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INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

THE FLOOD EARLY WARNING SYSTEM IN THE ITAJAÍ RIVER BASIN: ITS INSTITUTIONAL STRUCTURE AND THE ROLE OF THE CIVIL DEFENCE

THESIS TO OBTAIN THE DEGREE OF

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ABSTRACT

Flood Early Warning Systems (FEWS) are crucial in flood risk management. They can help to reduce the impacts of floods by giving people more time to be evacuated from areas at risk to safety as well as to protect possessions. The present work aims to evaluate the FEWS found in the Itajaí River Basin, Brazil, with emphasis on its institutional structure and the role of the Civil Defence. Firstly, a stakeholder analysis was executed to identify the main institutions involved in the functioning of the FEWS. At the moment there are two telemetric networks at the basin level: the network of the State Secretariat of Sustainable Economic Development (SDS) which is monitored by the Operation Centre of the Warning System (CEOPS) and the network of the National Water Agency (ANA) which receives maintenance from the Research Company of Agriculture-Livestock and Rural Extension (EPAGRI). Weather forecasts are executed by the National Institute of Meteorology (INMET) and the National Institute of Space Research (INPE) at federal level, and by the EPAGRI at state level. Flood forecasts are executed by the CEOPS, but only for the city of Blumenau. The State Department of Infrastructure (DEINFRA) is responsible for the monitoring and operation of the flood contention dams of the basin. Also, the Itajaí River Basin Committee has been involved in flood risk management, and the Civil Defence of Santa Catarina (SDC) has put effort into a project for the amplification and improvement of the FEWS in the basin. In addition, some municipalities implemented their own FEWS through their Civil Defence Centres (COMDECs) after arguing that there is not an integrated FEWS at the basin level. Thus, the components of the FEWS from three cities (Blumenau, Rio do Sul and Itajaí) were studied through interviews with their COMDECs' coordinators. The COMDECs have many competences according to the legislation, from the creation of maps to the evacuation of the population, but most of the COMDECs of the basin lack a sufficient number of employees, structure, technical expertise and financial resources to carry out all these activities. Interviews based on the SWOT Analysis were executed with all stakeholders of the FEWS, in order to understand their different perspectives regarding the current FEWS. Most of the stakeholders mentioned the previous work of the CEOPS and the Itajaí River Basin Committee as strengths. As regards to weaknesses, stakeholders pointed out the need to have flood forecasts for more cities of the basin, the lack of monitoring stations and deficient radar coverage. The most promising opportunity seems to be the SDC's project which foresees the purchase of radar and more stations, as well as the creation of a situation room and operation centres at state level. Yet, all institutions involved in the FEWS are public and therefore vulnerable to political changes and governmental bureaucracy, so that a great challenge is to assure the continuity of the FEWS throughout the years.

Key-words: flood early warning system, floods, stakeholders, Civil Defence.

RESUMEN

Los Sistemas de Alerta Temprana (SAT) son cruciales en la gestión de riesgos de inundaciones, puesto que ayudan a reducir los impactos asociados, proporcionando más tiempo para la evacuación de la población hacia áreas menos expuestas, además de la protección de sus pertenencias. El presente trabajo tiene como objetivo evaluar el SAT en la Cuenca Hidrográfica del Río Itajaí-Açu, Brasil, con énfasis en su estructura institucional y el papel de la Protección Civil. Primeramente, un Análisis de las Partes Interesadas fue ejecutado para identificar las principales instituciones involucradas en el funcionamiento del SAT. Actualmente hay dos redes telemétricas en la cuenca: la red de la Secretaria del Estado de Desarrollo Económico y Sostenible (SDS) la cual es monitoreada por el Centro de Operación del Sistema de Alerta (CEOPS), y la red de la Agencia Nacional del Água (ANA) que recibe manutención por parte de la Empresa de Investigación de Agropecuaria y Extensión Rural (EPAGRI). Las previsiones meteorológicas son elaboradas por el Instituto Nacional de Meteorología (INMET) y el Instituto Nacional de Investigación Espacial (INPE) a nivel federal, y por la EPAGRI a nivel estatal. Los pronósticos de inundaciones son ejecutados por el CEOPS, pero solamente para la ciudad de Blumenau. El Departamento del Estado de Infraestructura (DEINFRA) es responsable por el monitoreo y operación de las presas de contención de inundaciones. Además, el Comité de Itajaí está involucrado en la gestión de los riesgos de inundación en la cuenca y la Protección Civil del Estado (SDC) se ha esforzado para la ejecución de un proyecto para la ampliación y fortalecimiento del SAT. Además de esto, algunas ciudades a través de sus Centros de Protección Civil (COMDECs) han puesto en marcha sus propios SATs con el argumento de que no hay un SAT integrado a nivel de cuenca. De este modo, los SATs de tres ciudades (Blumenau, Rio do Sul e Itajaí) fueron analizados a través de entrevistas con los coordinadores de sus COMDECs. La legislación atribuye varias responsabilidades a las COMDECs, desde la elaboración de mapas hasta la evacuación de la población, pero la mayoría de las COMDECs de la cuenca carecen de funcionarios, estructura, capacitación técnica y recursos financieros para ejecutar tales actividades. Se realizaron entrevistas a los involucrados en el funcionamiento del SAT, esto se llevó a cabo utilizando la técnica FODA con el fin de comprender sus diferentes puntos de vista. La mayoría de los entrevistados reconocieron el trabajo previo del CEOPS y del Comité de Itajaí como una fortaleza del sistema. En cuanto a las debilidades, los entrevistados señalaron la necesidad de tener previsiones de inundaciones para toda la cuenca, la falta de estaciones de monitoreo y la baja cobertura del radar. La oportunidad más prometedora parece ser el Proyecto de la SDC, el cual prevé la adquisición de un radar y el establecimiento de más estaciones, así como la creación de una sala de situación y centros de operación para elaboración y emisión del alerta. Sin embargo, las instituciones involucradas en el SAT son públicas y, por lo tanto, vulnerables a los cambios políticos y la burocracia gubernamental, así que un gran reto es garantizar la continuidad del SAT a lo largo de los años.

Palabras-clave: sistema de alerta temprana, inundaciones, partes interesadas, Protección Civil.

ABSTRACT

Hochwasser-Frühwarnsysteme (HFWS) sind sehr wichtig im Hochwasserrisikomanagement. Sie können helfen die Folgen von Überschwemmungen zu reduzieren, indem sie den Menschen mehr Zeit geben, sich aus gefährdeten Gebieten in Sicherheit zu bringen oder ihren Besitz zu schützen. Die vorliegende Arbeit zielt darauf ab, das im Itajaí Flussgebiet in Brasilien implementierte HFWS zu bewerten, mit Schwerpunkt auf dessen institutionelle Strukturen und der Rolle des Zivilschutzes. Zunächst wurde eine Stakeholder-Analyse durchgeführt, um die wichtigsten Institutionen, die an der Funktionsweise der HFWS beteiligt sind, zu ermitteln. Zurzeit gibt es zwei telemetrische Netzwerke in den Hochwasser-Einzugsgebieten: Das SDS-Netzwerk, das durch die CEOPS überwacht wird, und das ANA-Netzwerk, welches von der EPAGRI gewartet wird. Wettervorhersagen werden von INMET und INPE auf nationaler Ebene durchgeführt, sowie durch die EPAGRI auf staatlicher Ebene. Hochwasservorhersagen werden von der CEOPS erstellt, allerdings nur für die Stadt Blumenau. Die DEINFRA ist verantwortlich für die Überwachung und den Betrieb der Hochwasserschutzdämme im Flussgebiet. Außerdem ist das Komitee von Itajaí im Hochwasserrisikomanagement involviert und der Staatliche Zivilschutz (SDC) hat sich um die Realisierung eines Projektes zur Verstärkung und Verbesserung des HFWS bemüht. Darüberhinaus haben einige Gemeinden mit ihren Zivilschutz-Zentren (COMDECs) eigene HFWS umgesetzt, mit dem Argument, dass es kein integriertes HFWS im Einzugsgebiet gäbe. Aufgrund dieser Tatsache wurden die Komponenten der HFWS von drei Städten (Blumenau, Rio do Sul und Itajaí) mit Hilfe von Befragungen der Koordinatoren der COMDECs näher untersucht. Die COMDECs sind vom Gesetzgeber mit vielen Kompetenzen, von der Ausarbeitung der Karten bis zur Evakuierung der Bevölkerung, ausgestattet. Den meisten COMDECs mangelt es aber an Mitarbeitern, Fachkompetenz und finanziellen Ressourcen zur Durchführung aller notwendigen Aktivitäten. Interviews auf der Basis von SWOT-Analysen wurden mit allen Beteiligten der HFWS durchgeführt, um ihre unterschiedlichen Ansichten zum aktuellen HFWS zu verstehen. Die meisten der Befragten hat die bisherige Arbeit der CEOPS und der Komitee von Itajaí als Stärken genannt. In Bezug auf die Schwächen, erwähnten die Beteiligten die Notwendigkeit einer Hochwasservorhersage für weitere Städte des Beckens, den Mangel an Meßstationen und eine mangelhafte Radarüberdeckung. Der aussichtsreichste Ansatz scheint das Projekt des SDC zu sein. Dieses sieht den Kauf von Radar und mehreren Messstationen vor, sowie die Schaffung eines Lagezentrums und Operationszentren auf staatlicher Ebene. Allerdings sind alle beteiligten Institutionen von öffentlicher Hand und daher anfällig für politische Veränderungen und staatliche Bürokratie, so dass es eine große Herausforderung sein wird, die Kontinuität des HFWS im Laufe der Jahre zu gewährleisten.

Key-Wörter: Hochwasser-Frühwarnsystem, Überschwemmungen, Stakeholders, Zivilschutz.

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ANA: Agência Nacional de Água
(National Water Agency)

ANATEL: Agência Nacional de Telecomunicações
(National Agency of Telecommunication)

ANEEL: Agência Nacional de Energia Elétrica
(National Agency of Electrical Energy)

ARDEC'S: Áreas de Defesa Civil
(Areas of Civil Defence)

AVADAN: Formulário de Avaliação de Danos
(Damage Evaluation Form)

CELESC: Centrais Elétricas de Santa Catarina S.A.
(Company of Power Plants of Santa Catarina)

CEMADEN: Centro Nacional de Monitoramento e Alertas de Desastres Naturais
(National Centre of Monitoring and Warning of Natural Disasters)

CENACID: Centro de Apoio Científico em Desastres
(Centre of Scientific Support to Disasters)

CENAD: Centro Nacional de Gerenciamento de Riscos e Desastres
(National Centre of Risk and Disaster Management)

CEOPS: Centro de Operação do Sistema de Alerta
(Operation Centre of the Warning System)

CEPED: Centro de Estudos e Pesquisas em Desastres
(Centre of Research and Studies in Disasters)

CERH: Conselho Estadual de Recursos Hídricos
(State Council of Water Resources)

CIASC: Centro de Informática e Automação do Estado de Santa Catarina
(Centre of Informatics and Automation of Santa Catarina)

CIRAM: Centro de Informações de Recursos Ambientais e de Hidrometeorologia
(Centre of Information on Natural Resources and Environment)

CLIMERH: Centro de Integração de Meteorologia e Recursos Hídricos
(Integrated Centre of Meteorology and Water Resources)

CNRH: Conselho Nacional de Recursos Hídricos
(National Council of Water Resources)

COMDEC: Coordenadoria Municipal de Defesa Civil
(Municipal Civil Defence Centre)

CONDEC: Conselho Nacional de Defesa Civil
(National Council of Civil Defence)

CONSEG: Conselho Comunitário de Segurança
(Community Council of Security)

CPRM: Companhia de Pesquisa de Recursos Minerais
(Geological Survey of Brazil)

CPTEC: Centro de Previsão de Tempo e Estudos Climáticos
(Centre of Weather Forecast and Climate Studies)

CUCA: Cadastro Único do Cidadão Atingido
(Unique Register of Affected Citizen)

DCP: Data Collection Platforms

DEINFRA: Departamento Estadual de Infraestrutura
(State Department of Infrastructure)

DETER: Departamento de Transportes e Terminais
(Department of Transport and Terminals)

DIRH: Diretoria de Recursos Hídricos
(Board of Water Resources)

DISME: Distrito de Meteorologia
(District of Meteorology)

DNAEE: Departamento Nacional de Águas e Energia Elétrica
(National Department of Water and Electric Energy)

DNOS: Departamento Nacional de Obras e Saneamento
(National Department of Works and Sanitation)

EPAGRI: Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina
(Research Company of Agriculture-Livestock and Rural Extension of Santa Catarina)

FAAVI: Fundação Agência de Água do Vale do Itajaí
(Water Foundation of the Itajaí River Basin)

FEWS: Flood Early Warning System

FURB: Universidade Regional de Blumenau
(Regional University of Blumenau)

GOCNAE: Grupo de Organização da Comissão Nacional de Atividades Espaciais
(Group of National Commission in Space Activities)

GRAC: Grupo de Atividades Coordenadas
(Group of Coordinated Activities)

GTC: Grupo Técnico-Científico
(Technical-Scientific Group)

INMET: Instituto Nacional de Meteorologia
(National Institute of Meteorology)

INPE: Instituto Nacional de Pesquisa Espacial
(National Institute of Space Research)

IPA: Instituto de Pesquisa Ambiental
(Institute of Environmental Research)

ISDR: International Strategy for Disaster Reduction

JICA: Japan International Cooperation Agency

MCTI: Ministério de Ciência, Tecnologia e Inovação
(Ministry of Science, Technology and Innovation)

MDA: Ministério de Desenvolvimento Agrário
(Ministry of Agrarian Development)

MIN: Ministério de Integração Nacional
(Ministry of National Integration)

NGA: Normas Gerais de Ação
(General Norms of Action)

NOPRED: Notificação Preliminar de Desastres
(Preliminary Notification of Disasters)

NUDEC: Núcleo Comunitário de Defesa
(Community Nucleus of Civil Defence)

OFDA: Office of Foreign Disaster Assistance

PNDC: Política Nacional de Defesa
(National Politics of Civil Defence)

PNPDC: Política Nacional de Proteção e Defesa Civil
(National Politics of Protection and Civil Defence)

PNRH: Política Nacional de Recursos Hídricos
(National Politics of Water Resources)

RENER: Rede Nacional de Emergência de Radioamadores
(National Network of Emergency of Amateur Radio)

SAR: Secretaria de Estado da Agricultura e da Pesca
(State Secretariat of Agriculture and Fishery)

SDC: Secretaria de Estado da Defesa Civil
(State Secretariat of the Civil Defence)

SDR: Secretaria de Desenvolvimento Regional
(Secretariat of Regional Development)

SDS: Secretaria de Estado do Desenvolvimento Econômico Sustentável
(State Secretary of Sustainable Economic Development)

SEDEC: Secretaria Nacional de Defesa Civil
(National Secretariat of Civil Defence)

SEGEO: Secretaria de Geologia de Blumenau
(Geology Secretariat)

SEI: Secretaria de Estado da Infraestrutura
(State Secretariat of Infrastructure)

SHR: Secretaria de Recursos Hídricos
(Water Resources Secretariat)

SIH: Secretaria de Infraestrutura Hídrica
(Secretariat of Water Infrastructure)

SINDEC: Sistema Nacional de Defesa Civil
(National System of Civil Defence)

SNGRH: Sistema Nacional de Gerenciamento de Recursos Hídricos
(National System of Water Resources Management)

UDESC: Universidade do Estado de Santa Catarina
(University of the State of Santa Catarina)

UFSC: Universidade Federal de Santa Catarina
(Federal University of Santa Catarina)

UNIVALI: Universidade do Vale do Itajaí
(University of the Valley of Itajaí)

WMO: World Meteorological Organization

1 INTRODUCTION

The number of people living in areas hazardous to natural disasters has grown dramatically over the past half century (Hansson *et al*, 2008). It is believed that of all natural disasters, floods have an impact on the greatest number of people across the world (Moore *et al*, 2005). For instance, the floods of 1999 in Venezuela caused the loss of 30,000 lives, destroyed 23,200 houses and caused damage in more than 64,700 (Hansson *et al*, 2008). Severe floods in China and Bangladesh are also associated with many deaths and human suffering. The Great Flood of 1993 on the Mississipi River caused economic damages of roughly USD 20 billion to the USA (Johnson *et al*, 2004).

In Brazil major floods have caused on average 120 deaths a year and between 2000-2009 annual economic losses of USD 250 million (Swiss Re, 2011). According to the EM-Database (2012), the most recurrent disasters in Brazil are flash and river floods (57% of records from 1948 to 2011), followed by landslides (11%). Likewise droughts are severe disasters in the country affecting on average almost 3 million people per event, most of them in the Northeast of Brazil (EM-DAT, 2012).

Floods have caused negative effects in all regions of the country. Floods in the states of Rio de Janeiro and São Paulo killed more than 800 people and left 100,000 homeless people in January 2011 (Swiss Re, 2011; EM-DAT, 2012). A year before, a landslide caused by heavy rains in the city of Angra dos Reis (in the state of Rio de Janeiro) killed 74 people in a tourist area (MIN, 2011). In April 2009 floods caused economic losses of USD 500 million to the North-eastern state of Maranhão, as the railroad transport from the ore mines in Carajá to the Itaqui Port in São Luís was interrupted (Swiss Re, 2011). In November 2008 floods and landslides in the Southern state of Santa Catarina caused 135 deaths (SDC, 2008) and damage to the sector of economic activities estimated at roughly USD 800 million (JICA, 2010).

Disasters in Brazil are usually linked to severe atmospheric instability, which functions as the trigger for floods, tornados, hail and landslides (IFRC, 2012). However, many aspects are involved in the context of flooding, and not only the occurrence of high rainfall rates, so that disasters should be understood as the correlation of two factors: Risk and Vulnerability. As stated in Romero & Maskrey (1993), risk refers to any phenomenon of natural or human origin which implies a significant change in the environment in which a community is situated. The authors define vulnerability as the incapacity of a community to absorb the effects of a certain change in its environment. For instance, society's vulnerability to floods can be associated to precarious economic conditions, unstable soils and bad location of housing. In this context, large disasters are related to dangerous natural phenomena occurring in vulnerable communities (Romero & Maskrey, 1993).

Flood risk management aims to reduce the probability of impacts from floods, in order to minimize the threat to human life and properties, at the same time as making use of natural resources for the benefit and well-being of people (Defra, 2004; APFM, 2008). Flood management cannot assure a complete elimination of flood risks, but at least can mitigate them (APFM, 2008). In terms of physical features, flood risk management involves complexity, uncertainty and large temporal and spatial scales. Regarding social characteristics, it includes conflicting interests between stakeholders, a plurality of values and diffuse responsibilities (Kenyon, 2007). In addition, Plate (2002) describes that many engineers have only a narrow view on floods, and consider the solution to floods to be a

logical process from studies of hydrological methods to the implementation of physical works. Yet, not only engineers are involved in the process of flood risk management, but also many sections of society, from political decision makers to people that are directly exposed to floods (Plate, 2002).

Flood risk management may include both structural and non-structural measures (Friesecke, 2004; Posthumus, 2008). Structural measures are those that alter the fluvial system by retaining, draining off or changing the direction of water from flooded areas (Tucci, 2005). Examples of structural measures are the reservoirs which retain part of the flood water volume, maintaining a river flow lower than that which can flow along the riverbed. The reforestation of watersheds and correct agricultural practices are also structural measures which can help the control of soil erosion and forest covers. However, such measures imply high costs and sometimes they become unviable (Tucci, 2005).

Non-structural measures attempt to improve the coexistence between people and floods. These measures comprise flood insurance, flood adapted housing, zoning of flood prone areas, and flood early warning systems (Andrade Filho *et al*, 2000). Flood insurance provides economic protection to people and companies in cases of losses due to flood events; however most victims in developing countries would not be able to afford such insurance. Flood adapted housing like floating structures or elevated structures on stilts have been used in riversides communities in the Amazon Rainforest in Brazil, but these practices might not be allowed in countries with strict flood defence policy (APFM, 2007). Zoning consists of a group of strict rules to the occupation of areas according to its likelihood of flooding (Tucci, 2005). Lastly, flood early warning systems (FEWS) are an important tool for flood prevention as they can help to reduce the impacts of floods by allowing people to be evacuated from areas at risk to safety, and to protect possessions and property (Sene, 2008).

Framework for Flood Early Warning Systems

The ISDR (United Nations' International Strategy for Disaster Reduction) defines early warning systems as "the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response" (ISDR, 2006). To meet such purpose, a flood early warning system is formed by several components which should be integrated to assure its efficiency (Attorneys-General's Department, 2009). The ISDR mentions that an effective early warning system should comprise of four interconnected elements: risk knowledge, monitoring and warning system, dissemination and communication, and response capability (ISDR, 2006).

With reference to Risk Knowledge, risk and vulnerability assessments and maps provide important information to establish priority areas for mitigation and prevention strategies and to design early warning systems (UNEP, 2012). Monitoring and Warning refer to the detection of rainfall and river flows that can lead to flooding, through sensors or conventional measures, and the prediction of river levels during flood events (Attorneys-General's Department, 2009). To execute flood forecasts, data should be accurate and preferably available in real-time (ADB, 2006). Furthermore, warning services should have a scientific basis for the execution of flood forecasts and should operate consistently 24 hours a day (ISDR, 2006).

As regards to Dissemination and Communication, well-timed warning information should be delivered to those who are likely to be affected by a certain flood event (ADB, 2006). Messages

should be kept simple and should contain useful and reliable information, in order to enable the understanding of warnings by the public and by the organizations involved (ISDR, 2006; GTZ, 2009; UNEP, 2012). The combination of several communication methods is essential to avoid the failure of one method and to assure that all individuals of a community are warned (ISDR, 2006). Lastly, Response Capability requires that communities at risk take into account warnings and adopt a safe behaviour. This entails educational works and preparedness programmes promoted by disaster management authorities (ISDR, 2006; UNEP, 2012). Also, action plans should be well practised with institutions and communities involved (ISDR, 2006).

Effective early warning systems should combine all these components (Figure 1), supported by good governance and institutional arrangements (ISDR, 2006). If one of these components does not work well, the entire system might be compromised. For instance, accurate warnings might have no impact if the population does not know what to do in disaster situations or if warnings are received but not further disseminated by disaster management agencies to the population (UNEP, 2012).

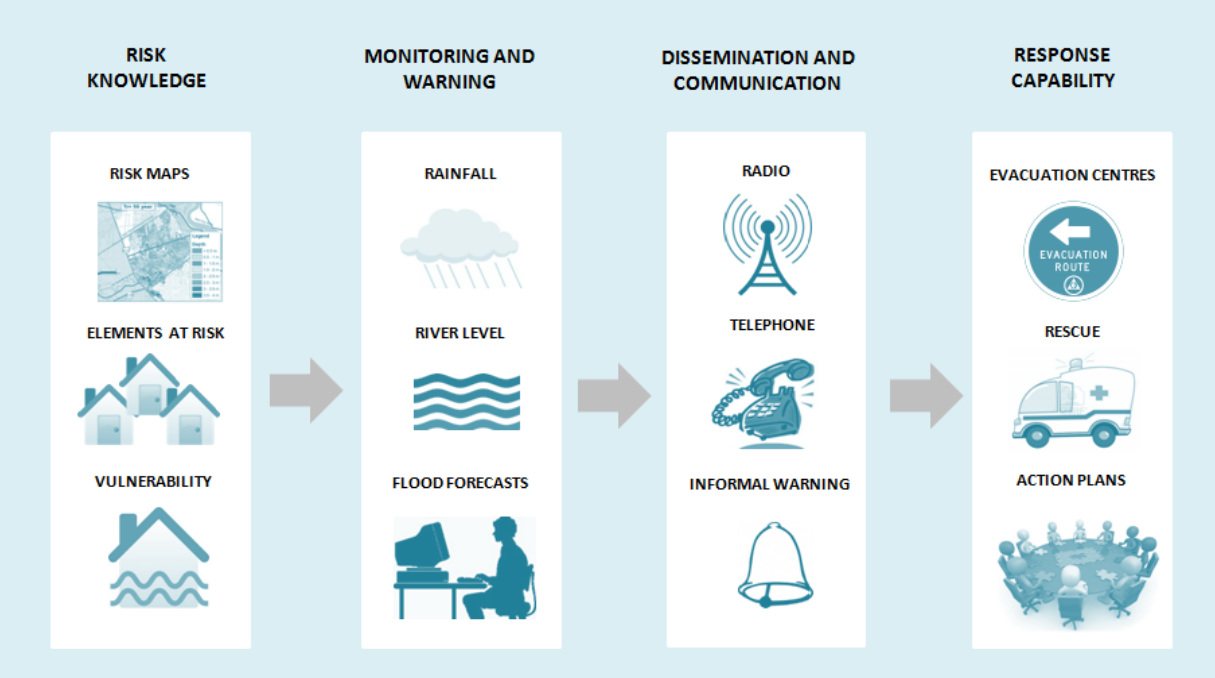

Figure 1 – Components of an effective flood early warning system. Source: Adapted from GTZ, 2009.

Itajaí River Basin

The present work aims to study the Flood Early Warning System found in the Itajaí River Basin, in the Southern State of Santa Catarina, Brazil (Figure 2). The Itajaí River Basin is the largest watershed of the state with a total area of 15,100 km^2. Its water is drained from the west to the east and its main river (Itajaí-Açu) feeds directly into the Atlantic Ocean. It is formed by 53 municipalities, accounting 1,232,267 inhabitants, which represents almost 20% of the population of the state of Santa Catarina (SPG, 2012). The municipalities of the basin and their respective populations are presented in Annexes 7.1 and 7.2.

The Itajaí-Açu River's width varies throughout its course, since the main river is formed by the convergence of several affluents (Itajaí do Sul, Itajaí do Oeste, Itajaí do Norte (Itaputã), Benedito, Luiz Alves and Itajaí Mirim). The Itajaí River Basin contains a drainage density of 1.55 km/km^2, and the average flow in the city of Blumenau, for example, is 140 m^3/s. Also, the minimum flow during droughts is 15 m^3/s, while the maximum flow in flooding situations can reach the value of 5,000 m^3/s (Herrmann, 2010).

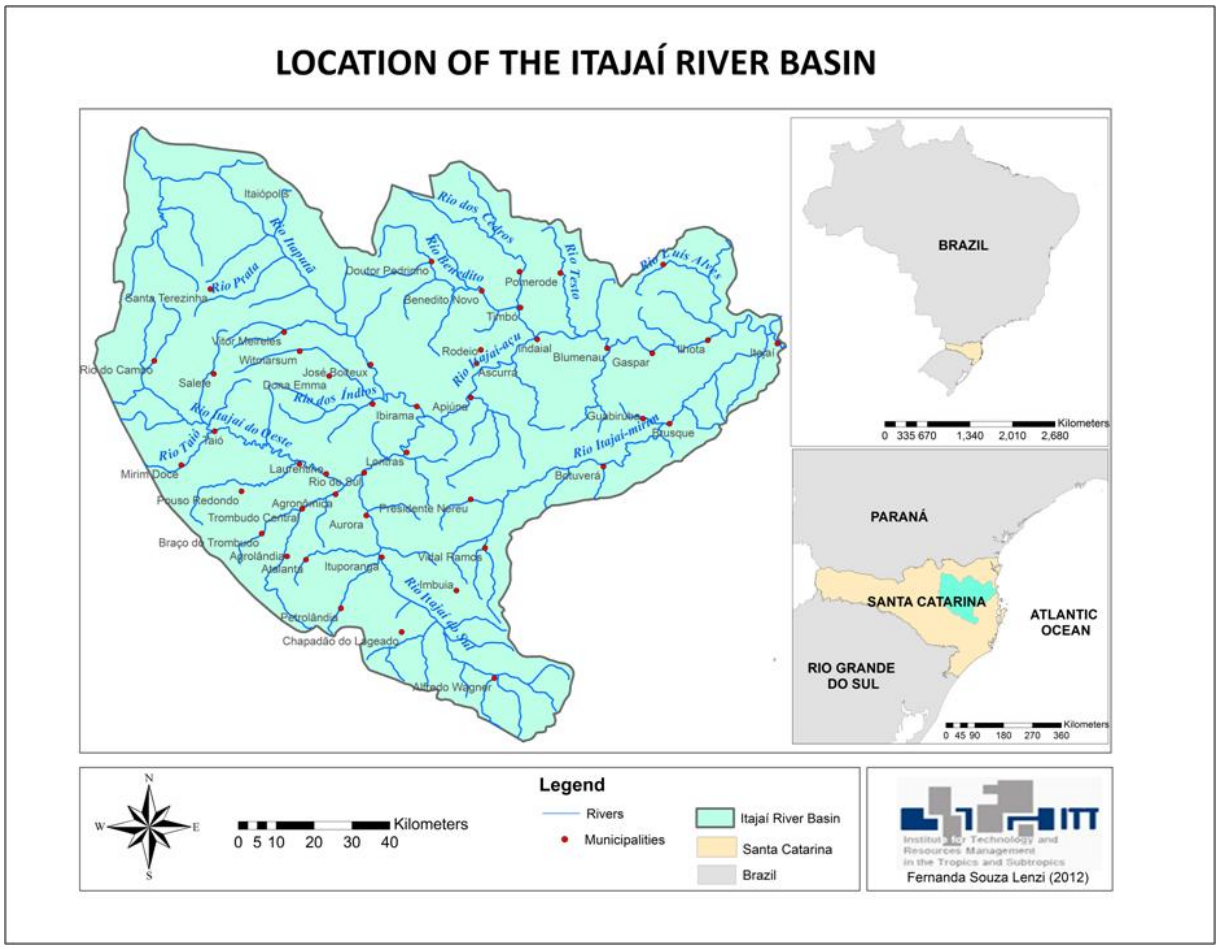

Figure 2– Location of the Itajaí River Basin and its main rivers.

