at the same latitude, such as Alaska or Siberia, Norway has a milder climate due to the effect of the warm Gulf Stream. The seaports are ice-free, even in the northern regions. Snow that falls along the coast melts almost immediately, whereas Norway's inland regions have cold winters, rich with snow.

The future climate will bring more rain in areas that already are rich with precipitation. An increase in mean temperature between 2 and 5 degrees can be expected by the end of this century, with great variations in seasonal temperatures and between regions of Norway. The temperature rise is most pronounced in the winter season and in the northern regions of the country. During the first decades of this century, there will be more snow in the mountain areas. The effect of temperature rise will eventually be more dominant and the snow will transition to rain, even at high altitudes.

The main challenges on the Norwegian road network come from more precipitation generally, and especially from more frequent heavy precipitation. There will be a higher risk of floods and erosion. There will also be a higher risk of landslides, some of them occurring at new locations and in changed forms. More slush avalanches, debris flows and mudflows are expected. Areas exposed to stable winter conditions today may experience

higher exposure to repeated freezing and thawing. Reduced accessibility and regularity on the road network should be expected, placing higher demands on road operation and preparedness.

Figure 2 - In Eikesdalen (central Norway), mid July 2013, following heavy rain, several debris flows occurred in the same day, clogging culverts and causing serious damage and road closure. Photo: Anne Marit Øksenvåg Johansen

2.2. The Norwegian Public Road Administration's actions to addressing these challenges

The awareness of climate change at the NPRA and its impact on roads originated from the work on landslide protection. The concern was that existing and planned protection measures would not be sufficient in a wetter climate. In 2007, a research and development programme entitled "Climate and transport" was initiated, with the aim of investigating all fields of the NPRA's work with respect to climate change and of proposing remedial measures [1]. The project budget was € 2.2 million, in addition to internal resources.

The R&D programme **"**Climate and transport" focused on flood and erosion protection, protection from landslides and avalanches, bearing capacity of roads, winter operation, collection and processing of data, and preparedness measures. The programme investigated available databases and the NPRA's needs, specifications for design and practice and the need to revise them, and existing preparedness plans and the need to develop them. The results from the R&D programme have been published in a series of reports including amendments to the NPRA's manuals of design and practice [2].

During the course of the R&D programme "Climate and Transport", we gradually became more aware of the following:

- Impacts of climate change have to be considered as early as possible, as early as in the project planning phase;
- Adaptation measures should integrated and carried out as a part of planned maintenance work and repair;
- Collaboration is a precondition for adaptation, from technical cooperation on the level of state agencies to the financial coordination between sectors, on the ministry level.

These three “lessons learned” have been principles for all future R&D work and implementation efforts.

2012 was the starting year of a four-year R&D programme entitled “Natural hazards – Infrastructure, floods and slides” (NIFS), a cooperation between the NPRA, the Norwegian National Rail Administration (JBV) and Norwegian Water Resources and Energy Directorate (NVE) [3]. The budget is € 4.5 million; a shared effort between the three state agencies, in addition to considerable internal resources. The NIFS project focuses on issues of common interest, seeking joint solutions and synergy effects, as well as a way of coordinating the agencies’ roles in the national management of hazards from floods and landslides.

In addition to these two R&D programmes, many other actions and efforts, originally not defined as adaptation work, were important for adaptation to climate change. As this paper will try to demonstrate, climate adaptation consists mostly of making adjustments to prioritised “usual” activities, the importance of which grows in the aspect of climate change.

3. ADAPTATION OF THE NORWEGIAN ROAD NETWORK TO CLIMATE CHANGE

Adaptation to climate change can roughly be divided into the following steps:

- providing a good description of the climate we are anticipating;
- recognising the challenges this climate will have on the road network, transportation and infrastructure in general;
- recognising necessary – and feasible - remedial measures;
- defining modes of prioritization.

These steps do not follow such a clear sequence, and they can not be dealt with independently of other work carried out by a road agency.

At the start of the NPRA’s work on adaptation to climate change, important and valuable work on landslide and avalanche protection had been going on for years. Maintenance procedures and preparedness plans were also being revised in response to i.a. extreme weather events and the damage they caused. The national administrative and political framework for adaptation to climate change, however, was initiated after the R&D programme had started.

