Workshop
"Regional early warning systems for rainfall- and snowmelt-induced landslides. Need for an international forum?"

Summary report

Graziella Devoli

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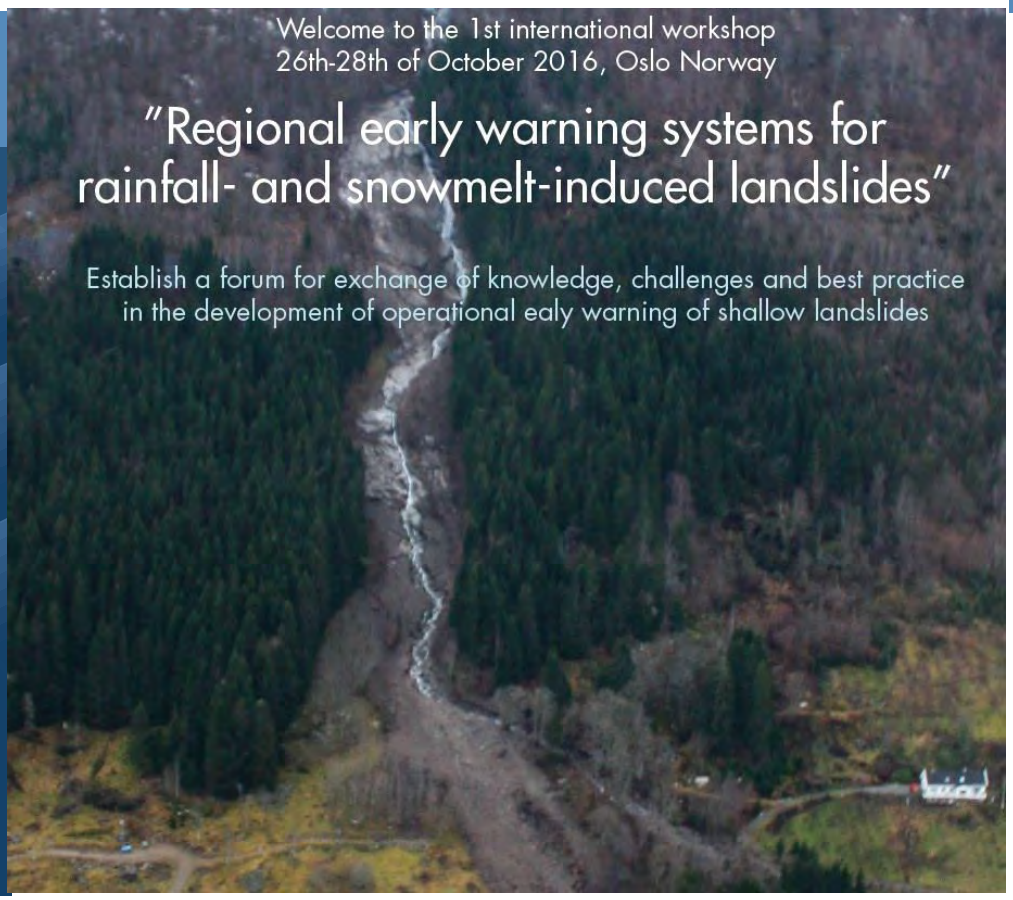
2017



RAPPORT

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Workshop "Regional early warning systems for rainfall- and snowmelt-induced landslides. Need for an international forum?"

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Sammendrag: This document summarizes the main outcomes from the first International Workshop on "Regional early warning systems for rainfall- and snowmelt- induced landslides" promoted and organized by the Section for Forecast of Flood and Landslide Hazards at NVE. The workshop was held in Oslo, Norway, from 26th - 28th of October 2016.

Emneord: Regional landslide early warning system, rainfall-induced landslides, jordskredfare, varsling

Norges vassdrags- og energidirektorat
Middelthunsgate 29
Postboks 5091 Majorstua
0301 OSLO

Telefon: 22 95 95 95
Telefaks: 22 95 90 00
Internett: www.nve.no

Preface

Since 1989 the Norwegian Water Resources and Energy Directorate (NVE) has had an operational 24-hour flood forecasting system for the entire country. From 2009, NVE is also responsible to assist regions and municipalities in the prevention of disasters posed by landslides and snow avalanches. Besides assisting the municipalities through implementation of digital landslides inventories, susceptibility and hazard mapping, areal planning, preparation of guidelines, realization of mitigation measures and helping during emergencies, NVE have developed a regional early warning for soil slides, debris flows, and slush flows coordinated with the existing flood warning systems. This service, operational since autumn 2013, is developed in cooperation with the Norwegian Public Road Administration (SVV), the Meteorological Institute (MET) and the Norwegian National Rail Administration (BANE NOR). This positive and solid partnership has demonstrated that multi-disciplinary and inter-institutional collaboration is an important success factor in early warning.

NVEs goal with the organization of an international workshop was to gather international experts, to exchange experiences and knowledge regarding methods, models and data used in daily warning evaluations, as well as to discuss operating practices and communication procedures.

