STATENS GEOTEKNISKA INSTITUT
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Baltic Challenges and Chances for local and regional development generated by Climate Change

-Tools for soil movements (landslides and erosion)

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Tools for soil movements (landslides and erosion)

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PREFACE

This report is part of the project Baltic Climate, financed by EU Baltic Sea Region Programme 2007-2013 and the partners. Although this report hasn't been implemented in the vulnerability assessments conducted within BalticClimate, supporting material on soil movements was whished for. Therefore this report was compiled. The results in this report can be used as complement to The Baltic Climate Toolkit for spatial planning on regional, local and detailed level. The main purpose of the toolkit section is to highlight the importance of **climate change mitigation and adaptation aspects in spatial planning.** http://www.toolkit.balticclimate.org

The work presented here has been done by the Swedish Geotechnical Institute (SGI) on behalf of the Centre for Climate Science and Policy Research (CSPR) in Sweden.

In this report, only the parts of the Baltic Climate Toolkit (BCT) where soil movements are considered are described in brief (Chapter 3). The aim with Chapter 3 is to indicate for those working with the Baltic Climate toolkit if there are other and more detailed tools that can be used as a complement to BCT for aspects regarding soil movements. The aim with this report is also to inform on where to find more information about those tools. Thereafter, the tools identified as a result of a questionnaire as well as from the investigation are presented. Some other more general tools for Climate Adaptation are also presented. In Chapter 5 a comprehensive tool used by SGI is described and examples are described in Chapter 6.

The presented tools are intended to give information for policy makers, spatial-planners and business people that there are tools that can be used to consider soil movements like landslides and erosion for spatial-planning, and for measures in already built areas. It is not possible to give general recommendations about the tools, because they are depending on e.g. the soil conditions and weather conditions on the site. The actual work with the tools, and the decision on which tool or combination of tools to use for the actual site, is intended to be done by experts in the geotechnical field.

The reviewers of this report have been Yvonne Andersson-Sköld and Bengt Rydell, SGI. Comments on the report have been received from Johan Alberth and Julie Wilk, CSPR. They are gratefully acknowledged.

Sincerely,

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CONTENT

Appendix

1. Questionnaire about tools/models for soil movements
2. List of participants in Baltic Climate and their tools/models
3. List of other organisations tools/models

1 SUMMARY

In order to establish resilient communities, mitigate damages, adapt the built environment and establish a sustainable society, there is a need for a sound decision basis for buildings, infrastructure, industry and the environment. One cornerstone to reach a sustainable development is to take natural hazards into account. Therefore a survey has been made of different tools/models for spatial planning to assess aspects like local consequences of flooding, landslides or erosion, for the situation today and also for consequences due to Climate Change. The tools regarding soil movements can be used as complement to more general toolkits e.g. toolkit in the Baltic Climate (BC) project. In the BC toolkit the question to consider soil movement is raised, and suggestions on how to deal with them are given in this report. The survey has been based on a literature study and a questionnaire sent to partners in the BC project, member states of the "International Strategy for Disaster Reduction" and partners cooperating with Swedish Geotechnical Institute (SGI). The investigation shows that there is a general lack of tools for soil movements in the countries in the Baltic Sea Region and that most of the existing ones does not take climate change into consideration. However, methods have been developed in Sweden during the last years.

In Chapter 4 tools, models or methods[1], used in other countries, which could be used as complement to the BC tool kit, are described. When and how to use them depend on the specific situation and soil conditions for the actual site. Many of the tools mentioned can be used only for one specific problem. In Chapter 5 a tool for managing and assessing the risk related to soil movements, developed by the Swedish Geotechnical institute (SGI), is described. This tool is described more in detail than the others, as it provides a structured procedure for working with soil movements.

The natural hazards that can be dealt with in the SGI model are mainly landslides, erosion and consequences of flooding. The version of the model presented in this report has not been reported before. The model describes the potential risk related to a particular natural hazard, including identifying prerequisites or the probability that it will occur combined with the related consequences it may cause. For potential hazards the output can be a hazard map, and for potential risk areas the output can be a risk map. Relevant tools for identifying and assessing risk mitigation strategies can be databases or other information on previous experiences of strategies including pros and cons. They also can be descriptions of functionality and related costs for investment. Hazard and risk mapping could be carried out using different methodologies which are described in the report. For possible measures in spatial planning or for adaptation of the built environment socio-economic analyses and environmental assessments could be carried out. National and regional inventories of the natural hazards are necessary for spatial planning, to get an overview of risk areas or making priorities for preventive measures. At the local level the SGI tool can be used as a base for spatial planning, decision making of alternative measures in a municipality or at a specific location. The tool can also be used before investments are made in an area. The SGI tool has been used in practical

[1] The words tools/models or methods are used interchangeably in the report, but depending on which word that best suits the situation.

cases both on a regional and local level and examples are provided in the report in Chapter 6.

In Chapter 7 a short introduction is given to a method for risk analysis and risk management for road owners in Europe, with regard to climate change. Chapter 8 compiles some examples of general methods for climate adaptation.

2 INTRODUCTION

The Swedish Geotechnical Institute (SGI) has, on behalf of Centre for Climate Science and Policy Research (CSPR) within the project Baltic Climate, carried out a survey on existing tools/ models for spatial planning used in the transport or the housing sector. The aim was to investigate the use of tools/models to assess aspects like local consequences of landslides or erosion, for the situation today and also for consequences due to Climate Change. The tools regarding soil movements can be used as complement to more general toolkits e.g. toolkit in the Baltic Climate project.

The survey has been based on a literature study and a questionnaire (Appendix 1). The questionnaire has been sent to the partners and associated members in the Baltic Climate project and also to member states of the "International Strategy for Disaster Reduction" (ISDR). Permission for sending the questionnaire has been issued by UNISDR the secretariat for ISDR. Also other contacts with people working with landslides and erosion have been taken in order to get further information about existing tools. The results from the questionnaire are shown in this report, Appendix 2 and 3.

In order to establish resilient communities, mitigate damages, adapt the built environment and establish a sustainable society, there is a need for a sound decision basis for buildings, infrastructure, industry and the environment. One cornerstone to reach a sustainable development (including economic growth) is to take natural hazards into account. By incorporating natural hazards like landslides and erosion and risk mapping into long-term plans for urban areas, new developments can be diverted away from risk areas and the risks in existing urban areas can be reduced. Assessment of activities for prevention of landslides and coastal hazards should be used to maximise the benefits of measures or investments. Furthermore, attention should be given to integration of landslides and coastal hazards into the decision making process and for coastal hazards particularly into the Integrated Coastal Zone Management (ICZM).

In many countries, investigations have started to identify risks of natural hazards such as coastal erosion, landslides and flooding, but the investigations do not always incorporate the effects of climate change. Furthermore, the investigations are normally restricted to currently developed areas.

Urban areas close to the coast, rivers or waterways can be affected by coastal erosion, flooding and instability of slopes. The predictions on global climate change include sea level rise, increased precipitation and runoff and more intense and damaging storms will increase the threats of natural hazards. Such risks are, in addition to environmental threats, highlighted especially in the Baltic Sea region. In Wiréhn et al. (2011) the current knowledge on climate change impacts on the Baltic Sea Region (BSR) is summarised. A general outlook for flood events as interpreted from the results in Lehner et al. (2006) in the BSR is shown in *Table 2-1*.

Table 2-1. General outlook for flood events (Wiréhn et al. (2011), Lehner et al. (2006)) (↑↑ Considerable increase; ↑ Slight increase; ~↑ Outcome uncertain, increase tendency)

	SWE	FIN	EST	LAT	LIT	RU	GER
Change	↑↑	↑↑	~↑	~↑	~↑	↑	~↑

The current knowledge on direct effects of climate change on soil movements with evaluations of future risks in Sweden is presented in a report from the governmental investigation by the Swedish Commission on Climate and Vulnerability (SOU 2007:60) and more in detail in the appendix B14 describing the risks for landslides, erosion and flooding in future climate (Alm et al., 2007). According to the review performed in this project, climate change impacts on the natural environment are at present not including any similar or corresponding investigations in the other BSR countries.

As a basis for the governmental investigation a study reported in Fallsvik et al. (2007) investigated potential future projections of erosion, ravine formation, landslide and mud flows in Sweden for the period 2071-2100. The study was made as a comparison to the reference period 1961-1990 and was based on regional scale climate change simulations by the Swedish Meteorological and Hydrological Institute (SMHI), using RCA0/RCA3 based on ECHAM4 A2 (Persson et al., 2007, Fallsvik et al., 2007). In addition, the SMHI hydrological model HBV was used for discharge calculations. The analysis was only performed for areas vulnerable to erosion, ravine formation (or gully development), landslide and mud flows (or debris flow). A general projection of future erosion, ravine formation, landslide and mud flow risks in Sweden is illustrated in *Table 2-2*.

Table 2-2. Climate change impacts on natural environment in the Baltic Climate countries (Wiréhn et al. (2011) ↑ Slight increase; ↓ Slight decrease; — Not included in the analysis)

Climate change impacts on:	**SWE**	**FIN**	**EST**	**LAT**	**LIT**	**RU**	**GER**
Erosion	↑ and ↓	—	—	—	—	—	—
Ravine formation*1)	↑ and ↓	—	—	—	—	—	—
Landslide	↑	—	—	—	—	—	—
Mud flow*2)	↑ and ↓	—	—	—	—	—	—

*1) Also called gully development.

*2) Also called debris flow.

As can be seen, the trend depends on several factors and there may be either a general increase or decrease for most of the events apart from landslides where there is a general increasing trend. However, even for the probability of landslide there will be a slight decrease in some of the areas susceptible for landslides. The landslide risk is estimated to increase for almost all of the analysed areas apart from a few regions in the south-eastern parts of Sweden where the probability is projected to decrease or to be unchanged. For further details see Fallsvik et al. (2007).

The erosion risk will change in many of the analysed areas. There will be both an increase and decrease. Increased erosion risk in river banks is expected for the south west coast and parts of the north east coast (Fallsvik et al. 2007). In some regions in eastern Sweden the erosion risk is expected to decrease. Coastal erosion will increase due to sea level rise along almost all the Swedish coasts, especially in the south parts as an effect of isostatic land rise.

The estimated change of ravine formation showed the same tendency as erosion, namely, the south west coast and the north east coast are projected to have increased risk of ravine formation. The risk of mud flow is projected to increase in the north western half of Sweden; more than half of the analysed area is projected to have increased mud flow risk.

An important input to the calculations and analysis in general is the climate scenarios, but the modelling of climate scenarios is not included in this report. However it is important to follow the development in climate analysis and update the analysis for soil improvement if the results of climate analysis change largely.

Below, in Chapter 3, there is a short description of the parts in the Baltic Climate toolkit where soil movements are considered. The aim of Chapter 3 is to describe for users of the Baltic Climate toolkit that there are a number of more detailed tools that can be used as a complement to the toolkit for aspects regarding soil movements. The aim with this report is also to inform on where to find more information on the tools.

In Chapter 4, tools, or models, which could be used as complements to the BC toolkit are described. When and how to use them depends on the specific situation and soil conditions for the actual site. Many of the tools mentioned can be used only for one specific problem. In Chapter 5, a tool for managing and assessing the risk related to natural hazards such as landslides, erosion and flooding is described. This tool is described more in detail than the other models, as it provides a structured procedure for working with soil movements. For some of the parts in the tool in Chapter 5 examples are given in Chapter 6 and Chapter 6.3 on how the methodology has been used. In Chapter 0 a short introduction is given to a method for risk analysis and risk management for European roads, with regard to climate change. Chapter 8 is dealing with examples of general methods for climate adaptation.

3 BALTIC CLIMATE GENERAL TOOLKIT

The Baltic Climate Toolkit can be used for planning on the regional, local and detailed level. The main purpose of the toolkit section is to highlight the importance of climate change mitigation and adaptation aspects in planning (http://balticclimate.dms.ee/). The toolkit is developed in the project Baltic Climate, financed by EU Baltic Sea Region Programme 2007-2013 and the partners. The aim with this chapter is to indicate for users of the Baltic Climate toolkit that there are a number of more detailed tools that can be used as a complement to the toolkit for aspects regarding soil movements. The parts in the toolkit are mentioned in this chapter. The tools on soil movements are described in Chapter 4, 5 and 0 and consist of climate and vulnerability analyses concerning natural hazards (e.g. erosion, landslides, flooding). They can be used for adaptation aspects especially for spatial planning for new areas and also in already built areas to ensure a safe, healthy and sustainable society.

The Baltic Climate toolkit is divided in three parts for three different types of users: policy makers, spatial planners and business people. The analyses described in the toolkit can be performed on the national, regional and local levels.

Decisions made in planning create a built environment that lasts for decades and thus the adaptation aspect is crucial. Adaptation to the future climate conditions, including flooding etc. should be one of the starting points of the planning process proposed in the Baltic Climate toolkit.

The users for whom the tools in this report will be most useful is spatial planners and policy makers. In this chapter the sections of the Baltic Climate toolkit that involve natural hazards, like landslides, erosion and floods, will be presented Suggestions on how to deal with soil movements are given in this report.

3.1 Tools for spatial planners

The Baltic Climate toolkit for spatial planners, see *Figure 3-1* helps to identify the role of the planning process in dealing with the issue of climate change.

