Flood Warnings in a Risk Management Context
A Case of Swedish Municipalities

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Abstract

As a result of the United Nations’ International Decade for Natural Disaster Reduction (1990-2000), and recent high profile disasters, disaster risk reduction has climbed high on the international political agenda. There has been a paradigm shift from reacting to disasters towards preparing for and mitigating effects of disasters. Among the measures that have been highlighted on the disaster risk reduction agenda are early warning systems. In a Swedish context, there is a demand for early warning capabilities for various types of flood risk. Municipalities carry the primary responsibility for managing flood risks and early warning has the potential to facilitate decision-making and ultimately reduce flood losses.

The aim of this thesis is to describe how a variety of flood warning signals are used in the risk management process of Swedish municipalities, how they can contribute to the flood risk reduction process, and which factors are associated with effectiveness and successful reduction and management. The thesis is based on two papers.

Paper I is based on interviews with three key respondents from Swedish municipalities that have invested in and established local early warning systems. The paper shows that the possible effects from a local early warning system are not only reduced flood losses but also potential spin-off benefits, the occurrence of which is dependent on factors such as organisational culture and the functioning of the wider risk management system.

Paper II is based on interviews with 23 respondents at 18 Swedish municipalities, who have responsibilities related to flood risk management, and one respondent who works at SMHI with hydrological warning. The paper shows that municipalities can use a variety of complementary flood warning signals to facilitate decision-making for a proactive flood response. This is, however, not systematically the case as benefits are dependent on available resources.
The theoretical and empirical contribution of this thesis is the further development of existing conceptual models of early warning systems with respect to the broader risk management system and an investigation into the use of complementary warning signals. By examining the impact of these issues at the local level, this thesis adds to our understanding of the value of specific disaster risk reduction practices, particularly with regard to the intricacies of implementation and use of early warning systems in a local flood risk management context.

**Keywords**

Early warning systems, floods, natural hazards, municipality, risk management, preparedness, disaster risk reduction.
Sammanfattning


Målet med denna avhandling är att belysa hur en mångfald av tidiga varningssignaler används i riskhanteringsprocessen hos svenska kommuner, hur de kan bidra till översvämningsriskreducering, samt vilka faktorer som är associerade med effektivitet och framgångsrik riskreducering och -hantering. Avhandlingen bygger på två artiklar.

Artikel I är baserad på intervjuer med tre nyckelpersoner från tre svenska kommuner som har investerat i och upprättat lokala varningssystem. Resultatet visar att effekterna av ett lokalt varningssystem inte bara är minskade konsekvenser av översvämningar, men också potentiell spin-off-nytta, vars förekomst är avhängigt faktorer såsom organisationskultur och funktionen hos det bredare riskhanteringssystemet.

Artikel II är baserad på intervjuer med 23 personer med ansvar för översvämningshantering på 18 svenska kommuner, samt en person som arbetar på SMHI med hydrologisk varning. Resultatet visar att kommunerna kan använda en mångfald av kompletterande varningssignaler för att underlätta beslutsfattande vid hantering av översvämningsrisk. Detta är dock inte systematiskt uppbyggt eftersom nytten är avhängig att tillräckliga resurser finns tillgängliga.
Det teoretiska och empiriska bidraget av denna avhandling är en vidareutveckling av existerande konceptuella modeller av system för tidig varning avseende kopplingen till det bredare riskhanteringssystemet, samt en analys av användandet av kompletterande varningssignaler. Genom att studera betydelsen av dessa spörsomål på lokal nivå, kan denna avhandling bidra till vår förståelse av värdet av specifika katastrofriskreduceringsåtgärder, i synnerhet med avseende på svårigheterna med implementering och användande av system för tidig varning i en lokal riskhanteringskontext.

**Nyckelord**

Varningssystem, översvämning, naturolycka, naturkatastrof, kommun, riskhantering, beredskap, katastrofriskreducering.
List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.


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For paper I all data collection, analysis and most of the writing was done by Erik Persson. Erik Persson was also the main contributor to study design, theory and conceptualisation, with input from supervisors Lars Nyberg, Inge Svedung and Charles Parker.
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Thesis

Introduction

In 2005 the international community convened at the World Conference on Disaster Reduction in Kobe, Japan, where they made a commitment to address disaster risk reduction and to engage in a ten year results-oriented plan of action, called the Hyogo Framework for Action (HFA). While the HFA ends in 2015, this was a strong signal that disaster risk reduction was a key part of the international political agenda (UNISDR, 2005). The link between disaster risk reduction and sustainable development was clear from the beginning, and was asserted in the HFA as well as in the outcome document adopted at Rio+20, called The Future We Want (United Nations, 2012). The HFA stated that: “There is now international acknowledgement that efforts to reduce disaster risks must be systematically integrated into policies, plans and programmes for sustainable development. […] Sustainable development, poverty reduction, good governance and disaster risk reduction are mutually supportive objectives, and in order to meet the challenges ahead, accelerated efforts must be made to build the necessary capacities at the community and national levels to manage and reduce risk” (UNISDR, 2005, p. 1).

There is a shared understanding within the disaster risk reduction community that a proactive behaviour, as opposed to reactive behaviour, is the preferred general strategy to reduce the overall costs of disasters. Disasters are defined by UNISDR (United Nations International Strategy for Disaster Reduction) as “a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources” (UNISDR, 2009). Whether the likelihood of disasters will increase as a result of global climate change or not remains to be seen, but the effects of disasters today
are already unacceptable and truly hampering human progress (Guha-Sapir et al., 2013; Wisner et al. 2012, UNISDR, 2005).

The rise and prosperity of industrial societies has arguably taken place in a hostile environment, and disaster risk is a result of the exposure of vulnerable human interests to hazardous forces, such as floods, droughts, storms, earthquakes, and volcano eruptions (UNISDR, 2005). It has been argued that industrial societies face hazardous forces and succeed in their response more often than not, and that disasters are departures from how society normally functions, and also that recovery means a return to normal. However, such a perspective does not account for a more complex view on what makes people, groups and societies vulnerable. Vulnerability is defined by Wisner et al. (2004, p. 11) as “the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard”. According to this view, hazardous events may well contribute to triggering a disaster, but the main focus should be on how social systems develop vulnerabilities and make disasters possible. Managing disaster risk is therefore not only about managing hazardous events, but also by managing vulnerability, its causes, and the ways to adapt response (Wisner et al. 2004).

As part of a global movement to manage disaster risk, governments are currently undertaking a large variety of measures, trying to address the multitude of natural hazards they are facing. While long-term approaches are required for implementing effective disaster risk reduction policies, it is still more common to adapt short-term approaches. Turning this relationship around is a great challenge for the world’s governments, where the scientific community also can contribute (Wisner et al. 2012). When it comes to managing disaster risk in Europe, and particularly flood risk, there has been an emphasis on the use of structural protection works and flood sensitive land management systems. Increased levee height and river control in some places has even led to amplified risk and more severe consequences of floods (Di Baldassarre et al. 2009). As a way of managing residual risks, and as part of a policy shift towards non-structural measures (Blöschl, 2008), early warning systems (EWSs) are being developed on international, national and local
levels (Handmer, 2001). An effective use of EWSs is partially a way of considering vulnerability in disaster risk reduction, in that it aims to “empower individuals and communities to respond appropriately to a threat in order to reduce the risk of death, injury, property loss and damage” (Bureau of Meteorology and Australian Emergency Management Institute, 1993).