Climate change will have impacts on almost every field of work in a road administration. That is why the R&D programme “Climate and transport” put effort into building on all ongoing work relevant to climate adaptation. Investigations of the impacts of climate change revealed some new aspects and gave new directions to the ongoing work. It was important to propose measures that, as far as possible, fit into existing systems, plan and projects, in order to facilitate their implementation. This is *mainstreaming adaptation*, and it seems to be a generally accepted way of work, i.a. EU Climate Adaptation Policy [4].

In the following, the authors will look back and recognise the important elements of the framework for adaptation to climate change: systems, routines, procedures or documents that provided an important basis for adaptation work. By making adjustments to include the aspect of climate change, these systems and routines become adaptation tools.

Figure 3 – Snow avalanches are a frequent cause of road closure in Norway, E136 Romsdalen in 2010. Photo: Norfilm.

4. NATIONAL FRAMEWORK FOR ADAPTATION TO CLIMATE CHANGE

4.1. Public meteorology and hydrology data

In Norway, meteorological and hydrological data are easily accessible to public. The website eklima.met.no, operated by the Norwegian Meteorological Institute, offers free access to weather- and climate data, from historical data to real time observations and statistics. In addition, the NPRA has its own climate stations, and so does the National Railway Agency. Data from various owners are being combined into one large common database. This requires good control of data quality and compatibility of databases.

The Norwegian Water Resources and Energy Directorate and the Meteorological Institute operate the website www.senorge.no, which provides free access to daily updated maps of snow, weather and water conditions and climate in Norway. Topics include: water (run-off, soil saturation), weather (air temperature, precipitation), snow (depth, fresh snow, melting snow) and climate (current and future). This web portal was the basis for the development of a risk management tool, xgeo.no, and a national alert system for avalanches and floods. See 6.3.

4.2. National regional climate projections

The report "Climate in Norway 2100", published by the Norwegian Climate Centre* in 2009, provides the official basis for adaptation in Norway [5]. The report launched the work and was a basis for assessment in the national vulnerability survey, which was finalised in 2010, see 4.3. It gives a thorough overview of the climate in Norway, past, present, observed trends, and finally the results of calculations for climate trends towards the end of this century. Three levels of projections are described: low, middle and high projection. The forecasts are calculated for the whole country, and for each of six temperature regions and 13 precipitation regions. Calculations are performed and presented as annual average values and projections of seasonal change – winter, spring, summer and fall.

"Climate in Norway 2100" has provided a very valuable basis for all adaptation work in Norway. Climate projections from this work have also found their way into web portals and other tools that provide meteorological and hydrological information, such as the previously mentioned SeNorge.no. Climate projections have also been presented and published in simple user-friendly formats, e.g. the interactive web maps shown on the adaptation portal www.klimatilpasning.no [6].

An updated version of this report, following the findings of the IPCC's 5th assessment report [7] is to be presented in September 2015.

4.3. National vulnerability survey and white paper

In 2008, the government appointed a committee to carry out an in-depth analysis of the vulnerability and the needs of society to adapt to climate change. The committee delivered its report NOU 2010:10 "Adapting to a changing climate" to the Ministry of the Environment in November 2010 [8]. The survey was performed for all sectors in Norway and for all levels of management, from municipal to state level.

In spite of the recognised challenges the transportation sector is facing with respect to climate change, the adaptive capacity of the sector was found to be satisfactory. This conclusion was reached based on the following criteria:

- organisation – management, legislation, information;
- resources: financing, technology, human resources;
- knowledge base for adapting to climate change, including maps, databases, expert knowledge, etc.;
- prioritisation – investment, understanding the risks, adaptation goals as stated in strategic documents.

Good adaptive capacity is not an expression of the work already done, but rather an expression of ample possibilities for carrying out adaption work in the transportation sector.

The vulnerability assessment from 2010 was the basis for the Norwegian white paper 33 (2012-2013) "Climate Adaptation in Norway", published in May 2013 [9]. The white paper emphasised the shared responsibility, from the individual to the organisational level, and the importance of knowledge and cooperation. In addition, it provides a valuable practical instruction: when assessing the consequences of climate change and the need for adaptation, one should use the *high* projection of climate parameters. This requirement

* Comprises the Norwegian Meteorological Institute, Bjerknes Centre, Nansen Centre, the Norwegian Oceanic Research Institute and the Norwegian Water Resources and Energy Directorate (NVE)

simplifies the decisions concerning what climate to adapt to. For some road projects, this requirement will have an impact on the choice of the design solution or the dimensions of an asset. The white paper is available in Norwegian text only, but reference to it is made in the report “Norway’s Sixth National Communication under the Framework Convention on Climate Change” [10].