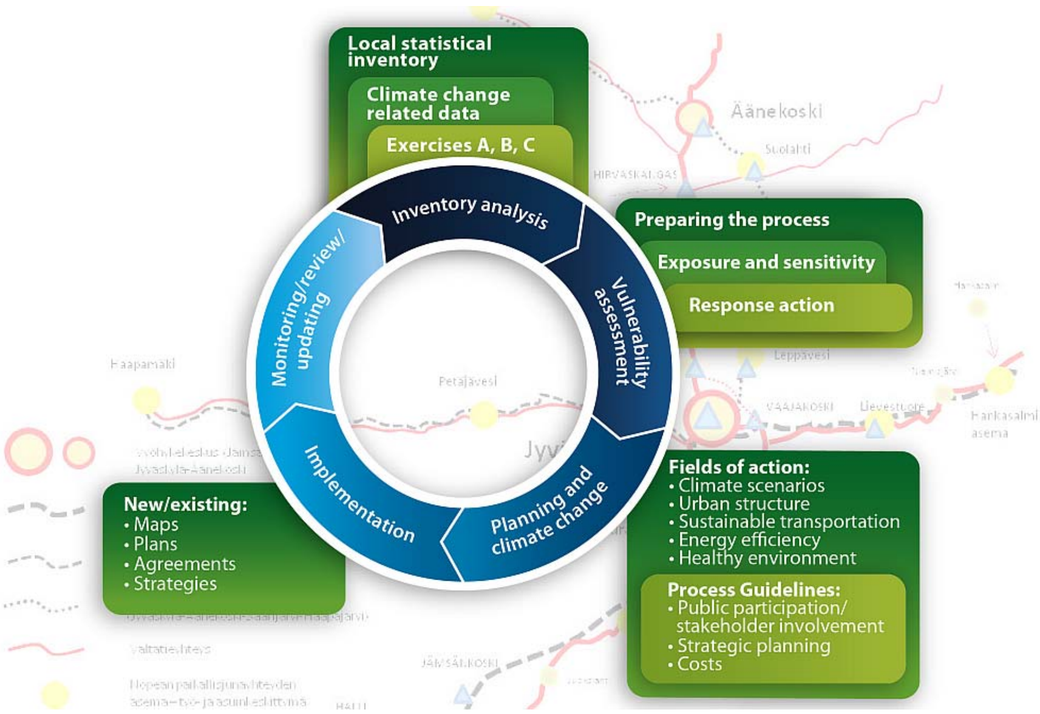

Figure 3-1. The Baltic Climate toolkit for spatial planners. (http://www.toolkit.balticclimate.org/en/spatial-planners/introduction).

The process starts with the Inventory Analysis of necessary data to assess local challenges and chances generated by climate change. The inventory is followed by the Vulnerability Assessment of the local area. The Planning and climate change section (see *Figure 3-2*) gives a detailed overview, in the case of natural hazards, on the effects of climate change on planning. The Implementation stage includes new/existing maps, plans, agreements and strategies and those can include the impacts of natural hazards.

The spatial planners' planning process is schematically present in *Figure 3-2* and the sections especially dealing with landslides, erosion and flooding are shown under "Planning and climate change". These are "Local climate and future climate change scenarios" and "Compact and diverse urban structure".

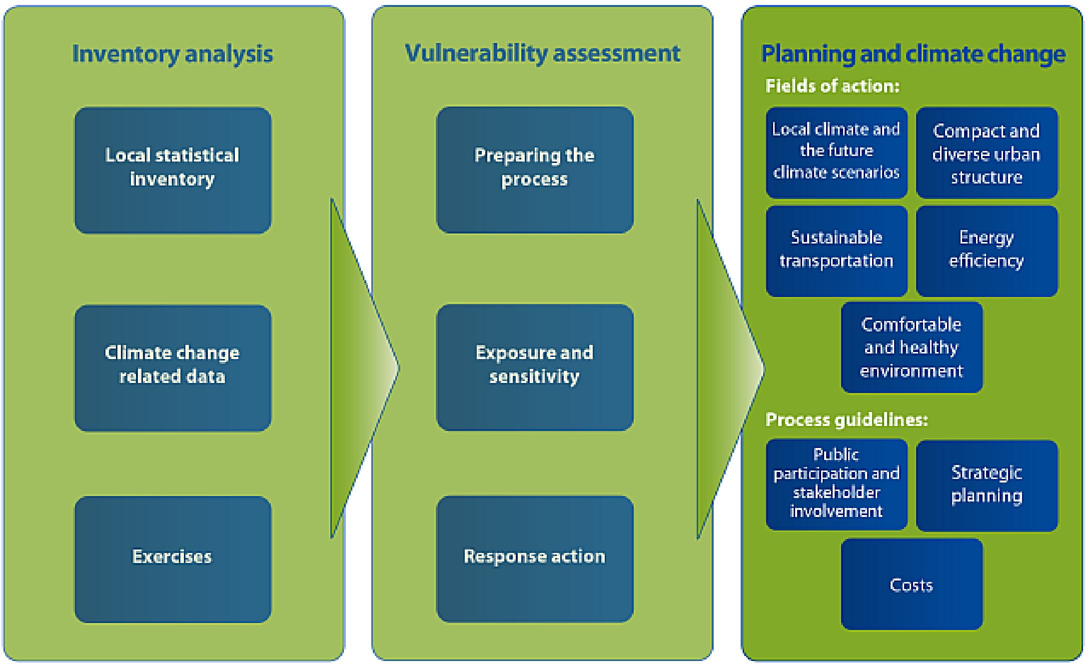

Figure 3-2. The planning process for spatial planners. (http://www.toolkit.balticclimate.org/en/spatial-planners/planning-and-climate-change).

The different steps that include soil movements in these sections, taken from the BC homepage (http://www.toolkit.balticclimate.org) are described below.

3.1.1 Local climate and the future climate scenarios

- Minimise the risks caused by the extreme meteorological events

Heavy rains will increase the need for storm water management. A compact urban structure with non-permeable (i.e. asphalt) surfaces increases the chances of urban flooding if storm water management systems are not updated to the future requirements. Green areas can act as buffer zones for urban flooding and protection against erosion. In areas with less dense population, heavy rains can also create problems for the infrastructure, e.g. smaller roads can be damaged by landslides, and river banks can collapse.

- Account for climate change risks and impacts within the impact assessment processes related with planning

Prevent or minimise building in areas with climate risks. It is essential to determine areas at risk for floods, landslides, erosions and other risks and restrict building in these areas and protect these vulnerable areas. Good tools for identification of these areas are existing topographic maps or flood risk maps. Highly vulnerable areas can benefit from the use of warning systems (heavy rain or heavy wind).

3.1.2 Compact and diverse urban structure

- Implement and promote compact and sustainable land use

Analysis of the present structure will identify opportunities for compact urban and spatial structure. Detailed analysis of the present land use and the future needs can also bring about new innovations. Pay special attention to the existing area's location, housing types, and the efficiency of present land use. Roads and other infrastructure should be planned in a way that also the future climate conditions are taken into consideration (landslides, heavy rains, frost etc.).

3.1.3 Climate change impact scenarios

Under the section Climate Change related data, *Figure 3-2*, there is a sub section for future climate where several climate change impact scenarios are divided into sectored themes. The one that consider soil movements is natural environment.

- Natural environment

This section points out the direct effects of climate change on soil movements with evaluations of future risks in Sweden (SOU 2007:60 and Fallsvik et al., 2007). The future projections of erosion, ravine formation, landslide and mud flows for Sweden 2071-2100 compared to the reference period 1961-1990.

Comment: In this report a tool for dealing with infrastructure is given in Chapter 7. Other methods to assess risks for floods, landslides, erosion, ravine formations and debris flows in building areas where future climate conditions are considered, are reported in Chapter 4 and 5.

3.2 Tools for policy makers

For the category policy makers there are also parts of the Baltic Climate toolkit considered with natural hazards such as flooding, landslides and erosion. In the section "Getting into action" there is a subsection for "Plan and implement". This subsection is divided into regional, general and detailed planning level. For these levels there are parts concerned with soil movements which are presented in this chapter.

3.2.1 Regional planning level

- Identifying possibilities and challenges in present and future climate

One factor to consider is minimising the risks of flood, landslides and erosion.

3.2.2 General planning level

- Minimising the risks of flood, landslides and erosion

Like in the regional planning also in general planning level one of the factors to consider is to minimise the risks for soil movements.

An example is given from the county of Gävleborg, who has been working with the challenges of climate change, both positive and negative. Several of the challenges are related to the increased risk of soil and ground movements such as erosion, ravine formation and debris flow but also flooding. (http://www.toolkit.balticclimate.org/en/policy-makers/getting-into-action/plan-and-implement/general-planning-level/program-for-comprehensive-plan-for-gavle-municipality).

Comment: In this report tools or models to assess risks for floods, landslides and erosion in new or existing building areas are reported in Chapter 4 and 5. Some of the tools can be used both for regional, local and general planning level depending on the available input. In this report also a tool for dealing with infrastructure is given in Chapter 7.

3.3 Future climate scenarios

Within the Baltic Climate project future climate scenarios were prepared for Target Areas in Estonia, Finland, Germany, Latvia, Lithuania, Russia and Sweden. The results can be found on the web site for the project.

Comment: The climate scenarios within the Baltic Climate could be used with other tools depending on which spatial level that are being studied.

4 MODELLING TOOLS FOR SOIL MOVEMENTS

An inventory was made of models/tools for soil movements (landslides, ravine formation, mud flow and erosion). A questionnaire (Appendix 1) was sent to the Baltic Climate partners and associated organisations in BSR and to other relevant organisations outside the project. A literature survey was also conducted. The tools in this chapter can be used as a complement to the Baltic Climate toolkit. It is not possible to give general recommendations about the tools, because they are depending on e.g. the soil conditions and weather conditions on the site. The actual work with the tools, and the decision on which tool or combination of tools to use for the actual site, is intended to be done by experts in the geotechnical field. The aim with the presented tools is to give an overview of different tools and ideas on how to consider different geotechnical aspects for the particular situation. The choice of the tools and or combination of tools will always depend on if the purpose of the tool matches the requirements of the actual case. There are also references on where to get more detailed information about each of the tools.

4.1 Modelling tools used among partners in the Baltic Sea Region

One aim with this project as a part of the Baltic Climate was to investigate the general use of tools/models in the spatial planning process, as well as the use of tools/models used to assess aspects like local consequences of landslides or erosion, for the situation today and also for consequences due to climate change. To be able to investigate if model/tools for soil movements that also take climate change into account are currently in use among the countries in the BSR, a questionnaire was sent to the partners and associated organisations in BC. The questionnaire is shown in Appendix 1 and a list of participants in BC is shown in Appendix 2 together with more information about the models/tools in use.

The survey showed that the BalticClimate participants from Germany plan to use the BC toolkit and they have not used any other models for soil movements. In Estonia, one answer mentioned that general tools used included sustainable principles fixed in the municipality general strategy and land use plan. Another answer from Estonia showed that there is a need for a model for infrastructure. In Finland the BC toolkit will be used for regional planning and there are flood hazard maps available on national level. They also have an industry SWOT-tool as a decision tool for Climate Adaptation. In Lithuania there is a model for erosion in sea banks and also a decision tool for Climate Adaptation on ministry level.

The investigation shows that there is a general lack of tools for soil movements. Except for the Lithuania erosion tool, the other mentioned tools in the questionnaire do not include soil movements. In Sweden, there is a model currently developed and used by SGI that assesses soil movements with consideration to the impacts of climate change. It will be described in Chapter 5.

4.2 Model tools outside BSR

A survey of tools/models of soil movements was also conducted outside the BSR to determine if any tools for soil movements exist and could be of use as a complement to the BC toolkit. Therefore the questionnaire in Appendix 1 was sent to member states of the "International Strategy for Disaster Reduction" (ISDR) and also to other contacts that SGI has who deal with landslides and erosion. Results from the questionnaire are shown in Appendix 3. The questionnaire was answered by persons from France, Hungary, Italy, Norway, Poland and Slovakia where models for soil movements are in use. The models in Hungary, Italy, Poland and Slovakia do however not take climate change into consideration.

In France there is a deterministic model for risk/hazard mapping coupled with a probalistic geomechanical model. For erosion there is a hill slope physical model. Some works from France are described in Chapter 4.2.3.

In Hungary a geological hazard source register is available, which can warn, at settlement level, the existence of some incident(s)/phenomena or unfavourable conditions.

There are risk maps for many urban areas. For larger regions/areas mapping is in progress. At the settlement structure plan (spatial planning) level, geological conditions and risk sources are/can be taken into consideration. The Hungarian Office for Mining and Geology on the basis of legal requirements provides data and opinions as a respective authority to the National, Stressed Regions to County and Settlement structure plans. Due to the lack of detailed maps covering the whole country, the Hungarian Office for Mining and Geology in many cases is able to make only large-scale awareness rising. At those places where detailed maps already exist, it is able to make detailed recommendations. Before the end of 2011, EU Member States are invited to further develop national risk analysis, maps (Council conclusions on Further Developing Risk Assessment for Disaster Management within the European Union 8068/11 during the Hungarian EU Presidency). Before the end of 2012, the European Commission, based upon the available national risk analysis for flooding, will prepare an overview of the major natural and man-made risks that the EU may face in the future. According to these approaches, National Directorates General for Disaster Management (NDGDM) has already started the work to further analyse national risks.

In Italy, landslide and flood risk is regulated by a national law which introduces specific governmental agencies in charge of land planning and management, called Basin Authorities. Accordingly, 36 Basin Authorities were created, national, inter-regional or regional. Each authority has produced from 1999 onward its own Hydro geomorphological Setting Plan, which comprehends landslide and flood susceptibility/hazard and risk maps. Regarding the methodologies adopted, a variety of models have been used, from euristic to statistical.

In Norway the Directorate for Civil Protection and Emergency Planning has a general model/guide for land use planning. The Norwegian Water Resources and Energy Directorate have the administration/responsibility for floods and landslide in Norway. They also have specific model/guideline to handle this. Models from Norway are described in Chapter 4.2.4.

In Poland there are different kinds of risk/hazard mappings available. They are also using X-beach model for coastal erosion and overflow implemented as an Early Warning System for storm impact developed in 7FP MICORE project.
http://www.micore.ztikm.szczecin.pl.

In Slovakia maps exist of the susceptibility of landslides, landslide risk and of landslide hazards. For erosion there is a susceptibility map. The models used are described in Chapter 4.2.5.

The literature survey revealed that a large range of conference papers can be of interest when working with soil movements for example papers from the Ventor (2007), Landslide and Climate Change, International Conference. In the proceedings, papers on particular soil conditions or weather conditions can be found. Fish et al. (2007) describes the EU project "Response: Applied earth science mapping for evaluation of climate change impacts on coastal hazards and risk across the EU". The described methodology employs commonly available digital data sets in GIS to assess regional-scale levels of coastal risk through production of series of maps. The outputs of the methodology comprise factual data maps and thematic maps and non-technical summary maps as planning guidance. An application and implementation of the Response methodology for the Aquitaine and Languedoc Roussillion coast lines is described by Vinchon et al. (2007).

Interesting new papers have also been found in the proceedings from the Conference Rome (2011), Second World landslide Forum, arranged by International Consortium on Landslides (ICL), a worldwide network for landslides research.