The weather in the Itajaí River Basin is marked by hot and humid summers and mild winters, with average annual temperature between 19 and 21˚C. The occurrence of rain in the Itajaí River Basin is seen during 120 to 180 days per year and the relative humidity of air is greater than 80% (FAAVI, 2010). The Itajaí River Basin presents an average annual rainfall rate of 1560 mm (JICA, 2010). Furthermore, the basin is completely contained in the domain of the Atlantic Rainforest. Today, the area of the Itajaí River Basin consists mainly of forests (64.6%) and agriculture/pasture (36.7%) (JICA, 2010). As regards to topography, the Itajaí River Basin is surrounded by mountains ranging from 200 m to 1750 m of altitude. These altitudes diminish towards the coast and the low slopes of the Itajaí River (1.60 m/km in the last part) contribute to the occurrence of large flood plains which receive sediments over time (Figure 3), especially beginning with the municipality of Blumenau (FAAVI, 2010).

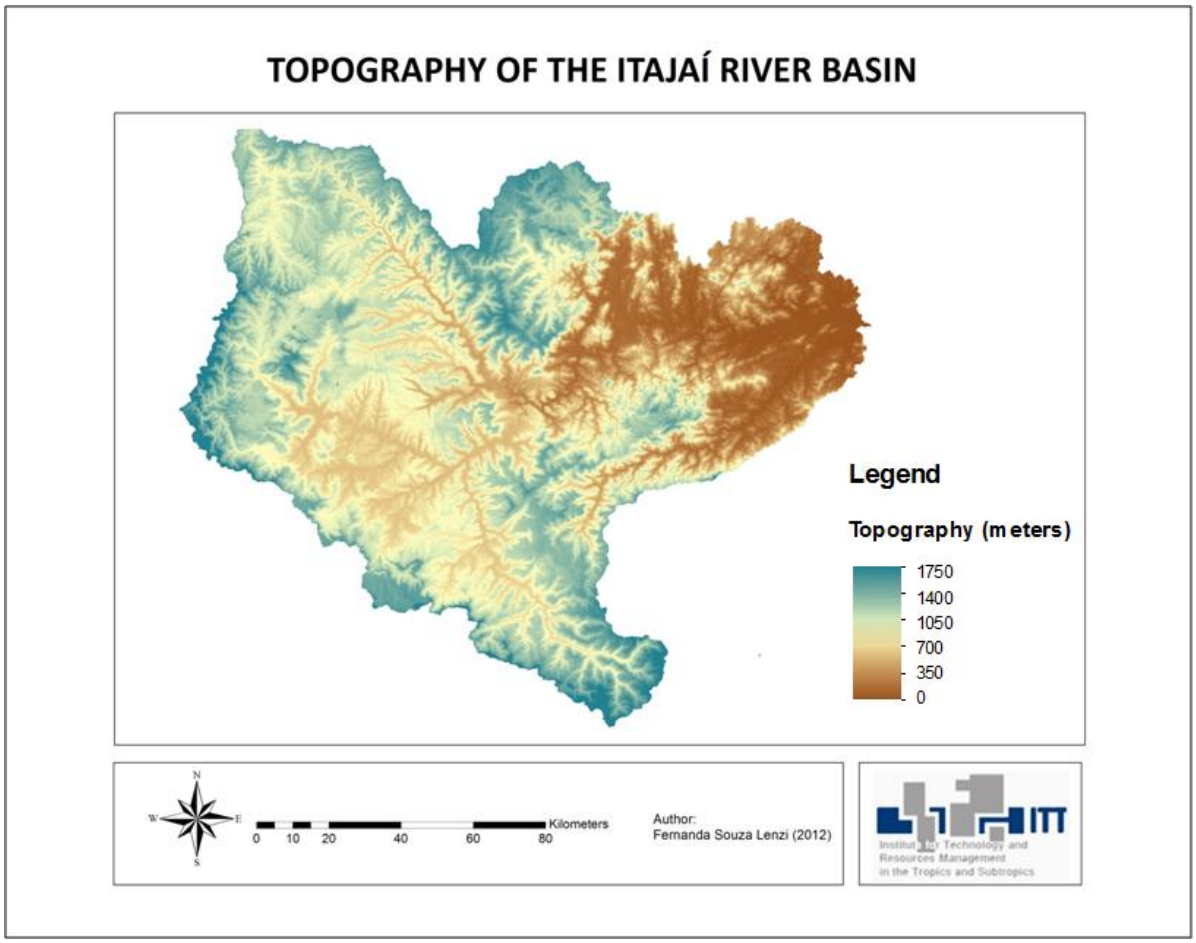

Figure 3 – Topography of the Itajaí River Basin.

Since its colonization by German and Italian immigrants, the riverside communities throughout the Itajaí-Açu River and its affluents have suffered from damage caused by repetitive flooding. The intensification of flood damage in the region has been associated with the processes of socioeconomic development and generation of an urban territory, which have caused effects in the soil characteristics and in the utilization of natural resources (Mattedi *et al*, 2009). Today roughly 80% of the basin's population live in urban zones (SPG, 2012), with great concentration in the cities of Itajaí (in the river's mouth), Rio do Sul, Blumenau and Brusque (190 km, 70 km, 50 km from the river's mouth, respectively) (SDC, 2012).

The municipalities of the region are distributed into three microregions (High Valley of Itajaí, Medium Valley of Itajaí and Mouth of Itajaí River), which differ in both natural (geology and geomorphology) and socioeconomic characteristics. In the High Valley of Itajaí, forests were drastically removed in place of agriculture and livestock, such as the production of onions, rice, tobacco and pork. In the Medium Valley, the problem is mainly related to the unbridled occupation of hillsides. In the Mouth of the Itajaí River, apart from the problem of irregular occupation, there is a serious environmental problem concerned with sand extraction which contributes to the riverside erosion (JICA, 2010).

With reference to the economy of the basin, the service sector represents 50.2% of the local GPD, followed by the sectors of industry and agriculture (SPG, 2012). The Itajaí Harbour is responsible for majority of the exports of Santa Catarina and occupies the second place in the national ranking of containers movement (Porto de Itajaí, 2012). The economic importance of the Itajaí River Basin is increasing every year and it is also attracting new investments. Furthermore, the Basin has a good performance in terms of social indicators, for example the cities of Blumenau and Itajaí have Human Development Indices (HDI) of 0.855 and 0.825 respectively (PNUD, 2009). Mattedi *et al* (2009) points out that the Itajaí River Basin is in an unusual situation. At the same time that the region presents one of the highest HDI registered in the Brazilian metropolitan regions, the community is extremely susceptible to disasters. For example, 68 floods were recorded in the city of Blumenau in a period of 158 years (Mattedi *et al*, 2009).

Flood History and the Flood Early Warning System in the Itajaí River Basin

Throughout its history, the Itajaí River Basin has been affected by natural disasters, principally the phenomena associated with extreme rainfall rates. The Itajaí River Basin experiences both floods due to overflowing rivers and urban floods which are closely related to the increase of impermeable areas and lack of drainage capacity (Tucci, 2005). Significant damage to the economy and human suffering caused by flooding have occurred in the past, especially in the municipalities of Blumenau, Itajaí and Rio do Sul. Although registers of floods in the region date back to the 19th Century, only the recent flood events of 1983, 1984, 2008 and 2011 will be discussed in this section.

In 1983, severe river floods affected ninety municipalities of Santa Catarina during the period of May-July, resulting in 197,790 people becoming homeless and 49 deaths (Herrmann *et al*, 2009). The municipalities of Blumenau, Itajaí and Rio do Sul, registered the largest number of victims. For instance, the Itajaí-Açu River in Blumenau experienced a rise of 15.34 meters in water level. As a consequence, in Blumenau 50,000 people lost their homes and 8 deaths were recorded (Santa Catarina, 2010). The floods that lasted for 30 days were the outcome of rains that occurred with greater intensity during four consecutive days, resulting in precipitations of 210 mm in the basin. The floods of 1983 caused damage equivalent to a return period of 76 years and the maximum river flow registered was 4,760 m^3/s in the city of Indaial (JICA, 2010).

Only one year after the flood of 1983, the Itajaí River Basin was once again affected by extreme precipitations, leaving nearly 40% of the population of Blumenau displaced. The floods of August 1984 lasted 4 days and accumulated between 160 to 300 mm of precipitation throughout the region. The maximum flow was again observed in Indaial with 5,000 m^3/s, and the return period of this flood is estimated to be 66 years (JICA, 2010).

According to Mattedi *et al* (2009), it was only after the floods of 1983 and 1984, that new initiatives were commenced to research the interactions between natural and social factors and the occurrence of disasters. An example was the “Crisis Project”, created by the Regional University of Blumenau (FURB) with the purpose of developing non-structural measures for flood protection, involving weather monitoring, river level monitoring, hydrological prediction models and flood risk maps (Frank, 1995). In 1984, an automatic network of five rain and level measurement stations was installed in the Itajaí River Basin by the National Department of Water and Electric Energy (DNAEE). The monitoring and the execution of flood forecasts became an attribution to the FURB through the creation of the Operation Centre of Flood Early Warning System (CEOPS) (Tachini, 2003). At the time,

the telemetry's system consisted of Remote Terminal Units (RTU) connected to a central station through the telephone network (Tachini, 2003). In 1996 the DNAEE deactivated the referred network due to the costs with maintenance and the obsolescence of equipments (Severo & Cordero, n.d).

After a flood event that occurred in February 1997, it became clear that measures should be urgently adopted to assure the transmission of data (river's level and rainfall) to the CEOPS (FURB) and continue the operation of the flood early warning system (Tachini, 2003). Thus, the FURB initiated a project titled "Emergency Project" with the Civil Defence of Blumenau. This project comprised of a network of tele-observers placed at different points in the basin. The Observers refer to workers that check daily measures of rainfall and the river's level and transmit these data to the CEOPS by telephone (Severo & Cordero, n.d.).

In the same period, the DNAEE provided the installation of 9 automatic stations in the basin, in which the data were transmitted via satellite to the National Institute of Space Research (INPE) and then to the DNAEE in Brasília, where the data would become available on the internet. After the DNAEE was defunct, the National Water Agency (ANA) assumed the network via satellite in 2002 (Tachini, 2003). However, telemetric networks need to be regularly updated and proper maintenance should be provided. The equipment of the ANA's network became obsolescent through the years, and the CEOPS executed flood forecasts only with the data from the observers. Figure 4 shows respectively examples of conventional (limnimetric scales) and automatic stations used for flood monitoring.

Figure 4 – Example of conventional stations (observers) and automatic stations by using telemetry. Source: ANA (2012) and CEOPS (2012) respectively.

In November 2008 the state of Santa Catarina, and specially the Itajaí River Basin, was severely affected by landslides, flash floods and river floods. Before the event of 2008, the basin was usually affected by river floods, in which the water flow exceeds the riversides gradually, depositing the surplus water in an adjacent flood plain (Marcelino et al, 2004). However, flash floods are localized events which occur in small basin areas (few hundred square kilometres or less), with response times of minutes to a few hours (Norbiato *et al*, 2008). The population of the Itajaí River Basin was not prepared for flash floods or landslides, so that the consequences of the event of 2008 were

devastating. The Civil Defence of Santa Catarina registered 135 deaths, 78,656 homeless people and roughly 1.5 million of affected people in total (PPRD, 2009). The highest volume of precipitations occurred in Blumenau, where the value of 576 mm was reached during only four days (21st to 24th November) (JICA, 2010). The river's level arrived at 11.5 meters and the maximum flow registered in Blumenau was 4,200 m^3/s (JICA, 2010). The city of Itajaí had 95% of its area affected by flooding (DC Itajaí, 2012), whereas cities like Ilhota experienced landslides that caused 47 deaths (SDC, 2012).

The floods of 2008 were caused by rains with a return period of 5 years, showing that the problem was mainly due to the spatial distribution of the rain downstream of the Itajaí River Basin (JICA, 2010). Severe floods and mass movements lead to the rupture of gas pipelines, interception of land communication routes, impairment of port activities, rupture of electric energy supply and drinking water supplies, besides the large number of deaths and displaced people (Almeida & Pascoalino, 2009). The national government offered post-disaster financial aid of roughly USD 800 million, mostly designated to the Ministries of Health, Defence, Transport and National Integration, in order to give assistance and reconstruct the damaged infrastructure (Almeida & Pascoalino, 2009). Moreover, the costs of emergency activities were estimated at USD 1.3 billion, considering that roughly USD 122.7 million were designated to the recuperation of roads (JICA, 2010).

As a reaction to the event of 2008, the government of Santa Catarina created in December 2008 the GTC (Technical-Scientific Group). The GTC is a multidisciplinary group formed by representatives of several institutions, in charge of analysing and proposing measures for the minimisation of disasters in the state of Santa Catarina (PPRD, 2009). In November 2009 the government also signed an agreement of technical cooperation with the Japan International Cooperation Agency (JICA) for the production of a plan for disasters prevention and mitigation in the Itajaí River Basin (Comitê de Itajaí, 2011). Furthermore, in 2009 16 telemetric stations were installed in the Itajaí River Basin with financial resources from the government of Santa Catarina through the State Secretary of Sustainable Economic Development (SDS). An agreement was signed between the SDS and the FURB, in which the FURB through the CEOPS is in charge for the monitoring of the stations. The data from the SDS's stations are transmitted to the CEOPS by mobile phones. However, the ineffective maintenance of the equipment compromised the data transmission for six months in 2011, including the period in which the flood event of 2011 took place in the region. Consequently, the CEOPS executed flood forecasts mainly with the data from the observers.

The flood event of September 2011 had an impact on 100 municipalities in the state of Santa Catarina, affecting roughly 980,000 people and causing 3 deaths (SDC, 2012). The precipitations occurred between the 7th and 9th September and the highest volume registered in the basin was 309 mm (SDC, n.d). The city of Rio do Sul was one of the most affected municipalities during this event. The river's level in Rio do Sul reached the height of 12.69 meters, whereas the level of 6.5 m is already classified as an emergency level for the city (DC Rio do Sul, 2011). Even the flood contention dams found in the upstream basin experienced water spill-over (DC Rio do Sul, 2011). Several problems were found during the flood event of 2011. The SDS's network was not transmitting data on river levels and rainfall to the CEOPS, and in some places the observers had difficulty in accessing the limnimetric scales. Also, some local authorities could not access the online data of weather forecasts from other institutions due to the fact that websites were overloaded.

In late 2011 the ANA decided to install 10 automatic stations with data transmission via Satellite (GOES) in the Itajaí River Basin. They also provided redundant system for data collection in 5 points

of the basin. The data from the ANA's stations are automatically updated on their website, so that institutions of the state of Santa Catarina can get the information. Apart from the SDS's and the ANA's network, some municipalities of the basin, like the city of Itajaí, installed their own monitoring networks with the argument that the current flood early warning system does not meet the needs of most cities of the basin.

1.1 Justification of this work

As previously commented, an effective FEWS depends on the integration of four components: risk knowledge, monitoring and warning, dissemination and response capabilities. As reported by SDC (2012), the current FEWS in the Itajaí River Basin fails in most of the components. For instance, just a few areas of the basin have maps of flood and landslides risks. The existing monitoring networks are not integrated and flood forecasts are executed only for the city of Blumenau, and Rio do Sul has its own method for flood forecasting (SDC, 2012). As regards to dissemination, the Civil Defence of Santa Catarina warns Civil Defence Centres at municipal level though their website, emails or telephone calls, but sometimes the information does not reach its target in a timely manner (SDC, 2012). Lastly, most of the municipalities of the basin do not have contingency plans, so that flood events are usually faced by unprepared local authorities and population.

Moreover, every component of the FEWS in the Itajaí River Basin involves the work of several institutions at federal, state and local levels. However, the roles of each institution in the functioning of the system are not always clear in the Brazilian legislation. In addition, the overlap of responsibilities stated in laws may also hinder the integration of the institutions to work together. A clear panorama of the key institutions and the good understanding of their interagency arrangements are essential for the establishment of successful FEWS (Sene, 2008). In this context, this work aims to identify the stakeholders and their competences according to the legislation, in order to act as a starting point for the improvement of the FEWS in the Itajaí River Basin.

In Brazil the Civil Defence is the institution most closely involved in all phases of disaster risk management (prevention, preparation, response and reconstruction). Some Civil Defence Centres at Municipal Level (COMDECs) have evolved significantly in the last years, maybe due to the occurrence of recent disasters in the Itajaí River Basin, such as the floods of 2008 and 2011. Moreover, due to the lack of an integrated and effective FEWS at the basin level, some COMDECs are building their own systems at municipal level. In this context, it is important to study how COMDECs are dealing with floods and how they interact with other institutions of the basin in every component of their flood early warning systems.

Flood early warning systems are essential for giving people more time to be evacuated during flood events and to avoid economic damages and human suffering. Municipalities in the Itajaí River Basin have potential to invest money in flood prevention and institutions of the basin have acquired a lot of flood experience and expertise throughout decades. However, flood events in the region keep causing deaths and huge economic losses. Thus, this work endeavours to evaluate the current system by taking into account the standpoints of the key stakeholders in the flood risk management of the basin. This would provide a better understanding of the needs of the current FEWS, as well as help in the formulation of future strategies for its improvement.

1.2 Objectives

The objective of this thesis is to contribute in the reduction of impacts of flood events in the Itajaí River Basin, in particular:

(1) to identify the institutions involved in the functioning of the flood early warning system in the Itajaí River Basin and to suggest changes to strengthen this institutional structure;
(2) to analyse the work of Civil Defence Centres at municipal level (COMDECs), as regards to the components of an effective early warning system;
(3) to evaluate and suggest improvements for the existing flood early warning system in the Itajaí River Basin.

1.3 Methodology

Several technical approaches were used to meet the objectives proposed in Section 1.2. For Objective (1), a Stakeholder Analysis was executed to identify the main institutions involved in the functioning of the flood early warning system. A stakeholder analysis consists in the process of gathering and investigating qualitative information to determine the institutions or individuals that should be considered when developing or implementing a program (Schmer, 1999). The qualitative information used in this work refers to the existing Brazilian legislation at federal, state and municipal levels. An intense review of the available legislation plus the access to official websites enabled the identification of stakeholders and their responsibilities regarding the FEWS in the Itajaí River Basin.

In regards to Objective (2), the work of three COMDECs (Blumenau, Rio do Sul and Itajaí) was analysed by answering three questions: How was the Civil Defence in the past? How is the Civil Defence today? How could the Civil Defence be in the future? For the first question, as well as a literature review, interviews with ex-members of the Civil Defence were carried out, together with a review of the first laws related to these COMDECs. For the second question, interviews with the current coordinators of the target COMDECs were executed in April 2012 (Annex 7.5). Also, the COMDECs provided all the required material, such as flood risk maps and contingency plans. For the last question, suggestions given by the coordinators of the COMDECs were considered, as well as successful measures implemented in other countries, as researched in the literature review. Furthermore, the FEWS of the three cities were studied, taking into account the following components of an effective FEWS (Risk Knowledge, Monitoring, Warning, Dissemination and Response Capability).

For Objective (3), representatives of the institutions identified in the Stakeholder Analysis for the Objective (1) were interviewed in April and May 2012. The identity of the interviewees is not revealed in this work, given that the opinion of one interviewee may not necessarily indicate the perspective of its whole institution. Semi-structured interviews were executed to meet the four central aspects of the SWOT Analysis (Annex 7.4). Semi-structured interviews are suitable to work with small samples and to gather qualitative data (Laforest, 2009). Furthermore, this sort of interview provides a list of questions that are carefully designed to call forth the interviewee's ideas and opinions on a particular subject, unlike questions with preconceived choices (Zorn, 2005). In other words, semi-structured interviews aim to comprehend the interviewee's point of view rather than make generalizations about behaviour (Sociology Organization, 2008). In that way, some

verbatim quotations extracted from the interview's transcriptions were also included in this work to illustrate a certain standpoint. The SWOT analysis aims to identify strengths, weaknesses, opportunities and threats of a particular subject, based on the viewpoints of several stakeholders. In this context, interviewees of 10 institutions contributed to the SWOT Analysis of the flood early warning system in the Itajaí River Basin.

Figure 5 shows a scheme of the methodology used in this work. Further details on the methods are commented on throughout the chapters.

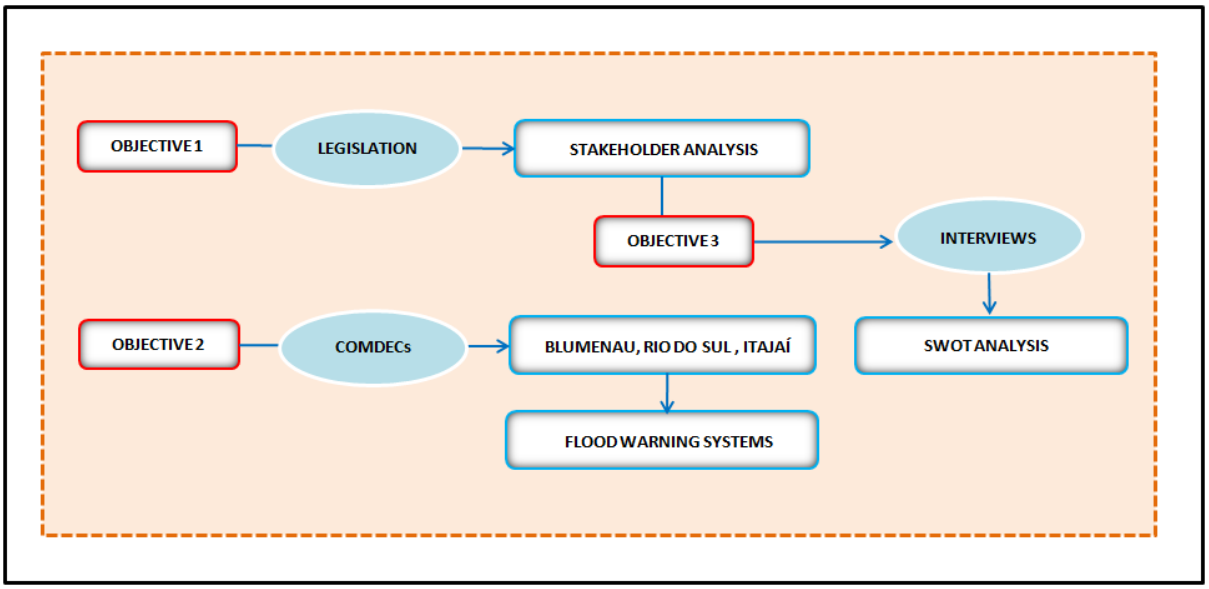

Figure 5– Scheme of the methodology according to the objectives proposed in this work.

1.4 Structure of the thesis

The present work contains three principal chapters, so that each chapter corresponds to one objective of the thesis. Chapter 2 gives an overview of the key institutions involved in the functioning of the flood early warning system in the Itajaí River Basin, and their responsibilities according to the current legislation. Chapter 3 presents the evolution of Civil Defence Centres in the Itajaí River Basin, in particular the COMDECs of Blumenau, Rio do Sul and Itajaí. Furthermore, a review of the components of their FEWS at municipal level is presented, as well as suggestions made in particular for the improvement of warning dissemination and response capability. Chapter 4 refers to the results of the interviews carried out with representatives from the involved institutions identified in Chapter 2. Interviewees identified the strengths, weaknesses, opportunities and threats regarding the FEWS at the basin level. Lastly, the conclusion includes the key aspects discussed in the previous chapters and suggestions based on the personal opinion of the author.

2 INSTITUTIONAL ARRANGEMENT AND OPERATIONAL INFRASTRUCTURE OF THE FLOOD EARLY WARNING SYSTEM

2.1 Institutional Arrangement

Institutional arrangement refers to the process of institutional interaction, where the role of each institution is properly characterized, as well as its interfaces with other institutions (Bohn, n.d). The identification of the relevant participants in a certain issue is called a Stakeholder Analysis, which aims to understand those involved in a project's behaviours, intentions and interrelations in the decision making process (Brugha & Varvasovszky, 2000). This analysis is an essential instrument to understand how systems work and change, by assessing the relationship of interested parties in these systems.

An effective flood early warning system has several components, from the production of risk maps to the actual response to disasters. In each of these components, different institutions or individuals, the "stakeholders", play a specific role in the system's functioning. In Brazil most of the institutions involved in flood management are public institutions and therefore are regulated by a specific legislation whether at federal, state or municipal level. In this context, the Brazilian legislation was the main source of information to build the institutional arrangement referred to the flood early warning system in the Itajaí River Basin. The main stakeholders and their competences according to the legislation are further discussed in this chapter.

2.1.1 Federal level

At the federal level there are five governmental sectors which are relevant to this work: Civil Defence, Water Resources Management, Water Infrastructure, Meteorology and the recently created Centre for Monitoring and Warning of Natural Disasters. The performance and structure of these sectors has changed through history, but especially at the end of the military dictatorship after which there was a transition to cooperative management through the Brazilian Constitution in 1988. Previously under the dictatorship, for example, water resources were managed by the command-and-control method, which means a monopoly of power and rights were given to the administrative bodies (Roehrig & Mello, n.d). The Constitution of 1988 promoted administrative decentralization in order to promote a more democratic system. Such decentralization can be specially observed in the Civil Defence and the Water Resources Management in Brazil, which are now organized according to the National System framework (see figures 5 and 6). Both the National System of Civil Defence and the National System of Water Resources Management are formed by deliberative (e.g.Council) and executive (e.g.Agency) bodies distributed into federal, state and local levels. Moreover, both the Water Resources Management and the Civil Defence Systems promote the participation of the population at local level through River Basin Committees and Civil Defence Centres at municipal and community levels.

2.1.1.1 Civil Defence

The term Civil Defence in Brazil refers to the group of actions designated to avoid or minimize disasters, to preserve the moral of the population and to re-establish the conditions of social normality (PNDC, 2007). The purpose of the Civil Defence is to promote the safety of the population, in circumstances of both natural and anthropogenic disasters (PNDC, 2007).

In Brazil the Civil Defence was initially implemented in 1942, during the Second World War, after the wreck of passenger ships in the Brazilian coast. With the purpose of assuring safety to the population, the federal government created the Service of Anti-Aircraft Defence and applied the mandatory teaching of Civil Defence in all educational establishments in the country (DC, 2012). Only in 1966 with the occurrence of a large flood in the Southeast of Brazil, the Civil Defence started to play a role in emergency situations related to disasters. A group of workers in the former State of Guanabara generated the first Plan of the Civil Defence at state level, defining the competences of several institutions involved with Civil Defence actions (Lopes *et al*, 2009).

In 1988, the Brazilian Constitution, in its Article 21 (Incisive XVIII), attributed to the Union the responsibility of planning and promoting the defence against public calamities, especially droughts and floods. To reach this goal, the National Politics of Civil Defence (PNDC) was published in 1995, in order to establish directives, plans and programs aiming to develop actions for disaster reduction, as well as to provide help and assistance for people affected by disasters (PNDC, 2007).

The structure of the Civil Defence is defined by the Decree n.5.376/05 of 17.02.2005, in which the responsibility concerned with disaster risk management is shared into the federal, state and municipal governments. The assembly of the Civil Defence bodies in Brazil form the National System of Civil Defence (SINDEC). At federal level, the National Secretariat of Civil Defence (SEDEC), belonging to the Ministry of National Integration, performs as the central organ of the Civil Defence in the country. The SEDEC comprises measures related to disaster prevention (evaluation and reduction of disasters), preparation (arrangements to ensure that communities can cope with disasters), response (relief and assistance to population) and reconstruction (reestablishment of public services and well-being of the population) (PNDC, 2007).

The National Council of Civil Defence (CONDEC) is responsible for the formulation and deliberation of policies and directives of the SINDEC (Brasil, 2005). At federal level, there is also the National Centre of Risk and Disaster Management (CENAD), which functions as a support tool in the structure of the SINDEC. It processes the information concerning risks and disasters, as well as it monitors daily adverse events, so that this information can be used for decision making (DC, 2012). The CENAD works in partnership with other institutions that may have the required human and material resources for the activities of the SINDEC (Lopes *et al*, 2010).

At the state level, the State Secretariat of the Civil Defence (SDC) was recently created in Santa Catarina through the Complementary Law n.534/11 of 20.04.2011. As stated in the law, the referred Secretariat is in charge of several activities, such as the coordination of the actions concerning the protection and civil defence in the state; execution of studies and research on disasters and risks; mobilisation of resources for disasters prevention and minimisation; and the dissemination of prevention behaviour in the society (Santa Catarina, 2011).