4.4. Climate service centre

Recognising the need to provide tailored climate data adjusted to the needs of users (from technical sectors, health, agriculture, etc.), the Norwegian Meteorological Institute launched a Climate Service Centre in 2014, www.klimaservicecenteret.no. The Climate Service Centre is under development, and it will further facilitate adaptation work in Norway.

5. THE NPRA’S OWN FRAMEWORK FOR ADAPTATION TO CLIMATE CHANGE

5.1. Adaptation in strategic documents - National Transport Plan

The main strategic document in the transport sector in Norway is the National Transport Plan (NTP) [11]. The NTP is a ten-year-plan, which is revised every fourth year, under the direction of the Ministry of Transport and Communications. The NTP outlines how the government intends to prioritise resources within the transport sector. The aim is to ensure efficient use of resources and to strengthen interaction between the four modes of transport: air, sea, rail and road transport. The main goals are: improved traffic flow, traffic safety, reduced GHG emission and universal design.

Each NTP starts by performing preliminary studies on important issues. Climate change and the transport sector’s need to adapt have been a part of the preliminary studies for the three past NTPs: 2006-2015, 2010-2019, 2014-2023. Although the need to adapt is recognised, there are no explicit investments in “adaptation to climate change”. Adaptation work is indirectly supported by investments in maintenance and renewal, and better preparedness.

5.2. Manuals of design and practice

The NPRA develops and uses its own series of manuals of design and practice. They are based on standards, but they contain additional explanations and requirements regarding road structures.

One of the first steps of adaptation work was to investigate the need for amendments to these manuals of design and practice: the manuals for road planning, construction, maintenance and management, as well as templates for contracts for maintenance and operation. A review of existing manuals was carried out as a part of the R&D programme “Climate and Transport”. Most of the amendments were carried out during the R&D programme, while some were formulated as proposals for a future revision of the particular manual.

5.3. Norwegian Road Databank

The NVDB is the Norwegian Public Roads Administration’s central database for the road network and associated technical data. For a continuous network, including all roads longer than 50 m, the NVDB collects more than 400 types of technical data: physical objects (e.g. culvert and railings), abstract objects (e.g. speed limits and traffic volumes) and incidents (e.g. traffic accidents and landslides). The NVDB is used mostly for operation and maintenance, but it is also a good source of information for adaptation work.

A review of the NVDB's functionality and content, however, concluded that some adjustments had to be made in order to make the NVDB a better tool for climate adaptation. The main issue was the lack of content relevant to climate adaptation, such as data on drainage structures, ditches and culverts. The NVDB leaves space for such information, but it is rarely filled out by the users.

5.4. Surveys of risk and vulnerability

As a part of road management, many forms of inspections, of surveys of standard or vulnerability are carried out regularly. It was necessary to identify the correct connections between surveys already being performed and the necessary assessments of vulnerability to climate change.

The NPRA carries out large-scale surveys on vulnerability of the road network. This is an action called SAMROS, and it was initiated by the Ministry of Transportation in 2005. The work consists of assessing all sources of risks that may cause road closure. The important risks in this respect are the ones that uncover a lack of alternative routes. Adding the aspect of climate change to this assessment is important for adaptation work altogether.

Other surveys to mention:

- The main routes in the national road network are submitted to a survey of functionality and standard as a part of each National Transport Plan (see 5.1). These surveys also contain a component of vulnerability to natural hazards, and should therefore always contain the aspect of climate change.
- A method for systematic assessment of standard of roads and road assets, including drainage and culverts, is currently under development (2015). The results of the assessment of standard will be saved in the road databank (NVDB) and be made available to the users. It is of great importance to include aspects of climate change in the assessment method.

6. ADAPTATION MEASURES

In 2013, the final report form R&D "Climate and Transport" was published, proposing four main groups of adaptation measures [2]:

- Measures for new roads: climate-adapted design and construction
- Measures for existing road network: climate-adapted operation and maintenance
- Preparedness measures adapted to a more demanding climate
- Developing a knowledge base for climate adaptation

Some measures were already implemented during the course of the programme. Others are works in progress, in the NIFS programme and otherwise.

In the following, these four groups of adaptation measures are described, as they are dealt with at the NPRA. Both finalised and ongoing work are included.

6.1. Measures for new roads – Avoiding vulnerability

The aim is to *avoid* excessive vulnerability by adequate planning and design. Climate should be considered in all planning processes, and as early as possible when developing a project. Here are the main amendments in design rules manuals concerning planning and design.