4.2.1 EU Project KULTURisk

An on-going EU project financed by the 7th Frame Work Programme is the KULTU-Risk project. It aims at developing a culture of risk prevention by evaluating the benefits of different risk prevention initiatives. This evaluation will be carried out by developing a novel methodology and referring to different types of water-related catastrophes, such as river inundations, urban flash floods, storm surges, rainfall triggered debris flows and landslides. The project has started in January 2011 and will continue until 2013.

In order to demonstrate the advantages of prevention options, an original methodology will be developed, applied and validated using specific European case studies, including trans boundary areas. The benefits of state-of-the-art prevention measures, such as early warning systems, non-structural options (e.g. mapping and planning), risk transfer strategies (e.g. insurance policy), and structural initiatives, will be demonstrated.

KULTURisk will focus on water-related hazards such as the likelihood and adverse impacts of water-related catastrophes that might increase because of land-use and/or climate changes. In particular, a variety of case studies characterised by diverse socio-economic contexts, different types of water-related hazards (floods, debris flows and landslides, storm surges) and space-time scales will be utilised.

More information about the project will be found at the website http://www.kulturisk.eu.

4.2.2 Landslide and ground water modelling in the UK

A selection of different programmes and projects in the UK that can be of interest for adaptation concerning soil movements is presented in the following section.

In the UK there is a Climate Impact Programme (UKCIP) that contains a range of tools, methods and guidance which can be used for climate adaptation. The programme demonstrates how and where they fit into a risk-based planning process. The tools are intended to help organisations identify how they might be affected by climate change and what they can do to minimise their risks or exploit the opportunities. There are different tools for e.g. different target groups like business and local authorities. There is also a National Appraisal of Assets and Risk from Flooding and Coastal Erosion. Examples are given on adaptation options at the website http://www.ukcip.org.uk/tools.

The impact of climate and climate change on slopes at infrastructure has been described in Loveridge et al. (2010). During the wet winter of 2000-2001 about 30 earthworks failures occurred in the Railtrack Southern Region. Considering data about past failures can assist in understanding risk factors for specific sites. These factors are set in the context of a changing climate to discuss how failure mechanism and risk assessments may need to be reassessed in the future. Important factors are soil strength, pore water pressure, permeability and vegetation. As rainfall intensity increases, the critical permeability for infiltration will also increase, and therefore sites at greatest risk from rainfall-triggered instability may change. More intense rainfall will mean that drainage and drainage maintenance become increasingly important.

In the project “The UK biological and engineering impacts of climate change on slopes (Bionics) described in Kilsby et al.(2009), the evidence suggests that climate change will have an impact on the behaviour of infrastructure slopes and their management. It also shows how climate data have been used in numerical and physical models and in full-scale tests to determine the magnitude and timing of the effects of climate change on infrastructure slopes.

The Ventnor Undercliff is an ancient landslide complex in the south cost of the Isle of Wight. The area is prone to ground movement and occasional landslide events. Investments in continuous monitoring and analysis of weather and ground movement data at key sites have been reported by Moore et al. (2010). Strong relationships have been found between rainfall, ground water and ground movement rates.

Scottish debris flow events of 2004 followed rainfall substantially in excess of the norm over 300 % of the 30-years monthly average and storm intensities of up to 150 mm/hour. The events intersected the strategic road network and people were airlifted to safety. This event is reported by Winter et al. (2011) and by Winter et al. (2010). A study started with the purpose of ensuring that hazards posed by debris flows were systematically assessed and ranked and that management and mitigation strategy was developed and implemented for the network. Reduction of exposure of road users forms the main focus. This led to a three-part management tool: Detection, Notification and Action which is described in detail in Winter et al (2011) and Winter et al (2010). A proposal has been made to introduce a reliable warning system based on these results. This involves relatively low cost measures.

Rouainia et al. (2009) have studied the effects of climate change on the slope stability of a railway cutting in clay in southern England. More specifically the shrinking and swelling due to infiltration and evapotranspiration has been modelled for different climate conditions. Successive cycles of shrinking and swelling can cause areas of reduced strength within a clay slope, leading to a progressive slope failure. Increased magnitude of these cycles has the potential to lead to slope failure in shorter times.

To describe the shrink-swell cycles, Rouainia et al. (2009) emphasized that mass permeability must be well known, since a high permeable soil allows for larger pore water variations at a certain depth than a low permeable soil. Rouainia et al. found that the mass permeability could differ three orders of magnitude from the permeability measured in triaxial tests, due to e.g. macro pores. Further, the type of vegetation significantly influences the evapotranspiration, such as water demand trees which cause larger shrink-swell cycles and therefore a faster strength degradation. However, the large suctions from the trees can counterbalance the strength degradation and increase the overall stability.

The climate change scenarios for southern England indicate increased rain intensity and decreased durations, leading to increased surface run-off and increased evapotranspiration. When comparing simulations with present climate and simulations with a 'future climate', Rouainia et al.(2009) found that, even though the shrink-swell cycle magnitude increased, the overall high suction cycle in the 'future climate' increased the stability of the slope.

Dixon et al. (2008) synthesize several studies from the UK concerned with slope stability in a changing climate. They conclude that slope stability calculations no longer can be calculated based on static information such as hydrological boundary conditions. It is suggested that models needs to incorporate short time and seasonal changes of pore pressures and handle future climate simulations. Dixon et al. further suggest integrating vegetation effects in the models, meaning that the models should handle the climate-vegetation-slope interactions.

Dijkstra and Dixon (2010) summarized much of the past research within the field of landslides and climate change. They brought to light many different approaches and emphasized the need of multidisciplinary research and a continued engagement between science based and engineering based approaches. In the paper six areas in which they mean there is an urgent need of future research were pointed out: (1) Soil parameter characterization, including variation and description of uncertainties; (2) Determining site-scale deviation from general characterizations, e.g. identifying locally overstressed zones; (3) Characterization of permeability and the links with infiltration and pore pressure in the slopes; (4) The effect of vegetation on pore pressures; (5) Key critical climate scenarios and the integration of these into a systems model, meaning the calculation needs to incorporate varying ground water boundary conditions; (6) Communicating the message of slope stability in a changing climate effectively to stakeholders and a wider public.

4.2.3 Landslide and ground water modelling in France

Baills et al. (2011) have developed a method for integrating climate change scenarios into slope stability mapping. The climate factor treated as a variable in the stability calculation is the ground water level. Ground water levels are calculated from a conceptual hydrological model driven by rainfall data, and are described as filling ratio of the maximum ground water level. The slope stability mapping is done spatially using a GIS system involving a stability calculation, also taking uncertainties in the geotechnical parameters into account.

To integrate the filling ratio of the maximum ground water level into the stability calculations, a mapping of possible minimum and maximum ground water levels has to be done beforehand. When the model has been set up it can be run using historical precipitation data and be calibrated to observed ground water levels and landslides. The model was tested in an alpine site in France called the Ubaye valley, and the steepest slopes were found to be most sensitive to high ground water levels.

4.2.4 Landslide modelling in Norway

Some examples of work in Norway with landslides and climate change are given in this chapter.

Various types of slope processes, mainly landslides and avalanches (snow, rock, clay and debris) pose together with floods the main geohazards in Norway. An interdisciplinary research project “GeoExtreme” has investigated the coupling between meteorological factors and landslide avalanches, by extrapolating this into the near future with a changing climate and estimating the socioeconomics implications (Jaedicke et al., 2007). Recorded historical events were compared with meteorological data. For example debris flow can be explained both by short-term intensive precipitation events as well as rain accumulation over a longer period of up to 15 days. Most likely this can be explained by surface erosion and slow build up of pore pressure. Snowmelt in spring is also a triggering factor in Norway. The methodology is to analyse the stability conditions for shallow landslides considering present and future precipitation scenarios, by coupling a hydrological model with infinite slope stability analysis. Taking the uncertainty of the data and difficulty to calibrate the model with actual events (from database), Monte Carlo simulations was used. The project focus was on national level and the results can be used for national priorities in climate change adaptation. Adaptation strategies need to consider regional differences.
An assessment of risks for adaptation to climate change for land-slides has been reported by Aaheim et al. (2010). The paper described how relatively detailed knowledge about probabilities of natural hazards can be used to make decisions to develop areas and control the risk within hazard zones. The purpose is to show how information can support decisions and to be able to identify unavailable information. An example is given from an land-slide prone area in Norway. There is a need to develop strategies that reduce the risks as effectively as possible for the resources set aside to adaptation.

The Norwegian Public Roads Administration has been working with a project about Climate Change and Transport during 2007-2011. The results are routines and handbooks for planning, building and management of roads. Documents for different type of landslides from the final seminar can be found at the website
http://www.vegvesen.no/Fag/Fokusomrader/Forskning+og+utvikling/Klima+og+transport/Informasjonsdager/Sluttseminar+2011

4.2.5 Landslide susceptibility assessment in Slovakia

In Slovakia a bivariate statistical susceptibility assessment has been used for the territory of Slovakia, Bednarik and Liščák (2010). Input data are Atlas of slope stability maps, digital maps of Quaternary genetical types, geological settings. The further input parametric maps are digital elevation model (DEM) derivatives - slope angle and slope aspect. DMR (or altitudes) is in close relation with climatic conditions. In their studies it has been shown that the slope deformations are almost uniformly distributed versus slope aspect. This is valid also for 551 newly evolved landslides of the year 2010 (e-mail contact Liščák 2011-09-28). The DEM was retrieved from the topography of Slovakia. Spatial information of the slope failures is the most important input factor in the process of landslide susceptibility assessment and it was retrieved from the Atlas of slope stability maps, where 21 190 slope failures were identified. The slope failure type was divided into block ridges, block fields, landslides, debris flows and rock falls. The landslides are the most abundant slope failures in Slovakia. The most effected categories are Flysch sediments and the slope deposits – colluvial and slope debris (deluvium). The output of the study is a prognostic map of landslides, see Figure 4-1. The model does not take climate change into account.

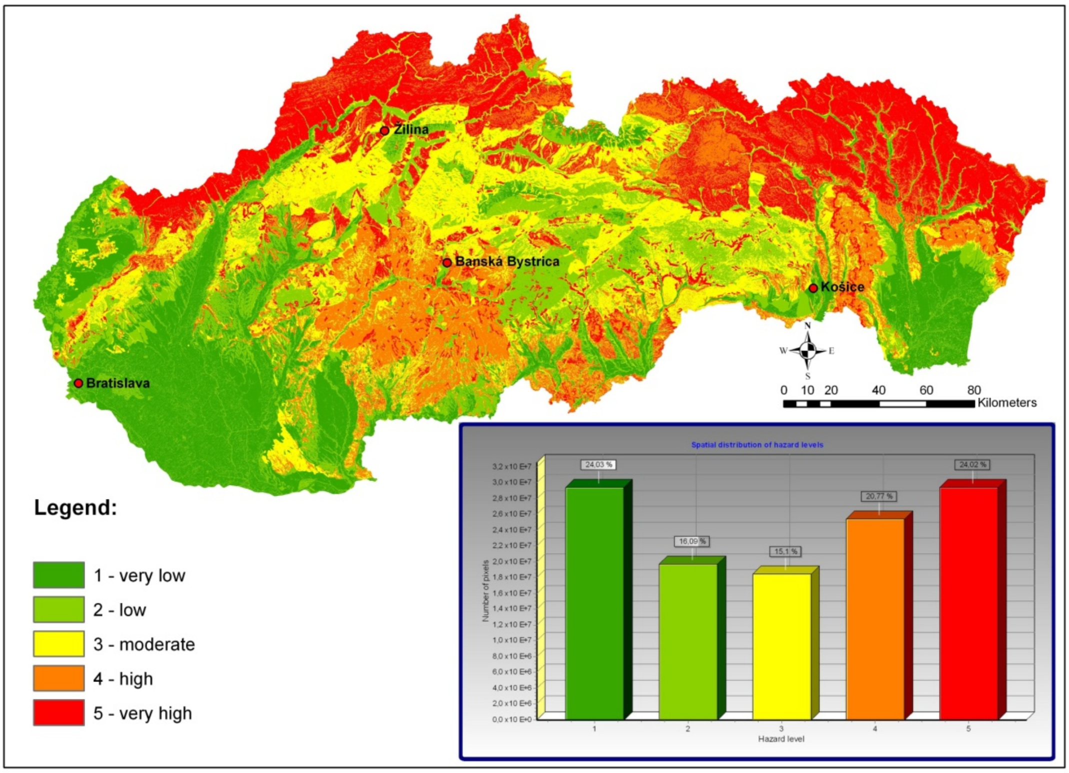

Figure 4-1. Prognostic map of the landslide susceptibility zoning. (Bednarik and Liščák, 2010).

5 CLIMATE AND VULNERABILITY ANALYSES- THE SGI METHODS FOR ASSESSING SOIL MOVEMENTS

SGI has two decision process models that are described in this report. The first one of them, a more general **matrix decision tool** shortly described in Chapter 8.2. The second one for **sustainable development and prevention of natural hazards** is more detailed and is described in this chapter. The latter model can be used for climate and vulnerability analyses as a basis for decisions concerning the best way to establish or to adapt built environment due to climate adaptation in land or in coastal areas. The two models can be used together or individually depending on the situation. For example, the matrix tool can be used in the later steps (sections 5.9 and 5.10) of the sustainable development tool described in this chapter for identifying the assets and consequences (sections 5.6 and 5.7).

The natural hazards dealt with in the SGI sustainable development model are mainly landslides, erosion and consequences of flooding. The model in this version presented here has not been reported before. The original model was developed for sustainable development in coastal areas (Rydell et al., 2008, 2011) but has been used also for other areas prone to natural hazards. The model is partly based on the results of the Interreg

Messina project (Messina 2006) and the EU Life Environment Response project (McInnes 2006). The process of the model is described in Figure 5-1. The model is based on identifying the prerequisites or probability for a natural hazard to occur (P) combined with its associated consequences (C) which will determine the risk (R = PxC). The entire model can be used or only parts of it depending on the situation. In this chapter a general description of the different stages in the model are given. In Chapter 6.3 some of the steps used in the Göta river valley investigation are described. The model has been used in practical cases both at a regional and local level, see Chapter 6.