The decentralization of the actions of the Civil Defence was demonstrated with the creation of Municipal Civil Defence Centres (COMDECs) and Community Nucleus (NUDECs) through the Decree

n.5376/05 of 17.02.2005. According to Lopes *et al* (2009), the creation of COMDECs is of great importance for the efficiency of the Civil Defence, given that it is in the municipality where the disasters really happen and communities are the first to feel the effects of damages, as well as the fact that federal aid can be delayed in arriving. The COMDECs are responsible for connecting operation centres and incrementing the activities of monitoring and warnings to improve flood prevention (Brasil, 2005). Nevertheless, Valencio *et al* (2009) point out that there are many Brazilian municipalities which lack Civil Defence Centres. In other cases, the COMDECs are created only on paper, so that the Civil Defence at Municipal level can declare an emergency situation or state of public calamity, through forms of Damage Evaluation (AVADAN) and Preliminary Notification of Disasters (NOPRED), to request the transfer of federal resources to the municipalities.

The involvement of the local population plays an important role in disaster prevention, so as to be aware of its vulnerability regarding floods or even to apply pressure on public authorities to minimize the risks (Vendruscolo, 2007). The NUDEC is formed by a community group, organized in a district, neighbourhood, or a community association. This group participates in the activities of the Civil Defence as volunteers. The implementation of NUDECs is particularly important in areas vulnerable to disasters, so that local communities can organize and prepare themselves against the occurrence of adverse events. COMDECs and NUDECs promote preventative structural and non-structural measures, creation of contingency plans and training of volunteers and technicians, as well as the organization of plans for the optimization of the state of warning during adverse events (Lopes *et al*, 2009).

Recently, in April 2012, the Law n.12.608/12, which institutes the National Politics of Protection and Civil Defence (PNPDEC), was sanctioned by the Brazilian President. According to the Law, it is a duty of the Union, States and Municipalities to adopt measures for the reduction of disaster risks, and these measures could involve both public and private entities and the society in general. The Law emphasizes that the uncertainty of the occurrence of disasters should not hinder the adoption of preventative measures (Brasil, 2012).

As mentioned in the referred Law, the federal government should create and maintain a system of information and monitoring of disasters. Also, the government should produce a National register of municipalities with areas susceptible to the occurrence of landslides, flash floods or correlated geological and hydrological processes. They should monitor the areas at risk and issue warnings to the population, with the support of states and municipalities (Brasil, 2012).

States are responsible for the creation of a Plan of Protection and Civil Defence at state level. This Plan should contain the identification of river basins with risks of disasters, as well as guidelines for governmental action, especially regarding the implementation of monitoring networks in the target river basins. Besides, they should help the Union and Municipalities in the execution of the activities established in the law, such as the identification and mapping of areas at risk.

As regards to the municipal government, they should inspect the areas at risk and avoid new occupations. The municipalities included in the National Register should implement the following aspects in their Master Plans: maps of areas at flood and landslide risks; parameters of land use and occupation; measures of urban drainage required for disaster prevention; and planning of actions for reallocating the population living in areas at risk (Brasil, 2012). Another interesting aspect of the referred Law is that schools should include principles of Civil Defence in their obligatory courses (Brasil, 2012), which would contribute to increase the risk perception of the population.

The structure of the Civil Defence in Brazil is shown in Figure 6. The competences of the institutions which form the SINDEC are described in Table 1, according to the current Brazilian legislation.

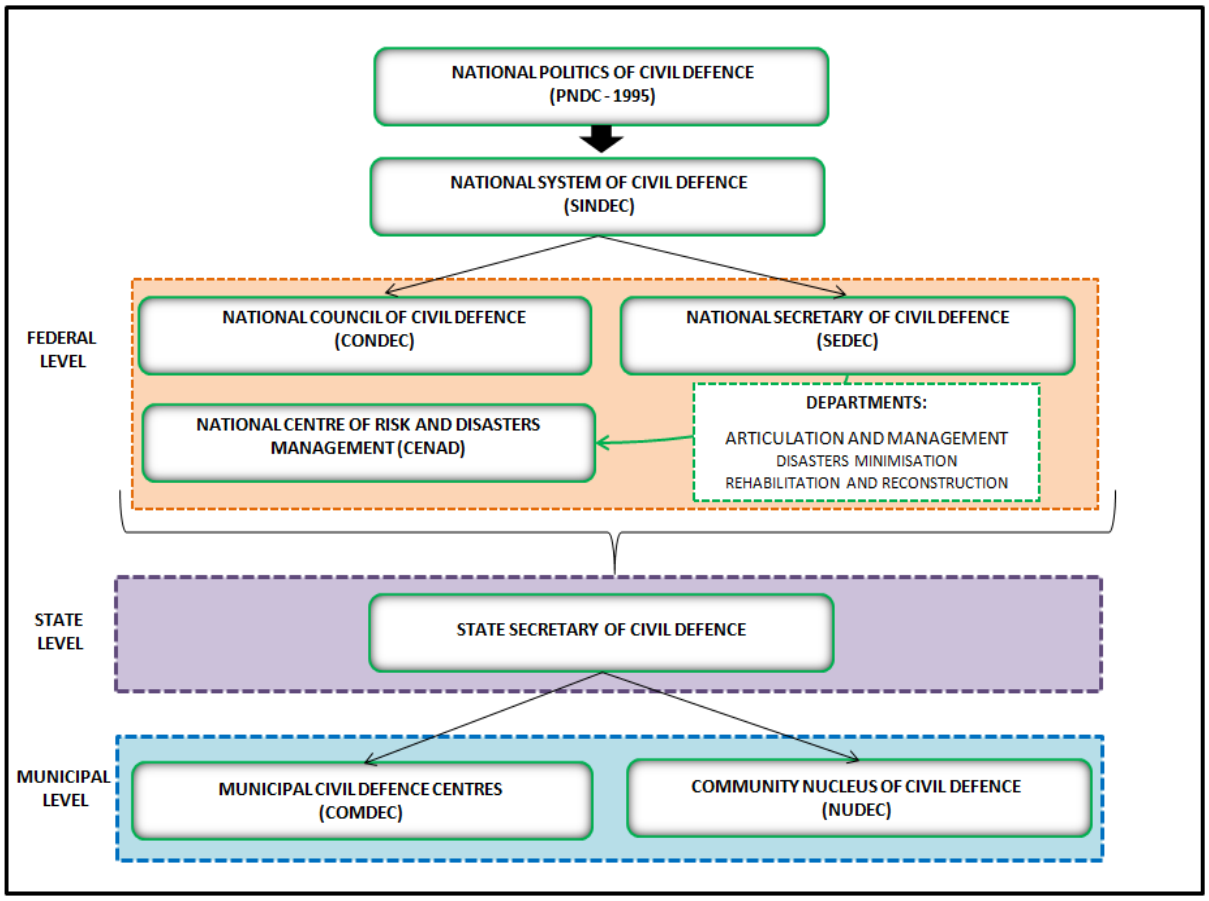

Figure 6– Scheme of the institutional framework of the National System of Civil Defence.

Table 1– Competences of institutions of the National System of Civil Defence (SINDEC).

FEDERAL LEVEL		
Institution	**Legislation**	**Competences**
National Council of Civil Defence **(CONDEC)**	Decree n.7.257/10 of 04.08.2010. (Article 6)	Formulation and deliberation of directives for the National Politics of Civil Defence (PNDC).
National Secretariat of Civil Defence **(SEDEC)**	Decree n.7.257/10 of 04.08.2010. (Article 5)	Coordination to the SINDEC, which will plan and promote actions to prevent disasters in the country; evaluation and reduction of disasters; performance in the imminence of disasters; prevention and minimisation of damage, assistance and relief to victims, and reestablishment of scenarios affected by disasters.

FEDERAL LEVEL		
National Centre of Risk and Disaster Management **(CENAD)**	Decree n.7.257/10 of 04.08.2010. (Article 5)	Management of preventative and response actions, as well as the mobilization of human and material resources, through a computerised system, in order to reduce the damage from disasters in communities; coordination of information about risks and monitoring of adverse events.
STATE LEVEL		
State Secretariat of Civil Defence **(SDC)**	Complementary Law n.534/11 of 20.04.2011. (Article 66)	Coordination of actions of protection and civil defence in the state (prevention and preparedness, assistance and relief to victims; recuperation of services; and reconstruction); execution of studies and research on risks and disasters; mobilization of resources for prevention and minimisation of disasters; dissemination of the prevention culture through the insertion of principles of protection and civil defence in the society; recommendations to relevant authorities about the interdiction of identified risk areas.
MUNICIPAL LEVEL		
Municipal Civil Defence Centres **(COMDEC)**	Decree n.5.376/05 of 17.02.2005. (Article 13)	Coordination and management of the Civil Defence actions at municipal level; inspection of buildings in risk areas and evacuation of the population of risk areas and vulnerable buildings; implementation of databases and production of maps concerned with multiple hazards and vulnerabilities; simulated exercises with the population; evaluation of damages in areas affected by disasters through the filling of formularies (AVADAN and NOPRED); support for the creation or interconnection with operational centres, and the development of monitoring and warning activities.
Community Nucleus of Civil Defence **(NUDEC)**	Decree n.5.376/05 of 17.02.2005. (Article 14)	Meetings and debates with the COMDEC and local communities; planning and promotion of the activities of the Civil Defence, especially for the creation of thematic maps; creation of contingency plans; training with volunteers to perform in disaster situations; coordination with institutions for monitoring, warning and alert, as well as the organization of convocation plan, in order to optimize the warning when disasters are imminent.

2.1.1.2 Water Resources Management

Water management in Brazil had been initially developed in a fragmented and centralized way. Until the nineties, each governmental sector (energy, sanitation, agriculture, etc) executed its own planning and measures. Also, water policies used to be defined by the federal and state governments, without the participation of municipal governments, water users or the society (Abers & Jorge, 2005).

Taking into account the current legislation, the Brazilian Constitution of 1988, through its Article 21 (Incisive XIX), attributes to the Union the competence of establishing a National System of Water Resources Management (SNGRH) and defining criteria for its right use. The Federal Law n.9433/97 of 08.01.1997 formed the National Politics of Water Resources (PNRH) and created the SNGRH in Brazil (Brasil, 1997). This system uses the river basin as a territorial area for action and each basin contains a river basin committee. With this system, the water management would become decentralized for the level of river basin and would integrate water management policies. Furthermore, it would involve all water users and communities in decision making process (Abers & Jorge, 2005).

As reported by Vendruscolo (2007), the National System of Water Resources Management (SNGRH) functions as an institutional structure for the cooperative management of water use in Brazil. It is structured into the three levels of government. At national level, it is formed by the National Council of Water Resources (CNRH); Water Resources Secretariat (SHR/MMA); National Water Agency (ANA). At state level, there are the State Councils of Water Resources (CERHs); and at local level, River Basin Committees and Water Agencies should be created so that the planning of water resources in the basin and the charge of water use could be accomplished (Bohn, n.d).

The **National Water Agency (ANA)** was created as a federal institution for the implementation of the National Politics of Water Resources (PNRH), through the Federal Law n.9984/00 of 17.07.2000. Among the competences attributed to the ANA, there is the responsibility to plan and promote actions designated to prevent or minimize the effects of droughts and floods in the scope of the National System of Water Resources Management, in collaboration with the central organ of the National System of Civil Defence, supporting states and municipalities. The ANA is also responsible for promoting the coordination of activities developed in the national hydrometeorological network in coordination with public or private entities which integrate or are users of this network (Brasil, 2000).

Today the ANA displays a large hydrometeorological database regarding river basins in the whole country, but it is worth saying that governmental activities in this type of monitoring began in the last century with the installation of stations by the National Department of Works and Sanitation (DNOS) and the National Institute of Meteorology (INMET). After institutional changes over the decades, the National Department on Water and Electrical Energy (DNAEE) was created in 1968. The DNAEE assumed the responsibility of applying the Water Code of 1934 and put effort into the creation of a National System of Water Resources Information (ANA, 2007). In 1997 these competences were designated to the National Agency of Electrical Energy (ANEEL) and lastly to the National Water Agency (ANA).

Nowadays the ANA collects data from the national hydrometeorological network, in particular the data concerned with precipitation, river levels, water quality and sedimentation. These data are registered in a database called HIDRO and available on the internet (ANA, 2007). As previously

commented, although the Itajaí River Basin is located within the boundaries of the state of Santa Catarina, the ANA has installed some stations in the basin.

The maintenance of the ANA's stations is executed by the Research Company of Agriculture and Livestock and Rural Extension (EPAGRI) at state level. The ANA has signed an agreement in 2011 with the EPAGRI, in which they transfer monthly the required resources for the operation and maintenance of equipment. This accord can be renewed until 2016 if the adequate conditions are maintained, such as price, technical capacity and results. Furthermore, the ANA has signed in 2009 a partnership with the Federal University of Santa Catarina (UFSC) to solve the matter of delayed payments to the observers, who execute daily measurements of the ANA's conventional stations.

Whilst at federal level, the ANA is responsible for executing water policies based in the legislation; at state level institutions are designated for the river basin management (Brasil, 2000). Given that the Itajaí River Basin is totally contained within the state of Santa Catarina, a Water Agency at state level should be created to execute these policies. **Water agencies** should be in charge of registering water users, charging the use of water, managing the works built with the tax revenue from water users, collecting funds, and creating the plans of river basins (Brasil, 1997).

An important strategy in the National Water Law (n.9.433/97 of 08.01.1997) is the formation of **River Basin Committees**. Committees are political organizations of decision making, formed by representatives of the Union, States, Municipalities located in the basin area; water users and civil entities of water resources. River Basin Committees should promote the debate of issues related to water resources and coordinate the actuation of intervening entities. Moreover, committees should monitor the execution of the Plan of Water Resources of the Basin (Brasil, 1997).

As stated in the Law 9.433/97 of 08.01.1997, water agencies should function as a technical and financial organ for river basin committees, giving structure to the functioning of committees. The Water Foundation of the Itajaí River Basin (FAAVI) was created as a private institution to meet this role. To implement these activities, the Foundation referred to is getting financial support from the Brazilian oil company Petrobras (JICA, 2010). However, the Water Foundation is not yet the water agency expected in the law, given that to use this title of water agency, the Foundation needs to have a management contract with the state government and the charge of water use should be working. Thus, the foundation is exercising the role of a water agency until it actually becomes formalized as an agency (Personal Communication with Dr. Beate Frank, 2012).

The Itajaí River Basin Committee was created by the State Decree n. 2109/97 of 05.08.1997 as a response to the insecurity associated with the lack of maintenance of the flood contention dams in the Itajaí River Basin, after the DNOS became defunct. Furthermore, there was the need to seek for more comprehensive solutions for the problem of flooding and to promote the sustainable use of natural resources (Frank & Bohn, 2003).

The Itajaí River Basin Committee is a public-private corporation with 50 members: 20 representing water users, 10 representing community organizations, 10 representing Municipal organizations and 10 representing the State and Federal organizations. Water users refer to entities associated with water supply, electrical energy, agricultural cooperatives, associations of industrialists, etc. Community organizations include universities, associations of municipalities, NGOs and indigenous communities. Lastly, Municipal, State and Federal organizations encompass banks, governmental Secretariats and Departments and the legislative assembly (Comitê do Itajaí, 2012).

The aim of the Itajaí River Basin Committee is to promote the integration of defence actions against droughts and floods and to assure the provision of adequate water to different uses (Comitê de Itajaí, 2012). According to Dr. Beate Frank, the River Basin Committee has put in a great effort to assure that the solutions implemented for flood prevention in the basin are indeed effective and sustainable, such as the interventions which help to retain water upstream of the basin. However, several measures implemented in the basin throughout the decades show that the actions are completely disintegrated with the policies of regional development. For instance, there are the solutions proposed by a report produced by the Japan International Corporation Agency (JICA) in 2010, which prioritizes huge structural works (Personal Communication, 2012).

According to GWP (2009), the Itajaí River Basin Committee has achieved the following results so far: recovery of more than 600 hectares of forest; a study of water demand and availability in the basin and a survey of roughly 9,000 water users; larger public involvement throughout the watershed, and accepted criteria for concessions (GWP & INBO, 2009). Despite the importance of committees in river basin management systems, they still depend on traditional sources of investments, which usually have their own mechanisms of eligibility and prioritization. Therefore they do not posses sufficient political and institutional legitimacy to influence the routing of investments towards their prioritized targets (Carneiro & Britto, 2009).

A scheme of the current structure of the National Water Resources Management in the country is presented in Figure 7. In addition, the competences of the institutions involved with water management in Brazil are shown in Table 2.

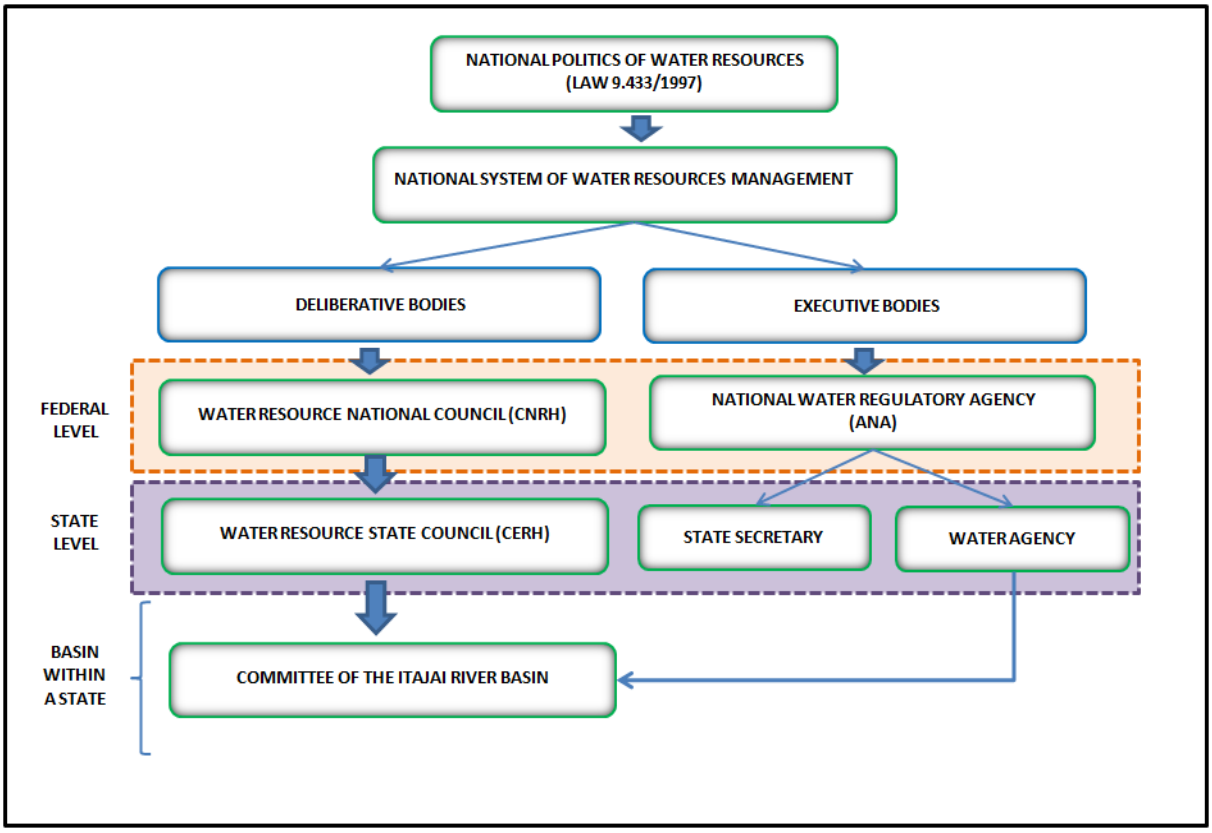

Figure 7 – Scheme of the institutional framework of the National System of Water Resources Management.

Table 2 – Competences of the institutions of the National System of Water Resources Management.

FEDERAL LEVEL		
Institution	**Legislation**	**Competences**
National Council of Water Resources **(CNRH)**	Law n.9.433/97 of 08.01.1997 (Article 35)	Coordination of water resources planning with national, regional, state and water users planning; establishment of complementary directives for the implementation of the National Politics of Water Resources (PNRH), among other competences.
National Water Agency **(ANA)**	Law n.9.984/00 of 17.06.2000. (Article 4)	Implementation, operation, control and evaluation of the tools of the National Politics of Water Resources; planning and promotion of actions designated to the prevention and minimisation of effects from droughts and floods, in coordination with the National Secretariat of Civil Defence; coordination of the activities developed in the ambit of the national hydrometeorological network.
STATE LEVEL		
State Council of Water Resources **(CERH)**	Decree n.1.003/91 of 12.11.1991. (Article 3)	Establishment of directives for the politics of water resources of the state of Santa Catarina; proposal of directives for the state plan of water resources' use; proposal of directives for the state programme for defence against floods.
REGIONAL LEVEL		
Water Agencies	Law n.9.433/97 of 08.01. 1997. (Article 44)	Maintenance of registers of water users; charge of water use; management of the System of Information on Water Resources in its area and scope of activity; agreements and contracts for financing and services for the execution of its competences.
River Basin Committees	Decree n.9.433 of 08.01.1997. (Article 38)	Debates concerned with issues related to water resources and coordination of the involved institutions; approval of the Plan of Water Resources for the basin; follow-up of the plan's execution and recommendations to meet its goals; establishment of mechanisms for charging the use of water resources and proposal of values to be charged.

2.1.1.3 Water Infrastructure

Considering the present Brazilian legislation, the **National Secretariat of Water Infrastructure (SIH)** is the institution at federal level responsible for the construction of works for irrigation and water supply (dams, pipeworks, channels), as well as works for macrodrainage (MIN, 2012). The SIH is found within the structure of the Ministry of National Integration (MIN), and its programmes of action follow the directives of the National Politics of Regional Development. As stated in the Decree n.7.226/2010 of 01.07.2010, the SIH should supervise the formulation of plans and projects for the usage of water; support the operation and maintenance concerning works of water infrastructure, as well as to regulate the concession of implantation, operation and maintenance of these works (Brasil, 2010a).

At the state level, the **State Secretariat of Infrastructure (SEI)** was officially created through the Complementary Law n.243/03 of 30.01.2003, which aims to develop all the regions of Santa Catarina in a decentralized way (Santa Catarina, 2003). The SEI is in charge of formulating the State Politics of Transport and Works, and developing activities related to the formulation of policies, plans, projects and the execution of works, including the ones for prevention and response to disasters, as presented in the Law n.534/11 of 20.04.2011. The referred Secretariat is formed by two departments: the State Department of Transport and Terminals (DETER) and the **State Department of Infrastructure (DEINFRA)**. The DEINFRA plays an important role in flood prevention, since it carries out the monitoring and operation of flood contention dams in the state of Santa Catarina.

Among the competences established in the Complementary Law n.382/2007 of 07.05.2007, the DEINFRA should implement policies for the infrastructure of transport, edifications and hydraulic works in the State of Santa Catarina. The DEINFRA's work comprises activities of planning, construction, operation, maintenance, adequacy of capability and expansion of works and services. It is also included the recuperation of target works for the Civil Defence (Santa Catarina, 2007b).

The Civil Defence and the DEINFRA work together in the functioning of the flood contention dams. The SDC and some COMDECs (Blumenau, Itajaí, Rio do Sul, Taió and Ituporanga) inform the river's level in the cities, so that the DEINFRA can decide whether they close or open the dams' flood gates. Depending on the rainfall rates, the dams are not able to avoid the flood, but to delay it, giving enough time for the Civil Defence to evacuate the population in downstream cities (Personal Communication with DEINFRA's worker, 2012).

A scheme of the institutions associated with hydraulic works and flood prevention are shown in Figure 8 and its relevant competences are abridged in Table 3.

Table 3 – Competences of the institutions involved with hydraulic works for flood prevention.

FEDERAL LEVEL		
Institution	**Legislation**	**Competences**
Secretariat of Water Infrastructure **(SIH)**	Decree n.7.226/10 of 01.07.2010. (Article 22)	Supervision in the formulation of plans, programs and projects for the use of water resources; support in the operation, maintenance and recuperation of works of water infrastructure; contribution to the formulation of the National Politics of Regional Development, among other attributions.

STATE LEVEL		
State Secretariat of Infrastructure **(SEI)**	Complementary Law n. 534/11 of 20.04.2011. (Article 74)	Development, in coordination with the Secretaries of Regional Development, of activities related to the planning and formulation of policies, programs, projects and actions referred to works, including the works for prevention and response disasters.
State Department of Infrastructure **(DEINFRA)**	Complementary Law n.382/07 of 07.05.2007. (Article 3)	Implementation of policies for the infrastructure of transport, edifications and hydraulic works in the state of Santa Catarina, comprising the activities of planning, construction, operation, maintenance, restoration, adequacy of capability and expansion of works and services.

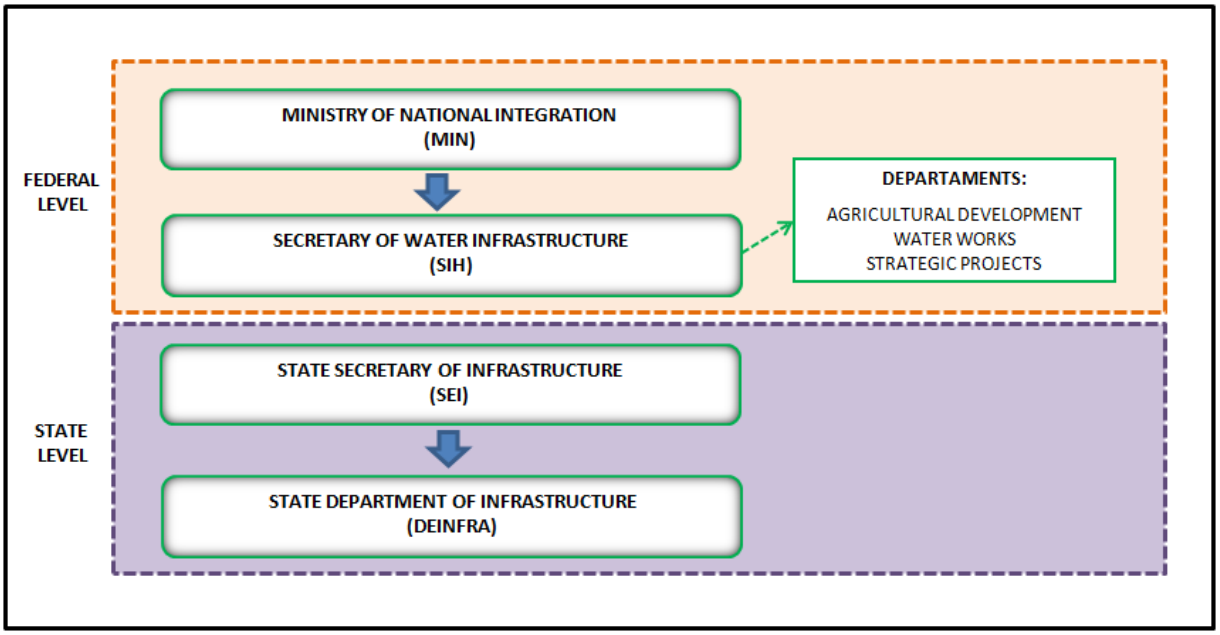

Figure 8– Scheme of the institutional framework related to hydraulic works and flood prevention.

2.1.1.4 National Centre of Monitoring and Warning of Natural Disasters

The National Centre of Monitoring and Warning of Natural Disasters, known as CEMADEN, is a federal institution created in 2011 within the structure of the Ministry of Science, Technology and Innovation (MCTI). According to the Decree n.7.513/2011, the CEMADEN has the following legal competencies: to create warnings of relevant natural disasters for the actions of the Civil Defence in the national territory; to produce and publish studies aiming at the production of necessary information for actions against natural disasters; to develop and implement observation systems for the monitoring of disasters; to develop and implement computational models; to operate computational systems for disasters warnings; to promote technical capacity; to issue warnings of natural disasters to the National Centre of Risks and Disaster Management (CENAD) and to help the National System of Civil Defence (Brasil, 2011a).

To meet these competences, the CEMADEN comprises of a team of geologists and disaster specialists who work 24 hours a day. The CEMADEN acquires environmental data through websites or through agreements with partaker institutions, such as the National Water Agency (ANA), National Institute of Meteorology (INMET) and the Air Force. These data are officially received in the CEMADEN, but they also have informal partners like farmers or cooperatives that share their data. Examples of data used by the CEMADEN are weather forecasts, radar data, radiosonde and data from meteorological stations. Having these data, the CEMADEN can develop a monitoring method, and constantly monitor the conditions in target municipalities.

There are two main criteria for the selection of the municipalities that will be monitored by the CEMADEN: registers of death due to disasters and mapping of risk areas. The risk maps are executed by the Brazilian Geological Survey (CPRM), which goes to the field and identifies the areas susceptible to river floods, flash floods and landslides. The Ministry of Cities and the Ministry of National Integration are the institutions which define the municipalities to be monitored (Personal Communication with Dr. Carlos Frederico Angelis, 2012). Seven municipalities of the Itajaí River Basin are monitored by the CEMADEN: Blumenau, Brusque, Gaspar, Ilhota, Luiz Alves, Rio do Sul and Timbó (CEMADEN, 2012) (Figure 9).