- Climatic conditions are included among the assumptions for designing roadways, implying mitigation of the consequences of flooding, landslides, erosion, heavy snowfall, etc.
- Alignment of the road should be chosen in such a way that the risk of flooding, landslides, drifting snow and similar weather impacts is reduced, or is easier to handle. Special attention should be given when crossing waterways, so that erosion problems can be avoided or limited.
- The vertical alignment should be chosen with respect to the 200-year flood level (not 100, as earlier). This is not a rigid requirement, because of other factors that need to be balanced. However, an extra safety margin must be decided in consultation with the NVE*. This emphasises the importance of updated design basis and hydrological expertise. 200-year flood levels shall also form the basis for bridge design, concerning free height and erosion protection.
- Landslide protection measures should be planned taking into consideration the impacts of climate change. There is a need for more expertise when it comes to debris flows and slush avalanches.

Figure 4 - Gudbrandsdal valley in central Norway experiences major floods in 2011 and 2013. Many examples of damage that started high upstream and have led to serious damage downstream, on the road or railway. Photo: Norfilm.

- Managing run-off water is recognised as an important part of road project documentation. Wherever applicable, road projects should be required to develop separate plans for storm water management.

* Norwegian Water Resources and Energy Directorate

- In order to ensure sufficient capacity of drainage structures, a robustness factor (or “climate factor”) has been added in the calculation of necessary capacity of drainage structures. This factor is higher than 1, but does not have a fixed value. It is chosen depending on the quality of available climate data, e.g. short-term precipitation. The robustness factor is a temporary solution. The NIFS programme is currently developing new design guidelines for drainage, to be published 2016. They will also provide a better basis for building more climate resilient roads.
- Comprehensive drainage solutions should be planned over a large area, not only along the road. Retention basins or terrain ditches should be used much more frequently than today.

Comprehensive drainage solutions for the protection of infrastructure (last bullet point) are one of the main activities in the NIFS programme. Analyses of recent floods have proved that the risk map is complicated, e.g. a poorly drained forest road or a bad culvert on a municipal road upstream may be the cause of serious damage to the main road downstream. The source of the problem may lie at a large distance from the road itself, and it could be difficult to reveal by usual risk assessment. One has to see the catchment as a whole. A pilot project in Gudbrandsdal valley, in central Norway, will provide valuable experience on the matter, see the example in Figure 4. The NIFS programme is following closely the development of a management plan for the catchment of the river Gudbrandsdalslågen.

6.2. Measures for the existing road network – Mainstreaming adaptation

Climate change emphasises the need to perform good maintenance and to reduce maintenance backlog. All scheduled maintenance and repair should include adaptation measures wherever necessary. The aim is to ensure *sufficient* capacity for the *remaining* service life of the asset. For that purpose, there is a need to adjust and expand methodology for the cost-benefit analysis, so that climate change is taken into account in a better way.

In order to be able to assign priorities, it is necessary to carry out a survey of vulnerable assets. Road stretches or assets can be vulnerable because of their exposure to unfavourable weather conditions, or due to their poor standard or insufficient design capacity. The NPRAs system for large-scale vulnerability assessment (SAMROS) was mentioned in 5.4. The R&D programme “Climate and transport” developed guidelines for adjusting SAMROS to include climate vulnerability. A more detailed vulnerability assessment is, however, being carried out as a part of improved preparedness plans, which are the subject of the next chapter, see 6.3.

Finally – operation contracts, signed on a 5-7 year basis, need to take into consideration the observed trends and the uncertainty of the climate, such as unusual weather combinations (winter flooding, sudden temperature changes), more vegetation along the road, temperatures around freezing point, drifting snow, etc. Contracts need to be formulated in a flexible way, in order to take into account the unpredictable elements.

6.3. Measures for improved preparedness – risk management

A storm in coastal central Norway in 2006 motivated more systematic work on exploring connections between historical and current weather data, ground data and weather related events. This was the start of a web portal developed through cooperation between the

NPRA, the NVE*, the JBV† and met.no, which served as a great starting point for more systematic work on adaptation to climate change. The web portal has gradually developed into a powerful risk management tool entitled www.xgeo.no.

xgeo.no makes better use of documented relations between weather, road data, ground data and weather related events on the road. By establishing unfavourable combinations of weather parameters, one can recognise situations that require higher preparedness. Threshold values of climate parameters are modelled and calculated, and three levels of elevated preparedness are described: yellow, orange and red. Action and responsibility are defined for each level. Figure 5 shows an example from xgeo.no.