Natural risk management requires high quality information to support effective decision-making. Hazard and risk mapping can be carried out using different methodologies depending on the scale or level of the mapping. Inventories of risks of natural hazards can be performed at the national, regional and local levels. National and regional inventories are mainly used for spatial planning, to get an overview of risk areas or making priorities for preventive measures. At the local level the tool can be used as a base for spatial planning and/or decision making of alternative measures in a municipality or at a specific location. The tool can also be used before investments are made in an area.

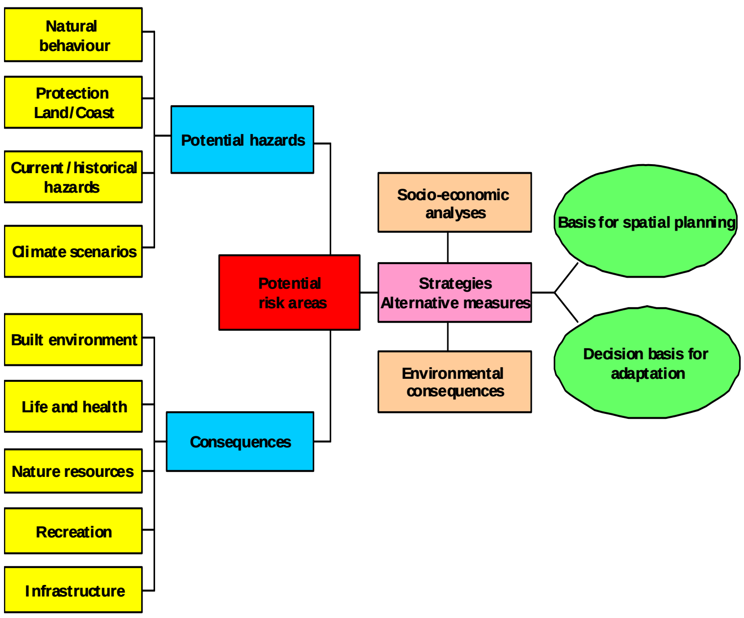

Figure 5-1. SGI decision process model for sustainable development.

At every step in the decision process model for sustainable development (*Figure 5-1*), more detailed tools/models or suggestions exist that help to handle the questions that arise at the actual step. For example under potential hazards the output can be a hazard map, and under the step potential risk areas the output can be a risk map. Other relevant tools for identifying and assessing risk mitigation strategies can be databases or other information on previous experiences of strategies including pros and cons. It could also be a description on functionality and related costs for investment. In the long-term perspective, it could also be more holistic assessments such as life cycle and multi-criteria analyses. In this chapter some of the steps are described in more detail than others, as they are lacking in other countries. If there is for example a mapping tool/model in another country that can be used instead of the one in this chapter, the other steps in the decision process model can be used together with that model.

The following sections are following the decision process model except from the assets that lead to consequences, where all the assets are given in Section 5.6. Focus has been put on potential hazards, Section 5.5, where detailed descriptions are given for different mapping methods.

5.1 Natural behaviour

Conditions which determine events that may lead to natural hazards are topographical, bathymetrical, geological, water and wind conditions as well as vegetation. Topographical conditions comprise steep and high slopes which are prerequisites for landslides as well as lowlands at the shoreline or close to lakes with flood risks. Bathymetrical data is important when evaluation coastal erosions processes. Geological conditions that determine prerequisites for landslides or erosion include soil layers with e.g. soft clay, silt and till. The model for estimation of natural risks in coastal areas is focused on erosion, stability and flooding of coastal areas including the shallow water, the beach and the dune and hinterland areas. Water conditions that constitute a risk include precipitation, high water levels and waves, water streams and high pore-water pressures in the ground. Wind in coastal areas generates high waves and sparsely vegetated areas are more exposed to wind and water.

Topographical- and bathymetrical conditions on land and in water can be determined from e.g. topographical maps, laser scanning, multi beam- or bathymetric measurements.

Since 2009, Lantmäteriet (the Swedish mapping, cadastral and land registration authority) in Sweden is carrying out airborne laser scanning (LiDAR) in accordance with a plan embracing the requirements connected to e.g. climate change. The aim is to produce a new Digital Elevation Model (DEM) with a standard error of less than 0,5 m for grid points in a 2 metre grid.

The high and low water levels in the sea and watercourses are also important to determine. For water courses, the streaming conditions must also be estimated. These parameters are important to consider also for new climate scenarios.

5.2 Protection land/coast

Existing protection measures on land or in the coastal areas will affect the assessment of potential hazards. The protection measures have to be investigated and the status of them should be determined.

5.3 Current and historical hazards

On-going and historical events should be identified. SGI has a database with maps and facts for most of the historical landslides (in soil or rock), gully development and debris flows. The database can be found on SGI website www.swedgeo.se/natural hazards.

For coastal erosion investigation and mapping has been done along the sea coast and around the lakes. The inventories give the conditions for erosion and in some cases also on-going erosion, depending on the information from the municipalities.

5.4 Climate change scenarios

Within the Baltic Climate project future climate scenarios, were prepared for Target Areas in Estonia, Finland, Germany, Latvia, Lithuania, Russia and Sweden and can be found on the homepage for the project http://balticclimate.dms.ee. These climate scenarios could be used with the SGI tool depending on what scale that is needed in the analyses and if it is detailed enough for the purpose.

5.5 Potential hazards

The *probability* for hazards such as erosion, landslides and flooding can be estimated. The potential hazards are affected by natural behaviour, protections, current and historical hazards and climate change scenarios described in Chapter 5.1 to 5.4.

In Sweden, national overview investigations of landslides, erosion an flooding are carried out and described below.

5.5.1 The Swedish landslide hazard mapping method for fine grained sediments

Following a catastrophic landslide in 1977, an overview mapping method for built up areas with inadequate safety concerning landslides in fine grained sediments was developed by SGI in the late 1970s (SGI, 1996, Fallsvik and Viberg, 1998). In 1988, the Swedish Commission on Slope Stability was initiated, with the task of initiating and coordinating research and providing information on slope stability and methods of stabilisation. In 1995, the Commission published guidelines for stability analyses of natural slopes (Commission on Slope Stability, 1995, Sällfors et al., 1996). The guidelines are structured in such a way that the investigation is carried out in several stages with increasing extent.

This Swedish landslide hazard mapping method for fine grained sediments (clay and silt), which has been developed successively, is used in a nation-wide programme for landslide risk reduction in built up areas administered by the Swedish Civil Contingencies Agency (MSB) (www.msb.se). The mapping method is divided in several stages which are described below. A more detailed description of the different stages can be found in Fallsvik (2007) and Löfroth et al. (2009).

Stage 1- Overview stability mapping

The overview stability mapping is called stage 1 and it is divided in a pre-study and two sub-stages:

- The purpose of the pre-study is to identify sub-areas in the municipalities considered to be mapped.
- The purpose of Stage 1a is to divide the land into areas with and without prerequisites for initial slope failure in clay and silt

- The purpose of Stage 1b is an overview assessment of the stability under prevailing conditions based on survey calculations to
  - Identify areas with satisfactory stability based on overview assessment
  - Mark areas which do not have satisfactory stability based on overview assessment and divide into areas in which detailed investigations are recommended or not recommended due to lack of buildings.
  - Mark areas where detailed investigations are considered to be particularly important.

The pre-study within built-up areas is carried out to get an idea of the investigation volume within each municipality. It is based on contact with municipalities, examination of geological and topographical maps, and an overview field inspection.

In *Stage 1a*, a division of the land is made into areas with and without prerequisites for initial slope failure in clay and silt. A division of the land into stability zones is made based on soil type and topography as well as information obtained from earlier geotechnical investigations carried out in the area or nearby, aerial photo interpretation and field inspections. An example is given in Figure 5-2.

Stage 1b comprises an overview assessment of the stability under prevailing conditions. The assessment is carried out with the aid of survey calculations based on information obtained from earlier stability investigations together with overview field and laboratory investigations in a selected number of sections. The results of Stage 1b consist of areas considered to have satisfactory stability and areas considered having unsatisfactory stability.

The results from Stages 1a and 1b are presented in colour on maps with scales from 1:5000 to 1:10,000. Other information of interest for slope stability, such as calculated sections, scars of old landslides, erosion in progress and the presence of quick clay can be shown on the same map.

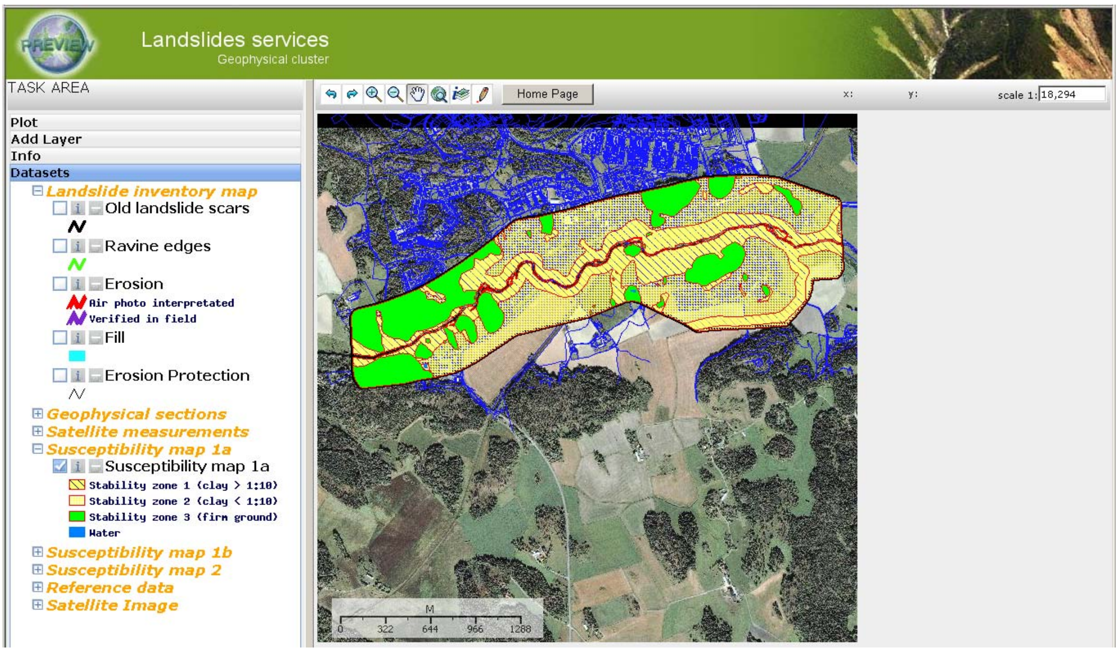

Figure 5-2. Susceptibility map from overview mapping in fine grained sediment, (stage 1a) for a test area used in the EU funded PREVIEW project (Löfroth et al., 2009)

If it is not possible to make the stability conditions clear based on the survey calculation carried out within stage 1b, or if an area cannot be classified as satisfactory stable, a detailed stability investigation is recommended (Stage 2).

Stage 2 – Detailed investigation:

Stage 2 comprises a detailed investigation and is eventually followed by an in-depth investigation. The principal aim of this stage is to clarify if there is a real stability problem or not and thereby establish the eventual need for remediation measures.

The detailed investigation is based on detailed geotechnical field- and laboratory investigations and stability calculations in a number of chosen sections according to the Guidelines for Slope Stability Investigations (Commission on Slope Stability, 1995). In these chosen sections regarded as the most critical, geotechnical field and laboratory investigations are performed. They should give information on among other things:

- the geometry of the ground surface including bottom level in watercourses;
- the soil profile and depth to firmer bottom layers
- the strengths properties of the soil
- levels of ground water and pore pressure, and
- occurrence of layers and quick clay.

Based on the field and laboratory investigations the prerequisites for the calculations are clarified. Slope stability calculations are then carried out with both undrained and combined analysis. Slope stability calculations are normally carried out for circular slip surfaces by using reliable computer programs. When the geometry of the slope demands, the calculations are carried out for planar and arbitrary shapes of the slip surfaces.

The results of the overview mapping will be found at the MSB website, https://msb.se/sv/Forebyggande/Naturolyckor/Oversiktlig-stabilitetskartering/

5.5.2 The Swedish landslide hazard mapping method for till and coarse soils

Mass movements in till and coarse sediments can generally occur in different parts of Sweden. Landslides in slopes occur primarily due to ground water flow and to high pore water pressures in the soil layers. In gullies problems occur due to landslides and triggering debris flows as well as erosion in the flanking slopes. A method for mapping and investigating areas with prerequisites for mass movements in till and coarse grained sediments have been developed in the early 2000s (Fallsvik et al., 2003, Lundström et al., 2007, and Rankka and Fallsvik, 2005). It is used in the nation-wide programme for landslide risk reduction in built-up areas administered by MSB (se also section 5.5.1). The structure of the method for till and coarse grained sediments is adapted to the corresponding structure for hazard mapping in fine grained sediments.

The purpose of the mapping is to find areas where the landslide risk or the debris-flow risk is estimated to be too high, and as a result detailed investigations need to be carried out. The method for overview mapping of stability and run-off conditions uses among other things information on geology, topography, vegetation, run-off conditions and soil movements occurred earlier. In the mapping model a division is made between debris-flows in gullies and brook valleys and mass movements in till slopes.

Stage 1 – Overview stability mapping

As for the landslide hazard mapping method for fine grained sediments, the overview stability mapping for till and coarse soils is called stage 1 and it is divided into a pre-study and two sub-stages, stage 1a and 1b (Fallsvik et al., 2003).

The purpose of the pre- study is to identify and show sub-areas in the municipalities considered to be mapped. Only built up areas are studied. A field visit to all investigation areas is included and the choice of areas is done together with a representative of the municipality. An example is given in *Figure 5-3*.

Stage 1a is carried out in the areas chosen in the pre-study. The purpose of this is to survey if prerequisites are present for debris-flows and mass movements as landslides to arise. Stage 1a comprises an overview mapping of the topography, soil conditions and hydrological conditions as well as other factors of importance for the stability conditions, e.g. vegetation, old scars of landslides and debris flows, magnitude of erosion activities, impact of human activity and eventual existing preventive measures. The stage is based on studies of topographic, geological and eventual geomorphologic maps together with air photo interpretation and field control. The result of the mapping is reported in photographs, field protocols and maps at the scale 1:10 000.