This thesis aims to make a contribution to both research and practice in the disaster risk reduction field, with particular emphasis on the intricacies of implementation and use of EWSs in a local flood risk management context.

**Risk Management and a Systems Perspective**

The risk management process builds upon three main elements: risk analysis, risk evaluation and risk control/reduction (Rausand, 2011). Its main principle is “to identify, analyse and assess potential hazards in a system or related to an activity, and to identify and introduce risk control measures to eliminate or reduce potential harms to people, the environment, or other assets” (Rausand, 2011, p. 10). When the process has been run through, it starts over in a feedback loop. Since circumstances regarding risk and safety change over time, risks can never be overcome indefinitely, which prompts the risk management process to be cyclical and repetitive. Risk management is by nature a learning process, where knowledge builds on prior experiences (Rausand, 2011).

Another central theme of risk management is that the responsibility for safety lies in the hands of those who are concerned with it, implying that they should be a part of the assessment processes as well (Dawson et al. 1988). Risk management in society as a whole or within organisations is understood as processes performed and influenced by many actors within a system (Rasmussen and Svedung, 2000).

A system can be defined as a “set of interrelated elements” that share a purpose or goal (Vicente, 1999, p. 9; Branford, 2007), and systems theory is focused on these elements or components as a whole, not as separate parts. It is the interaction and fit of the components that determine the properties of the system, not the nature of
the components themselves (Leveson, 2002; Skyttner, 2005; Larsson et al. 2010). A useful perspective on society or an organisation as a system, with dynamic interactions between humans and technology, deals with what is sometimes called socio-technical system. Examples of human and technological components that interact in socio-technical systems are physical processes, procedures, laws, staff members, managers and supervisors. These interacting components are in turn affected by activities of the organisations involved, regulatory bodies and the government, as well as external pressures of society, relating to technological, political and financial circumstances (Rasmussen and Svedung, 2000; Vicente and Christoffersen, 2006). Examples of socio-technical systems have historically been nuclear power plants, airports, hospitals, etc, but in modern society basically any organisation that deals with potentially hazardous events in their operations can be considered a part of a socio-technical system (Rasmussen and Svedung, 2000). For example, a municipality that manages flood risk could be viewed as a complex socio-technical system, which in turn interacts with other organisations with regard to the use of early warnings.

Rasmussen and Svedung (2000) have developed theory about socio-technical systems in a risk and safety context, its properties and design. Rasmussen created a hierarchical model of the socio-technical system to illustrate the different levels and the interactions that define the system. The bottom level deals with activities that directly relate to management of the hazardous process; the second level deals with work that is designed to control the hazardous process; the third level deals with management and supervision of the staff; the fourth level deals with the behaviour of the organisation itself; the fifth level deals with regulatory bodies that oversee activities related to the hazardous process; and the top level deals with government and control of safety through policy and legislation. The way that the levels in the socio-technical system interact is through a flow of feedback loops between the levels, in the form of decisions (e.g. laws, regulations, plans) that are sent downwards, and information (e.g. observations, reports, reviews) that is sent upwards. The control of the hazardous process will be lost if the exchange of decisions and information throughout the system does not work. Safety in a socio-technical system is therefore not only affected by activities that occur in direct
interaction with the hazardous process itself, but by activities at every level and by the interaction across the levels in the socio-technical system (Rasmussen and Svedung, 2000, Vicente and Christoffersen, 2006, Branford, 2007).

According to Rasmussen (1997), decisions made by individuals at several levels interact to cause disasters. These decisions are generally variations of normal behaviour which releases a sequence of events that has been influenced by other individuals’ decisions in the system. Because what happens in the system is integrated and interlinked over time and space, individuals have no ability to see and comprehend the system as a whole. One decision, regardless how normal it may be perceived in a local context, can seem to be the cause of a disaster (Svedung and Rasmussen, 2002). Systems theory, however, has the ability to tell a different, more complex story (Branford, 2007). Just like disasters caused by natural hazards have been viewed as a departure from how society normally functions (Wisner et al. 2004), it is actually a result of normal behaviour in a socio-technical system, where a long series of feedback loops of decision and information exchange between interacting levels as well as influence of the surrounding environment have created vulnerabilities and insufficient capacities to manage a hazardous event, during what is sometimes called the incubation period (Svedung and Rasmussen, 2002; Branford, 2007; Dekker and Pruchnicki, 2014).

**Disaster analysis**

Management of disaster risk with a purpose of predicting, preventing or mitigating the consequences of disaster, can be deconstructed into four disaster phases: Prevention; Preparedness; Response; and Recovery (Fig. 1). It is important to note that it is not always easy to determine the boundaries between the phases – it is useful to think of the disaster phases as interlinked (Halldin et al. 2011; Wisner and Adams, 2002; Lindell et al. 2006).

The prevention and preparedness phases occur in the time before a hazardous event, while response and recovery occur during and after. The prevention phase deals with efforts to reduce vulnerabilities through activities such as physical planning, technical measures, training, community participation, etc. The
preparedness phase deals with the capacity of societies to act in accordance with early warnings to reduce the impact of the hazardous events. The response phase deals with the actions and measures that are taken as the hazardous event happens and directly after. The recovery phase deals with rebuilding and reconstructing society towards functionality, but more importantly, towards reduction of risk and vulnerability. From a governance point of view it is vital that the disaster analysis address the outcome of previous mitigating efforts and address the role of different societal functions engaged on different levels. (Halldin et al. 2011; Wisner and Adams, 2002; Lindell et al. 2006, Rasmussen and Svedung, 2000).

**Disaster phases**

![Disaster Phases Diagram](image)

Figure 1. Disaster Phases. This figure is taken from Halldin et al. (2011), Science Plan for the Centre for Natural Disaster Science (CNDS).

**The Role of Preparedness**

While the ability to respond effectively in a disaster is crucial for saving lives, the time and money invested in prevention and preparedness before the event has potential to keep a hazardous event from even becoming a disaster. Preparedness can be defined as “the knowledge and capacities developed by governments, professional response and recovery organisations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions” (UNISDR, 2009). This capacity to anticipate, respond to and recover from impacts of hazardous events fundamentally builds on the concept of vulnerability (Wisner et al. 2004). It is also clear that success in the prevention and preparedness phases are of utmost importance for the
effectiveness of the response and recovery phases (Halldin et al. 2011; UNISDR, 2005).