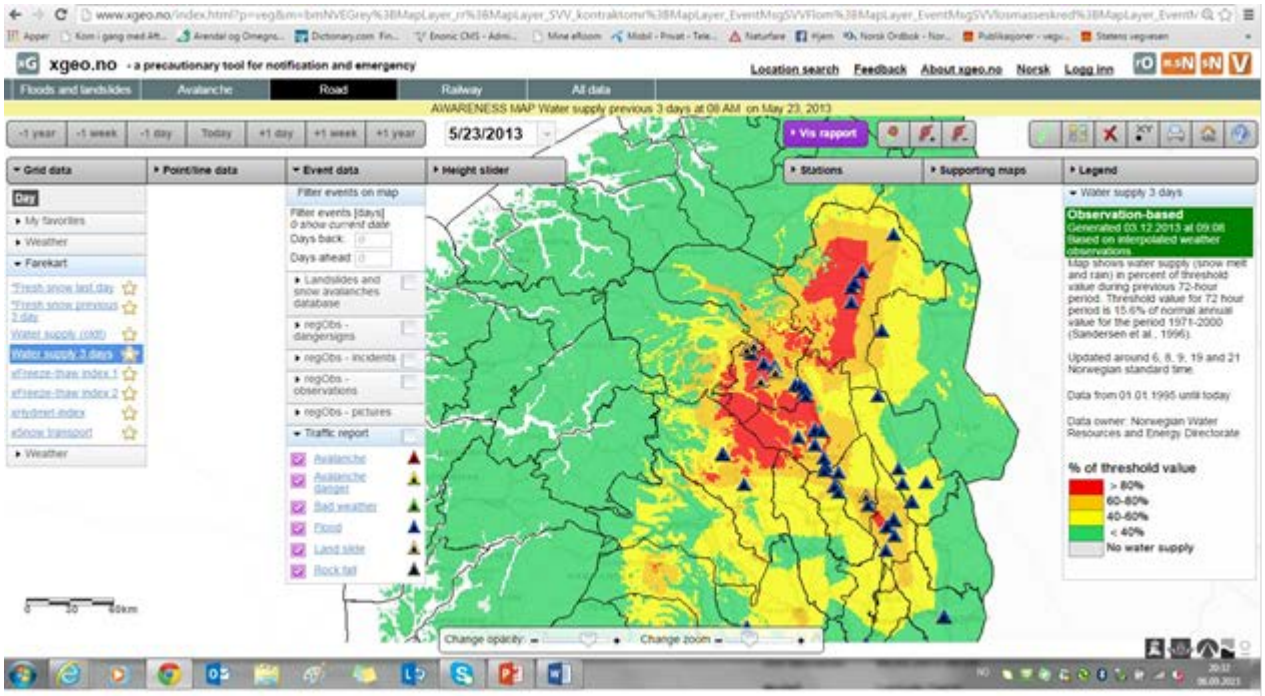

Figure 5 - Example from xgeo.no, showing areas where precipitation reached threshold alert values - yellow, orange and red. The triangle symbols show the registered floods in the area.

The stepwise preparedness system is a marvellous tool for adaptation to climate change, and it is being implemented at the NPRA. It is also the basis for a common alert system for floods and landslides, www.varsom.no. Warnings of flood, snow avalanche and debris landslides are issued to road operators, road users and the general public.

Efforts have been made to provide better map-based information from road owners to contractors, as parts of preparedness plans for natural hazards. Templates for preparedness plans are under continuous development, based on experiences in the use of the first editions. The plans build upon registrations of events and assessed vulnerability for natural hazards. Mapped information provide a good basis for operating the road network, see Figure 6.