Stage 1b is comprised of an assessment of the stability conditions based on information from Stage 1a. Similarly to the hazard mapping for fine-grained sediments the purpose of Stage 1b is: an overview identification of areas with satisfactory stability; an overview identification of areas where the stability is expected to be unsatisfactory and therefore needs to be investigated and marking of areas where detailed investigations for landslides and debris flows are considered to be particularly important.

During the classification work the mapped area is divided in areas with landslide and debris flow hazard in slopes and areas with debris flow hazard in gullies. The susceptibility for landslides and debris-flows in slopes is carried out based on a combination of overview stability calculations (safety factor) and other influencing factors. The main factors are: slope stability, hydrology (catchment area, groundwater erosion etc.), soil conditions (vegetation coverage and existence of fallen trees, roads, ski slopes etc.), downfall of boulders, earlier soil mass movements and existing preventive constructions. The susceptibility for debris flows in gullies is based on already occurred debris flows and by mapping and compiling factors that could contribute to triggering of a debris flow. In general there is a combination of six main factors: topography (gully length, gully bottom inclination etc.), hydrology (catchment area, water tributary creeks etc.), soil conditions (soil cover, soil types, amount of loose material etc.), land use (type of vegetation, existing roads etc.), earlier soil mass movements and existing preventive constructions. The result of the analysis in Stage 1b is compiled on specially designed forms. This result is compared with earlier occurred mass movements and with compiled reference objects and a classification is made. The result of the mapping and classification is reported on a map at the scale 1:10 000.

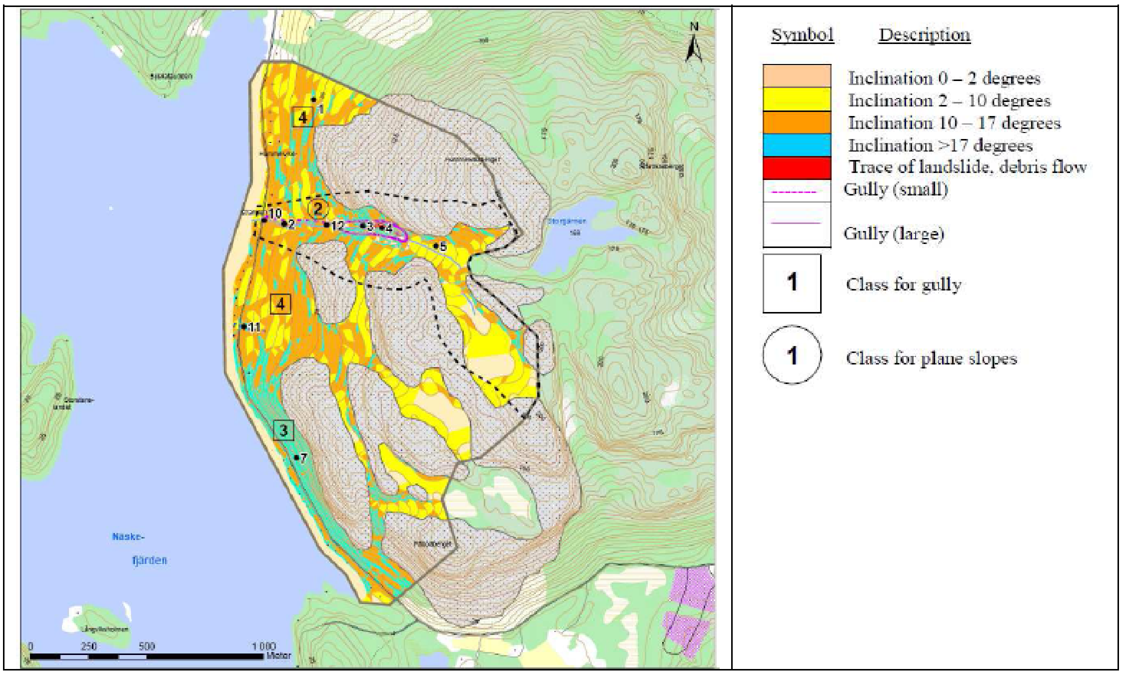

Figure 5-3: Example of susceptibility map from overview mapping in till and coarse grained sediments (modified from www.msb.se)

Stage 2 and 3 – Detailed investigation

In areas where a need for further investigations is assessed by the overview mapping in Stage 1b, a detailed investigation ought to be carried out and, where it demands, suggestions for remedial measures also need to be made.

In the detailed investigations the hazard of mass movements in slopes and gullies is divided into two main categories: landslides in open slopes and debris flows in gullies. The two categories require different field investigations and different types of data input (Rankka and Fallsvik, 2005).

The landslides and shallow erosion hazard is normally affected by: the inclination of the slope; type, strength and depth of soil; groundwater conditions; vegetation; possibility of water infiltration and man-made features. The hazard is mainly presented as a factor of safety and a description of the possibility of erosion.

The debris flows are mainly affected by the volume of water, the peak discharge that can reach the gully in one occasion and the volume of available soil material transportable by the water. It is necessary to calculate the peak discharge, determine the run-off conditions, the precipitation and the amount of available soil material.

The results of the overview mapping will be found at the MSB website, www.msb.se.

5.5.3 Mapping of coastal areas

For coastal areas the coast is divided into sections with similar physical properties. For each of these sections, the hazards are identified by evaluation of the present state of the coast. This includes the geomorphology, the topography and bathymetry as well as the driving forces such as water levels, waves and water currents. Existing coastal protection will have influence on the possible hazards and should be presented. Based on this information, a coastal geomorphologic model can be established. On-going and historical events should be identified, although it may sometimes be difficult to access such data. This will be applied to the coastal model and together with the climate change scenario for the chosen time period the *probability* for hazards such as erosion, landslides and flooding can be estimated.

In Sweden, an overview mapping of the prerequisites of coastal erosion of the Swedish coasts, larger lakes and rivers has been carried out by SGI and maps will be found at the SGI website, www.swedgeo.se

5.5.4 General inundation mapping

The flooding is depending on the sea level and the water level in watercourses. Flooding is also depending on high wind and low air pressure. In many countries there are on-going works with inundation mapping due to EU directive. In many cases the mapping is done only for today's climate. For the purpose of planning for climate adaptation the mapping has to be complemented with analyses for climate change scenarios.

In Sweden The Swedish Civil Contingencies Agency (MSB) compiles and maintains general inundation maps along watercourses and some lake shores. The maps are intended for use during the planning of emergency services work and as a foundation for land use planning by municipalities. They can also be used as basic data for various risk and vulnerability analyses. The maps shows the areas impacted by the 100-year flood and the estimated highest flow for each watercourse. Currently the mapping is done for today's climate, but MSB wish to investigate how the mapping can be updated for new more detailed topographic data and scenarios for climate change. (https://www.msb.se)

In the SGI model the inundation maps from MSB can be used as an overview for water-courses. However for more detailed inundation maps where climate change scenarios are taken into account, hydraulic calculations have to be performed. The flood from sea level rise is shown on maps for different climate change scenarios (example in *Figure 6-2*).

5.6 Assets

The assets at risk from landslides, erosion and flooding can include built environment, life and health, nature resources, recreation and infrastructure. For any specific project the actual assets have to be considered. A detailed model for evaluating assets is described in Section 6.3.

5.7 Consequences

Assets, which may be influenced, are identified as *consequences* of potential hazards. The assets are estimated in monetary or relative values. A detailed model for evaluating the consequences is described in Section 6.3.

5.8 Potential risk areas

The model for evaluation of natural risks in land or coastal areas is focused on erosion, stability and flooding. The principle is to identify risk areas based on the probability of an event and the consequences of the event. Risk areas need to be taken into account when decisions are made of the land use in a certain area or if adaptation measures have to be undertaken to protect any threatened built environment.

The risk areas can then be evaluated as a *risk value*, which is calculated as the product of probability and consequences when there are more detailed data available for an area. For works with comprehensive plans where data is not that detailed an evaluation is made of the interface between areas with risk for natural hazards and consequences for important society constructions.

5.9 Strategies and alternative measures

At the local level both for spatial planning and the built environment, the need for mitigation and adaptive measures must be identified, and data for the design and construction of such measures must be clarified. Requirements for remedial works can also be predicted using field-monitoring data, which may change the risk management philosophy from a reactive to a more pro-active one.

Mitigation measures for landslides, erosion and flooding risks often require levees, coastal protection and/or other stabilising measures. Such measures require geotechnical information during several stages of the planning and building process. In spatial planning, all factors that may cause risk for health and safety must be identified so that buildings and infrastructure will be located outside present and future risk areas or measures taken to secure these risk areas.

5.10 Socio-economic analyses

For possible measures in spatial planning or for adaptation of the built environment socio-economic analyses and environmental assessments are carried out.

When socio-economic analyses are made they have to be based on correct actual data and valid methods to predict future development for different alternatives/scenarios. This is the basis for establishing what is at risk and what countermeasures can be used to alleviate the potential problems. Also the stakeholders must be identified and the activities that are affected by possible changes to the land or coastal area. Analysis can be done for example by a Cost-Benefit Analysis (CBA). The basic way of working with a CBA model is to start by estimating total damage and loss for the "Do Nothing"-alternative. This value is later used as the benefit (or avoided damage) for the investigated options of preventive actions. The next step is to estimate the schedule and cost of implementing the options. Finally, if there still is a risk of damages for the investigated options; the cost of this is also calculated. For a CBA the selection criterion is that if the ratio between benefits and costs is greater than 1 (benefits divided by costs >1) the option is worth doing. The option with the highest benefit cost ratio gives "best value for money". More information on socio-economic analyses is given in Rydell et al. (2006).

5.11 Environmental consequences

Environmental consequences should be considered for the different alternatives/scenarios that are dealt with in Section 5.9.

5.12 Basis for spatial planning

For spatial planning, following the steps above, the decision makers will have a proper and transparent basis for discussion with different stakeholders and the final decision of the best available way to establish sustainable land and coastal areas.

5.13 Decision basis for adaptation

For the built environment, following the steps above, the decision makers will have a proper and transparent basis for the discussion with different stakeholders and the final decision of the best available way to adapt built environment on land and in coastal areas.

6 EXAMPLES FROM SWEDEN

6.1 Natural hazards and climate adaptation at region level - The County of Gävleborg

The counties in Sweden have since 2009 the responsibility to coordinate the regional climate adaptation work. This includes clarifying the risks for natural hazards and the consequences of climate change. SGI and SMHI have on behalf of the County of Gävleborg made a regional overview Climate and Vulnerability Analysis where areas have been identified where it might be a risk for flooding, landslides or erosion and the interface between those areas and important society constructions where it might cause damage on the constructions. The constructions can be e.g. roads, railways, dams, contaminated areas, enterprises with potential environmental hazardous activities or dangerous substances. The whole county has been investigated and a part of the investigation is shown in *Figure 6-1*. How the hazardous or contaminated areas have been classified is shown in the detailed legend below the figure. The results are intended to be used as a base for the county's work with climate adaptation and for the municipalities work with local authority risk and vulnerability analyses and spatial planning.

The report by Rydell et al. (2010) provides recommendations for spatial planning and adaptation of built areas in response to climate change in the County of Gävleborg. For new exploitation areas it is important to investigate the suitability of the ground for the intended plan purpose. Measurements might have to be taken to prevent damages on constructions due to natural hazards. Rydell et al (2010) provides an overview, but more detailed investigations of geotechnical, topographic and hydrological conditions have to be performed before more detailed plans are carried out at a local level.

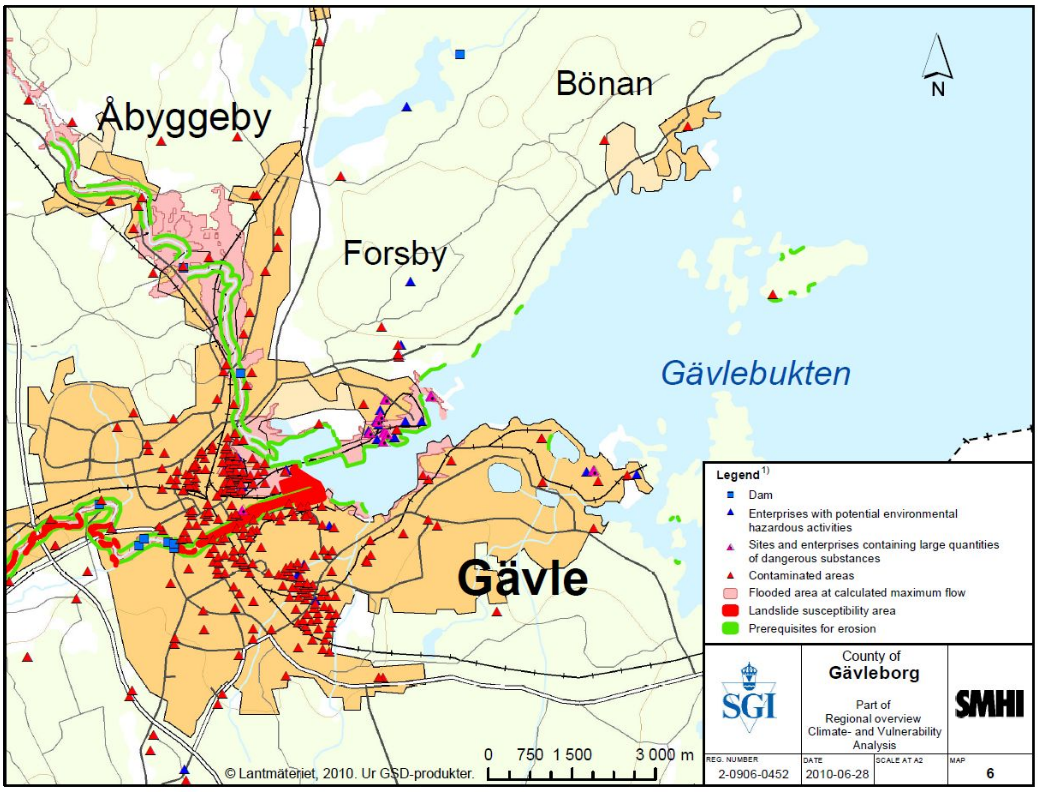

Figure 6-1. Part of regional overview Climate- and Vulnerability Analysis for the County of Gävleborg. (Rydell et al. 2010).