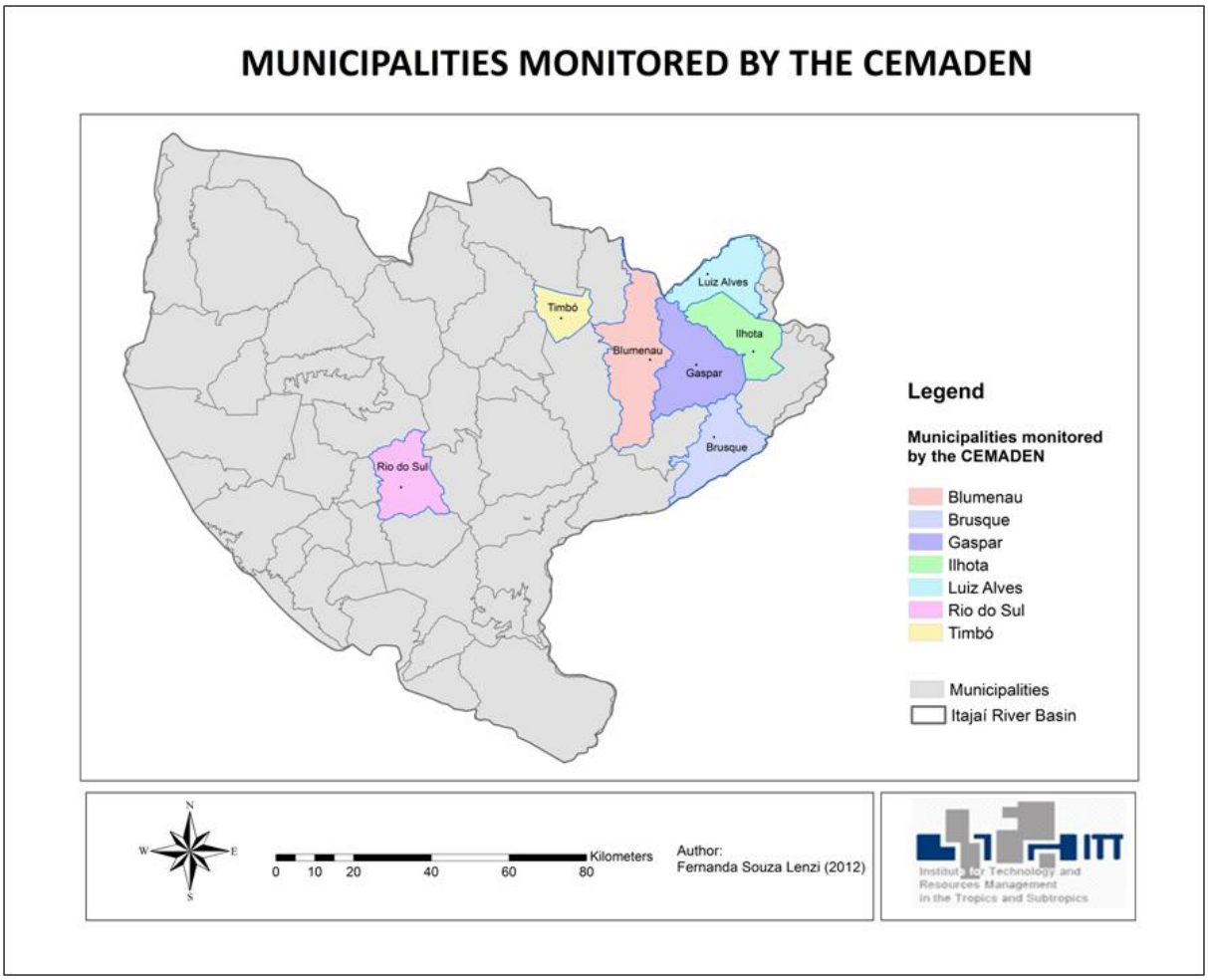

Figure 9 – Municipalities of the Itajaí River Basin monitored by the CEMADEN.

The CEMADEN was created to attend the CENAD, so if there is any critical situation in one of these priority municipalities, the CEMADEN will inform the CENAD, which is in charge of issuing this warning to Civil Defence Centres at State and Municipal levels. After receiving the warning, the CENAD executes complementary actions: consolidation of risk and disaster information, monitoring of adverse events, diffusion of disaster warnings and preventative orientations to the population, coordination of actions of disasters response, mobilization of resources for the ready response (MCTI, 2011).

Moreover, the CEMADEN has a project which aims to install roughly one thousand conventional rain gauges in poor communities in the country. The idea is that the inhabitants of these areas can monitor the condition and participate in the decision making process, which would be the evacuation, or not, of the area. Apart from that, the CEMADEN plans to buy an additional 3,000 automatic rain gauges to be installed in mobile phone towers, such as the VIVO and ANATEL. These rain gauges will be placed in the municipalities with mapped risk areas. This would include some municipalities in the Itajaí River Basin (Personal Communication with Dr. Carlos Frederico Angelis, April 2012).

The main competences of the CEMADEN are presented in Table 4. Figures 10 and 11 show respectively the institutional location of the CEMADEN and its work together in partnership with other institutions.

Table 4 – The competences of the CEMADEN according to the current Brazilian legislation.

FEDERAL LEVEL		
Institution	**Legislation**	**Competences**
National Centre of Monitoring and Warning of Natural Disasters **(CEMADEN)**	Decree n.7.513/11 of 01.07.2011. (Article 13)	Development of relevant natural disasters warning systems for the Civil Defence at national territory; performing of studies that aim to produce the necessary information to the actions against natural disasters; development of technical, scientific and innovation capacity to improve the warnings of natural disasters; development and implementation of observation systems for the monitoring of natural disasters and computational models; emission of warnings of natural disasters to the National Centre of Risks and Disasters Management (CENAD).

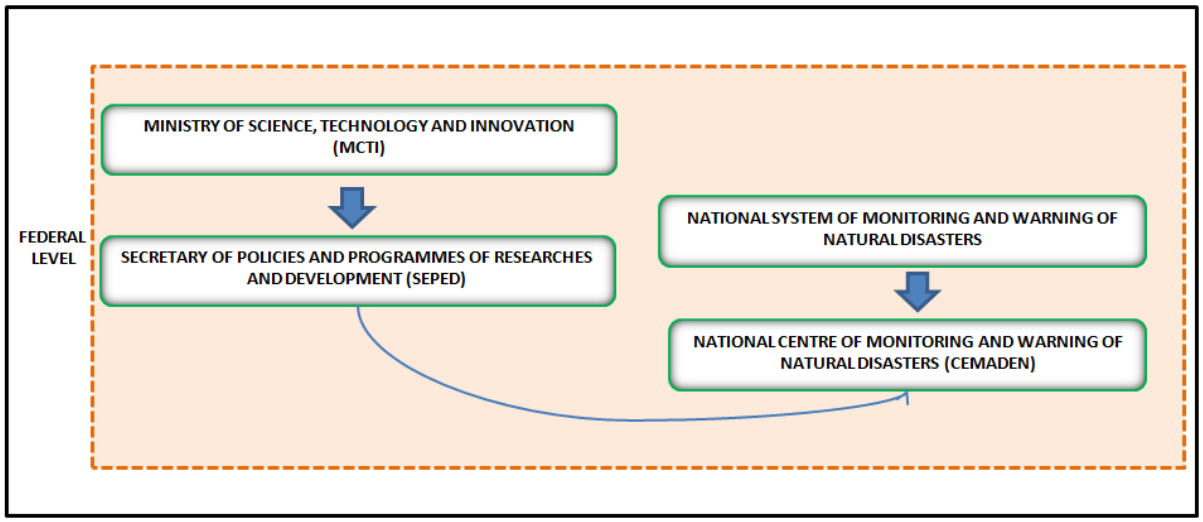

Figure 10 – Institutional location of the CEMADEN within the MCTI.

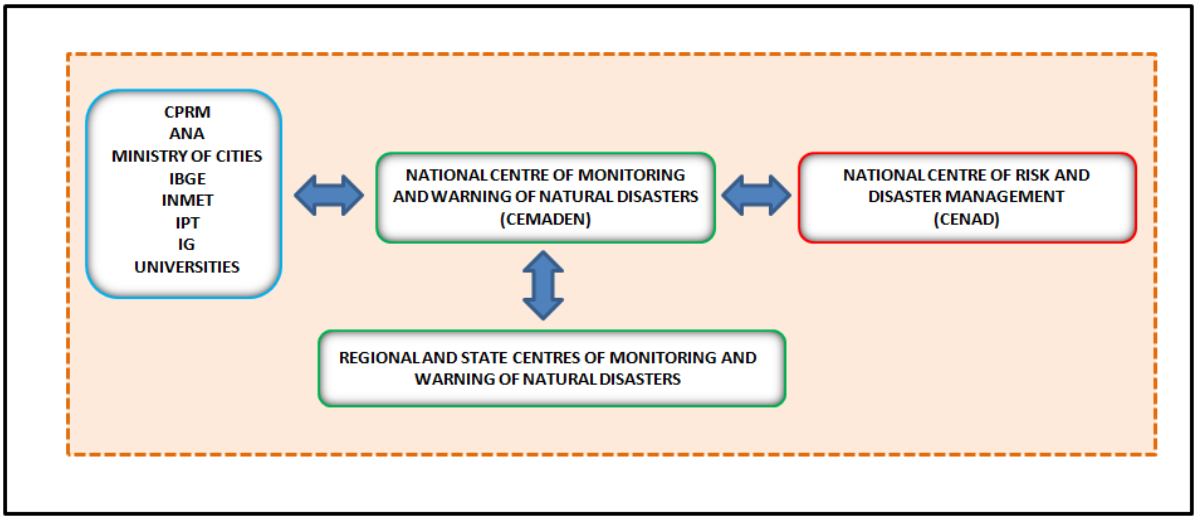

Figure 11– Scheme of the coordination of the activities of the CEMADEN with other institutions.

Source: Adapted from CEMADEN, 2011.

2.1.1.5 Meteorological Services

Meteorological forecasts are undoubtedly important information for the operation of flood warning systems. In some cases the prediction of rainfall rates are embedded into flood forecast models, and even in cases where the models only make use of river level data, experts in hydrology might consider weather predictions before issuing a flood warning to other stakeholders. In Brazil two institutions at federal level have the same task of weather forecasting: the National Institute of Meteorology (INMET) and the National Institute of Space Research (INPE). Both institutions produce daily weather forecasts through mathematical models connected to own super computers (Silva & Severo, 2003).

The Brazilian Meteorological Service began in 1909 with the Decree n.7.627, which established the creation of the Administration of Meteorology and Astronomy linked to the Ministry of Agriculture,

Industry and Commerce. At the time, weather forecasts and warnings were mainly designated to sailors and farmers. The National Meteorological Service is represented today by the **National Institute of Meteorology (INMET)**, which is subordinated to the Ministry of Agriculture, Livestock and Supply (Oliveira, 2009). According to the Law n.10.683/03 of 28.05.2003, the areas of meteorology and climatology are competences of the referred ministry (Brasil, 2003). Therefore, the INMET is the institution responsible for the production and maintenance of the National Politics of Meteorology (INMET, 2011).

The structure of the INMET is based in Regional Districts. The INMET coordinates more than 400 stations in the country and possess 10 Meteorological Districts (DISMEs) that receive, analyse and send these data to the Central Office in Brasília. The state of Santa Catarina is part of the 8th DISME located in the city of Porto Alegre, in the state of Rio Grande do Sul. Simulations are performed with the data collected from the stations (rainfall rates, wind, air humidity, pressure, etc), in order to study the weather's behaviour 24, 48, 72 and 96 hours in advance (INMET, 2012). Furthermore, satellite images and meteorological radars are used for weather forecasts for short term.

The **National Institute of Space Research (INPE)** also develops research and activities in the fields of meteorology, weather forecast and climatology. Space research in Brazil commenced with the creation of the INPE in 1961. The space dispute between the United States and the Soviet Union during the Cold War was the driver of the Decree n.51.133/61 of 03.08.1961, establishing the creation of the Group of National Commission in Space Activities (GOCNAE), which was the beginning of the institute (Câmara, 2011).

At present the INPE belongs to the Ministry of Science, Technology and Innovation (MCTI) and displays three Regional Centres located in the Northeast, Amazonia and South of Brazil. The activities developed in the INPE reproduce its strategic objectives outlined every four years. Some goals are the creation of operational centres of monitoring and modelling for space climate, natural disasters and land use changes in Brazil; and research concerned with impacts and vulnerability to global environmental changes (INPE, 2011).

Within the structure of the INPE, there is the **Centre of Weather Forecast and Climate Studies (CPTEC)**, which is in charge for weather forecasts in global and regional scales. According to INPE (2011), the CPTEC has increased the spatial resolution of its global atmospheric model (MCGA Model) from 200x200 km in 1994 to 20x20 km in 2011. Likewise its regional model (ETA Model) had its spatial resolution increased from 40x40 km in 1997 to 5x5 km in 2011. Today the weather forecasts are produced up to 15 days in forehand. The first seven days refer to forecasts analysed by meteorologists, and the remaining days are the graphical output of the model (CPTEC, 2012).

Meteorological warnings produced by the CPTEC-INPE are sent to the National Civil Defence (SEDEC), which will further contact the States and Municipalities, in cases of weather conditions that are likely to cause impacts. The CPTEC has three levels of meteorological warnings (Silva Dias, n.d.):

1) *Observation*: the phenomenon is expected to occur within a period greater than 5 days.
2) *Attention*: the phenomenon is likely to occur in the next four days, or in the next 24 hours according to a less reliable forecast. In the latter case, the CPTEC sends daily meteorological bulletins to the SEDEC.
3) *Special Meteorological Warnings*: a severe meteorological phenomenon is expected to happen in the next 24 hours, according to a highly reliable forecast.

Although the INPE and the INMET have made an effort to improve its activities on weather forecast throughout the decades, experts in Meteorology criticize the lack of a meteorological data system in a unified database. Several institutions at federal and state levels, as well as private institutions, develop meteorological activities independently from each other and sometimes they execute a redundant service. As commented on by Silva & Severo (2003), this situation could be improved with the creation of a national agency of meteorology, in the same way that happens with the electricity and the water (ANEEL and ANA respectively). Effective meteorological surveillance especially for smaller areas can definitely improve the efficiency of flood warning systems (Silva & Severo, 2003).

Figures 12 shows the institutional framework of the two main institutions at federal level in charge of meteorological activities and their competences are shown in Table 5.

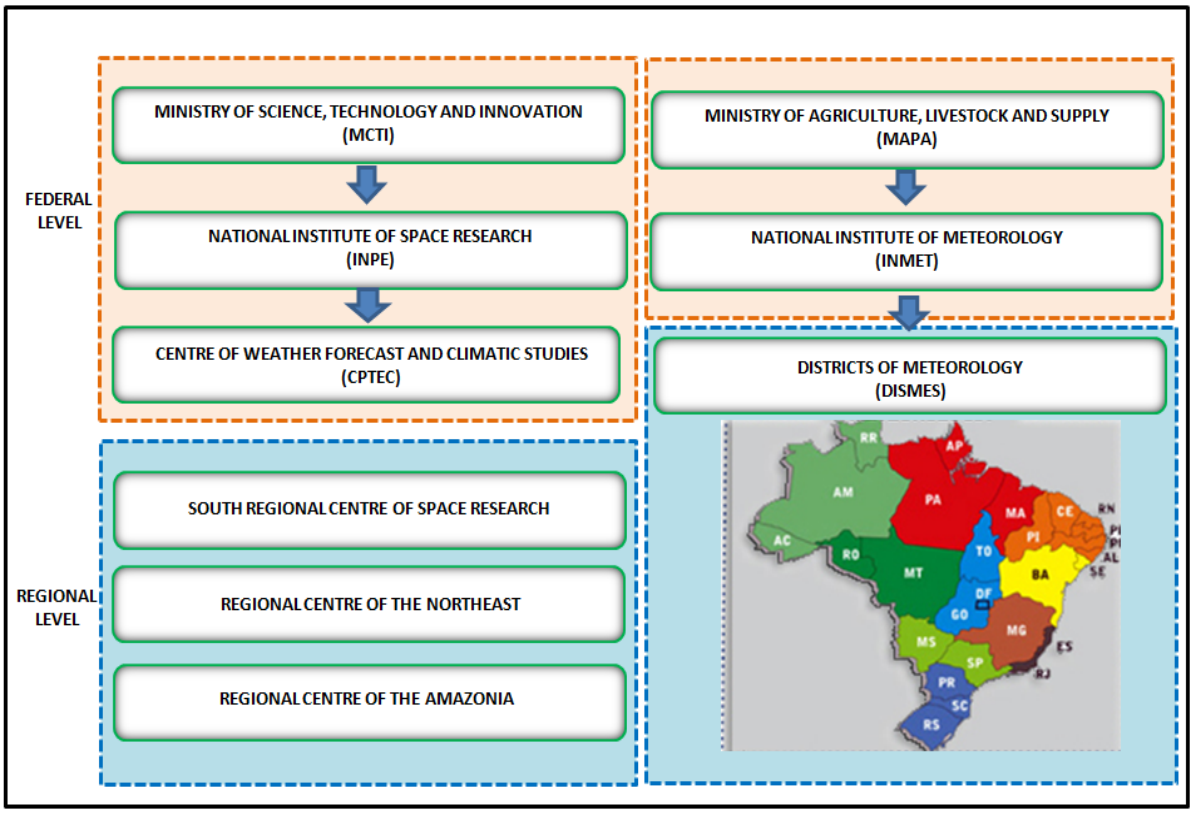

Figure 12– Institutional framework of the INPE and the INMET.

Table 5 – Competences of the institutions at federal level involved with Meteorology.

FEDERAL LEVEL		
Institution	**Legislation**	**Competences**
National Institute of Meteorology **(INMET)**	Management Report of 2010 (INMET, 2010)	Establishment and maintenance of the National Politics of Meteorology; meteorological and climate studies and surveys applied to the Agriculture, Science and Technology; execution of weather forecasts; maintenance and operation of the meteorological network and the national meteorological telecommunications, integrated to the international network.

FEDERAL LEVEL		
National Institute of Space Research **(INPE)**	Master Plan of INPE 2011-2015	Expansion and consolidation of competences in weather forecast and climate and global environmental changes; expansion and consolidation of competences in science, technology and innovation in space and terrestrial environment areas to respond to national challenges.
Centre of Weather Forecast and Climatic Studies **(CPTEC)**	Master Plan of INPE 2011-2015	Weather forecasts in global and regional scales; products from satellites: forest fires, rain measured by satellites and radars.

2.1.2 State Level

In the state of Santa Catarina there are four stakeholders whose activities are related to the flood early warning system in the Itajaí River Basin: the Civil Defence of Santa Catarina, the DEINFRA, the EPAGRI and the SDS. The first two stakeholders have already been commented on in the previous section, while this section will discuss the work of the EPAGRI and the SDS.

2.1.2.1 EPAGRI-CIRAM

An important stakeholder in the institutional framework of the flood early warning system in the Itajaí River Basin is the Research Company of Agriculture and Livestock and Rural Extension of Santa Catarina, or simply EPAGRI. This referred company was created in 1991 and is connected to the structure of the State Secretariat of Agriculture and Fishery (SAR). As stated in the Complementary Law n.381/07 of 07.05.2007, the EPAGRI is responsible for planning and executing the Politics of Research and Diffusion of Technologies for Agriculture, Livestock, Forests and Fishery in the state of Santa Catarina (Santa Catarina, 2007a). To meet these objectives, the EPAGRI is formed by regional offices distributed throughout the entire state. Besides, it includes four specialized centres (CEPAF, CEPA, CIRAM, CEDAP), and among these centres the CIRAM is of particular interest in this work.

The **CIRAM (Centre of Information on Natural Resources and Environment**) was created in 1998 with the purpose of integrating data and information concerned with environmental resources, and creating a centre for the delivery of specialized services (CIRAM, 2012). Since the extinction of the CLIMERH (Integrated Centre of Meteorology and Water Resources) in 2004, the sectors of Meteorology, Hydrology, Stations for Data Collection and Information Technology became an attribution of the CIRAM (Ramos, 2011).

As regards to Meteorology, the CIRAM executes daily weather forecasts (24 and 48 hours in advance). Apart from that, the CIRAM performs a monthly climate forecast for every three month term, taking into account the behaviour of the temperature and the precipitation in the region. Furthermore, every day the CIRAM presents disaster forecasts due to intensive rainfall rates by combining a risk map with a vulnerability map for the entire state. The risk map is updated daily with the rain forecast for the next 24 hours obtained through numerical models and the precipitation which occurred in the last 24 and 48 hours, measured by meteorological stations and satellites. The

vulnerability map (Annex 7.3), which is a static map, was built based on environmental and socioeconomic information (CIRAM, 2012).

The bulletins of weather forecasts are released to the public through the internet and the media. In cases of extreme events, the CIRAM will directly contact the Civil Defence of Santa Catarina by telephone (Ramos, 2011). Moreover, to disseminate the weather forecasts as well as to avoid the frequent calls to the meteorologists of the CIRAM, the centre has today recorded messages available through telephone and the teleweather for all regions of the state. These messages contain information about the weather conditions, maximum and minimum temperature, wind speed and direction and sea level (Ramos, 2011).

An important role of the EPAGRI-CIRAM refers to the maintenance of the stations which belong to the ANA, in the Itajaí River Basin. These stations were installed in 2010 and since then the CIRAM should have executed the maintenance of these stations. However, they used to have four employees working specifically for the stations' maintenance for the entire state, but at the moment there is just one employee executing the maintenance of conventional stations and surprisingly no one for the automatic stations. Yet, they are trying to solve this problem either through a public tender or through the release of a monthly financial resource for hiring an outsourced company for maintenance (Personal communication with representatives of the EPAGRI-CIRAM, April 2012).

The competences of the EPAGRI and the CIRAM are resumed in Table 6, and their institutional location is presented in Figure 13.

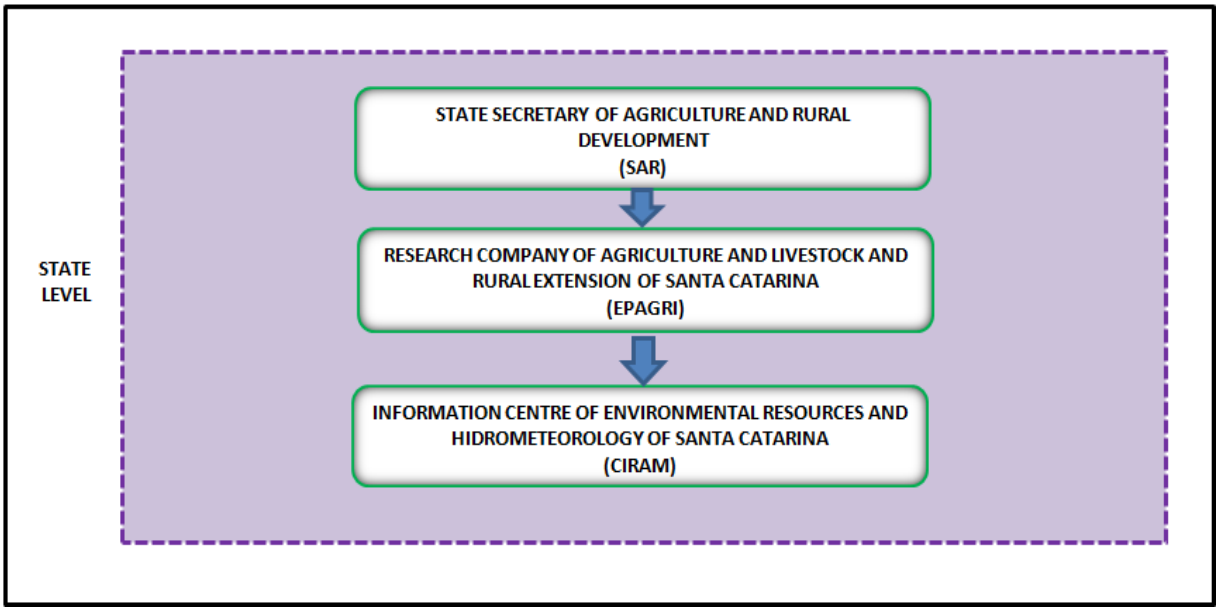

Figure 13– Institutional framework of the EPAGRI-CIRAM.

Table 6 – Competences referred to the EPAGRI and the CIRAM.

STATE LEVEL		
Institution	**Legislation**	**Competences**
Research Company of Agriculture and Livestock and Rural Extension of Santa Catarina **(EPAGRI)**	Complementary Law n.381 of 07.05.2007. (Article 112)	Planning, coordination and execution of the state politics of research (e.g. meteorology, water resources), transference and dissemination of technologies for agriculture, livestock, forest, fishery and technical assistance in Santa Catarina, among other attributions.
Centre of Information on Natural Resources and Environment **(CIRAM)**		Integration of data and information of environmental resources, development of research and technologies and the delivery of specialized services.

2.1.2.2 State Secretariat of Sustainable Economic Development

The State Secretariat of Sustainable Economic Development, known as SDS, is another stakeholder involved with flood management in the state of Santa Catarina. Being a governmental institution, the SDS is vulnerable to changes each time a governmental mandate ends. In this context, the SDS had its name and competences modified throughout the years. The scheme below shows the evolution of the institution, from its beginning in 1983 as a Planning Office to nowadays as the State Secretariat of Sustainable Economic Development (Figure 14).

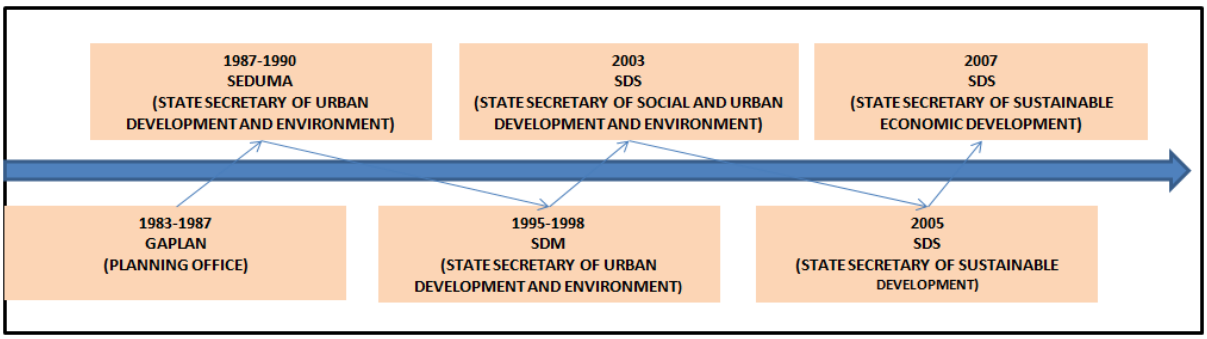

Figure 14– Scheme of the SDS's evolution throughout the years.

According to the Complementary Law n.381/07 of 07.05.2007, the SDS is responsible for planning and formulating the policies of water resources, environment, climate changes, and payments for environmental services and sanitation in the state of Santa Catarina. The SDS should also coordinate and regulate the granting for water use and control the concessions issued. Moreover, the law attributes to the SDS the responsibility of coordinating the implementation of the hydrological network for the monitoring of the main rivers and springs of the state (Santa Catarina, 2007a). For

instance, the SDS obtained in 2009 the financial resources which were used for the implementation of a telemetric network in the basin.

The Secretariat, in particular the Board of Water Resources (DIRH), does not have the required structure to implement activities related to flood management, but they seek subsidies in order to make agreements with other institutions that can actually execute these activities, such as the installation of rain gauges or monitoring of the network. The SDS works for the state as a whole, but given that the Itajaí River Basin displays a large register of flood occurrences, the SDS prioritizes many actions in this region.

Today the SDS is involved with several activities which are linked to the flood early warning system of the region. According to the SDS's worker, the SDS had developed from 2010 to 2012 a survey from aerial photographs with scale 1:5,000. This has generated a complete cartographic basis that can be useful for the creation of maps of risks. Another action of the SDS is the coordination of the hydrogeological mapping of Santa Catarina, in partnership with the Geological Survey of Brazil (CPRM). This will also contribute to the development of maps of risk areas and landslides. Besides, through the programme SC Rural, which promotes rural development and family farm's competitiveness in the state, the SDS aims to subsidy the maintenance of the meteorological radar located in the municipality of Urubici, in order to avoid the possibility that a radar stops transmitting data especially during critical events like floods (Personal communication, 2012).

The main competences of the SDS related to flood management and a scheme of its institution framework are presented in Table 7 and Figure 15.

Table 7 – The competences of the SDS according to the legislation of Santa Catarina.

STATE LEVEL		
Institution	**Legislation**	**Competences**
State Secretariat of Sustainable Economic Development **(SDS)**	Complementary Law n.381/07 of 07.05.2007. (Article 72)	Coordination of the implantation of the hydraulic network of the main rivers and springs of Santa Catarina; creation of planning and management tools of water resources by river basins, encouraging the creation, the strengthening and operational capacity of river basin committees.