Oslo, January 2017

Morten Johnsrud
Director

Hervé Colleuille
Head of Section

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Summary

This document summarizes the main outcomes from the first International Workshop on ”Regional early warning systems for rainfall- and snowmelt- induced landslides”. This workshop was promoted and organized by the Section for Forecast of Flood and Landslide Hazards responsible for the coordination of flood and landslide hazards forecasting and warning system at the Norwegian Water Resources and Energy Directorate (NVE). The workshop was held in Oslo, Norway, from 26th - 28th of October 2016 and fifty participants from ten different countries attended. International experts in the fields of rainfall-induced landslides, meteorology, hydrology and early warning systems (EWS) were gathered to share experiences and knowledge on operational regional early warning systems and to discuss the need for international forum in the future.

1 Introduction

Rainfall- and snowmelt induced landslides, usually described as rapid mass movements such as debris flows in steep channels and shallow debris slides and debris avalanches in open steep slopes, annually cause significant economic damage and affect large areas, particularly when (transport) infrastructure networks are affected. Their spatial occurrence of landslides can be forecasted in advance through combined regional and local early warnings in certain regions given our understanding of the interactions between precursors and triggers, however the prediction of exact initiation area still remain difficult to address.

An overview of the different types and characteristics of existing early warning systems is presented in Stähli et al. 2015. Many local early warning systems exist at specific sites where extensive monitoring provides detailed information, while a few countries systematically operate national early warning systems for landslides (mainly constrained to shallow landslides). Among them Norway, Italy, UK, El Salvador, Taiwan.

The **Section for Forecast of Flood and Landslide Hazards** is responsible for the coordination of flood and landslide hazards forecasting and warning system at the **Norwegian Water Resources and Energy Directorate (NVE).** This section has organized the 1st International Workshop on ”Regional early warning systems for rainfall- and snowmelt- induced landslides” to gather international experts in the fields of rainfall-induced landslides, meteorology, hydrology and early warning systems (EWS) to share experiences and knowledge on operational regional early warning systems and to discuss the need for an international forum in the future.

The workshop was held in Oslo, Norway, from the 26th to the 28th of October 2016. Fifty participants attended from mainly European countries and USA.

This document summarizes the main outcome of the workshop.

2 About the Workshop

This workshop was organized with the purpose to establish a forum for exchange of knowledge, challenges and best practice in the development of operational early warning of shallow landslides and debris flows.

2.1 Objectives

- Overview of countries and institutions that work with operational EWS at national/regional level for rainfall- and snowmelt induced landslides like shallow soil landslides, debris avalanches, channelized debris flows and slush flows.
- To gather international experts.
- To exchange experiences and knowledge regarding methods, models, data used in daily warning evaluations, as well as to discuss operating practices and communication procedures.

- To create a future network of international experts in rainfall- (and snowmelt) induced landslides.

- Better interaction between meteorological, flood and landslide forecasting services on national/regional level.

The workshop did not extend to include discussions about monitoring and early warning at local level.

2.2 Participants

The purpose of the workshop was to gather public bodies that were known to run operational EWS or potentially interested in the organization of national EWS. The invitation was sent mainly to European countries (Italy, Spain, Slovenia, Austria, UK, Switzerland, Sweden, Iceland, France), as well as Taiwan, South Korea and USA. The following institutions accepted the invitation:

- British Geological Survey (BGS, UK)
- Germany's National Meteorological Service (DWD, Germany)
- Icelandic Met Office (IMO, Iceland)
- Met Office (UK)
- National competence centre for Industrial Safety and Environmental Protection (INERIS, France)
- National Research Council (CNR) - Research Institute for Geo-Hydrological Protection (Irpi, Italy)
- Regional Agency for the Protection of the Environment (ARPA Piemonte, Italy)
- Swedish Geotechnical Institute (SGI, Sweden)
- Swiss Federal Institute for Forest, Snow and Landscape Research (WSL, Switzerland)
- The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (die.wildbach, Austria)
- University of Salerno (UNISA, Italy)
- U.S. Geological Survey (USGS, USA)

In addition the following Norwegian institutions were invited and attended the workshop:

- Geological Survey of Norway (NGU, Norway)
- Norwegian Geotechnical Institute (NGI, Norway)
- Norwegian Meteorological Institute (MET, Norway)
- Norwegian National Rail Administration (BANE NOR, Norway)
- Norwegian Public Road Administration (SVV, Norway)
- Norwegian Water Resources and Energy Directorate (NVE, Norway)
- University of Oslo (UiO, Norway)

The complete list of participants is presented in the Appendix A.

2.3 Workshop Agenda

NVE proposed the agenda of the workshop, while the topics for the group discussion were selected based on the proposals received from all participants.

The workshop comprised the following five parts.