[1)] Detailed legend description

	Enterprises with potential environmental hazardous activities as defined by the Swedish Environmental Code, Chapter 9 Section 6.
	Sites and enterprises containing large quantities of dangerous substances. (Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances (as amended) is a European Union law aimed at improving the safety of sites containing large quantities of dangerous substances. It is also known as the Seveso II Directive.
	Contaminated areas investigated and classified according to the Swedish Environmental Protection Agency's Methods for Inventories of contaminated sites (MIFO).

6.2 Natural hazards and climate adaptation on a local level - Nynäshamn municipality

The municipalities have to make comprehensive plans and detailed development plans for the built and planned environment. To consider the consequences of climate change on the planned and existing built environment SGI and SMHI have on behalf of Nynäshamn Municipal made an Overview Climate- and Vulnerability Analysis as a base for the Municipal Comprehensive Plan 2010 (see Rogbeck et al. 2009). When working with comprehensive plans normally detailed data is not available, so the evaluation was made of the interface between areas with risk for natural hazards and consequences for important society constructions. The aim with the work was to clarify the consequences due to increased rain fall and sea level rise for different scenarios. Areas with risks for flooding, landslides or erosion have been investigated and the risk areas are illustrated in maps. The interface between those areas and important society constructions has also been shown. An example of such a map is shown in *Figure 6-2*. The flooding from sea level rise is shown in the figure for different scenarios, the levels are shown in *Table 6-1*. As shown in the figure and table there can be rather different results depending on which scenario that are used. It is important to compare different scenarios and act for uncertainties. The report gives recommendations for spatial planning and adaptation of built areas due to climate change. It also shows strategies and examples of measurements to be taken to prevent damages on constructions due to natural hazards.

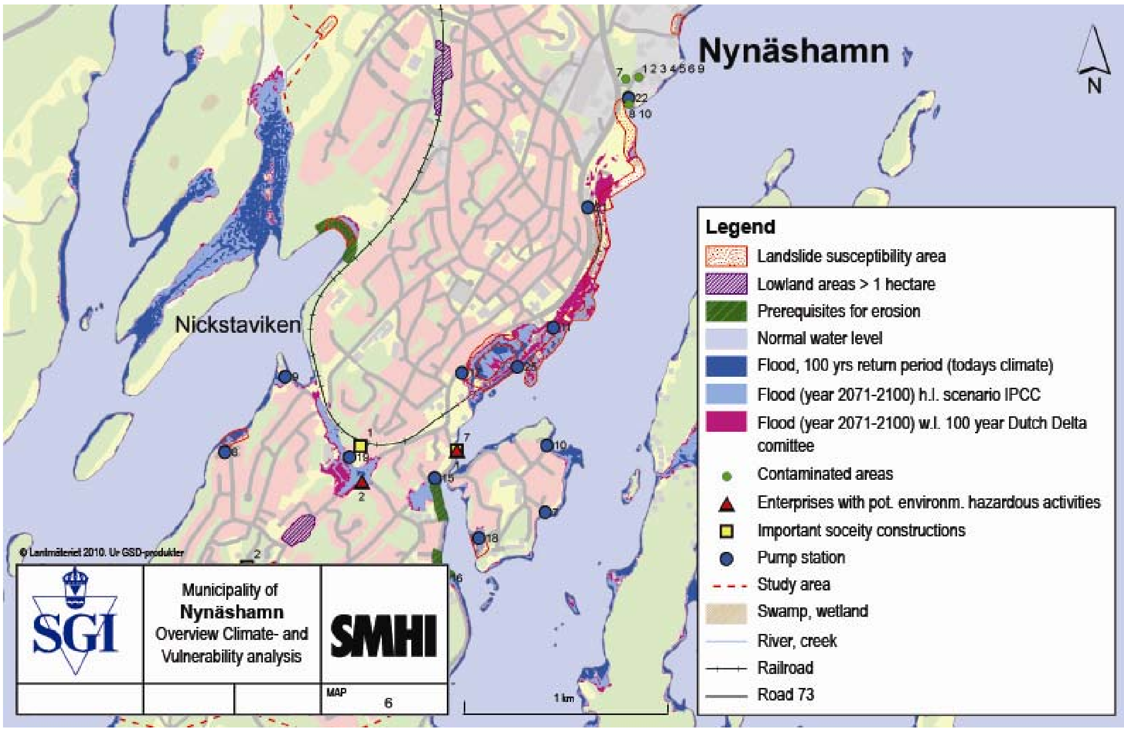

Figure 6-2. Part of Overview Climate- and Vulnerability Analysis for the Municipality of Nynäshamn. (Rogbeck et al. 2009).

Table 6-1. The sea level for determination of flood along the coast of Nynäshamn (given in meter in the Swedish height system RH00).

Case	***Level (RH00)***
1. Flood, 100 years return period (today's climate)	0.68
2. Flood calculated future (year 2071-2100) high level scenario according to IPCC	1.30
3. Flood, future (year 2071-2100) water level with 100 years return period, according to the Dutch Delta committee	1.71

6.3 Landslide risk assessment - the Göta River Valley

In 2008 the Swedish Government commissioned SGI to perform a comprehensive inventory of the landslide risk in the Göta river valley, to limit the consequences of climate change on society (Tremblay et al., 2011). The project will be finalised in March 2012. The Göta river valley is about 90 km long and it extends from the largest lake in Sweden, Lake Vänern in the north to the city of Gothenburg in the south. The investigations include field- and laboratory investigations and stability calculations as carried out in a detailed stability investigation according to the Swedish Commission on Slope Stability (1995). In addition several prerequisites and conditions for stability have been run as separate projects, such as mapping and handling of quick clay, groundwater and pore pressure, erosion conditions, climate scenarios and methodologies, on how to estimate probabilities for and consequences of landslides,. In this chapter some of the general steps from Chapter 5 are described further with the methods used in the Göta river valley project.

6.3.1 Probabilities of landslides

The methodology on how to estimate probabilities of landslides is based on a methodology previously used in the Göta river valley (Ahlén et al., 2000). It describes a way of calculating the probability based on uncertainties and natural variations in the parameters that influence stability. Estimates of the probability of landslides are carried out as a complement to the traditional calculation of safety factor against stability failure, which has been calculated for vertical sections across the slope approximately every 500 m along the river. A number of these have been selected as "type sections", for which reliability analyses are performed. The "type sections" are idealised in the spirit of the Direct method, established by Janbu (1954). The uncertainty of the governing parameters are investigated and specified with the statistical measures standard deviation and mean value. The probabilities of failure are calculated according to the method FOSM (First Order Second Moment) and the results of the calculations are given as probability of failure and safety index. The result is transferred to a 2D map with five classes of probability (Berggren et al., 2011).

6.3.2 Groundwater and pore pressure

The methodology suggested in the Göta river valley commission for estimating maximum pore pressure conditions used in slope stability calculations is based on a simple and conceptual model idea. The estimation is suggested to be done using pen and paper in a process where the conceptual model gradually is compared with new ground water level observations, either verifying or rejecting the model. A rejection of the model means the model has to be revised until an acceptable deviation from the observations, and thus a good description of the field conditions, is obtained.

In the Göta river valley a typical soil profile is dominated by low permeable clay overlaying a high permeable friction soil layer. Further, the uppermost meters of the clay generally form a high permeable dry crust. In some areas permeable layers also are present within the clay profile. The pore pressure estimation model is suggested to be based on the principle of high permeable soil layers determining the pore pressure conditions within the clay. Consequently, the water transported in the clay is neglected in comparison to the much larger amounts transported in the permeable layers, resulting in linear pore pressure gradients within the clay.

The creation of the pore pressure model requires good knowledge of the soil conditions, and a soil model is therefore suggested to be constructed in a preliminary design. At the next stage, the general hydro geological condition of the area, including infiltration areas and main ground water flow directions, should be studied and implemented in the model. Also, reasonable levels for the free ground water level within the dry crust region and pore pressure levels in deeper permeable layers must be estimated. Generally, hydrostatical conditions can be assumed within the uppermost five meters of the soil.

The pore pressure model then has to be compared with ground water measurements. The observation stations should be installed in strategically chosen areas, such as where drained shear stress is estimated to be determining the stability. Generally this corresponds to relatively shallow soil layers. However, a few observations in deeper layers, to improve the understanding of the general hydro geological situation also is advisable.

Ground water level measuring can be done at any time of the year. It is, however, a great advantage if observations can be done in different times of the year to capture the fluctuation magnitude. Since the ground water levels vary over the year, the observations always must be related to the general hydro geological situation of the area. A methodology, developed by Svensson and Sällfors (1983), for calculating a maximum ground water level based on a relatively small number of observations is recommended. This methodology uses a comparison of the observed ground water levels with measurements from long-term observation stations within the same area.

For handling the effects of uncertainty in estimation of maximum pore pressures, as well as the uncertain effects of climate change, sensitivity analyses are suggested. By changing the permeable layers pressure levels one at a time in a slope stability calculation, an understanding can be obtained of the slope's sensitivity for pore pressure changes in different areas. Focus in the estimation of maximum pore pressures should then be put to the most sensitive areas. As mentioned above, this normally corresponds to relatively shallow soil layers. Regarding effects from climate change in the sensitivity analysis, it has been suggested to increase the pore pressure levels relative to the estimated maximum levels in today's climate. Reasonable increments have been estimated to maximum 0.5 m for the free ground water level within the dry crust, and around 1 m for pressure levels in permeable friction soil layers under the clay.

6.3.3 Consequences

In parallel to estimation of the probabilities of landslides, the project has developed a method to identify, map and when possible assess consequences of potential landslides throughout the studied area. The method has been developed from a previously used methodology (Alén et al., 2000) and the new methodology has been reported by Andersson-Sköld (2011a) and Andersson-Sköld et al. (2011b). The method comprises:

- identification of consequences
- identification of objects that may be affected
- assessment of the probability that a specific event will occur
- method for monetary assessment

Much work has been invested in identifying relevant factors (e.g. population, property, contaminated land, transportation network, industry), method to make monetary valuation of the consequences of importance and to estimate the vulnerability. The work has been divided in the societal consequence sectors: buildings; transport (road, rail, shipping), exposure, vulnerability and life; environmentally hazardous activities and contaminated sites; water and sewage systems; nature; culture; energy and electric supply systems; trade and industry.

The consequence is set to be the product of the inventory of elements at risk, value per unit area, the vulnerability and the exposure (*Figure 6-3*). The result is presented in a 2D map with five consequence classes given in MSEK/ha.

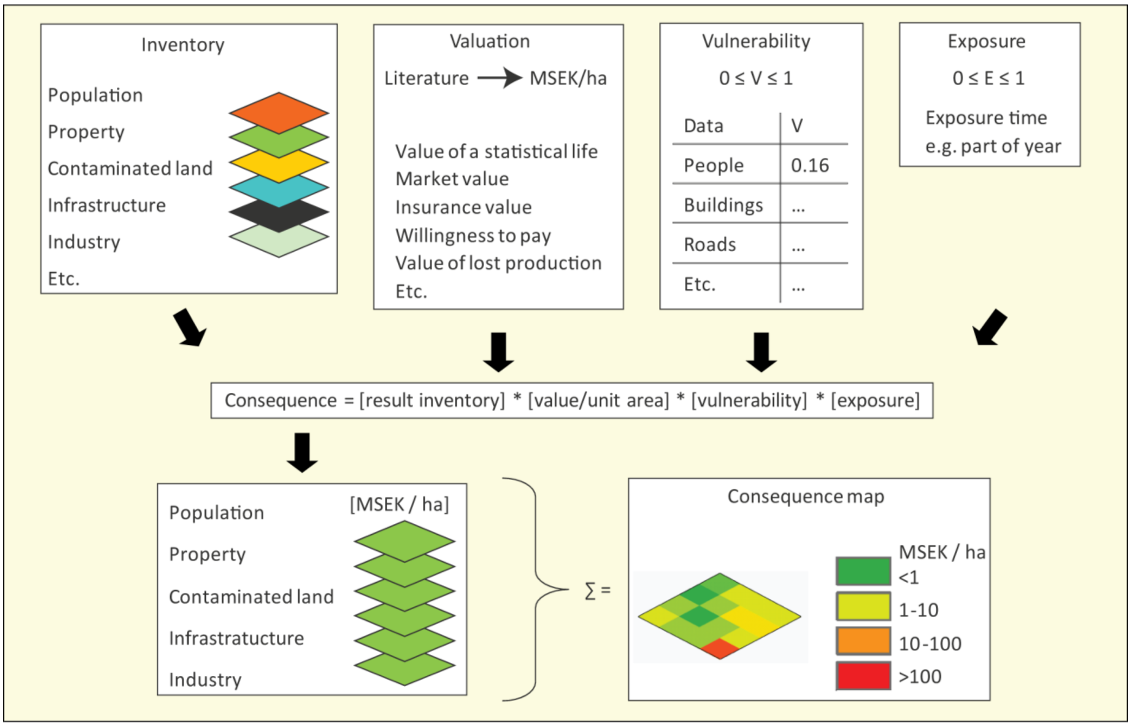

Figure 6-3. Schematic sketch of how consequence is estimated and transferred into 2D map. The consequence is set to be the product of the number or density of objects obtained in an inventory, the value per unit area, the relative vulnerability and relative exposure time. The sum of the consequences for all object categories is plotted in a 2D map using GIS techniques. (Falemo and Andersson-Sköld 2011). (The colures of consequences have been changed in later works).

6.3.4 Potential risk areas

The principle is to identify risk areas based on the probability of an event and the consequences of such an event. In this case the five classes of probability and consequence, respectively, are combined in a risk matrix from which three classes of risk are identified (Figure 6-4);
- acceptable risk
- unsafe risk level (investigation required)
- unacceptable risk level (preventive measures are required).

The outcome of the risk analysis will be presented in maps over the investigation area illustrating the extent of the three risk levels. The principles in Figure 6-4 and results from Göta river valley are reported in Andersson-Sköld (2011a).