Building preparedness in society is a costly and time consuming process, most likely to be associated with setbacks. In the end, it is the societies that manage to continually strive toward prevention, preparedness and with reduction of vulnerability in mind that have the best chance of surviving in the long run. Disaster risk reduction has received global attention as of late, and the world in the wake of global climate change is at a crossroads, where the prevailing route arguably is the one of preparedness and adaptation (Wisner et al. 2012; UNISDR, 2005).

What constitutes preparedness in effect depends on the type of risk that is being dealt with. It can also often be difficult to isolate and identify a preparedness measure; as such, measures are often embedded in other types of spending, such as infrastructure or planning strategies. It is imperative for those who make budget decisions to find the most cost effective spending options, since resources are scarce. Spending money to prevent loss of money is also a classical economic problem, especially when it comes to motivating it in the context of a democracy. The World Bank (2010) has identified three spending items that are desirable for disaster risk reduction – critical infrastructure, environmental buffers and EWSs. While it is difficult to do an internal ranking of which types of measures are most cost-effective – it is context dependent – it is clear that the most benefits of any of the three is best realised when linked with spending and improvements in the other areas (The World Bank, 2010). The benefit of an EWS is greatly limited if it is not part of a greater risk management system where resources have been allocated for other measures and strategies, such as critical infrastructure, emergency planning and risk awareness, etc. (Parker et al. 2007).

Early Warning

Early warning as a concept is not limited to one particular research field. Early warning is discussed in relation to economic crises, currency crises, disease and virus epidemics, armed conflicts and natural hazards, to name a few (Bussiere et
al., 2006; Kaminsky et al., 1998; Lowe, 2011; Laurence, 1998; Basher, 2006). The common denominator for all these fields is that a system for early warning is deployed to inform of a danger (threatening economic, environmental or health values) that is likely to occur in the future. The main aim of any EWS is to enable preparation for the danger and trigger appropriate actions that will mitigate the danger or allow the people at risk to avoid it. A classic example of this is when canaries were carried into coal mines to alert miners of the presence of gases (e.g. methane) that can lead to an explosion. Canaries are sensitive to toxic gases, and if they died it indicated to the miners that they were in imminent danger (Dale, 2001).

There are many different definitions of early warning, depending on the context. According to UNISDR, early warning can be defined as the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organisations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss (UNISDR, 2010).

**Early Warning Systems for Disasters**

When disaster strikes, one question that often is asked is if it could have been prevented in any way. This very question was asked after the Indian Ocean tsunami that claimed 250,000 lives in 2004, and after the Cyclone Nargis in Myanmar that claimed more than 130,000 lives in 2008 (IFRC, 2009). These disasters, along with several other high profile events additionally spurred the attention to and improvement of EWSs for natural hazards that had begun gaining momentum by the end of the 20th century (UNISDR, 2006a). To this day three global early warning conferences have been held (1998, 2003 and 2006) with the objective of catalysing efforts to examine what was working and what was not working with EWSs. Following the 2005 World Conference on Disaster Reduction and the HFA, as well as the third early warning conference in Bonn, Germany in 2006, progress was reached in linking early warning to early action and disaster risk reduction (UNISDR, 2005; 2006b). While the greatest efforts in the recent decades have gone into research on developing the technical capacity to detect and produce good warnings, a new consensus emerged from the conference processes: The ultimate
The purpose of early warning is to trigger action to prevent or mitigate a disaster, a purpose that does not only rely on technically precise warnings but also on an understanding of risk and vulnerability, and a link between those who disseminate the warning information and those who are to receive the information and act appropriately upon it (IFRC, 2009). From this analysis EWSs have been broken down into four elements, separate yet interlinked. These four elements include the development and operation of EWSs in regard to: (a) knowledge of risks faced; (b) technical monitoring and warning service; (c) dissemination of meaningful warnings to those at risk; and (d) public awareness and preparedness to act (Villagrán de León, 2012; UNISDR, 2006b). This new perspective is also referred to as a people-centred approach, meaning a larger focus on the social and psychological aspects of early warning and early action and on promoting a culture of preparedness, as opposed to a culture of reaction and short-term response. This focus also implies a shift from a hazard-oriented focus to a vulnerability-oriented focus (Villagrán de León, 2012; IFRC, 2009).

The fundamental problem with the current status of early warning as a practice, as addressed in the Global Survey of Early Warning Systems, is that failure in any one of the four elements will likely mean failure in the whole system (United Nations, 2006). As has been stated on several occasions, the last two elements of EWSs are the ones most likely to fail – dissemination of meaningful warnings to those at risk and public awareness and preparedness to act (UNISDR, 2005; 2006b; United Nations, 2006; IFRC, 2009; Drobot and Parker, 2007). This was what happened in the case of the Cyclone Nargis. The technical part of the EWS worked properly – it was rather failures in communicating the warning information and preparedness to act that resulted in the devastation (IFRC, 2009).

The major gaps in knowledge that need to be filled in order for EWSs to be effective have been identified by the international political and scientific communities to be in those two elements. Salvano Briceño, director of the UN interagency secretariat of UNISDR at that time, pointed out that “a weak link in the early warning chain is the institutional capacity of countries to act on available warnings and forecasts. An even greater shortcoming remains in the capacity to
communicate this information to vulnerable communities” (Briceño, 2006). In conclusion, the crucial questions revolve around the link between the organisations issuing warnings and the organisations receiving warnings, but also linked to how the public receive warnings and how the warnings are to be acted effectively upon (UNISDR, 2005; 2006b; United Nations, 2006; IFRC, 2009; Drobot and Parker, 2007).

**Early Warning Systems for Floods**

According to the Centre for Research on the Epidemiology of Disasters (CRED), hydrological disasters have been the most abundant disasters and together with meteorological disasters accounted for 80% of total occurrence in 2013 (Guha-Sapir et al., 2013).

Floods can occur in connection to rivers, lakes, and the ocean, to heavy rainfall and to dam breaks. Flood risk can be influenced in three major ways: by decreasing exposure to the hazard; by decreasing vulnerability; and by increasing capacity. Reducing the flood risk by removing the exposure is not considered to be the most practical option – water can be moved and detained, but human settlements are generally difficult to move with short notice (UNEP, 2008).

An EWS is a tool that can aid the capacity to respond to floods in the short term, but in the long term the implementation of an EWS also has the potential to contribute to increased awareness and preparedness, and reduce vulnerability (Parker and Priest, 2012).

As structural protection works appear not to be feasible for reducing flood risk, early warning, behavior change, awareness and preparedness has become more central to the risk management approach (Nye et al., 2011, UNISDR, 2005). At the same time, surveys in Hungary, The Netherlands, Germany and the UK revealed that there is a growing dependence on EWSs (Parker and Priest, 2012). Since the mid 1990’s there have been many examples of European initiatives to improve EWSs. In another survey of thirty European countries, conducted by the European Environment Agency and the German Ministry for the Environment, 70 % of the
countries were planning or had implemented forecasting and information policy initiatives and about 13% of those were considered ‘effective or necessary’ (EEA, 2007; Parker and Priest, 2012).