1. Presentation of the state of the art about national and regional EWS in the different countries
    - Norway, USA, UK, Iceland, Italy, Austria, Switzerland and Sweden
2. Presentation of experiences from case studies
    - Iceland, Switzerland, USA, Norway and UK
3. Posters
4. Group discussions on 4 main selected topics
5. Discussion about "Need for international network/forum and international collaboration for rainfall- and snow melt induced landslide early warning?". How we can exchange best practice?

The detailed workshop agenda is presented in Appendix B and the pdf versions of the presentations are available at varsom.no in the following links:

http://www.varsom.no/en/news/workshop-on-regional-landslide-early-warning-systems/; http://www.varsom.no/en/news/better-landslide-warning-to-be-better-prepared/.

2.4 Topics for discussion

The first day was dedicate to summarize the state of the art about early warning systems in the countries represented at the workshop. Four main topics were identified as common challenges and these were discussed during the afternoon of 2nd day.

Topic 1. The importance of reliable landslide data and feedback from field as essential information for thresholds development and evaluation of warning performance.

Theme's leaders: Helen Reeves (BGS), Manfred Stähli (WSL)

- Is there any systematic registration of landslide events in your country after a specific rainfall/snowmelt event? Which institution collects the data and how does it collect it? (Public or private institutions; fieldwork; newspapers; databases?)
- What kind of challenges do you have to face? (Landslide database construction; accuracy and uncertainty; impact/severity categorization)
- How are data used in EW for post-analyses? What kind of experiences are available for exchange?

Topic 2. Thresholds and hydro-meteorological data. Recognition of dynamic thresholds and accounting for antecedences and triggering conditions.

Theme's leaders: José Cepeda (NGI), Søren Boje (NVE)

- Which parameters are used in your country to define landslide thresholds?
- Which parameters are used in your country to define landslide thresholds?
- How do we present thresholds? How often do we update them?
- What kind of experiences are available for exchange?

Topic 3. How do we know if a system works, or does not work? (Methods, tools and concepts for the validation of operational landslide early warning systems, and for the evaluation of their performances)

Theme's leaders: Mads-Peter Dahl (NVE), Luca Piciullo (UNISA)

- Has your country established procedures to evaluate the performance of early warnings? (Are they, for instance, part of a meteorological or hydrological hazard warning-system?)
- What methods or tools are used in your country to assess their efficiency? Is there some entity that evaluates them? Can you point out any challenges in that respect?
- What kind of experiences are available for exchange?

Topic 4. How do we best use the forecasts, and other products, prepared by the systems? How do we communicate the risk?

Theme's leaders: Dennis Staley (USGS), Per Glad (NVE)

- What kind of methods or tools do we use to disseminate our warnings to the public?
- How do we know if our warnings are reaching the community? How does the population in general perceive them?
- What kind of role should we assume if emergency responses are not in place?

3 Outcomes

3.1 State of the art

From the of the state of the art presentations it could be concluded that the forecasting of rainfall- and snowmelt- induced landslides is a multi-disciplinary field, that requires collaboration among disciplines, more so than for other natural hazards. It also requires pragmatic approaches to forecasting at an operational level, to the validation of models, and to establish proper communication.

Norway, Italy and UK have a national operational EWS in progress. USA have a regional EWS for part of the western USA with a focus on EWS for post-fire landslides. The other countries have capabilities that range from a local EWS (for example for torrents exposed to debris flows or, in areas of deep-seated landslides, a site-specific fully operational system), to no operational EWS. Many countries report work in progress.

Science behind the forecast

It was observed that the science behind the operational forecasts is generally based on a good understanding of the processes causing landslides and, in particular, on a good connection between landslide process understanding and meteorological forecasts (at suitable spatial and temporal resolution).

However, it is clear that there is a need to use a common terminology, including that related to landslide related jargon, to the methods used, and to the common descriptors such as 'what constitues an extreme event".

Methods, tools

The Traffic-light^{+} system (green, yellow, orange and red) used by most, but this is not necessarily an easily recognisable system. Green is not 'nothing happens' and red is not 'Armageddon', therefore descriptive warnings should also be provided. In addition, people have different cultural associations with the colours.

The stakeholders/emergency authorities receiving the landslide warnings have to make their own assessment at a local scale using their own experience (expert knowledge) and additional local information on hazard and vulnerability. Sometimes it can be useful to provide the raw information to an individual stakeholder, so that they can incorporate the information into their own systems.

Sometimes it can be confusing for receivers when they get three different warnings for flood, snow and landslides at the same time, like in Norway. The snow avalanches warning follow international standards based on 5 danger levels, while flood and landslide warning use 4 awareness level based on the Meteoalarm principle (i.e return period). Therefore a red level for snow avalanches has a different meaning than a red level for floods and landslides, and is can also be interpreted differently by different end-users/targets (emergency authorities, skiers, tourists). Translation/interpretation is therefore required by key actors who receive the information and who can then transfer the information to their target groups in an appropriate way.