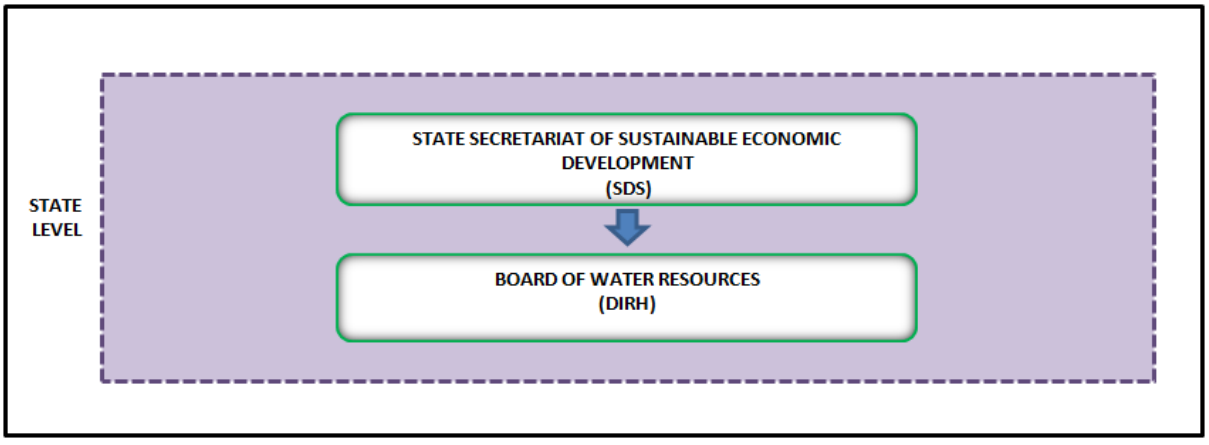

Figure 15 – Institutional framework of the State Secretariat of Sustainable Economic Development.

2.1.3 Regional level

At regional level two stakeholders have been closely involved in the functioning of the flood early warning system in the Itajaí River Basin: the Itajaí River Basin Committee connected to the Water Foundation, and the CEOPS through the Regional University of Blumenau (FURB). The Itajaí River Basin Committee has already been discussed in this work within the framework of water resources management in Brazil, and the role of the CEOPS will now be further analysed.

2.1.3.1 CEOPS-FURB

After the flooding of 1983 which severely affected the Itajaí River Basin, the Regional University of Blumenau (FURB) created the "Crisis Project", with the purpose of developing non-structural measures, such as weather monitoring, river level monitoring, models of hydrological forecasts and maps of flood risks (Frank, 2003). In 1984, the National Department of Water and Electrical Energy (DNAEE) installed a telemetric network of five automatic stations for rain and river level data collection in the municipalities of Blumenau, Apiúna, Ituporanga, Taió and Ibirama (CEOPS, 2012).

Together with this project, the **CEOPS (Operation Centre of the Warning System)** was created under an agreement signed in August of 1984 between the FURB and the DNAEE. In this agreement the DNAEE assumed the responsibility of the network's maintenance, whilst the FURB should operate the CEOPS, through the Crisis Project. The CEOPS was in charge of executing the monitoring of the weather, river level and precipitation in the Itajaí River Basin (CEOPS, 2012).

The Crisis Project was further replaced by the Institute of Environmental Research (IPA), which was officially installed in 1996. The IPA plays the role of providing an information service on floods, which has great demand in the community (Frank, 2003). Since the IPA's creation, the CEOPS became part of this institute (CEOPS, 2012). The FEWS in the Itajaí River Basin was firstly created to provide flood forecasts to the entire basin, but due to the hydrological characteristics of the basin and technical constraints, the forecast of river's levels are executed only for the city of Blumenau. As explained before, at the end of 2009 the FURB implanted a new telemetric network with financial resources from the state government (SDS). The CEOPS still has the incumbency of monitoring this telemetric network in the Itajaí River Basin and keeps executing flood forecasts for Blumenau. Moreover, the CEOPS execute studies in Meteorology and Hydrology (CEOPS, 2012).

Representatives of the CEOPS complain about the lack of financial resources for the maintenance and operation of the centre. For instance, this agreement between the SDS and the FURB provided the maintenance of the telemetric network only up to a year after its installation. In 2011 there was a problem in the software used in the telemetry, but there was no maintenance of this network or any resources available to hire an outsourced company to execute this maintenance. As a result, the CEOPS had not received hydrological data from the stations during six months, which unfortunately coincided with the period in which severe flash floods and landslides occurred in the Itajaí River Basin. At the moment, some members of the CEOPS are voluntarily executing a basic maintenance of the sensors, but the network's maintenance is definitely an unsolved problem in the functioning of the flood early warning system (Personal communication with Prof. Dr. Ademar Cordero, 2012). Also, it is important to highlight that the CEOPS is formed by a group of professors of the FURB, so that they have other activities, such as lectures, apart from the operation of the CEOPS.

Further information concerned with the CEOPS's activities will be presented in the next chapter. The CEOPS' competences as well as its institutional framework are presented in Table 8 and Figure 16.

Table 8 – Main competences of the CEOPS and the FURB/IPA related to flood management.

REGIONAL LEVEL	
Institution	**Competences**
Regional University of Blumenau **(FURB)** Institute of Environmental Research **(IPA)**	Research, extension and services in the environmental area; responsibility of maintaining the CEOPS as a permanent program in the University (Bohn, 2005).
Operation Centre of the Warning System **(CEOPS)**	Weather studies (collection of meteorological data and satellites images, analysis of mathematical models of forecast); monitoring of river levels and hydrological forecasts; technical reports and research.

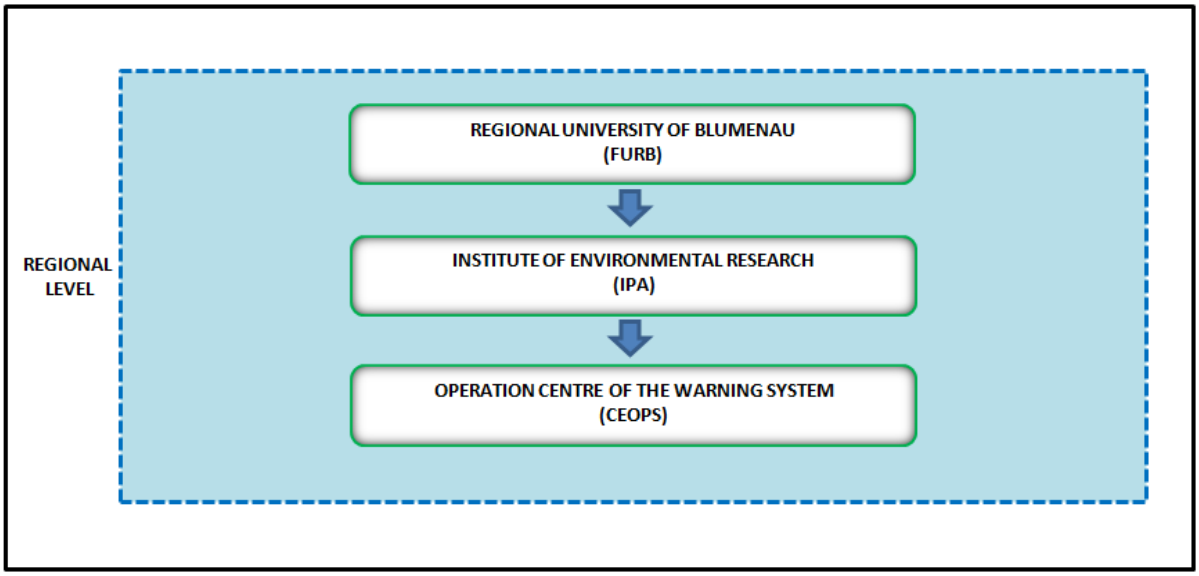

Figure 16 – Institutional framework of the Operation Centre of the Warning System (CEOPS).

2.2 Operational Infrastructure

2.2.1 Flood Prevention Works

There are three flood contention dams in the Itajaí River Basin (Figure 17): Oeste dam (*Itajaí do Oeste* River), Sul dam (*Itajaí do Sul* River) and Norte dam (*Itajaí do Norte* River). They were built by the now defunct DNOS, and today the Ministry of National Integration is performing in its place. There is an intention to transfer the responsibility of the dams from the federal level to the state level, given that the Itajaí River Basin is totally contained within the state of Santa Catarina. The dams were built with federal resources, but their operation and maintenance are executed by the DEINFRA at state level. An agreement was signed in 1994 to initiate the transference of this responsibility, but this process is still ongoing. However, the Union can only deliver a heritage, like dams, if all aspects of the system of dams are functioning adequately. One of these aspects would be the flood early warning system, which is not yet solved institutionally.

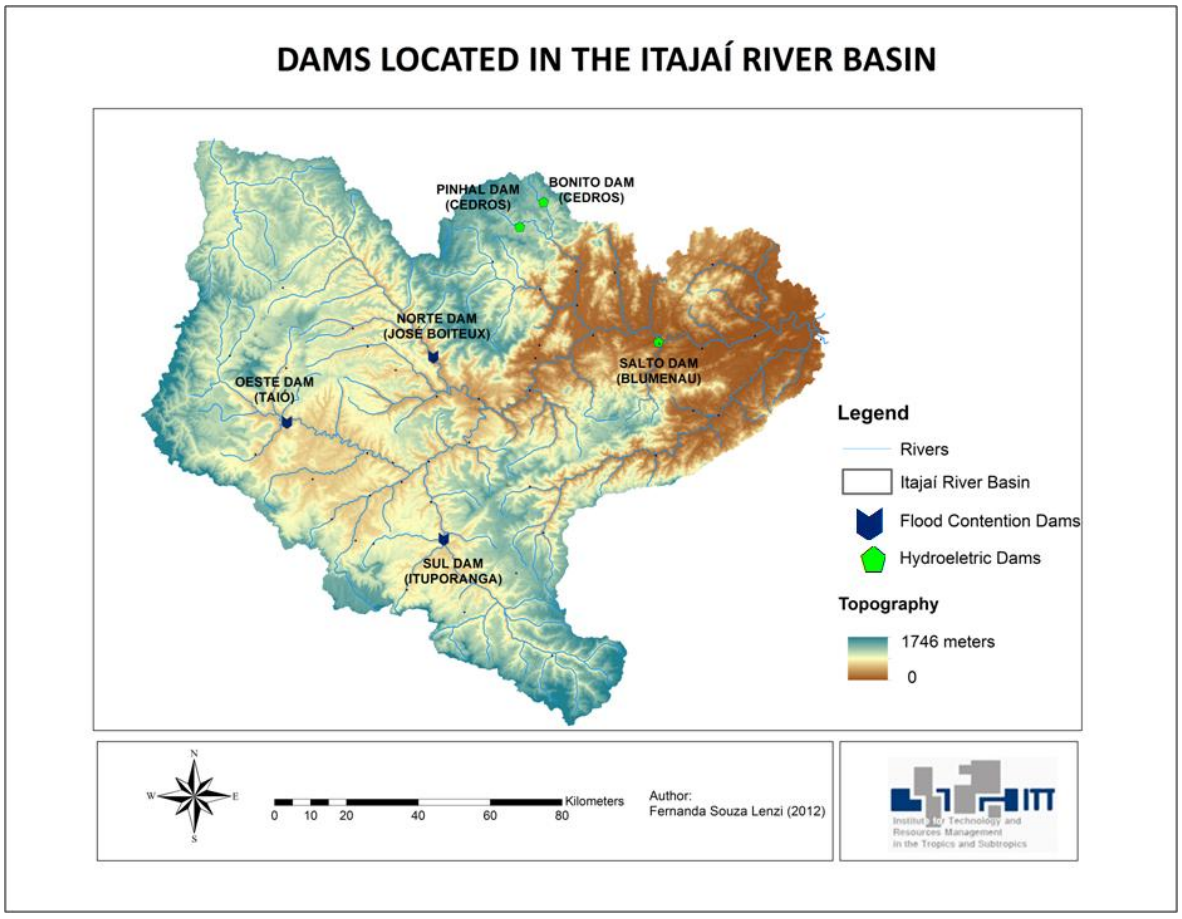

Figure 17– Location of the flood contention dams and hydroelectric dams in the Itajaí River Basin.

The energy power for the functioning of the flood gates can come from three different forms. If the electricity concessionaire fails to transmit energy, the DEINFRA use its generators. Considering an even more critical scenario in which the generators fail, the DEINFRA's workers connect a car engine to the pump, in order to actuate the gates. Moreover, since 2005 the DEINFRA started the modernization of the dams and its flood gates. Today the dams are monitored by video cameras and there are sensors for the filling level of the reservoirs in each dam. These data are sent through satellite to the DEINFRA every 30 minutes and available on the internet for the society (DEINFRA, 2012).

Furthermore, the dams are monitored by operators who stay 24 hours a day in the locality. Operators currently use standard rain gauges to measure the precipitation. Moreover, through an agreement between the DEINFRA and the ANA, more 22 stations (rain and river level measurement) are expected to be installed particularly for the dams monitoring (CIRAM, 2011). The EPAGRI will execute the installation of these sensors, but the maintenance will be a responsibility of the State. Mobile phone via GPRS is the dissemination technique that will be used in this monitoring system.

The technical characteristics of these dams are shown in Table 9, which was produced from the data from DEINFRA (2012). These dams are exclusively for water contention; therefore their reservoirs are kept empty during non-rainy periods. The reservoir's volume of the Sul and the Oeste Dam are 93.5 million and 83.5 million cubic meters, respectively (DEINFRA, 2012). Both dams overflow easily as occurred during the floods of 2011. As regards to the Norte Dam, which has a reservoir capacity of

357 million cubic meters (DEINFRA, 2012), even if it rains intensively, the reservoir will not be filled up and the risk of overflow by the spillway will be small.

Table 9 – Characteristics of the flood contention dams. Source: DEINFRA (2012).

Name	Norte Dam	Sul Dam	Oeste Dam
Location	José Boiteux - SC	Ituporanga - SC	Taió-SC
Start of operation	1992	1976	1973
Type	Rock-fill dam	Rock-fill dam	Gravity dam
Area of contribution for the basin	2318 km²	1273 km²	1042 km²
Dam height	58.50 m	43.50 m	25 m
Reservoir capacity	357 million m³	93,5 million m³	83 million m³
Crest length	400 m	390 m	422 m
Spillway level	302 m	65 m	360 m
Crest level	309 m	309 m	309 m
Reservoir area	14 million m²	8.4 million m²	9.5 million m²
Number of flood gates	2 units (crest of 2.6m)	5 units (1.5m diameter)	7 units (1.5m diameter)
Number of galleries	1 Gallery with 3 gates blocked by dumps	1 Gallery (1.5m diameter)	1 Gallery (1.5m diameter)

Moreover, there are three large hydroelectric dams in the Itajaí River Basin (Figure 17), which belong to the CELESC (public organization responsible for electricity in the state of Santa Catarina): the Rio Bonito Dam, the Pinhal Dam and Salto Dam. They display only infrastructure for energy generation and a spillway. The first two hydroelectric dams are located in the Cedros River and the Salto dam is located in the Itajaí-Açu River near the city of Blumenau. Although these dams are exclusively for hydropower, the CELESC reduces by up to 50cm the water level in the reservoirs according to the rain forecast as a measure of flood detention (JICA, 2010). Their capacity of energy generation are 24.602MW (Rio Bonito dam), 8.4MW (Pinhal dam) and 6.7 MW (Salto dam) (JICA, 2010).

As stated in JICA (2010), there are no dykes or remarkable rectified channels, so that the river almost completely maintains its natural form throughout its course. There is only partial intervention, such as concrete cradles as part of the Port of Itajaí and a rectified channel in the Itajaí Mirim River. These rectification works were built as flood control works with the purpose of increasing the water runoff capacity and decreasing water floods more rapidly. However, this has caused negative impacts in the downstream region, which becomes easily flooded, due to its lack of runoff capacity.

2.2.2 Infrastructure for weather forecasts

As previously explained, there are two institutions at federal level who execute weather forecasts for the country: the INMET and the INPE. In total there are 19 meteorological stations of the INMET in the State of Santa Catarina, out of which four are located in the Itajaí River Basin (INMET, 2012). The system of data collection and dissemination is executed through geostationary satellite and mobile telephony, which operate continuously even if there are failures in the energy supply or local telephony. Data are disseminated in real time at the INMET's website and they have been used by economic sectors like the livestock and agriculture, as well as to support the Civil Defence (INMET Notícias, 2012).

As regards to the INPE, the institute makes use of Data Collection Platforms (DCPs) installed in partnership with other institutions like the ANA. There are more than 800 platforms installed in the national territory (19 DCPs in Santa Catarina and 8 in the Itajaí River Basin), which contribute to a weather forecast, studies on ocean currents, tides, atmosphere's chemistry and water monitoring (INPE, 2011). The DCPs are automatic stations attached to sensors that measure rainfall rates, solar radiation, wind, etc. These environmental data acquired from the DCPs are sent to satellites which retransmit these data to the INPE's stations in Cuiabá and Alcântara (Figure 18). After that, the data are sent to another installation of the INPE in Natal, where the data are treated and then distributed to the users of this system. In addition, the INPE receives images and environmental data from several satellites: CBERS, LANDSAT, RESOURCESAT, ENVISAT, AQUA, TERRA, MERIS, NOAA, GOES and METEOSAT. The INPE also distributes these images for free on the internet (INPE, 2011).

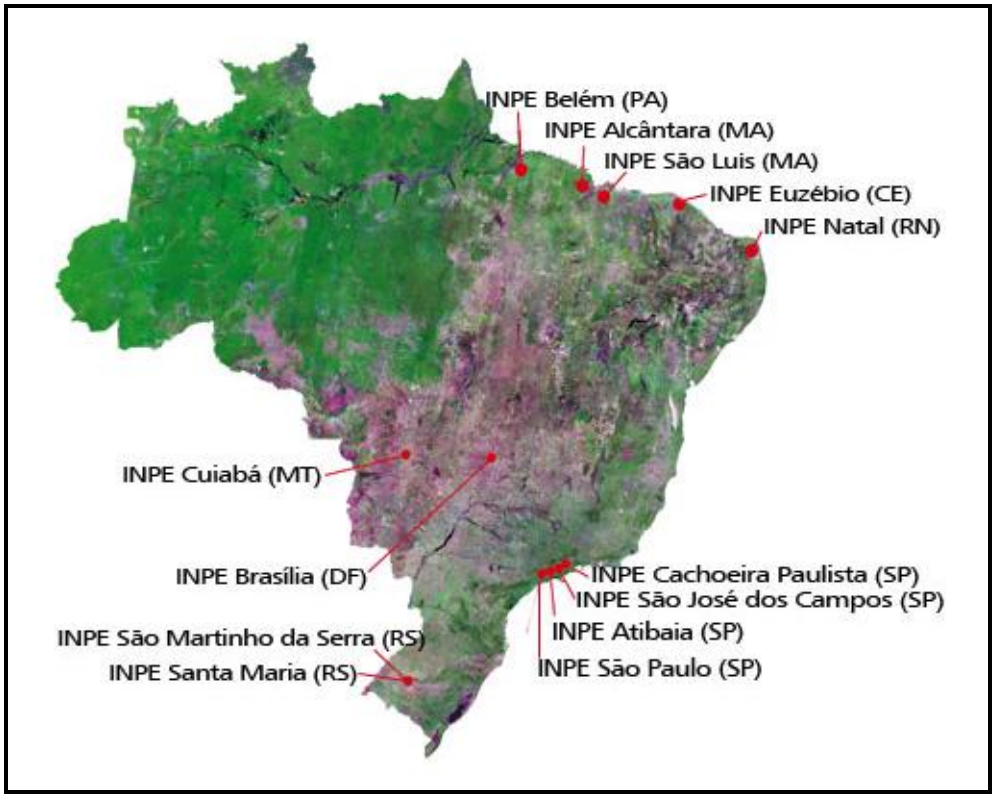

Figure 18 – Location of the INPE's installations in Brazil. Source: INPE, 2012.

At state level, the EPAGRI through the CIRAM executes weather forecasts for the state of Santa Catarina. To provide this sort of information, the CIRAM uses the data from monitoring stations which belong to various institutions like the ANA. A survey was executed in 2011, in order to account for stations operated by the CIRAM and to identify the areas in which there is a need to implement more stations aiming to research Meteorology, Hydrology and Agriculture (CIRAM, 2011). According to this report, there are 170 stations (conventional and automatic stations) which are active and make up part of the CIRAM's database. Among these stations, there are 20 which are found in the Itajaí River Basin and are used for the monitoring of precipitations (CIRAM, 2011).

Also, there is a Meteorological Radar located in the state of Santa Catarina (Figure 19). The Meteorological Radar, which belongs to the Brazilian Aeronautics, has the purpose of controlling military air traffic, but also monitors rainfall. At present, the Radar in Urubici is the only one located in Santa Catarina and does not cover the total area of the State. It monitors an area of up to 200 km radius and has a spatial resolution of 125 meters (Silva Dias, n.d.). In addition, the meteorological radar is located at the altitude of 1,822 meters, which means that rains formed under this altitude are not monitored (Silva Dias, n.d). The radar emits radio waves that are absorbed and reflected back to the receiver on collision with objects. The position of these objects can be ascertained from the reflected waves and their speeds from the Doppler Effect, i.e. the observed frequency change of a wave on reflection from a moving object (Kuhn, 1996).

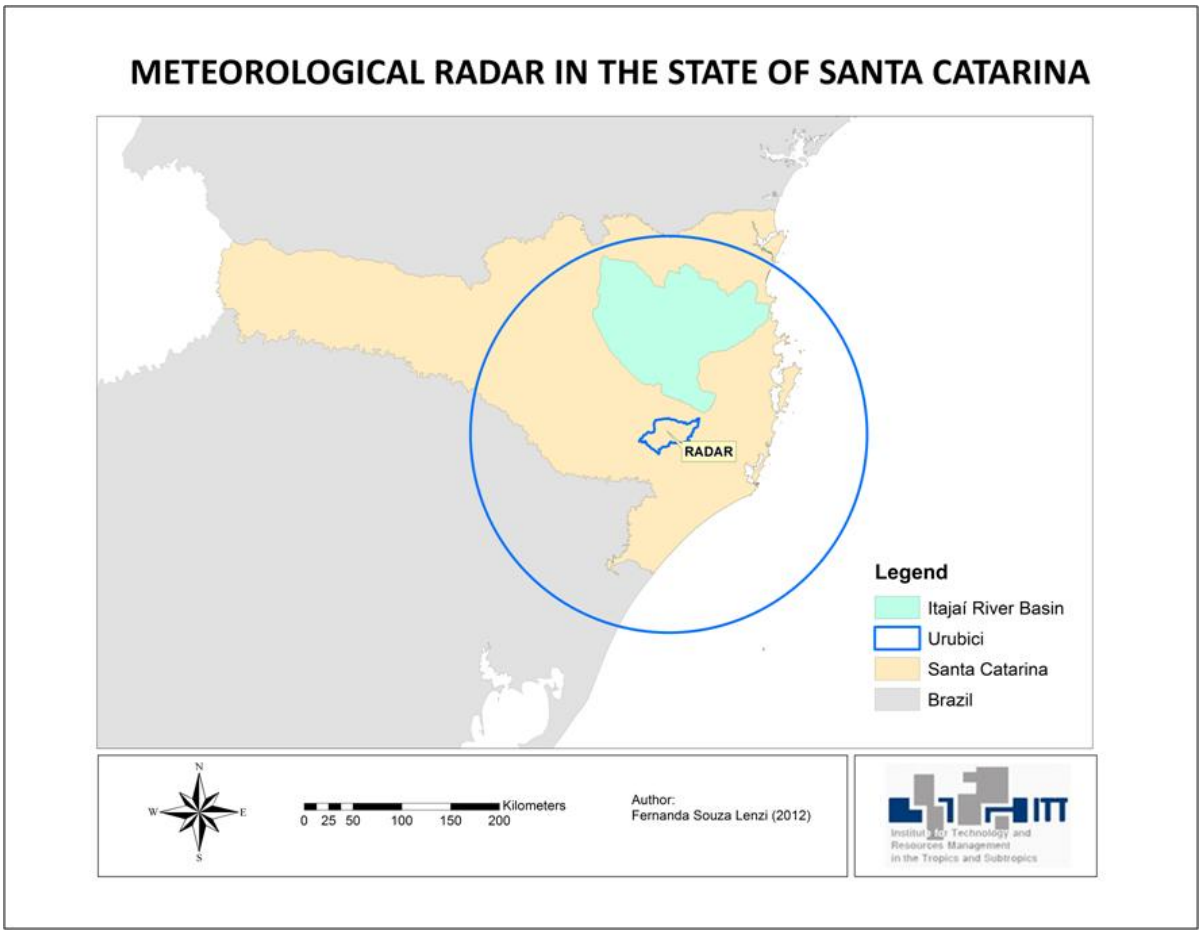

Figure 19- Location of the Meteorological Radar and its approximate coverage of 200km radius in the state of Santa Catarina.

2.2.3 Monitoring Stations in the Itajaí River Basin

The ANA has 43 stations (conventional and automatic stations) located in the Itajaí River Basin. 10 out of the 43 stations are automatic and were modernized in late 2011. These new stations transmit hourly data (precipitation and a river's water level) through the GOES's satellite. Also, in 5 of these automatic stations, the ANA implemented a redundant system for data collection (pressure sensors or radar sensors). This is extremely important to assure the continuity of the river's level measurement during situations of sharp oscillation of the river's level.

The SDS has a hydrometeorological network formed by 16 stations in the Itajaí River Basin. These automatic stations were installed in 2009 and data are sent through GPRS (mobile phones). Some municipalities of the Itajaí River Basin have their own monitoring stations. For instance, the city of Itajaí has 9 automatic stations with telemetry via radio located in the municipality's area. Figure 20 presents a map of the monitoring stations located in the Itajaí River Basin. The database HIDROWEB of the ANA was used for the placement of conventional stations (river's level and precipitation).

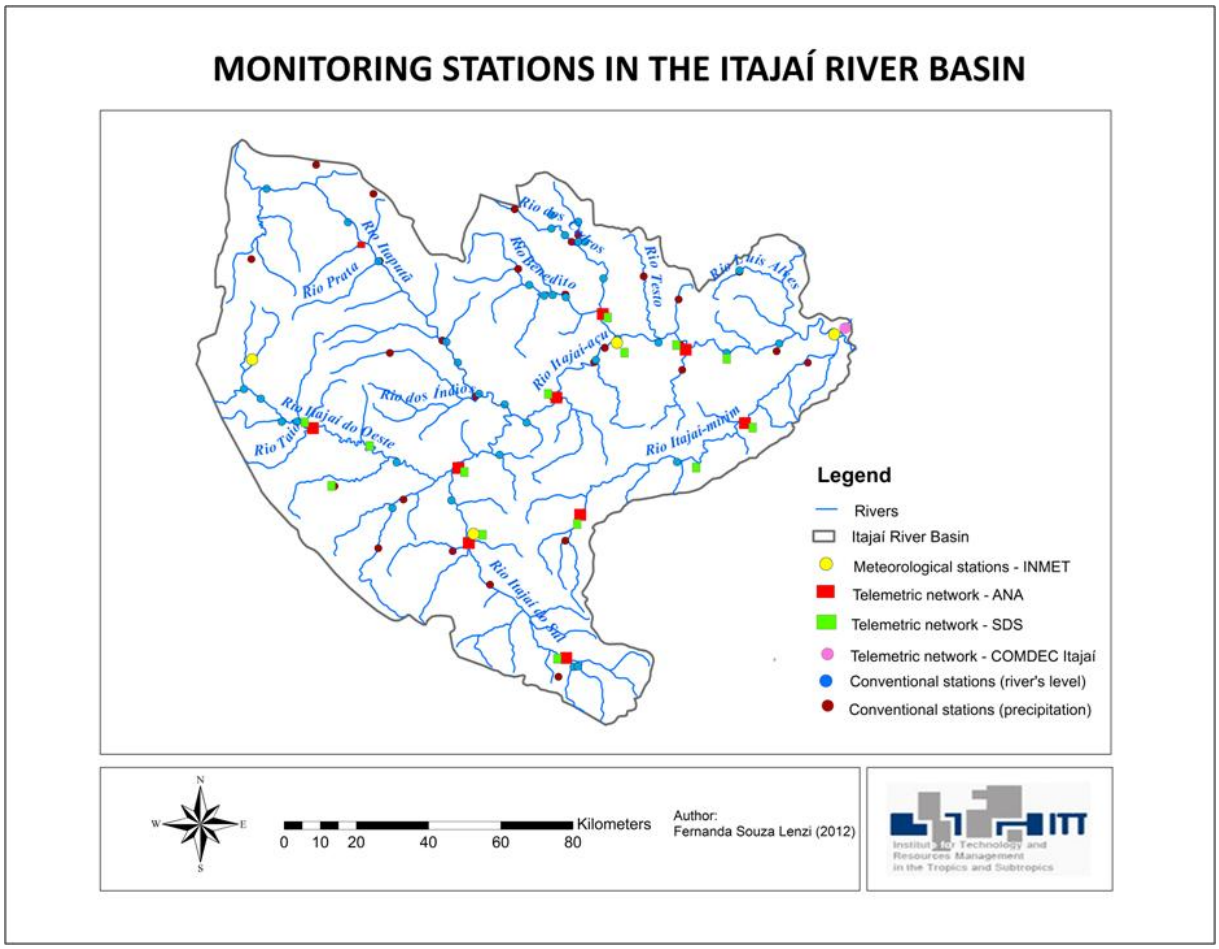

Figure 20 – Monitoring stations in the Itajaí River Basin.