Exploring the research field on EWSs largely confirms the picture painted by the United Nations and the Red Cross (UNISDR, 2005; 2006b; United Nations, 2006; IFRC, 2009). Most research on EWSs is technically, hydrologically and meteorologically oriented. There have been advances in meteorological, hydrological and engineering sciences in the past decades that have generated a range of new methodologies for forecasting weather and flood events. These advances have increased the potential to improve the accuracy and reliability of flood forecasts, to more precisely locate where and when extreme rainfall will occur, to extend flood warning lead time in short and long term and to measure the uncertainties associated with a flood forecast (Parker et al. 2009). Alongside these advances there have been contributions from social sciences, with a focus on human perceptions of risk information and risk communication (Drobot and Parker, 2007).

“Social science offers the potential for understanding how all of the actors in the flood warning systems perceive and might best be able to utilize the improved flows of data and information which technical advance generates.” (Drobot and Parker, 2007, p. 174)

The Basics of Early Warning Systems

An EWS can, in the form of a conceptual model, be described as a chain, comprised of five main parts with an outcome and a learning feedback loop. There are several supporting processes that work to aid the main parts of the chain, which all together strive towards the outcome of reducing flood losses, be they environmental, economic or human (Fig. 2) (Parker and Priest, 2012).
According to this model, the EWS begins with technical components that aim to discover if a flood is nearing. This is done by thorough modelling of the watershed and its characteristics and also meteorological prognoses. The EWS also relies on an understanding about vulnerabilities in the local community. The next step in the system is that the information about the flood needs to be communicated to the organisations and people who in different ways need to act (Parker and Priest, 2012). A problem that is well known is that those who produce warnings often mistakenly believe that their messages are received by individuals and communities who are perceptive and will take immediate, proper action after having been informed. However, the dissemination and reception of disaster warnings is a social, not a mechanical process. Three factors have been found to be important: message clarity, source credibility and the risk perception of the receivers (Parker and Handmer, 1998; Drabek, 1986). The fourth step in the system is that the concerned parties use the warning information in a damage reducing way. This depends on people’s assessment of the risks they are facing. Many factors can influence subjective risk perceptions of which official flood warnings are only one. Fundamental to people’s risk perception is their prior experiences.
with high water, as well as the feedback they receive from their immediate environment (Parker and Priest, 2012; Rosenthal and ‘t Hart, 1998; Drabek, 1986). The system ends with a crucial link – gathering of knowledge of the performance, and returning this knowledge to the organisation and the actors who run the system, enabling improvement. There are several key supporting processes that are important as they really are prerequisites for the system to function. These processes need to be in place for the system to work in an emergency, but take time and resources to establish and maintain. Key processes such as flood risk awareness and response preparedness will deteriorate if not properly maintained. Flood identification and mapping, another key process, needs to be evaluated regularly, as risk characteristics tend to change over time (Parker and Priest, 2012; Rosenthal and ‘t Hart, 1998; Rausand, 2011). The EWS chain is not to be understood as a linear process, as may be assumed from Fig. 2; it should rather be viewed as an integrated system, where the different actors within the EWS chain exchange information and data about “likely events, uncertainties surrounding forecasts and warnings, and appropriate risk reduction behaviours” (Drobot and Parker, 2007, p. 174).

As was addressed in the Global Survey of Early Warning Systems (United Nations, 2006), deficiencies can arise from any aspect of any component of the EWS chain. What is worse is that these deficiencies then are passed on downstream in the chain which may have an impact on the desired flood loss reduction. Due to the potential deficiencies at each of the five stages of the EWS that transfer through the chain, it is not certain in any way that scientific advances in weather and flood forecasting will lead to considerably reduced losses. There have been major flood events where EWSs have fallen short of what was expected of them, regardless of the fact that they were modern and scientifically advanced. The degree of success of EWSs is ultimately defined by the potential deficiencies, human factors and related social issues (Parker and Priest 2012). “Even in the most organized and disciplined societies with high levels of disaster preparedness, populations may not respond to warnings with disastrous consequences.” (Parker and Priest, 2012, p. 2928)
EWSs are not just about event-specific warnings, but also about year-round awareness raising and information provision. If this is successful it may create a context in which event-specific warnings are less crucial and make less difference because residents of flood risk areas are more flood aware and prepared. Early warning is not separated from general disaster risk reduction and it should not be viewed solely as a short-term way to avoid harm. In order to be effective, early warning has to be built into a setting of risk awareness and capacity to act. A robust early warning system relies heavily on a sound understanding of people’s behaviour, but demands also that the public and communities at risk are involved and are able to respond appropriately (Parker et al. 2007).

**Early Warning Systems and Communicating Uncertainty**

Predictive uncertainty is an inherent characteristic of flood prediction, and the uncertainties may lead to poor decisions down the EWS chain, which in the end may lead to objectives not being met. Hydrological models and the quality of measurements and forecasts of precipitation are factors determining the quality of flood forecasting. Weather forecasting, a prerequisite for flash flood, coastal flood and increasingly so river flood forecasting, presents many uncertainties and is also problematic for more than six days ahead. Methods for forecasting are steadily being developed and improved and are increasingly based on probabilistic predictions. One problem with that is that such information can be confused with inaccuracy, which can lead to reduced trust in warnings. In general, the degree of uncertainty that is associated with a flood warning increases as the warning lead time increases. The threat to life and property can be more accurately assessed through increased forecast accuracy, leading to an increased potential for flood loss reduction, but warning lead time is reduced with increased accuracy (Parker and Priest, 2012).

Information and data come to all of the actors in the early warning chain from different channels with varying importance, which demands that the ones receiving the information knows what to look for and what to do with the information. The actors that are exposed to the largest amount of information are the different groups of the public in society, but at the same time they have the least knowledge of what
information to use and what to discard. There is an important question of how to present this information to the public to yield the best loss-reducing effect (Drobot and Parker, 2007).

One of the answers to more effective flood warning response lie in making probabilistic predictions that can be interpreted realistically, giving a potentially longer lead time for different flood types (Parker and Priest, 2012). One of the major challenges when it comes to EWSs revolves around the communication of uncertainty data from scientists who are responsible for flood forecasting and warning, to how emergency service responders, utility companies and the public might deal with and utilize such uncertainty. The ability to warn about impending short lead-time hazard events is affected by technical innovations, increased mobility, an increasingly information-dependent society, population demographics, and capacity to interpret and act (Drobot and Parker, 2007). There are several studies that specifically have delved into the difficulties of communication between scientists and practitioners (e.g. Handmer et al. 2003; McCarthy et al. 2007; Faulkner et al. 2007).