Validation of the system

Many works in progress. Some methods are pragmatic, others are more sophisticated. There is a need to be more visible and publish our experiences in order to provide the critical service that is needed. There are two ways of assessment of performance: 1) warning performance (number of landslide events x warning level; 2) recipients survey (warning should made a better preparedness or action).

Communication

We are experts in validating the technical part, but not necessarily with the message transfer. We need to provide suitable communications about what to do in case of a particular warning/event, co-develop this with target communities and aided by other sciences, 'social' scientists, journalists, and recognize the diversity of public, taking example from the meteorological community. We need to transfer clearly level of uncertainty, relevance, describe properly the processes and all possible consequences at all phases. We need to translate regional view into local relevance.

We need to learn from the public, learning from their experiences. However, it takes a long time to get feedback from people, because it takes time to adjust. We need to investigate better who the recipients are of the information we generate. How to 'interpret' warnings, differences in communication with different target groups: road authorities, emergency responders, the public; physics remain the same but the messages need to be appropriate. End-users are heterogeneous, therefore different messages to different users, but where do liabilities lie? When things go wrong, who is the owner of the message…? Communication channels need to be robust, and should be efficient with no bottle-necks. An 'in-between' expert may be required. There are good examples of successful communication of warning messages in other countries like Nicaragua, Taiwan, Cuba, from which we could learn, where Civil Defence often is an intermediary between scientists and public.

It could be useful to develop joint protocols for the operational side of EWS. The scales need to be considered (and included in the terminologies), regional warnings could act as as a focus, for certain types of landslides. Localized warnings, extrapolated to larger areas, are also possible (e.g. US fire-affected areas).

It is important that stakeholders and end-users recognize the value of EW and that they are engaged in the process, providing constant feedback and playing a role in a forum.

Insurance companies can be regarded as stakeholders and have expressed interest in EW as landslide loss estimation is becoming of greater interest to them.

3.2 Outcomes from the group discussion section

The main conclusions from the group discussions were the following:

1) The importance of reliable landslide inventories.

The success of landslide forecasting depend on the registration of landslide events. Landslide events are used for both the development of thresholds and the evaluation of a sent warning to confirm if the warning was correct or not. Therefore is extremely important to confirm that a landslide event has occurred after a specific triggering rainfall event.

All the countries represented in the workshop rely on landslide databases at a local, regional or national level.

Austria – the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management has a landslide database that record data on landslides that have impact. Scientists will go out into the field and verify data. If a large number of events occurred, Universities are asked to collect data.

France - the Geological Survey is in charge of landslide susceptibility analyses, but there is no systematic registration of landslide events. There are others public institutions and local municipalities that collect this data.

Iceland - Met Office has a landslide and snow avalanche database that goes back to the earlier settlement of Iceland, but also the natural science institute collects data on landslides. Only the snow avalanche part is open to the public, not the landslide part. The general public can collect data in several ways. Landslide data are used for hazard assessment.

Italy - Data collected by a number of organizations, particularly the local authorities. Data is variable in quality and has a large amount of noise that makes it very difficult to generate statistics from it. There are problems in managing it. They have developed a number of tools for satellite information to generate landslide events.

Norway - NVE maintain a national database (www.skrednett.no) using nveatlas.no and xgeo.no to visualize landslide data collected/registered by road and railway authorities, municipalities, private consultants and public from field observations, historical documents or media. Landslide events can be recorded through www.skredregistrering.no, or using www.regobs.no. The database is used in hazard analyses and also in the development of thresholds. However getting good quality data, in terms of landslide type, especially for rainfall-induced events, and the time and correct date is a challenge as well to ensure data consistency. Like for Italy the quality of these data makes it very difficult to generate statistics from it.

Sweden - SGI has a database (https://gis.swedgeo.se/skred/) but there is not a systematic registration of landslide data. Only scientists can report and register events. SGI collect landslide data once a year from media reports etc . MSB (Swedish Civil Contingencies Agency) have a small database (http://ndb.msb.se/), but only collected when impact occurred.

Switzerland – There is a national database with a web tool commissioned by the Federal Office of the environment. There is a standardized form of data collection & entry. This will be publically available.
(http://www.wsl.ch/fe/gebirgshydrologie/wildbaeche/projekte/Hanmurendatenbank/index_EN).

UK - there is a systematic registration of landslide events into the national landslide database. The events are report from a variety of people (technical and non-technical); this helps with both susceptibility mapping and also developing of thresholds. This data has problems as there is limited information on dates associated with events.

The challenge for all is to get good quality of data – such as right type, locations and timing of event. All agree that the quality and the accuracy of data (timings & locations) is important for the development of EW post-analysis.