2.3 Conclusions about institutional and operational arrangements

This chapter aimed to identify the stakeholders and their responsibilities regarding the functioning of the flood early warning system in the Itajaí River Basin (Figure 21). At federal level, the ANA is in charge of the national hydrometeorological network, and consequently has installed a network of ten automatic stations in the basin. At state level, the SDS has the responsibility of coordinating the implementation of the network for the monitoring of rivers. In this context, the SDS subsidized a network of 16 stations which is monitored by the CEOPS. Also, the DEINFRA at state level is responsible for the monitoring and operation of the flood contention dams in the basin. At regional level, the Itajaí River Basin Committee receives the responsibility of supervising the activities of operation, maintenance and warning of the flood contention system of the basin.

Weather forecasts are executed by the INMET and the INPE at federal level, and by the EPAGRI-CIRAM at state level. Flood forecasts are executed by the CEOPS, but only for the city of Blumenau. The CEMADEN, which has been recently created at federal level, produces warnings of natural disasters to priority municipalities. Thus, there are seven municipalities in the basin that are monitored by the CEMADEN. The CEMADEN issues the warning to the CENAD, which will further contact the SDC and the COMDECs.

The SDC is responsible for the mobilization of resources, as well as the coordination of the activities of Civil Defence (disaster prevention, preparation, response and reconstruction) in the state of Santa Catarina. At municipal level, the legislation foresees many attributions to the COMDECs. For example, they are responsible for the implementation of risk maps, inspection of irregular occupation, emergency response and including the increment of monitoring and warning activities.

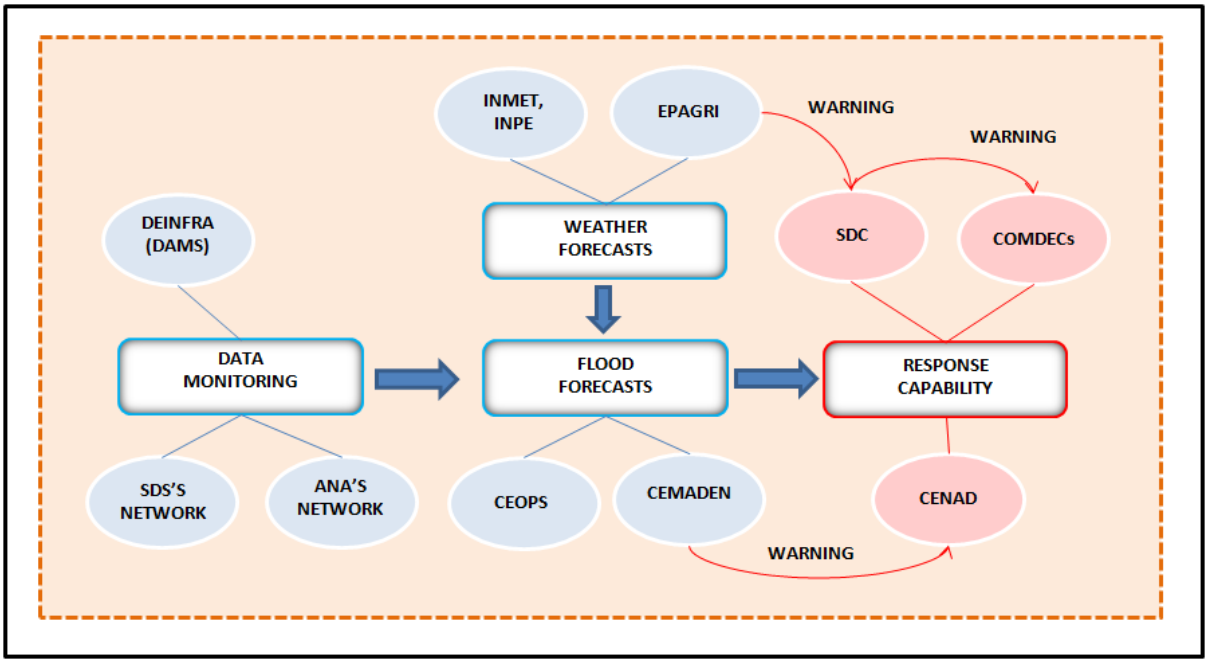

Figure 21– Scheme of the Flood Early Warning System in the Itajaí River Basin.

3 FLOOD EARLY WARNING SYSTEMS AND THE CIVIL DEFENCE AT MUNICIPAL LEVEL

This chapter aims to analyse the interface between the flood warning services (e.g. data monitoring, flood forecast) and the role of the Civil Defence itself, since messages delivered by flood early warning systems are only truly effective if the population and local authorities adopt a behaviour of risk reduction. Measures taken by each municipality of the Itajaí River Basin varies significantly. For instance, in most municipalities only one employee is responsible for all actions of the Civil Defence, whilst in Blumenau almost 60 employees are indirectly or directly working with the Civil Defence.

In this context, three municipalities (Blumenau, Rio do Sul and Itajaí) were selected for analysing their Flood Early Warning Systems (FEWS) at local level and the role of their Civil Defence at Municipal Level (COMDEC) (Figure 22). Perhaps because there is not an effective and integrated FEWS at the level of the Itajaí River Basin, municipalities are taking initiatives to build their own FEWS at local level. However, it is clear that rainfall rates arriving at the upstream basin can have huge effect at the downstream basin, so that having only punctual information might not be enough to forecast an oncoming flood.

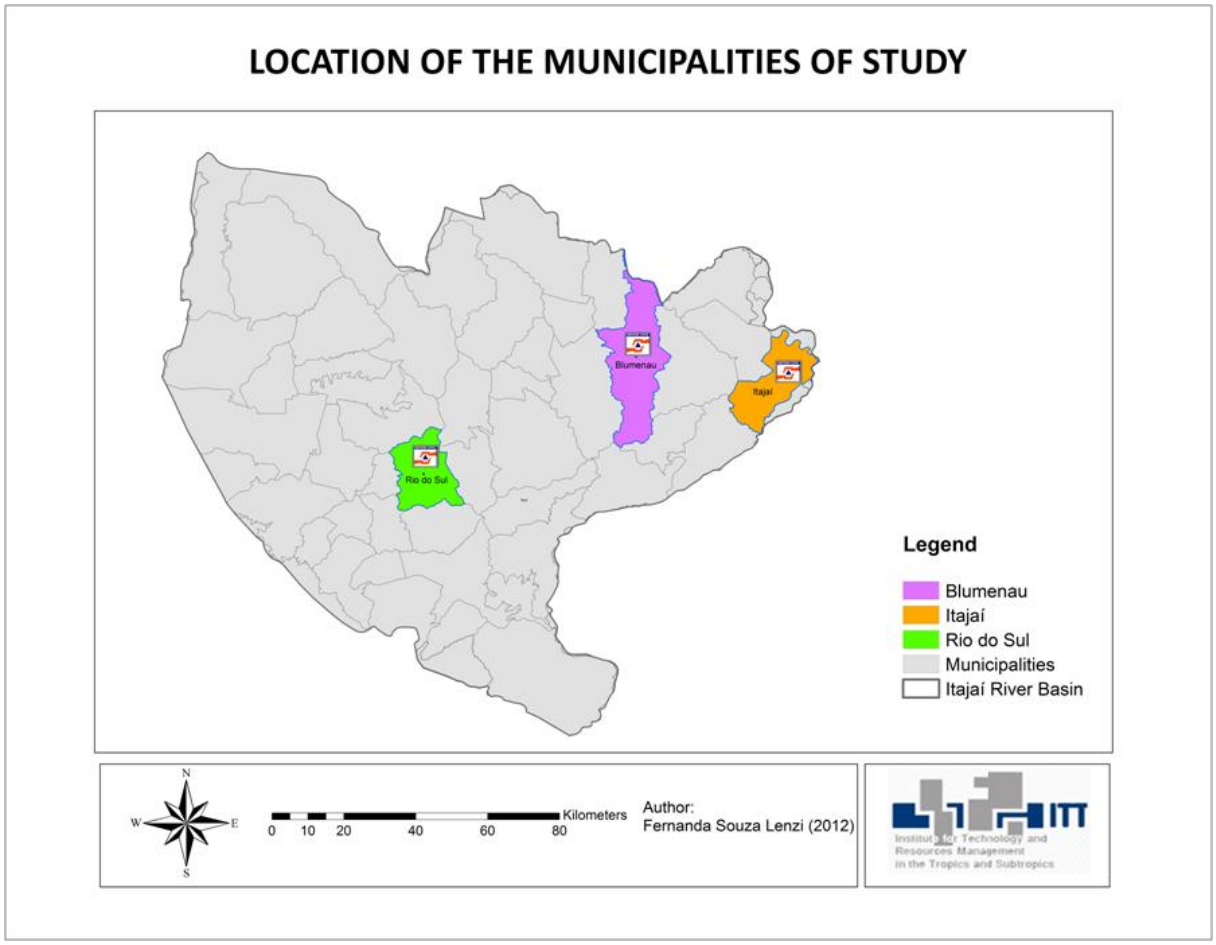

Figure 22 – Location of the municipalities of study in the Itajaí River Basin.

The reasons for choosing these three municipalities are: (a) the presence of a large population: Blumenau (309,011 inhabitants), Itajaí (183,373 inhabitants), Rio do Sul (61,198 inhabitants) (SPG, 2012); (b) the location of the cities, with the purpose of representing the three microregions of the basin: Rio do Sul in the High Valley of Itajaí, Blumenau in the Medium Valley of Itajaí, and the city of Itajaí in the Mouth of the River; (c) the substantial damage caused to the cities by floods throughout the decades; (d) the existence of COMDECs which are used as a reference in the state of Santa Catarina, although many constraints still remain.

The components of an effective flood early warning system (Risk Knowledge, Monitoring, Warning, Dissemination and Response Capability) will be analysed for the three selected municipalities, taking into account interviews with the coordinators of the COMDECs (Annex 7.5). To understand how their flood early warning systems could be more effective in the future, it is important to study how the Civil Defence has developed in the past and whether these developments have brought improvements. By studying the challenges faced by these COMDECs others municipalities of the Itajaí River Basin can learn from their experience.

In this context, to present an overview of the evolution of the Civil Defence Centres, as well as the constraints faced by them, three main questions were used as a guideline: How was the Civil Defence in the past? How is the Civil Defence today? How could the Civil Defence be in the future? For the first two questions, a research on the previous legislation and testimonies from members of the Civil Defence were the main sources of information. For the last question, suggestions based on the literature reviewed were proposed for Civil Defence Centres in general.

3.1 Blumenau

A map of the municipality of Blumenau is presented in Figure 23. This gives an overview of the major rivers, as well as the telemetric and conventional stations located in the city.

3.1.1 Evolution of the Civil Defence of Blumenau

The Civil Defence of Blumenau was created as a Municipal Commission of Civil Defence (COMDEC) through the Municipal Law n.1981/1973 of 20.12.1973 (PMB, 2012a). As mentioned in Article 5 of the Law, the Head of the Executive Power would designate governmental workers to form this COMDEC during an event. These employees would temporarily stop their normal activities in order to develop the activities of Civil Defence. Apart from the cases of public calamity or emergency situation, the COMDEC should monitor and identify adverse factors that could occur periodically in the municipality, as well as to produce plans to prevent the city from these factors (Blumenau, 1973). To analyse further the evolution of the Civil Defence of Blumenau, the Municipal Secretary of the Civil Defence of Blumenau, Mr José Egídio Borba, was interviewed. The following paragraphs are based on his statement.

According to his declaration, in the seventies the COMDEC of Blumenau was only the name of the institution, but there was not a physical structure for it. There was a “fictitious” coordinator of the Civil Defence, which was someone who only occasioned fulfilled this role. The coordinator would bring together workers from different sectors of the City Hall and coordinate the actions of Civil Defence. This situation persists today in most of the municipalities of Brazil, including municipalities of the Itajaí River Basin.

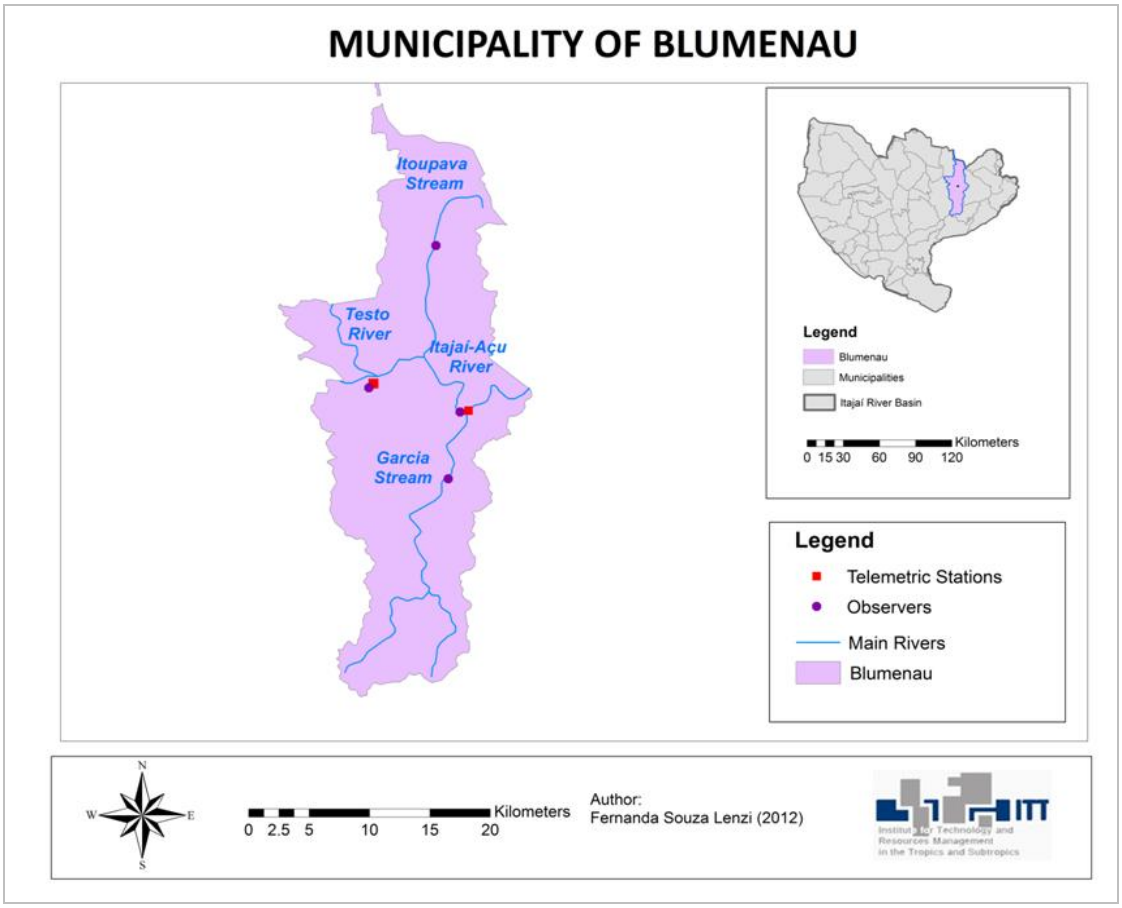

Figure 23 – Location of the municipality of Blumenau and its main rivers.

After the floods of 1983 and 1984, the need for a physical structure for the Civil Defence of Blumenau became clear. In 1989 the Department of Civil Defence was created with a strengthened structure and bound firstly to the Municipal Secretariat of Environment and Civil Defence and then directly to the Mayor's Cabinet (Tachini, 2003). At the time, measures of flood prevention began to be implemented in Blumenau, such as the Contingency Plan, Registers of Affected Areas and the Survey of Flood Heights.

Since then, Blumenau became a reference in Brazil with its know-how in tackling emergency situations like the occurrence of floods. However, in 2008, landslides of a great magnitude took place in the city and the Civil Defence of Blumenau was not prepared for this sort of event. There were no technical staff focused on landslides, so that the first concern was to bring geologists and specialists from other states to execute topographical surveys. This group of professionals identified several areas of flood and/or landslide risk in the city of Blumenau, compromising practically the entire city. However, investing money from the federal government into areas at risk is not allowed. In other words, any action of the Public Power in Blumenau would be forbidden. As a result, in 2008 the City Hall encouraged the creation of the Geology Secretariat to evaluate this situation and analyse the cartography of natural risks. Furthermore, in 2010 the Civil Defence of Blumenau was transformed into a Secretariat of Civil Defence, in order to enlarge its number of employees.

The Civil Defence of Blumenau is today formed by roughly 60 workers, distributed into the Board of Civil Defence, Board of Building Inspection and Postures, and Office of Reconstruction. The Board of Civil Defence deals mainly with the prevention and preparation actions related to disasters (flash and river floods, landslides, hailstorm and windstorm). The Board of Building Inspection aims to hinder the occupation of risk areas and areas of permanent preservation by inspecting works built without the authorization from the City Hall. Lastly, the Office of Reconstruction was created after the event of 2008 in order to execute the register of people who have been affected by landslides and floods. This Register is known in the city as CUCA (Unique Register of Affected Citizen).

To meet the demand of dwellings registered in the CUCA, the City Hall has given the opportunity to the population to enrol themselves in Housing Programs such as the Program "*My House, My Life*", which offers housing at a much lower price. Some prerequisites need to be met for signing up to such programs. For instance, only families whose homes or terrains were barred by the Civil Defence can participate in these programs. Another prerequisite defines that participating families need to have a monthly income of up to three minimum wages (PMB, 2012b). After having its inscription accepted, the resident signs a document to authorize the demolition of their previous house in a risk area. Up until now, 1,800 families were transferred to new apartments (PMB, 2012b), but almost 50% of the Blumenau's population live in risk areas. It is therefore a real challenge to find financial resources and available land to allocate to these inhabitants. Furthermore, some of the people, who were evacuated from areas at risk to new apartments, sold their previous houses in risk areas to new residents, putting other people at risk.

From the point of view of the coordinator of the Civil Defence of Blumenau, other constraints for executing their activities are the lack of financial resources and the lack of vocational training for employees of the Civil Defence. As regards to financial resources, he explains that resources from the federal governmental, through the filling of the forms NOPRED and AVADAN, used to be insufficient and to take a long time to arrive at the municipal level. To accelerate the payment of works and services, the National Secretariat of Civil Defence created, through the Decree n.7.505/2011 of 27.06.2011, a payment card to be used in the immediate response to an event (assistance to victims, re-establishment of the normality, etc) (Brasil, 2011b). For instance, during the flood event of 2011, the National Civil Defence sent R$1.5 million to the Civil Defence of Blumenau, in order to cover expenses for alimentation, temporary rentals, shelters, removal of rubble from the streets, etc. These resources arrived quicker, but the total damage for the city's reconstruction was estimated at roughly R$56 millions, therefore the City Hall had to afford most of the damage costs. Despite the constraints faced by the Civil Defence of Blumenau, the city has a well structured flood early warning system, which will now be discussed.

3.1.2 Flood early warning system of Blumenau

The information used in this section is the result of interviews with Prof. Dr. Ademar Cordero, who is a hydrologist of the Operation Centre of the Warning System (CEOPS), and with members of the Civil Defence of Blumenau, such as Mr José Egídio Borba and Mr Manfred Fritz Goebel. In short, the data monitoring is carried out by the CEOPS, which monitors the telemetric network of 16 hydrometeorological stations and uses the data from conventional stations which are checked by observers of the National Water Agency (ANA). The data from automatic stations are transmitted to the CEOPS through mobile phones via GPRS. The CEOPS will further insert these data into the ARMA Model to forecast the river's level in Blumenau up to 8 hours in advance. According to the forecast,

the CEOPS warns the Civil Defence of Blumenau, who will then perform the measures established in its Contingency Plan. The warning message to the population is disseminated through the internet and the media, in which official bulletins are published. Also, the Civil Defence activates telephones through the number 199 to serve the population. A scheme of the flood early warning system of Blumenau is presented in Figure 24, and its details are further discussed.

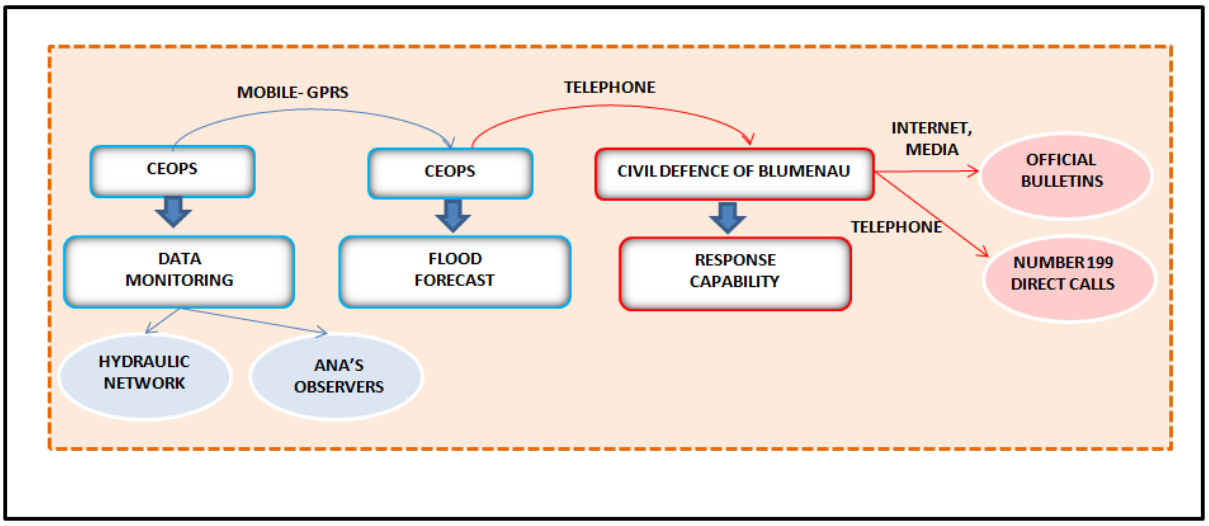

Figure 24– Scheme of the Flood Early Warning System of Blumenau.

Risk knowledge

The Civil Defence of Blumenau has the support of the Geology Secretariat, which today contains 18 employees from different fields (geologists, architects, civil and forest engineers and biologists). The Geology Secretariat (SEGEO) analyses the existing cartography of flood and landslides risks and sends technical reports to the City Hall declaring whether the area is suitable for constructions or not. According to the Law n.832/11 of 13.12.2011, the SEGEO should promote the geological mapping of target areas for the safety of the population, as well as implementing and managing a system for the monitoring and warning of heavy rainfall in the city of Blumenau (Blumenau, 2011).

Monitoring

At the moment, the data coming from the hydrometeorological stations is monitored by the CEOPS, which is located in the FURB. The CEOPS uses data from 16 automatic stations (Figure 25), which belong to the SDS. However, today there are 15 stations normally functioning, given that the station located in Mirim Doce was recently removed. These stations collect data every 15 minutes, but they were scheduled to transmit data to the CEOPS every hour. The dissemination technique used here is the mobile phone through GPRS. Pressure sensors are used for the monitoring of river's water level, so that sensors are placed underneath the water and they measure the water's depth through the water pressure incident on them.

Likewise the CEOPS checks on dedicated websites the data from the 10 redundant stations which belong to the ANA. Furthermore, the ANA employs people named as observers who check the values of river levels marked by limnimetric scales as well as the precipitation measured by standard rain gauges. The CEOPS receives these data by radio or cell phone directly from the observers. Using

these data collected by these conventional tools, the CEOPS can ensure that their automatic stations are working satisfactorily.

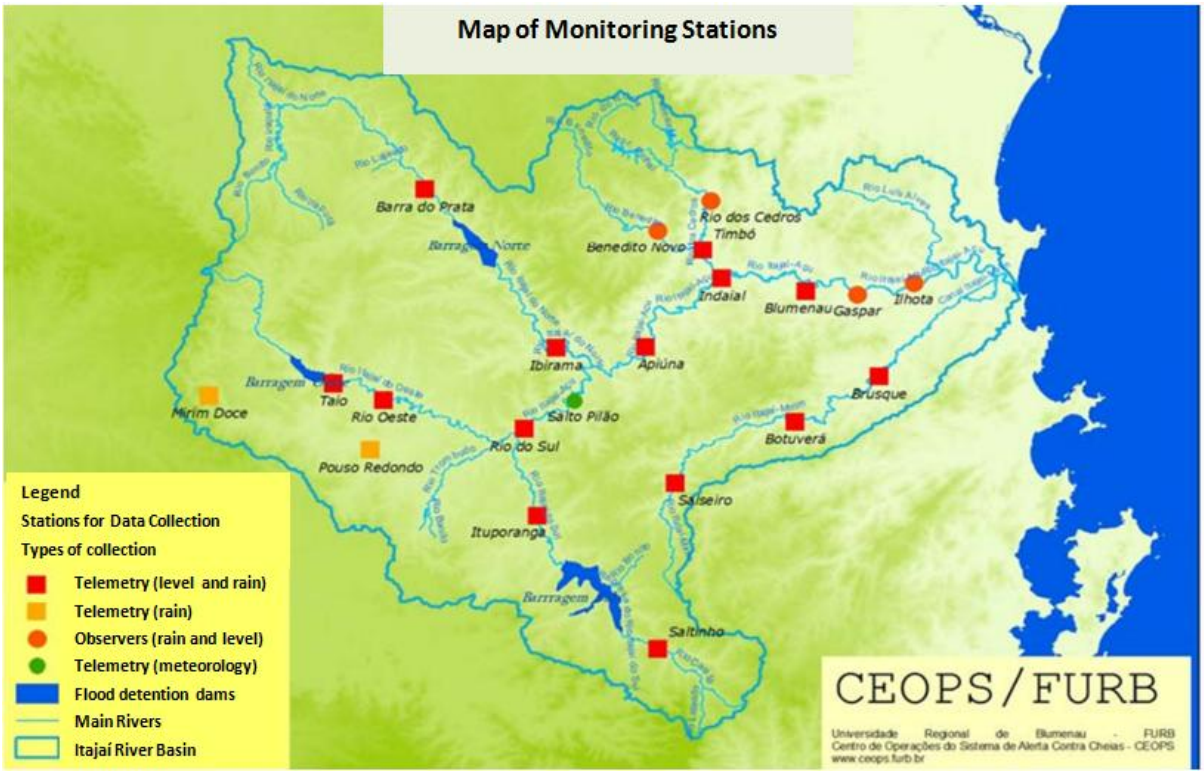

Figure 25– Location of the SDS's stations in the Itajaí River Basin. Source: CEOPS, 2012.

Warning

In particular for the city of Blumenau, the CEOPS receives the hydrological data and runs a model for flood forecasts. The model used by the CEOPS is a linear stochastic model, which presents an equation of linear differences with constant coefficients over time (Pinheiro, 2003). The software AST-3 is used to run this model called ARMA. The AST-3 was initially employed to understand how river basins behaved as regards to energy generation. This software was adjusted in the nineties and applied it to the conditions of the Itajaí River Basin. Several flood forecast models have been tested in the basin, and up until now the most satisfactory results were given by the ARMA Model.

The river's level in Blumenau is estimated through the river's levels detected in the cities of Apiúna and Timbó. For instance, the Equation 1 shows the river's level forecast in Blumenau (Pinheiro, 2003):

Equation 1:

$$Y(t) = 1.98063y(t-1) + 0.98506y(t-2) - 0.0902u_1(t-4) + 0.08732u_1(t-5) + 0.01806u_2(t-4) - 0.01411u_2(t-5) + 0.03083$$

In the formula, Y(t) refers to the river's level forecast in Blumenau after t hours; y is the value measured in Blumenau, u1 and u2 correspond to the values measured in Apiúna and Timbó (Figure 26), respectively.