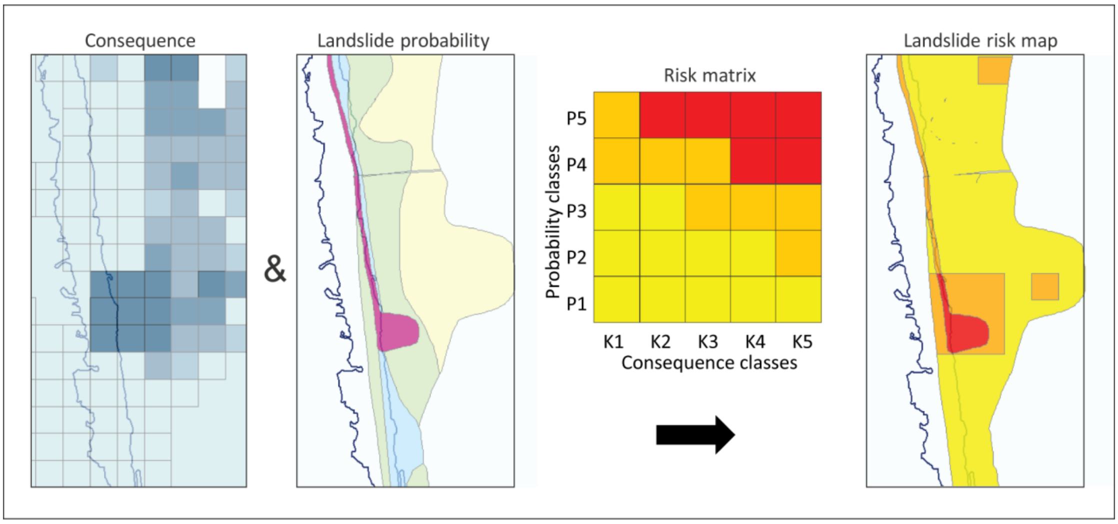

Figure 6-4. Illustration of risk analysis. Estimates of consequences of and probabilities for landslide are grouped into 5 classes and combined by GIS techniques in a risk matrix. The resulting pair of numbers, e.g. (P3,K3) are grouped in three risk classes; acceptable risk (yellow colour), unsafe risk level (orange colour) and unacceptable risk level (red colour). The different risk levels are subsequently illustrated in map view.

7 RISK ANALYSIS AND MANAGEMENT FOR EUROPEAN ROADS

In 2009 a project was started within the consortium ERA-NET ROAD, a collaboration between (at that time) eleven National Road Administrations in Europe. The objective for the project, RIMAROCC, was to develop a common ERA-NET ROAD method for risk analysis and risk management for roads in Europe, with regard to climate change. The RIMAROCC method is designed being general and to meet the common needs of road owners and road administrators in Europe (Lind et al., 2010, Bles et al., 2010). The method seeks to present a framework and an overall approach to adaptation to climate change and it is based on existing risk analysis and risk management tools for roads within the ERA-NET Road member states and others. The method is also in line with the ISO 31 000 standard on risk management.

When using the RIMAROCC method, the appropriate working methods depend on the scale of the analysis to be executed as well as available resources. The scales can be territorial, network, section and structure, each with different objectives. The framework consists of seven steps, each with a number of sub-steps, which are not always totally separate. The method is a cyclical process to continuously improve the performance and capitalise on the experiences. It starts with an analysis of the general context and ends with a reflective step where the experiences and results are documented and made available. The method consists of the following steps (*Figure 7-1*), with a description of proposed sub-steps in brackets:

1. Context analysis (Establish a general context as well as a specific context, risk criteria and indicators adapted to the particular scale of analysis)
2. Risk identification (Identify risk sources, vulnerabilities and possible consequences)

3. Risk analysis (Establish risk chronology and scenarios, determine the impact and evaluate occurrences and provide a risk overview)
4. Risk evaluation (Evaluate quantitative aspects, compare climate risk to other risks, determine acceptable risks)
5. Risk mitigation (Identify and consider options, negotiation with funding agencies, formulation of action plan)
6. Implementation of action plans (Develop an action plan on each level of responsibility and implement adaptation action plans)
7. Monitor, re-plan and capitalise (Regular monitoring and review, re-planning in the event of new data or a delay, capitalisation on return of experience of both climatic events and progress of implementation)

A more comprehensive description of the method is given in Bles et al. (2010).

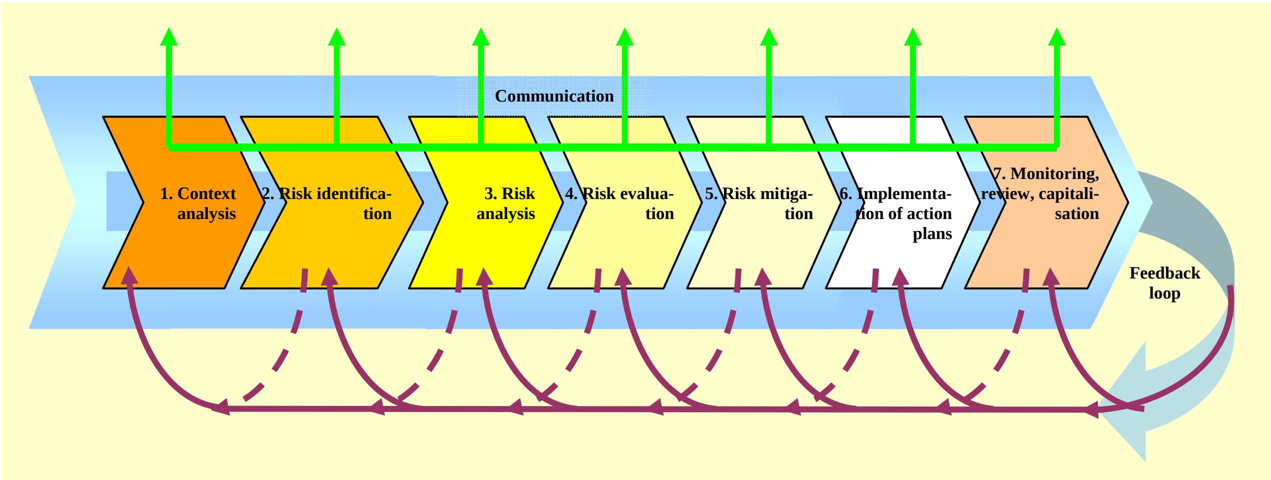

Figure 7-1. The seven steps of the RIMAROCC method. Observe the green arrows showing the very important continuous communication with stakeholders, external experts and others (Bles et al., 2010).

8 GENERAL METHODS FOR CLIMATE ADAPTATION

In this chapter some general methods for climate adaptation are described. The aim is to give a brief introduction to the tools. The tools can be used in combination with the soil movement tools presented in this report.

8.1 CSPR Adaptation Tool kit

A climate change adaptation tool kit has been developed at Centre for Climate Science and Policy Research (CSPR). The title is “A toolbox for climate adaptation processes”. The aim is to provide a basis for civil servants or other groups working with climate adaption to create a systematic and co-operative working process. The toolbox consists of a selection of tools for different parts of the process. For each of those there are given examples and instructions.

The suggested working process and the related tools are divided into the following steps:

1. Get started

Includes 5 tools that can be used to design and perform the process.

2. Assessing vulnerability.

Includes nine tools on important aspects that define vulnerability, i.e. exposure, sensitivity and capacity.

3. Managing vulnerability.

Includes two tools that provide methods to facilitate the compilation of the previous experience and results and how to continue the climate adaptation work.

The tools are based on current research and at the start of the report a description on the academic view on the relations and interlinks between climate change, vulnerability and adaption is presented.

The full process is recommended for a thorough process. The authors, however, also suggest that some of the tools can be used individually, or to use selected tools from each part of the process.

The toolbox (in Swedish) by Jonsson A. et.al (2011) and can be found at http://www.cspr.se/verktygsladan/hoger/1.295276/Verktygsladapdf.pdf.

Several of the tools are are contained in the BalticClimate toolkit and are also described by Hjerpe M. and Wilk J. (2010).
http://www.cspr.se/briefings/1.185983/briefingno5.pdf

8.2 Matrix Decision Support Tool

SGI has developed a Matrix Decision Support Tool for the evaluation of environmental, social and economic aspects of land use reported by Andersson-Sköld et al. (2011c). The tool has been developed by SGI in the project Climate Proof Areas, financed by EU in the Interreg IVB North Sea Region Programme and the Formas funded project "Bedömningar av sårbarhet, risk och anpassning inför klimatförändringar i städer och kommuner". The tool incorporates sustainability in a simple manner in the planning process of land use management. It is applicable for several different purposes, such as e.g. risk analysis of different measures suggested for contaminated sites, comparisons of different measures suggested for risk reduction of natural hazards, mitigations of risks associated with climate change or when evaluating any other land use alternatives or measures. The principle is given in *Figure 8-1*.

The aim with the tool is to provide a checklist and a methodology that promotes discussions in order to facilitate the identification and compilation of potential measures and consequences related to land use issues. In addition, it should contribute to a more transparent decision process and increase the traceability of the reasoning behind the decisions taken. The tool is based on classical technical risk- and vulnerability analysis, comprising all steps from risk/hazard identification to appraisal of measures. The different steps can be summarised as:

• risk/hazard identification,
• risk assessment,
• risk analysis - acceptance of risk and need for measures,
• suggestions of measures,
• documentation for evaluation and prioritising of measures and
• proposal for decision of measures.

The tool is intended to be used by both experts and policy makers (or persons who will present the alternatives for the policy makers) in order to demonstrate all kinds of consequences and present them to the whole group of stakeholders (experts, policy makers, the public etc.).

The Matrix Decision Support Tool (MDST) can be found in the report and can be downloaded as an Excel spread sheet from:
http://www.swedgeo.se/upload/publikationer/Varia/pdf/SGI-V613.xls
The report provides a further description of the MDST's components and gives instructions on how to use the tool.

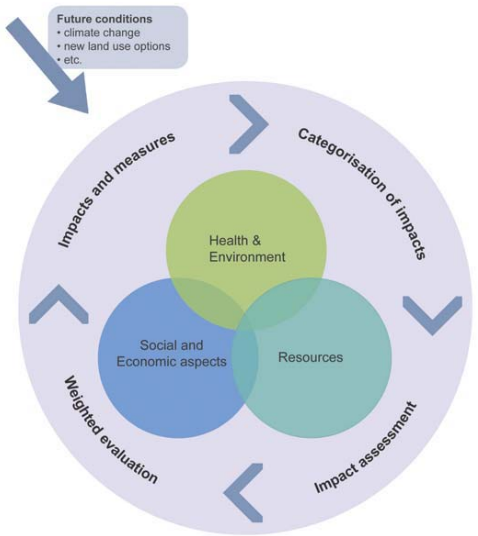

Figure 8-1. The MDST consists of four forms, which should be used in an iterative process. The detailed forms comprises the following steps: i) to identify impacts and measures; ii) categorisation of impacts; iii) impact assessment; and iv) weighted evaluation.

8.3 CPA tool box

A related project to Baltic climate is the Interreg IVB North Sea Program project Climate Proof Areas (CPA). The aim of CPA was to accelerate the climate change adaptation process in the North Sea Region (NSR) by means of joint development and testing of innovative adaptation measures. This was done in demonstration (pilot) locations that are exemplary for the NSR as a whole. On the strategic level, the partnership aimed at improving national and regional climate change adaptation strategies by means of working together on innovative pilot adaptation measures combining all available expertise.

The innovative pilots comprise a real life adaptation test lab in the NSR. One specific part of CPA was to create a toolkit for adaptation in the NSR.

The ambition of CPA toolkit is to offer a practical guidance for identifying and using helpful tools (Oostrom et al., 2011). The intended users of the toolkit are primarily process managers who are setting up or leading adaptation processes. The toolkit is a practical guide to identifying and using tools in such a manner that will lead to advancement in the decision making process by examples and experiences on tools from the CPA pilots. The guide provides a list of more than 30 tools that can be used and includes also where to find further information.

The tools included in the toolkit are instruments for supporting the climate adaptation process are not physical measures like dams, barriers, water storage etc. but tools that are helpful with dealing with the characteristics of climate proofing. Examples are methods used for identifying, evaluating and communicating the measures that can be taken and tools to facilitate the process to achieve the most sustainable alternative regarding social, health and environment and economic aspects. A tool can for example be a guide describing a process, a checklist, a model, an informative map etc. as well as a communication plan. A tool can be used to achieve a calculated result, a map as well as a way to perform a coherent set of actions. The tools used in the pilots are briefly described regarding its use, where in the decision process they are relevant and their pros and cons. A couple of tools labelled "recommended" are more fully described in the toolkit. These tools were particularly interesting or were helpful for the pilots in order to reach the objectives.

8.4 MSB Guideline for Risk- and Vulnerability Analysis

The Swedish Civil Contingencies Agency (MSB) has produced a guideline for local authority risk and vulnerability analyses (RVA), MSB (2011). To establish a RVA for the municipalities every four years is a requirement by law (2006:544). The handbook describes that weather conditions have to be considered in the work with different scenarios, but it does not mention future climate change. The risk assessment includes natural hazards like flooding and landslides.

8.5 Climatools

The Climatools research programme is run by the Swedish Defence Research Agency (FOI), in collaboration with the Royal Institute of Technology, Umeå University and the National Institute of Economic Research, on behalf of the Swedish Environmental Protection Agency. The results are eight different tools that assist decision makers mainly at the local and regional levels in adapting the society to the consequences of climate change. The focus of the programme is principally on areas such as health, habitation and infrastructure as well as tourism and outdoor life. The tools have been developed in close interaction with stakeholders, mainly officers in municipalities, and cover aspects such as ethics, economics and medicine with focus on handling uncertainties by using scenarios. They can be used in on-going planning processes such as comprehensive and detailed planning and risk and vulnerability assessments (http//www.climatools.se).

The tool that can be useful for dealing with soil movements is a guide for the integration of adaptation to climate change in local authority risk and vulnerability analyses (RVA), Mossberg Sonek et al. (2011).

Many county administrative boards have proposed that climate adaptation can be included in the municipalities existing decision-making processes as e.g. RVA and therefore these guidelines aid the municipalities in determining which aspects of climate adaptation should be included in a municipal RVA and which fall outside.

RVAs aim to identify measures both to handle extraordinary events when they occur, and to reduce the society's vulnerabilities to such events. From a climate adaptation view, this process is suitable for handling present and future consequences of climate extremes, which are predicted to occur more frequently and to be of higher magnitude as a result of climate change. Threats for critical society functions are included in the analysis. The time perspective is normally 0-10 years but can be prolonged if desirable. On the other hand, there are several aspects of climate adaptation that are less suitable to be handled within the process e.g. slow future changes of the climate, opportunities of climate change, non-critical society functions and a more long term perspective. The municipal authority is in the choice of extending the analysis to include these aspects, something that may require modification of the process, or decide to use other municipal processes for these aspects.