There is not consistency in data collection and problems with the naming of different landslide types. Need to ensure reliable data e.g. what type of landslide, created from what environmental data. Events that don't have impact are not systematically collected. Many countries record landslide data from social media, which is very helpful, but they need to be checked and qualified/validated. In Italy there has been a big reduction of the budgets to collect this data and there will be a challenge to maintain this. In Austria there is data, but there is smaller amount of very old historical data and not covering the data across the country to the same degree of density. In Norway most of the data are not recorded by experts, and hence there is a degree of uncertainty in the quality of the data. This therefore limits what parameters can be collected. One way of ensuring at least some of the important data is by ensuring that data is collected by a standard format. Most of the existing landslide data were not originally collected to help with thresholds development or to make statistics of it, but only to show where landslide have occurred. Very difficult to use the databases

statistically. Many countries have problems with the coordination of collection of systematic information into a systematic information database. In some countries sharing of landslide data between different organisations across a country can be problematic (France, Italy). This is not helpful for solving problems for the society or when carrying out research.

Stakeholders must be told about the importance of landslide registration and maintenance of inventories. It is important to let stakeholders know which data are necessary to collect.

2) Triggering conditions, antecedents and thresholds

Different threshold methods are used in the different countries/regions, considering different parameters, like for example daily or hourly antecedent rainfall and snowmelt, simulated soil moisture content, now-casting using weather radar. Sharing and testing threshold methods will benefit the partners of the community.

Table 1 summarizes the parameters used in the different countries to define landslide thresholds. In France there is no generalized methodology for generating thresholds. These are developed by academics for local catchment study areas.

The presentation of thresholds is done in different ways, mainly through internal reports and maps, web tools or through scientific articles. The development and updating of thresholds is ongoing activity and reviewed continuously, depending on the newly available data being sufficient and after every major events. In Norway the thresholds are reviewed regionally, while in the USA a real time updating is done with 15 min rainfall and burnt slope conditions. Some countries like Austria involve local government and provinces in the adjustment of thresholds.

3) Does the system work? Methods to evaluate the system.

Much work is in progress on this topic, learning mainly from other natural hazards about how evaluation is conducted. Only the countries with operational early warning system (like Italy, Norway, UK and USA) have started to establish procedures to evaluate the performance of the system.

For all of them the performance of the forecast rely on the occurrence of landslides during that particular triggering rainfall/snowmelt event. For the first evaluation, it is enough to know if landslides have occurred, but for some countries is important to know how many landslide occurred under a specific warning level. Therefore, upgrading of landslide inventories is mandatory after each forecast, in order to have the right number of landslide events.

ARPA Piemonte, Italy, has 2 warning levels, which are function of number of landslides. They carry out field surveys after an event to confirm the number of landslides. Performance analysis are carried out through a contingency table.

NVE, Norway has 4 warning level which are also function of expected number of landslides. In the short term (1 day - 1 week) after, the number of landslides is checked using newspaper analyses, report on real-time landslide databases, and real-time database reporting closure of roads. Fieldwork after events is not done systematically. In the long term, the number of landslides is controlled by how many are entered in the landslide database. It is a work in process. Evaluation is done every week following a method

established here, but recently a method proposed by the University of Salerno has been tested.

In UK the evaluation of the performance is a work in progress and mainly done for some case studies. They have warning levels for heavy rainfall conditions and learn from other natural hazards on how to evaluate the performance. They have flexible thresholds as function of the seasons.

AUSTRIA does not have a national early warning, but monitoring and warning at local level for deep-seated landslides exists, for which there is a yes/no warning system.

Other countries have not LEWS or works are in progress

In the evaluation of the performance it is important to consider that calibrations of rainfall thresholds are necessary, but also that thresholds should be flexible, and be a function of the season. We should also consider different methods for the performance evaluation. Many addressed the necessity to distinguish among the technical performance, the human evaluation and the user perception.

To increase the reliability of the system we could use media and communication tools in addition to fieldwork. Better weather forecasts to increasing the performance of site specific/regional warnings is also needed.

4) How to communicate risk?

The existing EWS distribute warning messages to the public and stakeholders through websites, email, SMS, social media (like Twitter, Facebook). Most of the countries communicate to 1st and 2nd responders, local authorities and partly media. Most rely on publishing warning using designated websites. Key institutions are obliged to confirm that the warning is received providing an important information loop. Some countries like Norway have started a subscription service, probably a good solution for 1st and 2nd responders, but can we expect the general public to have sufficient interest to pay?

The group also discussed about power outs, no internet, etc… Can we discard the radio as a means of communication in times of disaster?

The countries with operational systems have been busy in the recent years, since operations started, with the adjustment of tools and methods. They had no time to carry out surveys to investigate how receivers perceive the messages. All participants expressed the need of conducting *repeatedly* surveys to verify how end user perceive warning messages and if they take actions. Dialog between people issuing the warnings, local authorities and the public is needed.