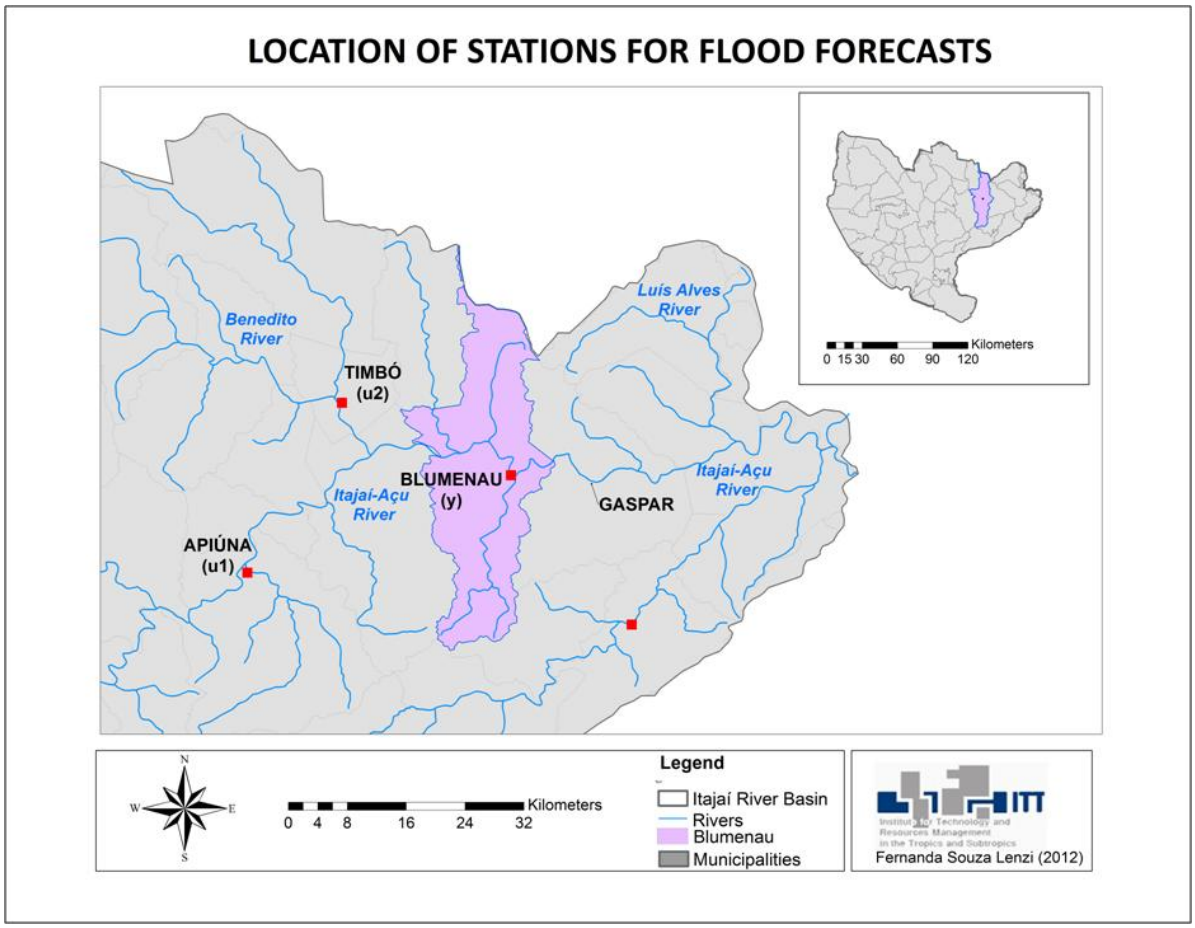

Figure 26 – Location of the stations used for the execution of flood forecasts for Blumenau.

This model was tested for 16 flood events (from 1972 to 1989) and uses linear regression coefficients higher than 0.99 for forecasts of 6 hours in advance, and 0.98 for 8 hours in advance (Pinheiro, 2003). Since the model does not include rainfall data, it does not generate good results for forecasts of more than 8 hours in advance. Furthermore, a member of the CEOPS highlights that this model can present considerable errors, so that it is important to have the added sensitivity provided by hydrologists who can adjust results manually, taking into account their own experience.

According to Prof. Dr. Ademar Cordero, the CEOPS executes flood forecasts only to the city of Blumenau, but using their model the river level of Gaspar can be easily estimated, given that this city is located only 20 km downstream from Blumenau and there is no other water entry in between. Therefore, the water which arrives in Blumenau will have effect in Gaspar two hours later.

Dissemination

With respect to warning dissemination, the CEOPS has the responsibility to warn only the Civil Defence of Blumenau. The CEOPS uses four different categories of situations according to the river's level in Blumenau (Figure 27). When the river's level is below 4 meters, there is a *Normal Situation*. This means that twice a day (7h and 17h) the real-time data from the stations are compared to the data from the observers. The *Attention Situation* refers to a river level ranging from 4 to 6 meters, whilst the *Alert Situation* corresponds to a river level between 6 and 8.5 meters. Lastly, the

Emergency Situation occurs when the river's level is superior to 8.5 meters (CEOPS, 2012). These former three categories form the *Special Situation*, in which data are checked every hour.

MUNICIPALITY	NORMAL	ATTENTION	ALERT	EMERGENCY
APIÚNA	NA < 4,0	4,0 < NA < 6,0	6,0 < NA < 8,5	NA > 8,5
BENEDITO NOVO	NA < 1,5	1,5 < NA < 2,5	2,5 < NA < 3,5	NA > 3,5
BLUMENAU	**NA < 4,0**	**4,0 < NA < 6,0**	**6,0 < NA < 8,5**	**NA > 8,5**
BRUSQUE	NA < 3,0	3,0 < NA < 4,0	4,0 < NA < 5,0	NA > 5,0
BOTUVERÁ	NA < 3,0	3,0 < NA < 4,0	4,0 < NA < 6,0	NA > 6,0
GASPAR	NA < 4,0	4,0 < NA < 6,0	6,0 < NA < 8,5	NA > 8,5
IBIRAMA	NA < 2,0	2,0 < NA < 3,0	3,0 < NA < 4,5	NA > 4,5
ILHOTA	NA < 6,0	6,0 < NA < 8,0	8,0 < NA <10,5	NA > 10,5
INDAIAL	NA < 3,0	3,0 < NA < 4,0	4,0 < NA < 5,5	NA > 5,5
ITUPORANGA	NA < 2,0	2,0 < NA < 3,0	3,0 < NA < 4,0	NA > 4,0
RIO DO OESTE	NA < 4,0	4,0 < NA < 6,0	6,0 < NA < 9,0	NA > 9,0
RIO DO SUL	NA < 4,0	4,0 < NA < 5,0	5,0 < NA < 6,5	NA > 6,5
RIO DOS CEDROS	NA < 2,0	2,0 < NA < 4,0	4,0 < NA < 6,0	NA > 6,0
TAIÓ	NA < 4,0	4,0 < NA < 6,0	6,0 < NA < 7,5	NA > 7,5
TIMBÓ	NA < 3,0	3,0 < NA < 5,0	5,0 < NA < 7,0	NA > 7,0
TROMBUDO CENTRAL	NA < 3,0	3,0 < NA < 4,0	4,0 < NA < 6,0	NA > 6,0
VIDAL RAMOS	NA < 3,0	3,0 < NA < 4,0	4,0 < NA < 5,0	NA > 5,0

Figure 27– Categories of situations according to river's level in each municipality. Source: CEOPS, 2012.

As it is shown in Figure 27, the levels established for the different categories vary according to the municipality, since the Itajaí-Açu River changes its characteristics (slope, altitude, etc) throughout its course. Furthermore, the levels established for Blumenau are likely to be changed. During the flooding of 2011 some points of the city that would usually be flooded with a flood height of 8 m were already flooded with lower heights. As a result, the Civil Defence and the CEOPS are reformulating these warning categories. Also, sub-basins of the Itajaí-Açu River are now being studied, using greater precision to measure river levels, topography and elevations.

Apart from warning the Civil Defence of Blumenau through phone calls, the CEOPS emits hourly bulletins with river level forecasts for Blumenau and Rio do Sul through its website (Figure 28).

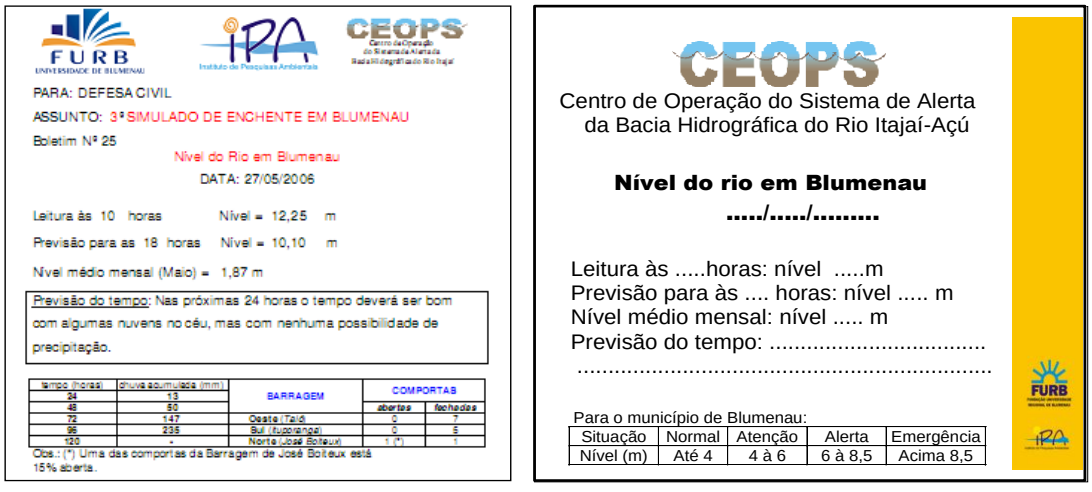

Figure 28 – Examples of messages issued on behalf of the CEOPS. Source: CEOPS, 2012.

Response Capability

After receiving the processed information from the CEOPS, the Civil Defence of Blumenau puts into action its Contingency Plan. This Plan was initially developed after the floods of 1983 and 1984, which were the largest events that Blumenau had experienced before the flood of 2008. The first Plan was designed only for river floods, but the event of 2008 was a completely different event, marked by flash floods and landslides of great magnitude. As a consequence, in 2009 the Contingency Plan was updated and increased the number of shelters for an evacuation of the population (DC Blumenau, 2009). Also, the plan is likely to be updated in terms of maps of risk areas being created and new areas susceptible to floods and landslides being identified.

The Contingency Plan aims to establish attributions to the various components of the Group of Coordinated Activities (GRAC), in order to minimize disasters in the phases of prevention and preparation, as well as to re-establish normality in the phases of response and reconstruction (DC Blumenau, 2009). The GRAC is formed by representatives of 32 entities: representatives of the federal level (Battalion, Federal Police, etc), state level (Fire Brigade, Military Police, CELESC, etc), municipal level (Secretariat of Works, Urban Services, Health Care, Social Assistance, Social Communication, etc) and the NGOs (CEOPS-FURB, Amateur Radio Clubs, Telecommunication entities, etc).

Amateur Radio Clubs have played an important role during critical situations in the Itajaí River Basin and are therefore worthy of a brief explanation. Amateur Radio is a telecommunication service carried out by volunteers for the own interests, but without any commercial purposes (ANATEL, 2012). In Brazil these volunteers have to be approved through an exam of the National Agency of Telecommunication (ANATEL) to obtain a permission to carry out such work. The amateur radio functions within specific radio frequencies, and is useful in supporting the work of the Civil Defence in remote areas when other telecommunication systems are compromised. Given their importance, a network of amateur radio broadcasters was created in Brazil to help disaster management agencies in the rescue of victims and the prevention of calamities in areas at risk. The network called RENER (National Network of Emergency of Amateur Radios) was officially created in 2001 and is subordinated to the National Secretariat of Civil Defence (DC, 2012). Amateur Radio Clubs are part of the GRAC and their activities are also included in the Contingency Plan of Blumenau.

Since there is no standard as of yet in Brazil to create Contingency Plans, the Plan of Blumenau was developed to meet exclusively the conditions and needs of Blumenau. In that case, the referred plan comprises adverse events like river floods, flash floods and landslides. The plan is divided into four parts called Annexes. The Annex A refers to the General Norms of Action (NGA), in other words, it establishes the activities that should be developed by each member of the GRAC as regards to the phases of prevention, preparation, response and reconstruction. For instance, during the response stage, the Telecommunication sector has the responsibility of distributing its employees for the maintenance of communication systems in strategic points of the city, whereas the CELESC should control the shutdown of electrical networks according to the water level (DC Blumenau, 2009).

The Annex B specifies the number and location of shelters, the team in charge for their coordination, logistic aspects and the shelters' structure (e.g. amount of stoves, refrigerators). To develop its actions, the Civil Defence of Blumenau divided the city into five Areas of Civil Defence (ARDEC'S), which are the North (N), South (S), East (E), West (W) and Centre (C), as shown in Figure 29.

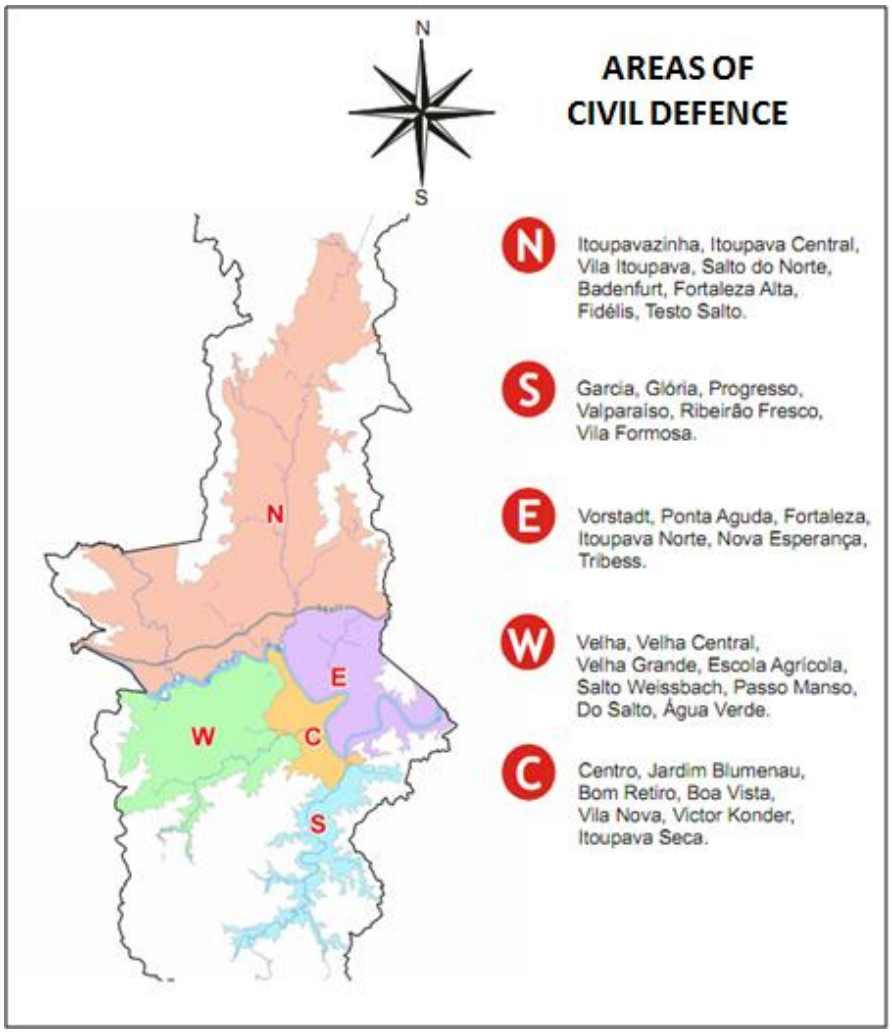

Figure 29 – Division of Blumenau into Areas of Civil Defence (DC Blumenau, 2009).

The ARDEC's encompass 64 shelters for the evacuation of the population. Shelters of the Civil Defence can be several establishments, such as churches and schools. These shelters were selected based on the security height of 17 meters, the available infrastructure, and the data collected from the floods of 1983, 1984 and 2008. For instance, during the flood of 2008, roughly 2,900 displaced people occupied 41 shelters in Blumenau (SDC, 2008). The coordination of these shelters will work under the responsibility of the Operation Centre of Civil Defence, which will be installed in the City Hall of Blumenau during the event (DC Blumenau, 2009).

The Annex C describes the logistic survey in the five Areas of Civil Defence, for example the location of supermarkets, gas stations, bakeries, pharmacies, health centres, etc. This annex is also outlined whether these establishments are found below the height of 17 meters, indicating that the population should be more cautious. Finally, Annex D, which is the only annex that is not available to the population, contains the list of telephones of representatives who form the GRAC.

The Plan foresees several activities to be executed by the Civil Defence, but only some of them will be selected in this section. With reference to the Prevention and Preparation Phases, the Civil Defence of Blumenau should maintain the plan updated and promote exercises of mobilization and training. They should inspect the 64 shelters, as well as to execute educational campaigns with

vulnerable communities to explain how they should proceed before, during and after an adverse event (DC Blumenau, 2009). According to members of the Civil Defence, at the moment they are not carrying out talks or training with the population, but before the event of 2008, they executed an educational campaign in which they visited houses in areas at risk to deliver a brochure titled "*Floods: the importance of prevention*". In this brochure, the ARDEC's and the shelters of Blumenau were listed and illustrated in a map. Also, tips of preventative measures and procedures to be followed during flood events were commented on using a simple language.

Another great aspect of this brochure is the section called "*Family Plan of Flood Prevention*", in which the dweller should answer five questions with the help of the agents of the Civil Defence. The questions are: What is the flood height of this street? In which predicted river's level you should start to remove your family and goods from the place? In which shelter of the Civil Defence or family's or friend's house would you go? How would you remove your goods (trucks, car, etc)? Who would help you to execute this removal? After having completed this form, dwellers would be more instructed to act during flood events. Furthermore, members of the Civil Defence stated that in some places there is a large turnover of dwellers, and several times the estate agencies themselves omit the fact that these residences are located in areas at risk. As a result, some people are settled in these areas without even being aware of the risks.

As commented on earlier the formation of community groups is an important strategy to prepare the community to face adverse events, not only natural disasters, but the Civil Defence as a whole. Members of the Civil Defence of Blumenau expressed the view that nowadays they are implementing again the NUDECS. A problem related to the NUDECs is that sometimes people get involved in these groups with ulterior motives such as to launch themselves in the political milieu as a Councillor. Also, the Civil Defence itself has some political positions and consequently every four years employees in these positions are likely to be changed, as occurs in most of the Civil Defence Centres in Santa Catarina. This makes it difficult to give continuity to a community work which should be developed over time. Before the event of 2008 the Civil Defence of Blumenau used to have several NUDECs working very well, but they ended due to these issues.

In relation to the Response Phase, among its attributions, the Civil Defence of Blumenau should activate the System of Direct Call, through the telephone 199, when the river's water level becomes higher than six meters. There are eight telephones to receive these calls, and employees provide information concerned with river level, weather forecast, river level forecasts, etc. In addition, the Civil Defence gives out Official Bulletins every hour on the internet. There is also a paper version of this bulletin which is sent to the Secretariat of Communication. The Contingency Plan specifies in advance the journalist which is in charge of taking this bulletin at the Civil Defence and distributing it into other press agencies. In addition to these activities, the Civil Defence is also responsible for filling the forms of Preliminary Notification of Disasters (NOPRED) and Damage Evaluation (AVADAN), both documents should be sent to the State Secretariat of Civil Defence, in order to request the transference of financial resources to the municipalities (DC Blumenau, 2009).

Lastly, during the Reconstruction Phase, the Civil Defence of Blumenau should remain in the state of readiness and support the demobilization of shelters. They should also support other Secretariats in the organization and distribution of donations to the affected population. Furthermore, they should update the report of Evaluation of Damages (AVADAN) and collect the data established by the norms of the Civil Defence of Santa Catarina (DC Blumenau, 2009).

3.2 Rio do Sul

Figure 30 presents a map of the city of Rio do Sul with its main rivers and monitoring stations. An overview of the evolution of the Civil Defence in Rio do Sul, as well as its flood early warning system will be further discussed.

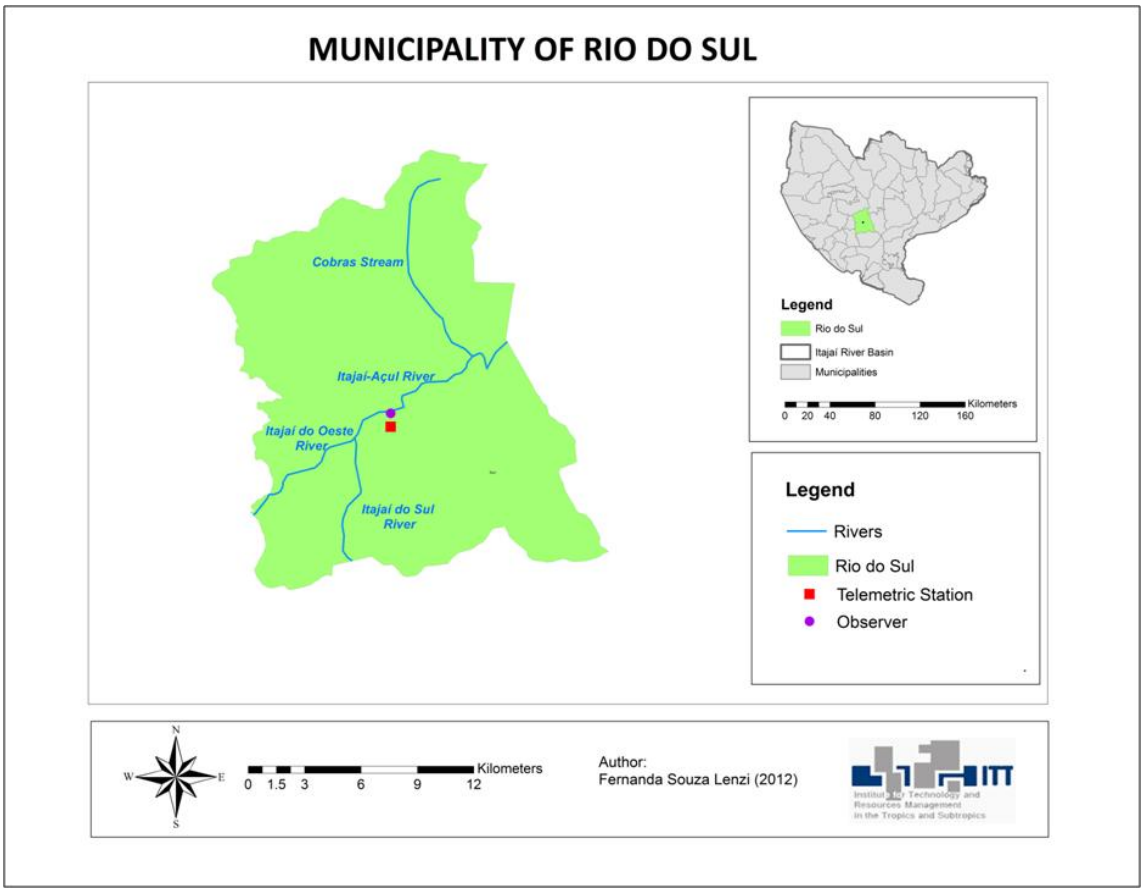

Figure 30 – Location of the municipality of Rio do Sul.

3.2.1 Evolution of the Civil Defence of Rio do Sul

It is believed that the Civil Defence of Rio do Sul was created a new several times by different Mayors. The Civil Defence of Rio do Sul was firstly formed as a reaction to the occurrence of the consecutive flood events of 1983 and 1984. At that time, the Municipal Commission of Civil Defence of Rio do Sul (COMDEC) was created through the Law n.1806/84 of 19.06.1984 (PMRS, 2012). The referred Law was further replaced by the Law n.2752/93 of 11.05.1993, when a new Commission of Civil Defence was implemented in the city (PMRS, 2012).

As a Commission, representatives of different sectors of the City Hall would only meet and execute the Civil Defence activities during the event of a flood. In 1997 the Decree n.335 specified the normative outlines of the Law n.2752/93 (PMRS, 2012). As stated in the Decree, the COMDEC should promote educational campaigns in schools, as well as to propose norms and plans to protect the population against adverse events in the municipality. Furthermore, the COMDEC should study and

propose recommendations regarding the consequences caused by human negligence that could cause an emergency situation in the city (Rio do Sul, 1997).

In 2005 the federal government reorganized the structure of the Civil Defence in Brazil through the Decree n. 5376 (Brasil, 2005). One of the Decree's ambitions was to homogenize the denominations used to represent Civil Defence Centres in Brazilian municipalities and states. With the new Decree, Civil Defence Centres at municipal level were renamed as Municipal Coordination Offices of Civil Defence (COMDEC). As a result, the Law n.4231/2005 created the COMDEC of Rio do Sul (PMRS, 2012).

To understand further about the evolution of the Civil Defence of Rio do Sul, an interview with Mr Alécio Leontino Pereira, who was the coordinator from 2005 to 2009, was executed in April 2012. The following paragraphs are based on his statements. He commented that, before 2005, the Civil Defence was basically something on paper. It did not exist in practice or at least there was no continuity throughout the years. For instance, there was no information available in a single computer found at the COMDEC. They had to start from the very beginning, for example they had to borrow a car from the City Hall each time they were going to monitor rivers or to inspect buildings in areas at risk.

With the purpose of building a new Civil Defence, they firstly composed a Flood Management Plan for the city of Rio do Sul. In this plan, they defined areas for evacuating people during flood events and also identified the entities involved with the emergency response. Furthermore, they drew up a law for the institutionalization of the Civil Defence of Rio do Sul referred to earlier. At the time, they applied for subsidies at the Civil Defence of Santa Catarina and at the City Hall. These financial resources were used for the purchase of the basic equipment to work, such as a computer and radios for communication. After that, the Civil Defence of Rio do Sul made an effort to establish a daily communication via radio with the Civil Defence of Blumenau and with the three flood contention dams located in the basin. This was achieved through the DEINFRA and financial resources given by the SDS.

According to the interviewee, people hardly spoke about the Civil Defence before 2005. This situation has changed and today the Civil Defence deals with floods and landslides, among other disasters. In his view, the Civil Defence has grown at all governmental levels, but in particular, mayors have become aware of the importance of the Civil Defence in their municipalities and get involved in the actions of the Civil Defence.

At the moment, the Civil Defence of Rio do Sul is officially formed by three employees. As explained by the current coordinator of the COMDEC, Mr André Gustavo Wormsbecher, the structure of the COMDEC is definitely not sufficient to act during large disasters. He points out that some municipalities should be followed as an example. For instance, Jaraguá do Sul has a multidisciplinary team in their Civil Defence, so that pedagogues can work with risk perception within the community, while geologists can study the vulnerability to landslides.

Besides the lack of human resources in the COMDEC of Rio do Sul, there are some constraints related to the transference of financial resources from the federal to the municipal level. Members of the COMDEC commented that resources designated to the response phase usually come quicker than resources for the prevention phase. Yet, several documents to declare the emergency situation and to report the damage are required by the National Civil Defence. For instance, they complained

about the lack of financial resources for immediate use during the event of 2011. They believe that a Payment Card of the Civil Defence should be available for prompt utilization or a Municipal Fund of the Civil Defence should be activated during disasters. Moreover, they comment that the National Civil Defence fails in terms of prevention, given that the resources for the prevention phase take a very long time to reach the municipalities. However, it is understandable that the National Civil Defence has only 10 workers to analyse more than 2,000 projects coming from all Brazilian municipalities.

3.2.2 Flood early warning system of Rio do Sul

The flood early warning system of Rio do Sul is discussed in this section, on the basis of an interview, carried out in April of 2012, with the present coordinator of the Civil Defence of Rio do Sul. In summary, the Civil Defence checks on the internet the river level data measured by an automatic station of the National Water Agency (ANA), as well as weather forecasts from several institutions (CIRAM, CPTEC, etc). They also receive, via radio or telephone, the data measured through limnimetric scales or standard rain gauges, which are checked by observers. Having obtained these data, the Civil Defence of Rio do Sul runs a model for daily forecasts which correlates river flow and precipitation. Also, a stochastic model run by the CEOPS is taken into consideration when forecasting floods for Rio do Sul. According to the river level forecasted, the Civil Defence of Rio do Sul will put into action its Flood Management Plan and will convene the other institutions defined in the Plan. The flood warning will be disseminated to the population through television or radio. Furthermore, the Civil Defence will activate three phone lines to serve the population through the number 199. Figure 31 shows a scheme of the functioning of the current flood early warning system in the city of Rio do Sul. Details on each one of the components of the FEWS will be further presented.

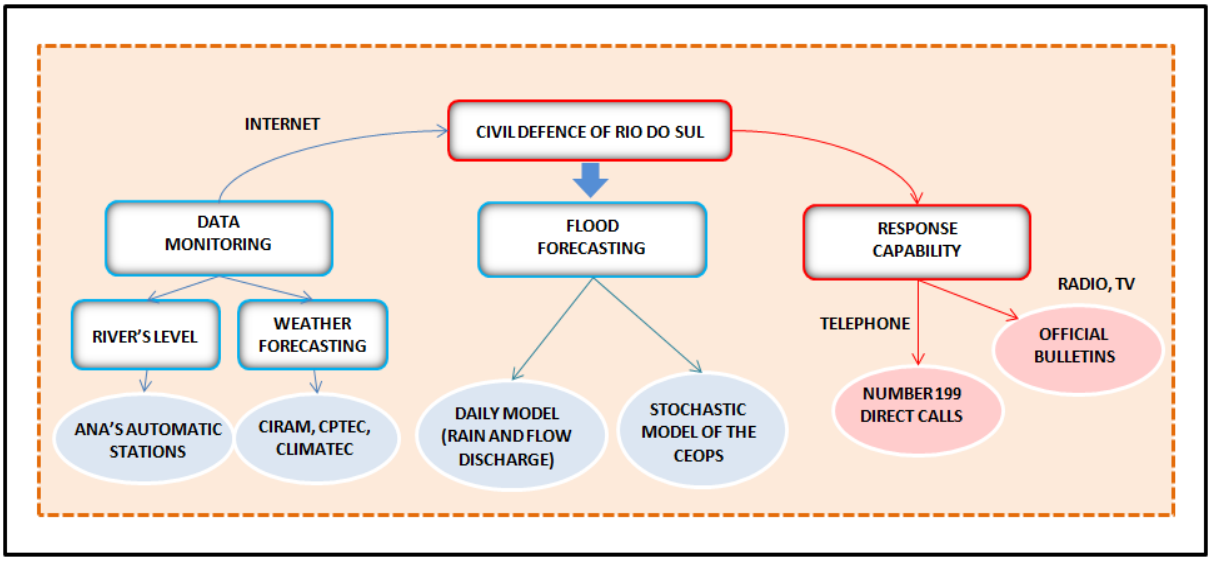

Figure 31 – Scheme of the Flood Early Warning System of Rio do Sul.