**Contingency Theory of Warning**

The contingency theory of warning, discussed by Bracken et al. (2008), deals with the fit of capacity and the strategic environment. An EWS, regardless what it is built for, can be deconstructed into two separate parts: the capacities of the organisation and the strategic environment. Capacities consist of the organisations ability to obtain, process and respond to a warning, while the strategic environment consists of the dangers and opportunities of the outside world. The idea is that capacities are not necessarily good or bad in themselves – the value or benefit of the capacities varies depending on what kinds of dangers are to be detected. A set of capacities that are designed to detect and disseminate warnings about tectonic plate movements are likely not effective for detecting and disseminating warnings about tropical storms. This perspective is important when talking about EWSs for floods as well, since there are different flood risk types, different vulnerabilities, and different capacities. Effective use of warnings is dependent on system design (Bracken et al. 2008).
Characteristics of Flood Types

There are different types of flood risk, of which the following three are mostly recognised in Sweden:

Pluvial flooding is highly probable but is generally a low threat to the public, and it mostly affects and requires response from local government. Pluvial flooding events are difficult to predict and to give effective warnings for since they form quickly, appear rather randomly in space, with very local results. Warnings about pluvial flooding are needed for the concerned local governments as well as the public, while it is mostly local government who is required to act.

Fluvial flooding is not as probable as pluvial flooding but can have more severe consequences, and it mostly affects and requires response from regional and local governments. Fluvial flooding events are easier to predict and it is possible to give warnings since they take longer time to form (compared to pluvial flooding) and are usually confined to known geographical boundaries. Warnings about fluvial flooding are mostly needed for the concerned regional and local and governments, since they are the ones who are affected and have a responsibility to act.

Flooding from dam breaks is extremely improbable, but can also have extremely severe consequences should one occur. Flooding from dam breaks affects and requires response from regional and local governments as well as the public. Depending on the cause of the dam break the possibilities for prediction and warning vary. If the cause for the dam break is extreme pressure from prolonged raining, it is possible to predict and give warnings. Warnings about flooding from dam breaks are needed for the national government, the concerned local and regional governments, and everyone who dwell in the affected area: permanent residents, commuters as well as tourists and temporary visitors.

This thesis is strictly concerned with management of fluvial flood risk.
Figure 3. Flood risk types in Sweden, after Rasmussen (1997) on hazard source characteristics. (P)robability means likelihood of a flooding event happening. (S)everity means severity of consequences if a flooding event happens. (C)oncerned unit in this case means how many units in society will be forced to take responsibility and act as a result of a flooding event. A pluvial flooding event in Sweden only demands response from the affected municipal organisation, whilst flooding from a dam break demands substantial response from all municipalities, organisations and people working and living in the affected area.

An EWS is supposed to give organisations and people enough time to reduce potential flood losses before a flood happens. It is nevertheless misleading to suggest that early warning is strictly a measure to deal with floods in a time of crisis. Looking at EWSs in a longer time perspective, the requirements for the warnings to be effective are just as important as the warnings themselves (Parker and Priest, 2012). No matter who is responsible for acting upon a warning, if a warning is to be effective, it is imperative that the warning system is part of a larger risk management strategy, where there is an ongoing process toward risk awareness and preparedness (Parker et al. 2007; Bracken et al. 2008; IFRC, 2009). This requirement is never more fitting than when discussing warnings for flooding from dam breaks. Lead times are generally very short and there is a multitude of different actors who need to know what to do as well as have the capacity to do it. In accordance with the contingency theory of warnings, it is evident that the required capacities needed to obtain, process and respond to a warning vary depending on which flood risk type is being addressed (Bracken et al. 2008).
Aim of Thesis

The aim of this thesis is to study the implementation and use of early flood warnings in a Swedish local risk management context. The thesis is comprised of three main objectives:

- To elucidate how and to what extent the establishment of local EWSs can generate added benefits throughout the wider risk management process.

- To map out how Swedish municipalities with potential significant flood risk gather and use early warning information from official and unofficial sources to develop a collection of information and data designed to facilitate decision-making for proactive response to floods.

- To contribute to the further development of existing conceptual models of EWSs with respect to the broader risk management system and an investigation into the use of complementary warning signals.
Methods

This thesis is based on two qualitative, comparative case studies, revolving around implementation and use of early warnings systems and signals for floods. The papers have separate data but employ similar methodological approaches.

The research focus has been shaped by extensive literature surveys, as well as discussions with supervisors and colleagues, participation in seminars and conferences. The experiences from the academic setting at Karlstad University with a special focus on environmental science, risk management and public health have also contributed to the preconceptions that have shaped the research focus, in particular, preconceptions along the lines of how society can be arranged and analysed through perspectives of systems theory (Rasmussen and Svedung, 2000; Branford, 2007). The experiences from the CNDS research school, with courses and seminars, but also the meetings and discussions with other disaster risk scholars has had an impact on shaping the research focus. This complete foundation has shaped the focus of the two papers.

The selected methods for the two papers are as follows: A comparative case study design (Kohlbacher, 2006; Yin, 2009) was utilized as a research strategy; the source material for the papers was drawn from qualitative interviews conducted by the author, and in the case of paper I, the interviews were complemented by the use of documentary evidence (Yin, 2011); and conventional content analysis (Hsieh and Shannon, 2005), was utilized as a method of analysis.

Case Study Approach

According to Yin (2009), the need for case studies originates from an aspiration to understand complex social and organisational phenomena by directly observing and studying current events. Comparative case studies cover more than one case, and can be used in an effort toward more generalisable knowledge about causal questions. Comparative case studies are concerned with the analysis and synthesis of patterns across cases that have focus or goals in common. This method makes it possible for researchers to retain holistic and significant features of events in the

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real world, for example managerial and organisational processes. The comparative case study is often the preferred strategy when asking questions of “how” and “why”, in particular in situations when the focus is on a contemporary occurrence, and where the researcher has little to no control over the events (Kohlbacher, 2006; Yin, 2009).

One of the dominant methodologies employed when carrying out case studies has been structured, focused comparison (George and Bennett, 2005), which has been utilized in both papers. The method is focused in that it zeros in on particular selected elements of the case and it is structured in that it makes use of particular questions or analytical categories to guide data collection and analysis. When conducting a comparative analysis of more than one case, the analyst asks the same questions of the different cases and examines the same relevant aspects in each case to provide analytical rigor (Ibid.).

Paper I is a case of implementation of local EWSs, the effects thereof, and the determinants to those effects. The original purpose was to find out why three municipalities had invested in and established local EWSs, despite the existence of a national EWS. The three cases were chosen as they were the only municipalities in Sweden that had invested in local EWSs. Only by comparing the cases could the overall research question regarding the impact of implementation of local EWSs be answered.

Paper II is a case of official and unofficial early warning signals utilization for floods, as well as which factors are important for this utilization. The purpose was to map out how 18 Swedish municipalities with potential significant flood risk gather and use early warning information from official and unofficial sources to facilitate decision-making for proactive response to floods. The 18 cases were chosen as they had recently been identified by a Swedish authority as facing fluvial flood risk to varying degrees. Only by comparing the cases could the overall research question regarding utilization of official and unofficial early warning signals for floods be answered.
Source Materials

In order to get to the depths of the data, the selected method for data-collection was the qualitative interview, as opposed to the structured interview, for the following reasons: There were some general questions that all respondents were asked, and there was a frame of thought related to the study objectives, but the entirety of questions were presumed to vary with the interview context, depending on where the dialogue went. The questions also were of the open variety, with the aim to get the respondents to express themselves in their own words and as elaborate as possible (Yin, 2011).