Table 1

Country	Ground condtions	n-day precip.	n-day water supply	Output hydrol. Model	Nowcasted data (radar-based)	Daily rainfall	Daily water supply	Short-term rainfall int.	Expert-based judgement	Prob. Of exceed. Level
Austria			x			x	x		X (meteor. Thresh)	
France	x	x				x				x
Germany										
Iceland		X (48 h)				x		X (6-hour)	x	
Italy – Piemonte – Shallow slides	X - diff. Thresh		x	X (soil moisture)					x	
... Debris flows					X			x		
Italy – National		X (n-hours and n-cum)						X (hourly)		
Norway			x	X (soil moisture)		x			X (for warning levels)	
Sweden*										
Switzer-land										
UK	x		X (1, 2, 3, ... n)	x (soil moisture)			X (forecasted)		X	x
USA-PFireDF										x

3.3 Conclusions from “Needs for international forum” section

All participants expressed the necessity to build up and be part of a community of experts in rainfall- and snowmelt induced landslides and to build relationships with others EU countries, for example. This will help to level up the quality of science, develop a theory (methodology, scale levels, communication procedures, etc) and build a consensus and standards, as for example is done by the international snow avalanches early warning community.

We should organize a community and hold an international forum with a select number of key people per country. Physical meetings are the best for a very effective exchange. We should expand to more countries, but we need common methods, and include end-user forum. We need target funding to develop the community. It is possible to show internal/external faces of the community…through web pages or a dedicated section in important conferences (like EGU, WLF, etc). The focus should be on regional warning and how these could assist local monitoring and local warning.

Next meetings could be dedicated to specific topics, like ‘communication’, ‘validation’, ‘models’, etc. The best is to start with small case studies, workshops (with prepared exercises), go through the exercise of forecasts and follow the whole process, use simulations to replay events, focus on work in practice.

A Forum is beneficial for us. A group in EWS is in agreement within the context of Sendai – strategy until 2030 to develop EWS, and help to deliver the Sendai objectives, and provide advice to civil contingency groups.

4 Conclusions

For the first time an international group of experts working with regional landslide early warning systems have been brought together to discuss the methodology used in the warning systems. Representative institutions for the following countries Norway, USA, UK, Iceland, Italy, Austria, Switzerland, France, Germany and Sweden participate to the 3 days international workshop organized by NVE in Oslo, Norway from the 26th to 28th of October 2016.

The types of landslides that were the focus of the workshop were rapid mass movements triggered by rainfall and snowmelt like shallow slides, debris flows and debris avalanches, however the warning of other type of landslide like deep seated slide was also mentioned, since it is carry out in some countries. The workshop has been discussing the state of the art on EWS in the different countries, providing overview of the countries that runs national regional EWS and the progress. The workshop discussed methods about how to predict and communicate risk related to rainfall and snowmelt induced landslides at a regional scale. The group discuss topic like the importance of landslide inventory, thresholds development, validation of performance. A major outcome of the workshop has been the establishment of an international group of expert working with the subject. The group

intend to have annual future meetings in order to share knowledge about all aspects of the methodology used for early warning of landslides at a regional scale.

For the NVE, the workshop proved an opportunity to present todays status of the Norwegian landslide EWS. The international community responded positive to the capabilities of the system, as inspiration for future work in their respective countries. Useful feedback was also addressed, such as how to communicate to end-users, how to continue to improve the work between Norwegian rail and road authorities and the NVE, and how to further improve the methods indicating increased risk of landslide hazard.

Internationally, the workshop will help the newly identified community in strengthening the methodology of all participants. Establishing the community could help to deliver the UNs Sendai framework addressing the problem of climate change to the change of regional scale patterns and frequencies of landslides. Also, the community should act towards stakeholders internationally via for example the EU climate services.

Appendix A – List of participants

List of international participants

Country	Institution	Name
Austria	The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management. (die.wildbach, Austria)	Rudolf Schmidt
		Margarete Wöhrer Alge
France	National competence centre for Industrial Safety and Environmental Protection (INERIS, France)	Stella Coccia
Germany	Germany's National Meteorological Service (DWD, Germany)	Stefan Bach
Iceland	Icelandic Met Office (IMO, Iceland)	Jón Kristinn Helgason
		Harpa Grímsdóttir
Italy	Regional Agency for the Protection of the Environment (ARPA Piemonte, Italy)	Roberto Cremonini
		Davide Tiranti
	National Research Council/Research Institute for Geo-Hydrological Protection (CNR-Irpi, Italy)	Fausto Guzzetti
	University of Salerno (UNISA, Italy)	Luca Piciullo
Sweden	Swedish Geotechnical Institute (SGI, Sweden)	Charlotte Cederbom
Switzerland	Swiss Federal Institute for Forest, Snow and Landscape Research (WSL, Switzerland)	Manfred Stähli
UK	British Geological Survey (BGS, UK)	Tom Dijkstra
		Helen Reeves
	Met Office (Met Office, UK)	Joanne Robbins
USA	U.S. Geological Survey (USGS, USA)	Dennis Staley