The guide suggests that the municipalities start to get an understanding of current vulnerability to today's climate related events. When having such an understanding, the next step is to analyse consequences of future climate events on present society. The final step includes discussions how to analyse future climate extremes on a future society. The guide also gives advice on how to identify future climate related extreme events that are critical for the municipality. The choice depends on a number of local factors such as historical climate variability, current vulnerabilities in various functions within the municipality in question, on-going and long-term climate change and known future vulnerabilities of the municipality. The guide in Swedish can be downloaded on www.climatools.se where also other publications can be found.

The tool gives examples of consequences related to soil movements such as landslides and erosion and give references to literature from SGI. The tool can be used as a base when dealing with climate adaptation concerning soil movements and can be combined with the SGI climate and vulnerability method in Chapter 5. In this case the effects of long-term climate change have also to be considered.

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APPENDIX 1

Questionnaire on tools and models for assessing local consequences for infrastructure and buildings within the transport and housing sectors

The Swedish Geotechnical Institute (SGI) will, on behalf of Centre for Climate Science and Policy Research (CSPR) within the project BalticClimate, make a survey on existing tools/ models for spatial planning used in the transport or the housing sector for infrastructure and buildings. The survey will be based on the attached questionnaire. The aim is to investigate the use of tools/models in general in the spatial planning process, as well as the use of tools/models used to assess aspects like local consequences of landslides or erosion, for the situation today and also for consequences due to Climate Change, or adaptation measures. The results from the questionnaire will be reported in English. The aim with the Questionnaire it to make an inventory of tools regarding soil movements and that, for example, can be used as complement to a more general toolkit.

The Swedish Geotechnical Institute is a sub partner to CSPR. The SGI is the Swedish national expert centre within the geotechnical field, dealing with geotechnical research, information and expert advisory services. The SGI has particular responsibility as a governmental expert body for safety issues relating to landslides and coastal erosion. The institute has participated in several EU projects concerning landslides and has also, for example, been working with Decision Support Tools for Evaluation of Environmental, Social and Economic Aspects of Land Use and Climate Change Adaptation Measures in the CPA and SAWA projects in the North Sea program (SGI Varia 613).

Urban areas close to the coast, rivers or waterways are at several parts affected by coastal erosion, flooding and instability of slopes. The predictions on global climate change include sea level rise, increased precipitation and runoff and more intense and damaging storms which will increase the threats of natural hazards. Such risks are, in addition to environmental threats, highlighted especially in the Baltic Sea region.

Risk mitigation and adaptation of urban areas constitutes huge challenges for society, and requires the contribution from all parts of society. Assessments of activities for prevention of coastal hazards should be used to maximise the benefits of measures or investments in the coastal zone, including the built environment, important habitats and infrastructure. More attention should be given to integrate coastal hazards into the decision making process and particularly into the strategy for sustainable coastal management and Integrated Coastal Zone Management (ICZM).

One cornerstone to reach a sustainable development (including economic growth) is to take natural hazards into account. By incorporating coastal hazard and risk mapping into long-term plans for urban areas, new developments can be diverted away from risk areas and the risks in existing urban areas can be reduced.

An example of decision process model is given in Figure 1. For every step within this, there are more detailed tools/models or suggestions on of how to deal with the question(s) involved in this actual step. For example under potential hazards the tool can be

a hazard map, and under the step potential risk areas the tool can be a risk map. Relevant tools for identifying and assessing risk mitigate strategies can be databases or other information on previous experiences of strategies including pros and cons and description on functionality and related
costs for investment and in a long time perspective, it can also be more holistic assessments such as life cycle and multi-criteria analyses.

Swedish Geotechnical Institute
Department of Geotechnical Design and Landslide Safety

Yvonne Rogbeck

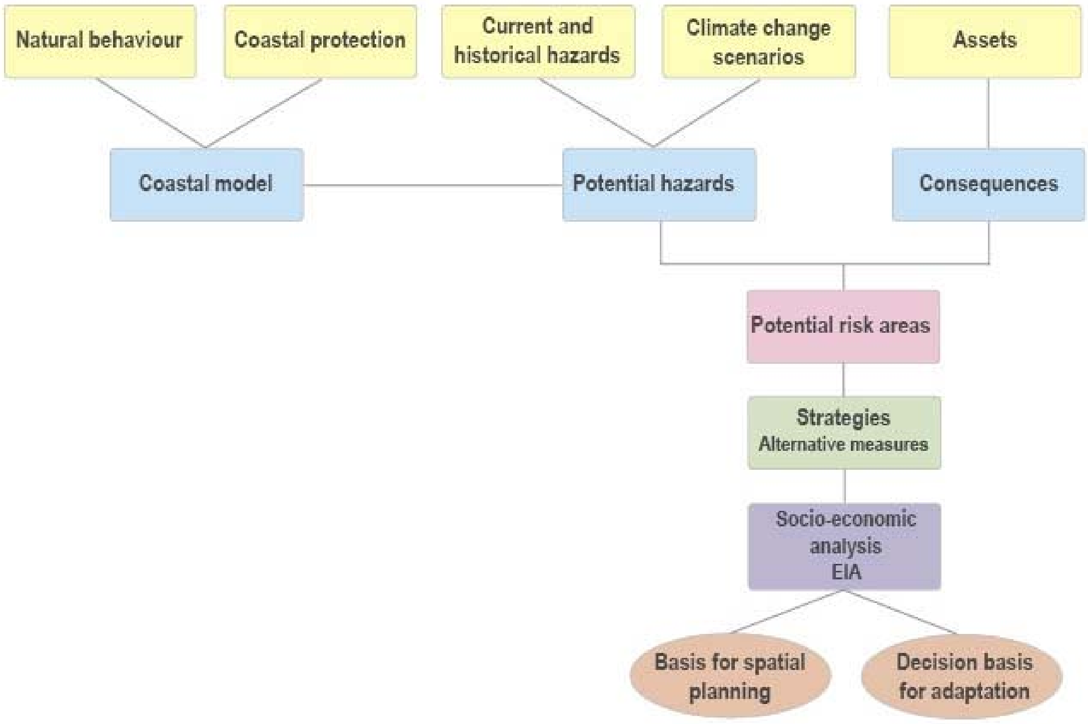

Figure 1. Example of decision model for coastal management

Name	
Organisation	
Country	
Contact information	

1	Are you using any kind of decision tool/model for spatial planning?	☐ Yes ☐ No, next question 12
2	The model can be used for	☐ infrastructure ☐ buildings ☐ other applications like
3	Is flooding taking into account in the model?	☐ Yes ☐ No
4	Is soil movements a problem in your country?	☐ Yes ☐ No, next question 12 ☐ Not to my knowledge, next question 12
5	Are soil movements taking into account in the model?	☐ Yes ☐ No, next question 12
6	Are landslides taking into account?	☐ Yes ☐ No, next question 9 ☐ Not applicable, next question 9
7	Is there a detailed model for land-slides, e.g. risk/hazard mapping?	☐ Yes, what kind? ☐ No
8	Is the landslide model taking Cli-mate Change into account?	☐ Yes ☐ No
9	Is erosion taken into account?	☐ Yes ☐ No, next question 12 ☐ Not applicable, next question 12
10	Is there a detailed model/tool for erosion?	☐ Yes, what kind? ☐ No
11	Is the erosion model taking Climate Change into account?	☐ Yes ☐ No
12	Are you using any kind of decision tool for adaptation due to Climate Change?	☐ Yes ☐ No

13	The model can be used for	☐ infrastructure ☐ buildings ☐ other applications like

Other comments

APPENDIX 2

Tools/models for soil movements among partners and associated members of Baltic Climate

	Institution			Contact			
Country Code	**Name**	**Legal status**	**website**	**Official contact person**	**Have models/tools for soil movements**	**Take climate change into account**	**Comments/more information**
DE	Academy for Spatial Research and Planning	academic/ scientific organisation	http://www.arl-net.de/	Dennis Ehm Sebastian Ebert Evelyn Gustedt Timm Wiegand	No		Will use the general tool developed in BC.
EE	Harjumaa County Government	regional public authority	http://www.harju.ee/	Heino Alaniit	No		Have a need of model for infrastructure.
	Saku Municipality	local public authority	http://www.sakuvald.ee/	Kalle Pungas	No, not a problem.		General tools are sustainable principles fixed in municipality general strategy and land use plan.
FI	Regional Council of Central Finland	regional public authority	http://www.keskisuomi.fi	Hannu Koponen	No		Will use the general BC model for regional planning. Have flood hazard maps on national level.
	Jyväskylä Regional Development Company Jykes Ltd	local public authority	http://www.jykes.fi/	Jani Viitasaari Pentti Kupari	No		Have industry SWOT-tool as decision tool for Climate Adaptaion.

	Institution			Contact			
Country Code	**Name**	**Legal status**	**website**	**Official contact person**	**Have models/tools for soil movements**	**Take climate change into account**	**Comments/more information**
LT	Lithuanian Institute of Agrarian Economics	academic/ scientific organisation	http://www.laei.lt	Virgilijus Skulskis Zivile Gedminaite-Raudone Rasa Melnikiene	Have a model for erosion in sea-banks.	Yes	Have also a decision tool for Climate adaptation on ministry level.
LV	Municipality of Ligatne	local public authority	http://www.ligatne.lv/index.html	Ainārs Steins Aija Ziedina	No		
PL	West Pomeranian Business School	academic/ scientific organisation	http://www.business-edu.eu/	Jerzy Rozwadowski Gabriela Gorewicz	Have a landslide model where flooding is taken into account.	No, not in the landslide model but in the spatial development plan.	Jan Smutek, Regional Office for Spatial Planning of Zachodniopomorskie Voivodship. Have spatial development plan and climate changes are built into the plan.
RU	Pskov State Polytechnic Institute	academic/ scientific organisation	http://www.ppi.psc.ru	George Varlamov			Olga Bakumenko answer that they have education of engineers about climate change adaptation.
SE	County Administrative Board of Gävleborg	regional public authority	http://www.gavleborg.se/	Daniel Andersson Lise Ekenberg	Yes	Yes	Using the Swedish Geotechnical Institute model
	Municipality of Söderhamn	local public authority	http://www.soderhamn.se/	Andreas Haberg	Yes	Yes	Using the Swedish Geotechnical Institute

	Institution			Contact			
Country Code	**Name**	**Legal status**	**website**	**Official contact person**	**Have models/tools for soil movements**	**Take climate change into account**	**Comments/more information**
				Ingemar Olofsson			model
	Municipality of Gävle	local public authority	http://www.gavle.se/	Lars Westholm Eva Bränlund	Yes	Yes	Using the Swedish Geotechnical Institute model
	Swedish Geotechnical Institute	gouvernment scientific institute	http://www.swedgeo.se	Yvonne Rogbeck Bengt Rydell	Yes	Yes	Swedish Geotechnical Institute's model is described in the report.

APPENDIX 3

Tools/models in countries outside BC

	Institution	Contact			
Country Code	**Name**	**Official contact person**	**Have models/tools for soil movements**	**Take climate change into account**	**Comments/more information**
FR	BRGM - Service Risques	Gilles Grandjean	Yes	Yes	Have a deterministic model for risk/hazard mapping coupled with probalistic geomechanical model. For erosion there is a hill slope physical model.
HU	National Directorte General for Disaster Management (NDGDM)	Orsolya Gerics	Yes	No	They have a geological hazard source register, which warns on a settlement level to the existence of some incident(s)/phenomena or unfavourable conditions. They have risk maps to many settlements. For greater regions/areas mapping is in progress at the moment. On the Settlement structure plan(spatial planning) level geological conditions, risk sources are/can be taken into consideration. Hungarian Office for Mining and Geology on the basis of legal requirements provides data and gives opinion as respective authority to the National, Stressed Regions to County and Settlement structure plans. Due to lack of detailed maps, covering the whole country, Hungarian Office for Mining and Geology in many cases is able to make only large-scale awareness raising. While at those places where already a detailed map exists, it can make detailed recommendations. Before the end of 2011 EU Member States are invited to further de-

	Institution	Contact			
Country Code	**Name**	**Official contact person**	**Have models/tools for soil movements**	**Take climate change into account**	**Comments/more information**
					velop national risk analysis, maps (Council conclusions on Further Developing Risk Assessment for Disaster Management within the European Union 8068/11 during the Hungarian EU Presidency). Before the end of 2012 the European Commission - based upon the available national risk analysis – will prepare an overview of the major natural and man-made risks that the EU may face in the future. According to these approaches, NDGDM has already started the work to further analyse national risks.
IT	Organisation Federico II University of Naples	Domenico Calcaterra	Yes	No	In Italy, landslide and flood risk is regulated by a national law (nr. 183 enacted in 1989) which introduced specific governmental agencies in charge of land planning and management, called Basin Authorities. Accordingly, 36 Basin Authorities were created, either national, inter-regional or regional. Each Authority has produced from 1999 onward its own Hydrogeomorphological Setting Plan, which comprehends landslide and flood susceptibility/hazard and risk maps. As regards the methodologies adopted, a variety of models have been used, from euristic to statistical.

	Institution	Contact			
Country Code	**Name**	**Official contact person**	**Have models/tools for soil movements**	**Take climate change into account**	**Comments/more information**
NO	Directorate for Civil Protection and Emergancy Planning	Nils Ivar Larsen	Yes	Yes	The Directorate for Civic Protection and Emergency Planning have an general model/guide for land use planning. Norwegian Water Resources and Energy Directorate have the administration/responsibility for floods and landslide in Norway. They also have specific model/guideline for handle this.
PL	The Polish Geological Institute - National Research Institute	Zbigniew Frankowski, Piotr Galkowski	Yes	No	They have different kind of risk/hazard mapping.
PL	University of Szczecin, Institute of Marine and Coastal Sciences, Remote Sensing and Marine Cartography Unit.	Kazimierz Furmanczyk	Yes, for erosion	No	They are using X-beach model for coastal erosion and overflow implemented as an Early Warning System for storm impact developed in 7FP MICORE project. http://www.micore.ztikm.szczecin.pl
SK	Ministry of the Environment of the Slovak Republic	Zelmira Greifova	Yes		There are the susceptibility map of the landslides, the map of landslide risk and the map of landslides hazard. For erosion there is a susceptibility map.

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