The interviews were mostly conducted over telephone. Interviewing over telephone is a widely used technique for collecting qualitative data. This method was deemed acceptable, mostly because the subjects to be discussed in the interviews were of a professional matter, and did not revolve around sensitive, personal issues (Burke and Miller, 2001).

For the sake of addressing validity in paper I, where the number of respondents was limited, analysis of key documents and reports from each municipality functioned as a form of triangulation (Malterud, 2001). In paper II, this was achieved by interviewing a larger number of respondents, as well as interviewing an employee at SMHI who could provide a different perspective (Ibid.).

Conventional Content Analysis

The papers are arguably of an inductive nature, as it is uncertain what information will be found in the data, which is why the method of analysis can be understood as conventional content analysis (Hsieh and Shannon, 2005). The process of conventional content analysis consists of open coding, creating categories and abstraction which can result in concept development or model building (Ibid.).

Content analysis fits well into the frame of a case study, as it permits valid inferences to be made from interview data to their context, providing new insights and knowledge of a phenomenon. Content analysis is good for processing large
data sets and it is also very flexible in that it allows data to be a variation of verbal and written data (Cho and Lee, 2014).

**Paper I**

The paper is based on qualitative interviews with three respondents who have responsibility for managing local EWSs at their respective municipality. Two interviews were conducted face-to-face, while one was conducted over telephone. The three municipalities were selected on the grounds that they at the time were the only municipalities in Sweden that had invested in and established local EWSs through an international consultant firm.

There were strategic reasons for interviewing the supervisors at each municipality, partly because they directly manage the EWS and partly because they are among the few at the respective municipality with an overview of the EWS. The supervisors have central positions and perspectives that correlate with the aims of the study. None of the supervisors work solely with the EWS. Supervising the EWS means regularly checking and analysing the results with a web interface, and communicating the results to other concerned actors, especially when water levels are rising. The supervisors also make sure that the EWS function properly.

The interview guide consisted of a battery of questions, for example: How does flood risk manifest itself in the municipality?; What are your experiences of previous flood events?; How was the decision to invest in a local EWS motivated?; How does the EWS relate to the flood risk management of the municipality?; Which actors are relevant in the warning chain?

To gain a broader perspective on the issue, key documents and reports from each municipality were also analysed, for example, comprehensive master plans and a flood investigation report for one of the municipalities. Each master plan was studied with respect to any reference to the EWS and the modelling that preceded it. This was made to strengthen the validity by triangulation (Mays and Pope, 2000), as well as to find out if the plans indicated spin-off effects and extended use of the EWSs.
The collected data was analysed under three analytical categories that were used to organise and interpret the empirical findings. The three analytical categories were:

1. Organisation and Responsibility
2. Relation to National EWS and SMHI
3. Spin-off Effects of Local EWSs

**Paper II**

The paper is based on qualitative interviews with 23 respondents at 18 Swedish municipalities, who have responsibilities related to flood risk management at their respective municipality. 20 interviews were conducted over telephone, while three were conducted face-to-face in one session. The eighteen municipalities were selected on the grounds that they had been assessed by the Swedish Civil Contingencies Agency to have potential significant flood risk, as per the EU Directive 2007/60/EC on the assessment and management of flood risks. One separate interview was made with a respondent at SMHI who works with hydrological warnings. The respondents at the municipalities mostly consisted of rescue service directors and safety coordinators. They were chosen explicitly on grounds that they worked with flood risk management and flood risk assessments. This was closely linked to one of the main queries of the paper – how they use early warning signals to facilitate decision-making for proactive response to floods. None of the respondents work solely with flood risk management and flood risk assessment.

The interview guide used for the respondents at municipalities consisted of a battery of questions, for example: How does flood risk manifest itself in the municipality?; Do you use flood warnings as a part of your flood risk management?; Is it challenging to interpret flood warnings with respect to uncertainties and probabilities?; What advantages/disadvantages come from receiving flood warnings/information from multiple sources?
The interview guide used for the respondent at SMHI consisted of a battery of questions, for example: How does SMHI work with hydrological and meteorological warnings?; How have you decided threshold levels for the different warning levels?; How does SMHI collect feedback from municipalities?

The collected data was analysed under three analytical categories that were used to organise and interpret the empirical findings. The three analytical categories were:

1. Role of official warning signals
2. Role of unofficial warning signals
3. Interpreting warning levels and uncertainty
Results

The following section is a summary of the results for each paper, divided into respective analytical categories.

Paper I

Organisation and Responsibility

The issue of responsibility was much discussed with the respondents from Municipality 3 and Municipality 2. The matter of responsibility was described by the Municipality 3 respondent as complex with a variety of actors playing different roles, all with different desires and goals for the local safety management. The Municipality 3 respondent had proposed a thorough risk and vulnerability analysis to be made, where different scenarios and the complex issues of responsibility and actor roles were to be elucidated. “I think that there might be ten or twenty people here in the municipality who maybe should have better knowledge of when it gets critical, who might get that, when we do this risk and vulnerability analysis, which would of course be one of the main points.”

The Municipality 2 respondent thought that the responsibility of different offices and units regarding flood management was clear, but that there seemed to be differing views elsewhere in the organisation on how the responsibility was distributed. There had been a lot of staff changes in the organisation and a challenge was to make everyone understand their responsibilities and what can be expected of them in a crisis. The fact that many people were new, from people on the shop floor level up to the municipal director, resulted in problems because of the unclear responsibility.

Relation to National EWS and SMHI

Relations with SMHI were not extensive in any of the studied municipalities. In Municipality 3, the respondent said: “I have not had that much cooperation with them actually, but that is mostly because we took this step and built this together with the private consultant firm. So, right or wrong, it simply has not happened that
way. […] We can see it as a choice of path when we did not give this contract to SMHI in the beginning.”

According to the Municipality 2 respondent, relations with SMHI had been somewhat strained. The respondent also alluded to the problems being about SMHI viewing the local EWS as competition. “I very strongly sensed that they thought that this is nothing that a small municipality should try to handle, so we were the competition, a competitor to them.” The respondent declared that the unclear distribution of responsibility between state and municipality and the lack of cooperation and partnership between them was a major problem.

*Spin-off Effects of Local EWSs*

Besides being used for its prime objective – reducing flood damage by giving flood managers enough time to respond, the establishment of EWSs in two of the three municipalities was found useful in other areas as well. The EWSs were built upon precise hydraulic and hydrologic models which gave a much better understanding of the behaviour of the watersheds. In Municipality 3, the models used in the EWS were also used when dealing with physical planning matters, especially close to lakes and rivers. For smaller municipalities, providing housing with proximity to water had been identified as a smart way of attracting people to move in, as a strategy to cope with urbanisation. The flood manager of Municipality 3 had noted that whenever there was talk about planning new housing close to water, he was consulted about the hydrological conditions and potential flood risk. “And in this case, it is very good. Some things would be possible even without the model, but we still have better knowledge than what is common when doing this type of planning. And you feel a bit more confident in those assessments.” In Municipality 3, the EWS was also used to better manage the municipality’s water regulation and hydro-power generation.