List of Norwegian participants

Institution	Name
Geological Survey of Norway (NGU)	Knut Stalsberg
Norwegian Meteorological Institute (MET), Oslo	Tor Skaslien
Norwegian Meteorological Institute (MET), Bergen	Geir Ottar Fagerlid
Norwegian Meteorological Institute (MET)	Helga Therese Tilley Tajet
Norwegian Geotechnical Institute (NGI)	José Cepeda
Norwegian National Rail Administration (BANE NOR)	Geir Vatne
Norwegian National Rail Administration (BANE NOR)	Per Lars Erik Wiréhn
Norwegian Public Road Administration (SVV), Oslo	Roald Aabøe
Norwegian Public Road Administration (SVV), Molde	Tore Humstad
Norwegian Public Road Administration (SVV), Oslo	Heidi Bjordal
Norwegian Public Road Administration (SVV), Region Midt, Trondheim	Gunnar Djup
Norwegian Public Road Administration (SVV), Region Midt, Trondheim	Martine Holm Frekhaug
Norwegian Public Road Administration (SVV), Region Nord, Tromsø	Johan Kristofers
Norwegian Water resources and Energy Directorate (NVE)	Søren Boje
Norwegian Water resources and Energy Directorate (NVE)	Hervé Colleuille
Norwegian Water resources and Energy Directorate (NVE)	Mads-Peter Dahl
Norwegian Water resources and Energy Directorate (NVE)	Graziella Devoli
Norwegian Water resources and Energy Directorate (NVE)	Inger Karin Engen
Norwegian Water resources and Energy Directorate (NVE)	Anne Fleig
Norwegian Water resources and Energy Directorate (NVE)	Per Glad
Norwegian Water resources and Energy Directorate (NVE)	Heidi Anette Grønsten
Norwegian Water resources and Energy Directorate (NVE)	Anne Haugum
Norwegian Water resources and Energy Directorate (NVE)	Hege Hisdal
Norwegian Water resources and Energy Directorate (NVE)	Morten Johnsrud
Norwegian Water resources and Energy Directorate (NVE)	Delia Kejo
Norwegian Water resources and Energy Directorate (NVE)	Ingeborg Kleivane Krøgli
Norwegian Water resources and Energy Directorate (NVE)	Heidi Lee
Norwegian Water resources and Energy Directorate (NVE)	Ann-Live Leine
Norwegian Water resources and Energy Directorate (NVE)	Zelalem Mengistu Tadege
Norwegian Water resources and Energy Directorate (NVE)	Aart Verhage
Norwegian Water resources and Energy Directorate (NVE)	Thea Caroline Wang
University of Oslo (UiO)	Simon Anfinnsen
University of Oslo (UiO)	Sara Bugge
University of Oslo (UiO)	Gaute Øyehaug

Appendix B - Program

Wednesday 26. October 2016

9:00-10:30	- Arrival and registration
10:30-10:50	**Opening and welcome** (Morten Johnsrud, NVE) - **Purpose of the workshop** (Graziella Devoli, NVE) *Room: Glomma (1st floor)*
10:50-12:00	**The Norwegian landslide warning system** - "*Regional early warning for soil slides, debris flows, and slush flow in Norway"* and *"The application of the landslide early warning along transportation lines in Norway* Hervé Colleuille, NVE and Tore Humstad, Norwegian Public Roads Administration, SVV) Questions (10 min) *Chair: Graziella Devoli (NVE)* *Room: Glomma (1st floor)*
12:00-13:00	*Lunch - Room: Glomma (1st floor)*
13:00-14:15	**State of the art about national and regional EWS in the different countries** 13:00-13:25 - *"Landslide and Debris-Flow Early Warning in the United States."* (Dennis Staley, USGS) (15 min) Questions (10 min) 13:25-13:50 - *"Daily landslide hazard assessments; the use of process models and weather regimes to enhance the capability to issue regionally specific forecast and provide longer outlooks."* (Tom Dijkstra, Helen Reeves, Katy Freeborough, Claire Dashwood, Joanne Robbins, Rutger Dankers, BGS-Met Office, UK) (15 min) Questions (10 min) 13:50- 14:15 - *"Early warnings for shallow landslides in Iceland"* (Harpa Grímsdóttir and Jón Kristinn Helgason, Vedur) (15 min) Questions (10 min) *Chair: Mads-Peter Dahl (NVE)* *Room: Glomma (1st floor)*
14:15-14:30	*- Coffee break*
14:30-16:30	**State of the art about national and regional EWS in the different countries** *Presentation of 15 min for each country*

14:30-14:55 - *"EWS for rainfall-induced slope phenomena: shallow landslides and channelized debris flows in Piemonte, Italy"*
(Davide Tiranti and Roberto Cremonini, ARPA Piemonte) (15 min)
Questions (10 min)

14:55-15:20 - "*Towards an operational rainfall induced landslide early warning system for Italy"*
(Fausto Guzzetti, CNR) (15 min)
Questions (10 min)

15:20-15:45 - "*Monitoring and early warning systems in Austria – an overview*" (Rudolf Schmidt and Margarete Wöhrer Alge, die Wildbach) (15 min)
Questions (10 min)

15:45- 16:10 - *"Early warning systems for landslides in Switzerland"*
(Manfred Stähli, WSL) (15 min)
Questions (10 min)