* Norwegian Water Resources and Energy Directorate
† Norwegian National Rail Administration

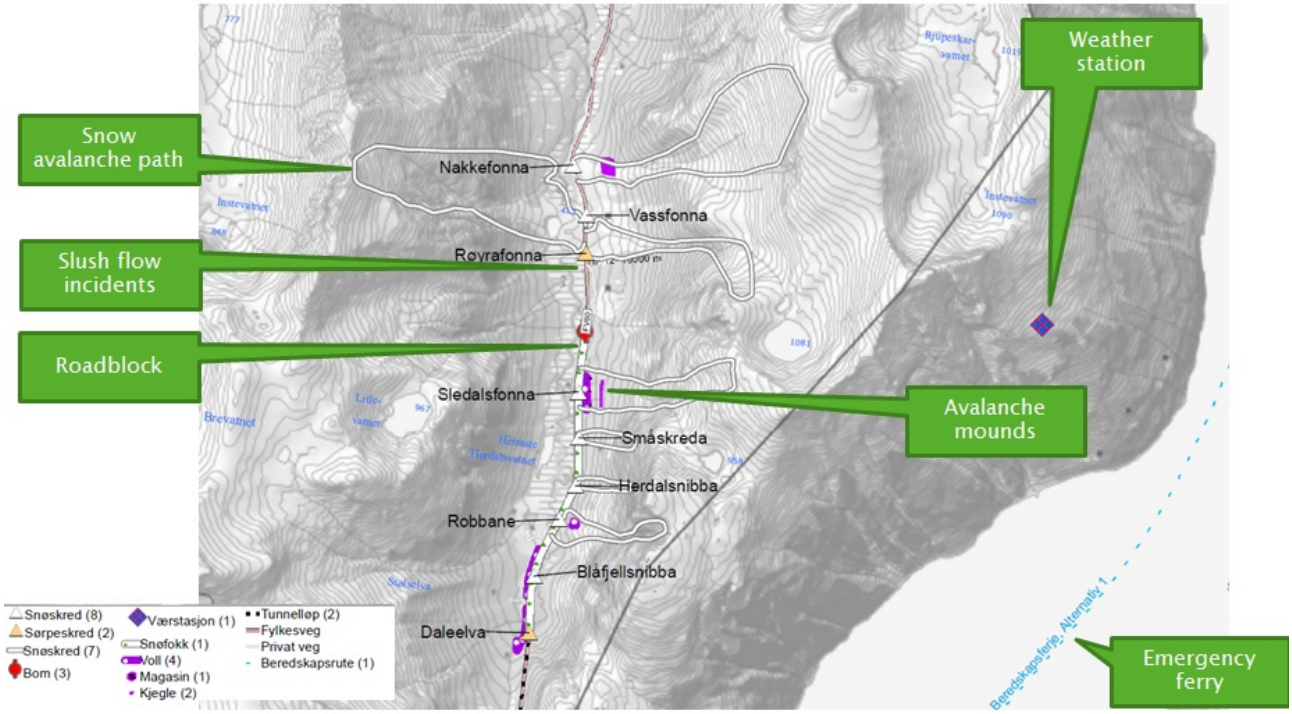

Figure 6 - Example of a map included in a preparedness plan for natural hazards in an operation contract region.

The entire preparedness system is dependent on good registration of events; this is the reason for investing in the simplification and better quality of the registrations, e.g. the development of electronic reporting and smart phone apps for registration of events. Training of contractors is provided by the NPRA for each new operation contract.

6.4. Improving the knowledgebase for adaptation

Road owners have to support national and international climate-related research and facilitate good coordination between projects. In addition, road owners, as users of climate data, need to indicate their needs and in that way contribute to interpreting the results of climate research for practical purposes.

Cooperation is a precondition for adaptation. At the ministry level, cooperation will ensure coordinated budgets in areas of work that are dependent on each other, e.g. transportation agencies will benefit from better investments in developing good meteorological data, flood statistics, etc.

The collaboration with the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian National Rail Administration (JBV) and the Meteorological Institute has proved to be essential for the adaptation work at the NPRA. It is the basis for the most valuable tools we have today, i.a. xgeo.no, and varsom.no.

7. SUMMARY AND CONCLUSIONS

This paper presents an overview of the work that is being done at the Norwegian Public Roads Administration on adapting the road network to climate change.

Adaptation to a changing climate is significantly helped by good collaboration between research environments in Norway, existing regional projections of climate change, free access to hydrological and meteorological data and political recommendations for adaptation.

The adaptation measures for roads make use of existing systems and processes, such as the National Road Databank (NVDB), manuals of design and practice and existing surveys of the road network.

Adaptation measures include:

- measures for new roads – the most important being adjustments of design rules;
- adaptation measures for existing roads – or adaptation as a part of maintenance;
- measures for improved preparedness for natural hazards – especially risk management tools and improved preparedness plans
- improving the knowledgebase for adaptation – obtaining better knowledge of climate change and of today's climate for the purpose of reducing uncertainty.

Cooperation between experts, sectors, and ministries is a precondition for adaptation to climate change.

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