In Municipality 2, the EWS models had been used to estimate different scenarios that could be used for planning. For example, the models were used when building the city’s nature centre and a bridge over the river. The Municipality 2 respondent, however, expressed some doubt that the knowledge was being used to its true potential.
Warning signals related to fluvial flood risk coming from the official system in Sweden plays a varying role in the eighteen municipalities. One respondent said that these kinds of warnings are not very important, since the build up to an actual flood problem is quite long. “Flood warnings should, in my opinion, rather be a confirmation of something that we already know, it should not come as a surprise.” While there were other respondents who shared this perspective, there were also respondents who viewed warning signals related to fluvial flood risk as significant. A recurring theme is that official warning signals are useful for adapting the organisation with regard to preparedness. Warnings make it possible to switch from a passive to an active preparedness mode, and it enables adjusting personnel, materials and other resources. In one municipality, the respondent acknowledged that it takes time to adjust from every day mode to crisis mode, and that official warnings can aid in motivating the organisation and gaining credibility for increased awareness: “If we have an official warning and an official warning level, that now we have a level 2 warning, then we have a jumping off point. So it gives legitimacy for taking measures, such as putting up barriers, adjusting dam output, etc.”

The variance in the use of official warning signals is likely influenced by many factors, for example resources, flood risk situation, vulnerability, geographical location, and size of organisation. One respondent in particular illustrated the importance of such factors: “Last fall, there was a level 3 warning for one of the rivers here, and when I spoke to the rescue services, they had not received one single phone call. That is the perspective here, not many people live along these rivers, so of course it would have been a lot worse if a similar warning had been issued further down south, in a larger community.” This respondent went on by saying that “if there is a level 2 warning, level 3 warning, I mean, it’s Mother Nature, there is really not much that can be done about it.”
Role of unofficial warning signals

The study found the greatest variance in the role unofficial warning signals played in the eighteen municipalities examined, where some do not acknowledge the use of any unofficial warning signals, while most acknowledge use of one source or more. The following is a presentation of the sources from which municipalities get unofficial warning signals.

A few of the respondents from the eighteen municipalities mentioned the river groups that they are members of, and how they use them. River groups can be used both strategically and operationally.

Several of the respondents said that they have a direct dialogue with the hydro-power companies. In times when a flood event has been imminent the municipality has received information on what the hydro-power company will do, compared to normal circumstances in which the hydro-power company only gives information on what they have done. The respondent commented on the reliability of this setup: “So we have a very good situation. I know that our County Administrative Board also thinks that we should be happy that we have communication with the water regulator, because it could be a lot worse, they don’t have any obligations to let us know how much water they are going to release.” Another respondent said that while their municipality gets a great deal of information from their hydro-power company, the responsibilities of the hydro-power companies are not always clear and these relationships are partially built on personal contacts and chemistry, as well as an effort from the municipality to uphold such relationships.

The respondents who acknowledged that they use warning signals from other sources than the national warning service also identified the benefits of doing so: “…we can see if it deviates, so we get different perspectives.” / “…because it comes from the hydro-power companies it doesn’t just come to us, but also to our friends along the river, which means that we can see that everyone gets the information.” / “…we get these signals at different times, and the earlier we get them the more preparations we can make, and that’s good. […] with more sources you can put them together and make your own assessments of how probable it is, if
it’s correct or not.” / “…you don’t have to sit in someone’s lap, and the more sources you have the better your accuracy will be, and the more indicators that point a certain way, the more likely it is that we’re going to have problems.”

At the same time, using multiple sources can be a bit demanding: “…it gets harder for us to – it’s easier to just pick a source and say that this is the truth. Naturally we always have to make interpretations.” / “If we get different answers from two separate sources, it means that we’ll have to watch more closely, and get in contact with the sources to see how they have reached their conclusions, what can they say to confirm their view, etc. So there’s a lot more work involved.”

*Interpreting warning levels and uncertainty*

There were no respondents who reported any difficulties interpreting warning levels from the national warning service. In general, official warnings and warning levels were perceived to be closely dependent of place characteristics. A couple of respondents said that there are no definitive translations between warning levels and response, and that it is very dependent on circumstance. [3a] There were some differences among the respondents in how the different warning levels should be interpreted, and there was a clear line between those who thought that level 1 warnings are meaningless, and those who thought it at least warrants raised awareness.

In the end, most of the municipalities acknowledged that they are dealing with uncertainty. Several respondents said that it is challenging to collect information from a variety of sources and having to make decisions based on that which can have major consequences. It not only requires that the information is available, but that information needs to be analysed and processed properly, and sometimes quickly. It also requires a good understanding of the complexity of meteorological and hydrological conditions.
Discussion

Paper I

This study investigated the adoption of flood EWSs at the local level in three municipalities in Sweden with the aim of shedding light on the role they did or did not play in the wider risk management process. In doing so the study provided answers to four questions: What are the motives for establishing a local EWS, despite the existence of a national EWS?; Are there any other positive or negative effects from establishing local EWSs besides reduced flood losses?; Does the occurrence of such effects vary between municipalities and if so, why?; How do the local EWSs relate to the wider risk management processes of the municipalities?

Local EWSs were established for various reasons, most notably to gain better overview of local flood risks and better and more coordinated use of other flood risk reducing measures. Local EWSs have a potential to reduce superfluous intermediate layers in the communication chain between local and national levels. However, the utility and efficiency of spreading local EWSs on a larger scale would be questionable. If every municipality that faced flood risks would develop its own individual EWS, it would result in unnecessary duplication and opportunities to pool resources would be lost.

There was added value, so called spin-off effects (see Fig. 5), from establishing local EWSs besides reduced flood losses. Examples of this was found in Municipality 3, where the establishment of the local EWS proved useful to the physical planning process, to the hydropower production and the water regulation, prominently by making relevant information available in a way that enhanced decision-making and planning. For example in the case of physical planning, zoning for housing in areas close to water were made with greater accuracy in relation to flood risks. The added value in Municipality 3 was mainly enabled by a functioning risk management system and an open and accessible organisational culture.
The positive effects of establishing local EWSs varied between the municipalities examined in this study. The main reason was differences in the organisational cultures of the municipalities. In Municipality 3 the organisational climate promoted discussion and elaboration, whereas in Municipality 2 benefits did not materialise, in part, due to the absence of a forum for communication and coordination. This finding confirmed insights from past research that organisational culture and management practices, in other words, software factors, loom large in determining whether putting an EWS in place will be a worthwhile investment.