Chair: Mads-Peter Dahl (NVE)
Room: Glomma (1st floor)

16:30-17:00 **Visit E-warning room**
Guide: Søren Boje (NVE)
Room: Flomvarslingsrom (3rd floor)

17:00-19:00 **Poster, Tapas and Drink**
Room: Vettisfossen (7th floor)
Logistic: Heidi Lee (NVE)

Thursday 27. October 2016

9:00-9:30 **State of the art about national and regional EWS in the different countries**
Presentation of 15 min for each country

9:00-9:30 - *"Early warning systems for rainfall-induced landslides in Sweden"*
(Charlotte Cederbom, SGI) (15 min)
Questions (10 min)

Chair: Graziella Devoli (NVE)
Room: Vettisfossen (7th floor)

9:30-10:30 **Experiences from case studies**
Presentation of 15 min and discussion

9:30-10:00 - Iceland - *"Permafrost landslide in Móafellshyrna mountain in 2012"*
*(*Jón Kristinn Helgason, Vedur) (15 min)
Discussion (15 min)

10.00-10:30 - Switzerland – *Case study from Swiss prealpine area (Emmental) from 2002 and 2005*
(Manfred Stähli, WSL) (15 min)
Discussion (15 min)

10:30-10:40 *Coffee break*

10:40-12:10 **Experiences from case studies**

10:40-11:10 - USA – *Case study on expansion of the post-fire debris-flow early warning system, currently operational in southern California, to other areas in the western United States ."*
(Dennis Staley, USGS) (15 min)
Discussion (15 min)

11:10-11:40 - Norway - *Landslide events in Gudbrandsdalen in June 2011 and May 2013*
(Søren Boje, NVE) (15 min)
Discussion (15 min)

11:40-12:10 - UK – *Antecedent precipitation as a potential proxy for landslide incidence in South West UK: a case study reflecting on 2012/2013 landslide season*
(Tom Dijkstra, Helen Reeves, BGS) (15 min)

Discussion (15 min)

Chair: Graziella Devoli (NVE)
Room: Vettisfossen (7th floor)

12:10-12:15 Practical information about Group discussion on selected topics (Graziella Devoli, NVE)

12:15-13:00 Lunch
Canteen NVE (1st floor)

13:00-14:30 **Group discussion on selected topics**

1. The importance of reliable landslide data and feedback from field as essential information for thresholds development and evaluation of warning performance. *Theme's leaders: Helen Reeves (BGS), Manfred Stähli (WSL)*
   Room: Eidefossen (1st floor)

2. Thresholds. Recognition of dynamic thresholds and accounting for antecedences and triggering conditions.
   Theme's leaders: José Cepeda (NGI), Søren Boje (NVE)
   Room: Tysso (1st floor)

3. How do we know if a system works, or does not work? (Methods, tools and concepts for the validation of operational landslide early warning systems, and for the evaluation of their performances)
   Theme's leaders: Mads-Peter Dahl (NVE), Luca Piciullo (UNISA)
   Room: Sauda (1st floor)

4. How do we best use the forecasts, and other products, prepared by the systems? How do we communicate the risk?
   Theme's leaders: Dennis Staley (USGS), Per Glad (NVE)
   Room: Skjøli (1st floor)

14:30-14:45 Coffee break

14:45-16:30 Short presentation by theme's leaders (5 min each) and discussion
Theme's leaders
Chair: Graziella Devoli (NVE)
Room: Vettisfossen (7th floor)

16:30 – 19:00 Free
19:00 – Dinner

Friday 28. October 2016

9:30-11:00	**Exchanging best practice and International collaboration. Needs for International network/forum for rainfall-induced landslide early warning?** Discussion on Future work Establishment: Do we need an international forum for landslides EWS? Purpose: Objectives of the forum? Possible topics? Organization: How the forum should be organized? How often? Where? *Introduction by: Graziella Devoli (NVE)* *Discussion leaded by: Fausto Guzzetti (CNR-IRPI)* *Room: Vettisfossen (7th floor)*
11:00 – 12:00	Summarizing results *Summary by: Tom Dijkstra (BGS), Fausto Guzzetti (CNR-IRPI)* *Room: Vettisfossen (7th floor)*
12:00-12:30	Closure of the workshop. Important achievements *Closure by: Graziella Devoli (NVE)* *Room: Vettisfossen (7th floor)*
12:30-14:00	*Lunch* *Canteen NVE (1st floor)*

Appendix C – Selected photos from the workshop

Workshop participants. (Photo: NVE)

Plenary session (Photo: H. Colleuille, NVE)

Plenary session (Photo: H. Colleuille, NVE)

Visiting the warning room at NVE (Photo: H. Colleuille, NVE)

Visiting the warning room at NVE (Photo: H. Colleuille, NVE)

Norges vassdrags- og energidirektorat

Middelthunsgate 29
Postboks 5091 Majorstuen
0301 Oslo

Telefon: 09575
Internett: www.nve.no