Since all three EWSs were quite new, it seemed possible that with additional experience and after additional cycles in the risk management process, more benefits from the EWSs would crystallise and become available. This was deemed dependent on the state of the risk management system in each municipality. In Municipality 3 the next step in the risk management process was expected to make more people in the organisation aware of the EWS and its benefits, making it possible to expand the discussion and find more uses for it.
The most important implication and contribution of this study was the widened understanding of the potential value of an EWS and of how the organisational culture and state of risk management system influence the extent to which the value added of a local EWS will be realised. This knowledge can be useful to others who are investigating the possibilities of investing in EWSs and what organisational structures and management practice are associated with getting the most out of these systems.

**Paper II**

This study investigated how Swedish municipalities gather and make use of early warning information from official and unofficial sources to develop a collection of information and data designed to facilitate decision-making for proactive response to floods. In doing so the study provided answers to four questions: What role do official warning signals play for flood response?; What role do unofficial warning signals play for flood response?; Which factors are determining the success of a municipality being able to make use of complementary warning signals?; How can a set of complementary warning signals help in removing the barriers to communicating and interpreting uncertainty?

The role of official warning signals varied in the municipalities. The variation was deemed dependent on several factors, most prominently size of the organisation and the population/area that is to be protected, and the characteristics of the flood risk. In large municipalities with large organisations, official warning signals were useful for adapting the organisation with regard to preparedness, as well as giving legitimacy to communication within the organisation and with the public at risk. In some of the smaller municipalities, where resources for flood response are very limited, official warning signals were not viewed as important. The use of warnings is closely linked to the capacities to act.

In municipalities where the flood risk is of slow onset character, official warning signals were viewed strictly as confirmation of something that the municipality should already know. Official warnings are not disseminated unless certain criteria
have been reached; quite close in time to when the flood actually occurs, and long
before that happens the flood risk management process in the municipality has
already been activated.

The role of unofficial warning signals varies even more than official warning
signals – some municipalities do not acknowledge the use of any unofficial
warning signals while most acknowledge use of one source or more. The most
prominent source of unofficial warning signals is hydro-power companies.
Through direct dialogue with people who work at a hydro-power company, a
municipality can take part of a constant flow of information that can facilitate their
decision-making and give them an advantage for managing the flood risk. One
respondent summed up the pros and cons of this kind of arrangement: “I call them

to get a picture of how it looks, how it goes, has the snow melting started, and it’s
very precise, the information I get from there. They can tell me that the water will
rise for two more days, and then it will start to sink. But it’s important to have a
good relationship with them, so that information can come both ways, so to speak.”

The role of social media was very limited at the time, but the potential for dialogue
had been identified in several municipalities and it was a work in progress to tap in
to that potential in the future.

While the flow of the official warning chain is mostly one-way communication
(see Fig. 6), several municipalities, as well as the respondent from SMHI, made
clear that two-way communication does happen, as SMHI plays a role in river
groups, have active communication with hydro-power companies, take part in
conferences during flood events, etc. From the stand-point of some municipalities,
however, this does not appear to be clear cut, and for the communication within the
official warning chain to be two-way, it is required that the municipality have the
resources and know-how to enable it. The municipalities have a need for local
adaptation of warnings, interpretations to specific contexts, and opportunity for
dialogue and this is done in some cases, and in other cases not as much. The flow
of the unofficial warning chain is more of two-way communication, but it even
more depends on resources, personal relationships and informal networks, etc. The
“good relationship” with the hydro-power company that one of the respondents spoke of is problematic, because the hydro-power companies have no legal obligations to constantly provide municipalities with information.

Receiving warning signals from a complementary set of sources can give the municipalities more perspectives and therefore a more complete picture of a situation; more time to prepare; better opportunities to assess probabilities; information independency; and a better opportunity to act appropriately, in proportion to what the flood risk demands. At the same time it is challenging, as it demands a deeper analysis, more communication within the organisation as well as with the different sources and other organisations. Receiving information from a variety of sources also requires that the municipality has a sound understanding of meteorological and hydrological processes, as well as the vulnerabilities in their area, in order to make proper assessments. Several respondents said that they need more information and that it needs to be adapted to local conditions. They would not mind a higher degree of uncertainty in the information, since they estimate that they have capacity break it down, interpret and assess it properly.
One issue that can be problematic when it comes to the use of unofficial warning signals is that it is dependent on personal relationships and informal networks. The time between serious flood events is often long, and these personal relationships might break down, due to personnel turnover in the organisations and/or that they are simply neglected and forgotten. This type of arrangement needs to be maintained over time, and without systematic efforts to keep up maintenance, it is necessary to question the reliability of the setup.

An approach to solving this issue could be to create a model for a periodically recurring review conference within a flood risk area where the different actors could evaluate and practice routines and cultivate relationships. This would be good for three reasons: it would make it possible to more clearly establish which actors are part of the system and what their respective roles are; this would make it easier for the national warning service to acknowledge other actors that contribute to the decision-making of the municipalities and therefore adapt their role towards a more integrated warning system (Parker and Handmer, 1998); and it would make it possible to not only sustain useful existing relationships – but to improve and optimise them, and to find new ones.
Conclusions

Swedish municipalities have a variety of strategies and measures at their disposal with regard to the management of flood risks. The development of early warning systems and signals has been shown to play an increasingly important role in risk management at the local level, and, based on the cases examined in this thesis, it is evident that the potential for a deepened and more diversified role for early warning exists.

Paper I demonstrates the value of a local EWS, as well as the importance of systemic factors, such as organisational culture and the functioning of the wider risk management system, that influence to what extent the establishment of local EWSs can generate this value throughout the wider risk management process.

Paper II demonstrates the value of collecting, analysing and acting on warning signals from a complementary set of sources, in that it can facilitate decision-making for proactive response to floods. It also identifies and discusses key systemic factors, such as personal relationships, informal networks, and other resources, that can inhibit the utilization of complementary warning signals.

The potential of EWSs, regardless if they are on a national or local level, is dependent on a mix of hardware and software factors, technically sound solutions paired with organisational capacity to communicate, coordinate, learn and adapt. The findings from both papers demonstrate the importance of these software factors, and how they determine the success of different aspects of early warnings.
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Flood Warnings in a Risk Management Context

Following the United Nations’ International Decade for Natural Disaster Reduction (1990-2000) and recent high profile disasters, disaster risk reduction has climbed high on the international political agenda. Among the measures that have been highlighted are early warning systems. For Swedish municipalities who are responsible for managing flood risks, early warnings have a potential to facilitate decision-making and ultimately reduce flood losses. This licentiate thesis, based on two papers, aims to describe how a variety of early warning systems and signals for floods are used in the risk management process of Swedish municipalities, how they can contribute to the flood risk reducing process, and which factors influence the success of this. Paper I shows that the possible effects from a local early warning system are not only reduced flood losses but also potential spin-off benefits, the occurrence of which is dependent on factors such as organisational culture and the functioning of the wider risk management system. Paper II shows that municipalities can use a variety of complementary flood warning signals to facilitate decision-making for a proactive flood response which, however, is not systematically the case as benefits are dependent on available resources.