Risk Knowledge

The Civil Defence of Rio do Sul has recently implemented the Decree n.2325/12 of 03.01.2012, which delimitates areas of risk in Rio do Sul and establishes measures for disaster prevention (Rio do Sul, 2012). The delimitation of areas of risk was based on geological reports developed by technicians of the city, together with specialized institutions, such as the CPRM, SDS, CEPED (Centre of Research and Studies of Disasters) and CENACID (Centre of Scientific Support to Disasters). These institutions identified 32 areas at risk, which are distributed into 4 categories of risk in the municipality. According to Figure 32, blue areas correspond to flood prone areas. The dark blue refers to areas with high flood risk in which the occupation is forbidden due to the low level of their terrain. Lastly, the light blue represents the areas in which occupation is allowed if some constructive techniques or mitigation measures are taken into account. The red colour represents the areas with high geological risk, in which the occupation is absolutely prohibited. The gray colour refers to areas which can be subjected to risks, but a detailed analysis of these areas was not accomplished. As stated in the Decree n.2325, projects aiming to build new constructions in these areas will have to present a geological analysis of landslide risks. Furthermore, the viability analysis will have to be previously approved by the Secretariat of Planning and Environment and the Civil Defence (Rio do Sul, 2012).

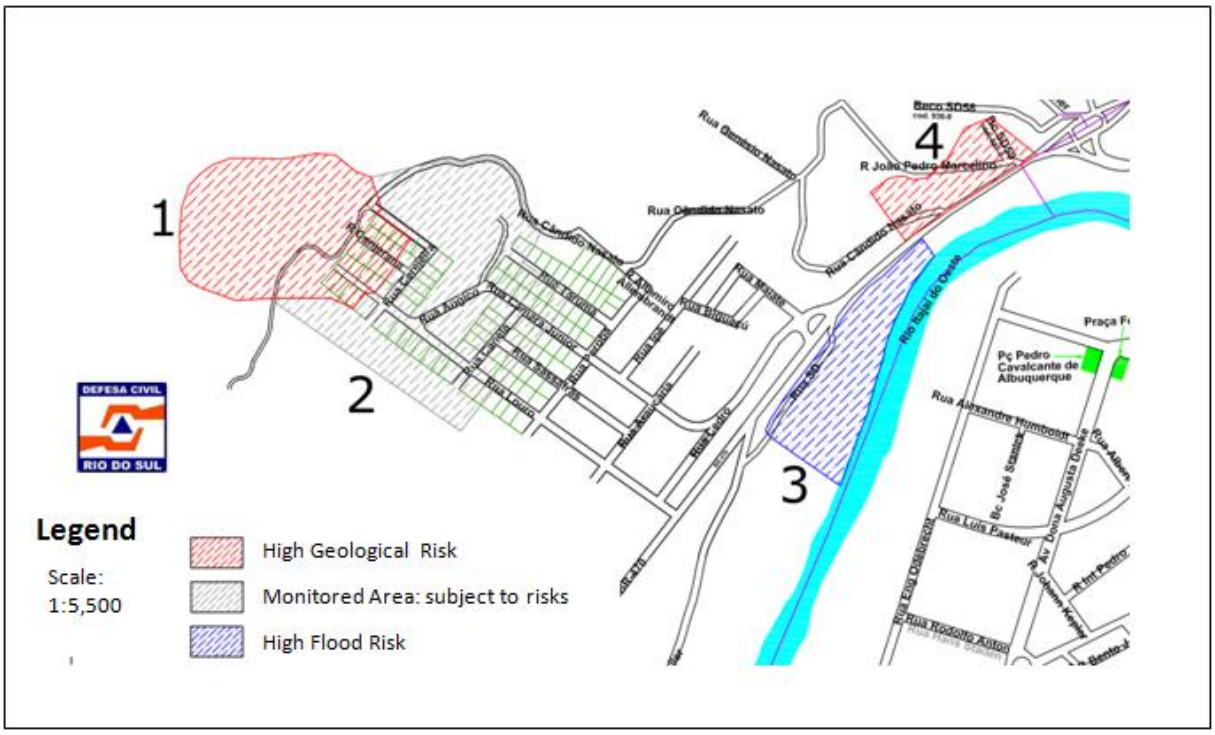

Figure 32– Mapping of risk areas for Rio do Sul. Source: DC Rio do Sul, 2012.

Monitoring

The Civil Defence of Rio do Sul uses the data from one of the stations which is part of the ANA's hydrometeorological network. This radar sensor hangs down from the bridge Ivo Silveira and works as a scanner, differently from pressure sensors which have to be submersed in water. Examples of a radar station and a pressure sensor are shown in Figure 33. The installation and the calibration of

the station in Rio do Sul were executed by the EPAGRI, who is also responsible for the station's maintenance. The EPAGRI's office in charge of the station's maintenance in Rio do Sul is the one located in the city of Urussanga; which is situated 230 km away from Rio do Sul.

Figure 33 - Example of a radar station and a pressure sensor respectively.

Source: Roehrig (2012) and Kaempfe (2012) respectively.

According to members of the COMDEC, the river's level monitoring is working satisfactorily by using this new sensor, but the pluviometry has to be adjusted as data have not been correctly transmitted since the flooding of 2011. The data concerned with river's level and precipitation should be sent every 15 minutes through satellite and available at the ANA's website. However, according to its positioning, sometimes the satellite does not transmit the data for up to 12 hours. Therefore, regardless of the technology being used, an observer checks twice a day (7h and 17h) the river's level marked by limnimetric scales, and once a day (7h) the pluviometry, in normal situations (river's level lower than 4m). When the river's level ranges from 4 to 5 meters, measures are executed by the observer four times a day. Lastly, when the river's level is greater than 5 meters, measures are checked every hour. The observers will further pass on these data to the Civil Defence of Rio do Sul through radio or telephone.

Warning

There are two models of flood forecasts which are used by the Civil Defence of Rio do Sul. One model was developed by the CEOPS and was actually adapted from the model used for Blumenau, which was previously explained. As it occurs in Blumenau, Rio do Sul also receives two river entries, the Itajaí do Oeste River and the Itajaí do Sul River. The model used is a stationary stochastic model of the type ARMA and the river's level forecast in Rio do Sul is estimated through the following Equation 2 (Cordero *et al*, 2011):

Equation2:

$$Y(t) = 1.24500\,y(t-1) + 0.25130\,y(t-2) - 0.41410\,u_1(t-4) + 0.36370\,u_1(t-5) + 0.06747\,u_2(t-5) - 0.06861\,u_2(t-6) + 0.04$$

According to the formula, Y(t) refers to the river's level forecast in Rio do Sul after t hours; y is the river's level observed in Rio do Sul, u_1 corresponds to the value observed in the municipality of Ituporanga (Itajaí do Sul River), and u_2 refers to the river's level measured in Taió (Itajaí do Oeste River) (Figure 34). The CEOPS's model achieves a high accuracy with a regression coefficient of 0.95 for river level forecasts up to 8 hours in advance, but again rainfall rates are not included in the model (Cordero *et al*, 2011).

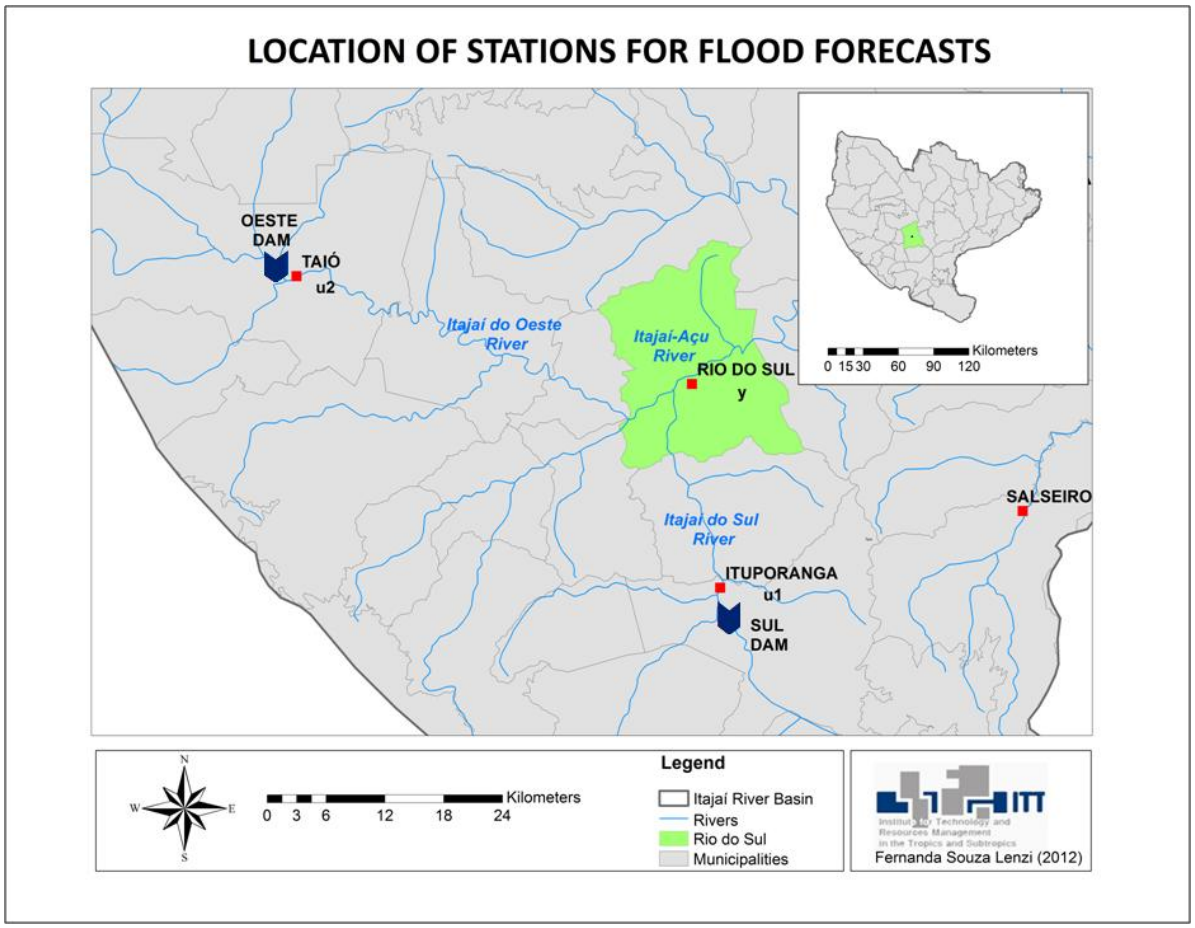

Figure 34 – Location of stations for flood forecasts in Rio do Sul.

Moreover, the coordinator of the COMDEC developed a model of multiple regressions by correlating the flow's increment and the rainfall occurred. This model takes into account daily averages of three monitoring points (Rio do Sul, Sul Dam and Oeste Dam). The river's level forecast for Rio do Sul is calculated according to the Equation 3 (JICA, 2010):

Equation 3:

$$Q(t) = 6.07 + 1.66(\textit{precipitation in Rio do Sul}) + 2.51(\textit{precipitation in the Sul Dam}) + 0.45(\textit{precipitation in the Oeste Dam})$$

However, this model was designed for a specific situation, considering that the river had already reached a certain level. Furthermore, the model has a regression coefficient of 0.7, which incurs more errors than the CEOPS's model. On one hand, the CEOPS's model can deliver a more accurate

flood forecast, but less in advance (8 hours). On the other hand, the COMDEC's model delivers a less precise forecast, but earlier by using meteorological forecasts executed by several institutions (EPAGRI-CIRAM, CPTEC, CLIMATEC, etc). Also, it is important to take into account that the river's level can rise or decrease several meters in the same day, so that one should be cautious when using models for daily forecasts. The Civil Defence of Rio do Sul uses both models, together with empiricism and experience from the dams' staff.

Dissemination

The Civil Defence of Rio do Sul monitors the river's level in the municipality and issues warnings according to the scale shown below. For instance, when the river's level exceeds 5 meters, there is an *Alert Situation*, so that the Civil Defence calls the Secretariat of Works and other municipal institutions to warn about the flood risk. When the river reaches levels higher than 6.5 meters, some houses begin to become flooded, so that the Contingency Plan should be set in motion.

CITY	NORMAL	ATTENTION	ALERT	EMERGENCY
RIO DO SUL	NA < 4,0	4,0 < NA < 5,0	5,0 < NA < 6,5	NA > 6,5

During a flood event, the population is warned every hour through television or radio. Reporters take the information concerned with flood forecasts directly with the Civil Defence and then disseminate them to the population. Also, the Civil Defence owns three phone lines to serve the population through the number 199. However, during the event of 2011, some emergency responders, such as the fire fighting brigade, were prevented from communication as their establishments were flooded. As a consequence, the Civil Defence received all calls intended for the fire brigade. Apart from the challenging task of answering all these calls with a meagre manpower, their phone lines got very busy and were not easily accessed by the population.

Moreover, members of the Civil Defence of Rio do Sul criticized the media's performance during the event of 2011. They argued that the media was disseminating, without checking it properly, untrue information given by some inhabitants; for example, information about false lootings or lack of provisions in certain areas. This caused a situation of insecurity in the society and dissatisfaction with the local authorities. An evaluation of the Flood Management Plan of Rio do Sul, which took place in December of 2011, suggests that a Communication Plan for disaster events should be made and periodic official bulletins with updated data divulgated. In addition, there is a need to define someone who gives information to the press during flood events, as well as training the press for the publication of correct information to the population (Rio do Sul, 2011).

Response Capability

Since 2005 the municipality of Rio do Sul has a Flood Management Plan, which was based on the Contingency Plan of Blumenau, so that several technical visits to the city were executed to study the plan and to further adapt it to the conditions of Rio do Sul. The Plan was updated last in 2010 as the result of a multidisplinary work among the institutions involved with disaster risk management (DC Rio do Sul, 2010).

As shown in the Contingency Plan of Blumenau, the Flood Management Plan of Rio do Sul presents the same structure divided into annexes. Annex A defines the responsibilities of all institutions which are part of the Group of Coordinated Activities (GRAC), which will cope with adverse events (flash

and river floods). Their activities refer to five components of disaster risk management (prevention and mitigation, preparation, response, rehabilitation, and reconstruction).

In Annex A several competences are designated to the COMDEC of Rio do Sul, but only some of them are mentioned here. For the Prevention and Mitigation Phase, the Civil Defence is in charge of registering pluviometric and fluviometric data, in order to study the risks and threats. Furthermore, they should submit proposals of studies and measures of risk reduction to the Mayor.

As regards to the Preparation Phase, the COMDEC of Rio do Sul should maintain daily contact with the Centre of the Dams Operations to obtain information on the level of the Itajaí-Açu River. Likewise they should follow weather forecasts given by the EPAGRI-CIRAM. Moreover, the diffusion of the plan within the community, as well as training exercises and educational campaigns, are responsibilities of the Civil Defence (DC Rio do Sul, 2010). However, the coordinator of the COMDEC admits that not much has been done to increase the community's capability to cope with disasters. For example, there are only three employees working in the Civil Defence of Rio do Sul, who had to focus their efforts on the city's recovery from the flood of 2011. At the moment there are none Community Groups of Civil Defence (NUDECs) in Rio do Sul, but they intend to implement them in the near future through reunions with neighbourhood associations. Also, a training with individuals responsible for shelters' management was executed last year (before the event of 2011), with the help of the UDESC (University of the State of Santa Catarina) and the OFDA (Office of Foreign Disaster Assistance). Yet, only half of the involved people came to this training, so that the Civil Defence wants to repeat this training this year.

With reference to the Response Phase, among several competences, the Civil Defence should initiate the mobilization of shelters according to river level forecasts. They are also responsible for coordinating response actions in the municipality and supervising the activities developed by the GRAC. Furthermore, they should complete the documentation established in the law (e.g. Decree n.7.257/10 of 04.08.2010) and send it to the competent authorities. During the Response Phase, the Civil Defence should request the support of institutions outside the municipality to help in the response and rehabilitation phases (DC Rio do Sul, 2010).

In the Rehabilitation Phase, the Civil Defence has the responsibility of filling the AVADAN as required by the National Civil Defence. Besides this they also inspect the places affected by adverse events according to the requests received. In addition, they are supposed to support the Secretariat of Social Assistance with the distribution of donations to the population. Lastly in the Reconstruction Phase, the Civil Defence of Rio do Sul should plan and control the application of resources for the recovery of physical, social and economic damage (DC Rio do Sul, 2010). All activities mentioned before are referred only to the Civil Defence of Rio do Sul, but the Annex A of the Flood Management Plan attributes responsibilities for roughly 30 institutions which form this group that will act during a disaster event.

The Annex B presents a description of the shelters used for people's evacuation. The Civil Defence of Rio do Sul divided the city into 7 Areas of Civil Defence-ARDEC's (Figure 35), which comprise in total 34 Shelters. Shelters were estimated to meet the evacuation of 3,200 people. In the flood of 2011, for example, they evacuated roughly 2,580 people. The security height of 15.08 meters was taken into account in the selection of shelters in the city. To check the capacity and the dimensioning of the shelters, the Civil Defence uses as reference the minimum needs for humanitarian response established by the United Nations Organization through the Sphere Project (DC Rio do Sul, 2010).

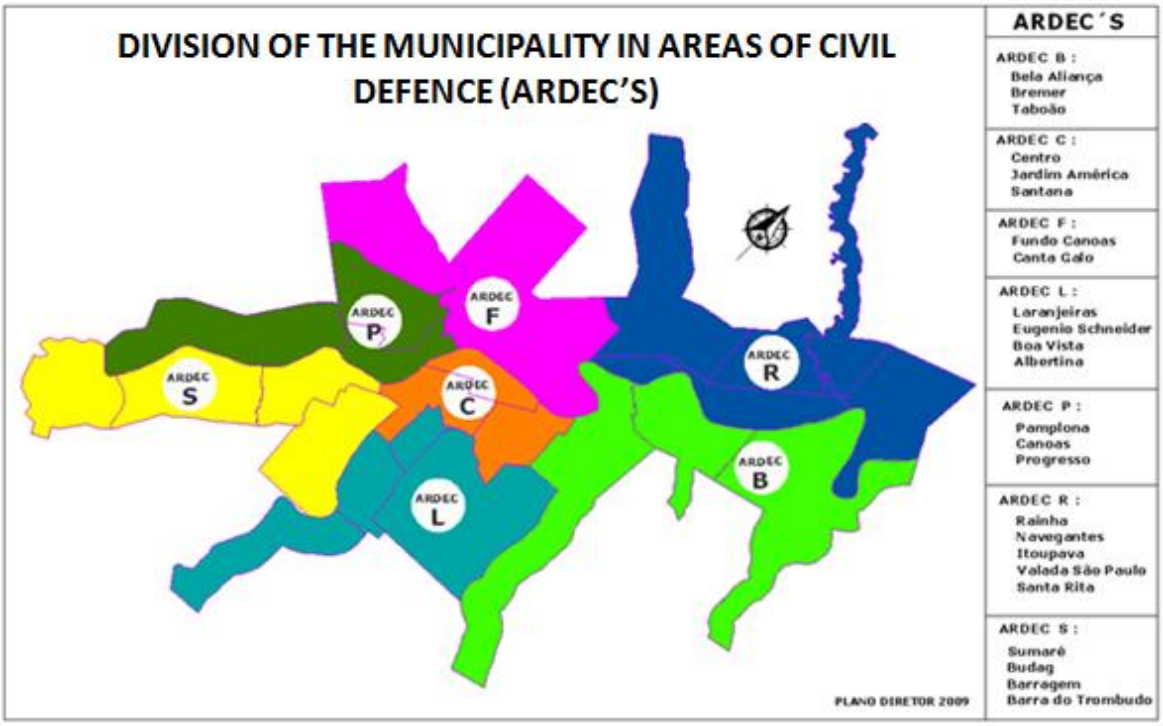

Figure 35 – Division of Rio do Sul into Areas of Civil Defence (DC Rio do Sul, 2010).

The Annex C refers to the representatives of each component of the GRAC, their telephone numbers and addresses. The Annex D presents a list of the city's streets, together with their heights. This can help not only in the selection of shelters, but also people can have a broader understanding on whether they live in areas very susceptible to floods or not. Lastly, the Annex E is not yet completed, but will be referred to the flood early warning system (DC Rio do Sul, 2010).

According to the coordinator of the COMDEC, the Flood Management Plan of Rio do Sul used to be efficient for small events, so that the Civil Defence was able to evacuate the population. However, the plan proved to be ineffective for a big disaster such as the event of 2011. Firstly, the Plan was meant only for events of flash and river floods, but the city was also severely affected by landslides. Today Rio do Sul has 32 areas of landslide risk, which makes it crucial that contingency measures for landslides in the Plan are put in place.

As noted previously, in December 2011, a seminar took place in Rio do Sul in order to evaluate their Flood Management Plan. On that occasion, 25 institutions involved in the activities of flood prevention, mitigation, response and rehabilitation, attended the seminar and shared their experience related to the event of 2011. The difficulties faced by each institution were discussed in the seminar, and some improvements were suggested with the support of the OFDA and the UDESC (Rio do Sul, 2011). For instance, the Civil Defence pointed out that it was difficult to identify the official river's level during the event, since limnimetric scales were flooded to over the maximum capacity. Moreover, flooded streets hampered the access to evacuation shelters and consequently the Civil Defence could not supply the shelters with food, water and other supplies. Furthermore, they mentioned that various institutions of the GRAC were not aware about the Plan's details, so therefore the Plan should be redistributed to these entities. Finally, meetings with neighbourhood

associations should be scheduled to assure that the population knows what to do in such situations (Rio do Sul, 2011).

3.3 Itajaí

A map of the municipality of Itajaí is given in Figure 36, in order to show its major hydrology. The city of Itajaí will now be discussed further in terms of Civil Defence and flood early warning system.

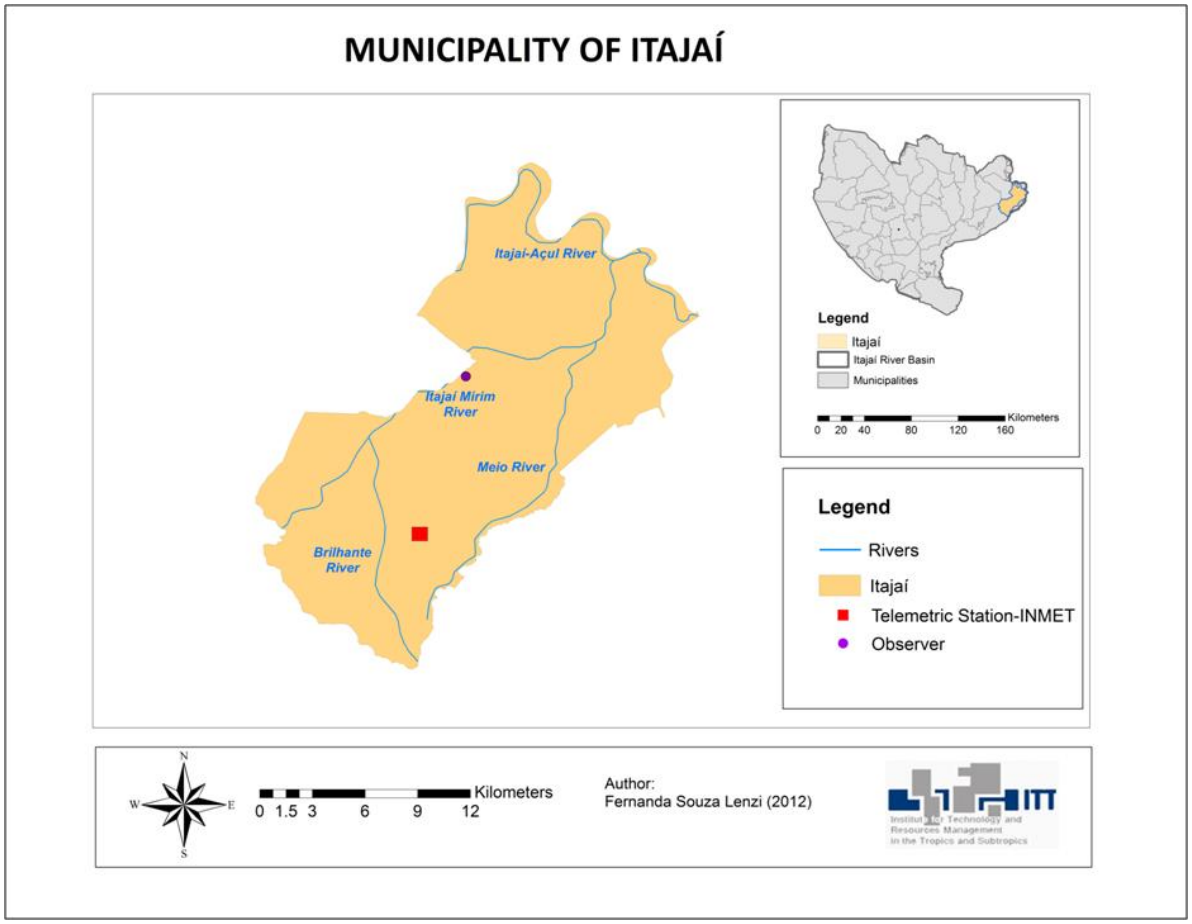

Figure 36 – Location of the municipality of Itajaí.

3.3.1 Evolution of the Civil Defence of Itajaí

As in Blumenau and Rio do Sul, the Civil Defence of Itajaí was originally conceived as a Municipal Commission of Civil Defence (COMDEC) through the Decree n.920/1973 of 26.01.1973 (Itajaí, 1973). As explained before, the commission consisted of a group of representatives from the municipal and state government and from the community that would only meet in cases of large social mobilization, such as during flood events. This situation persisted until 2005, when the Municipal Coordination Office of Civil Defence (COMDEC) was created through the Complementary Law n.68/05. The COMDEC was placed in the Secretariat of Safety and Social Defence. Thus, the COMDEC began to have a physical structure in 2005, but they still lacked skilled labour and adequate support to cope with disasters (DC Itajaí, 2012).

In November 2008 the city experienced severe flash floods, which affected 95% of the city's area, but unfortunately the Civil Defence and the population were not prepared for such an event. Also, the Civil Defence at the time did not have a contingency plan (DC Itajaí, 2012). Therefore, after the flood of 2008, governmental administrators realized that it was crucial to have a well structured and active Civil Defence in the municipality.

The current coordinator of the Civil Defence obtained financial resources from the City Hall to buy telemetry equipments, a container with the required material for shelters (e.g. mattress, blankets and pillows) and new boats (DC Itajaí, 2012). Furthermore, they employed more agents of the Civil Defence through a public tender which took place this year.

Apart from its coordinator, the Civil Defence of Itajaí is formed today by ten agents of Civil Defence and three Managers (Manager of Logistics, Manager of Operation and Manager of Preparation and Prevention). Agents of Civil Defence are divided into special work shifts, in order to assure that the Civil Defence of Itajaí can offer an uninterrupted service of 24 hours a day, as occurs in Blumenau. As regards to its physical structure, the Civil Defence is well equipped with two cars, five boats and a system for telemetry and radio communication (DC Itajaí, 2012).

At present, the COMDEC executes several activities based on the four pillars of the Civil Defence (prevention, preparation, response and reconstruction). With respect to flood prevention and preparation, the COMDEC has put effort into developing their own flood early warning system with stations financed by the City Hall of Itajaí. Moreover, projects connected to the Harbour of Itajaí have been developed in the city, such as the deepening of the harbour's channel which increased the runoff capacity of the river by 30-40%. These measures have the purpose of preventing not only floods, but also economic losses. The presence of such an important harbour expedites the recovery's time of the city. For instance, a large volume of sediments were deposited into the harbour's channel during the flood of 2011. The draft of ships' hull changed from 14 (before the flooding) to 10.5 (after the flooding). However, although the flood event is recent, the harbour's channel has already been dredged due to the economic benefits that the harbour provides at state and national level (Personal communication with Mr Everlei Pereira, 2012).

As regards to financial resources, the Civil Defence of Itajaí has great support from the City Hall. However, members of the COMDEC of Itajaí explain that the resources coming from the federal level are mainly designated to the response stage. They argue that there are difficult criteria used by the National Civil Defence for the release of financial resources for the prevention phase. For instance, the municipality is only considered as a priority for receiving resources for prevention, if it has already registered deaths due to landslides. In their view, this contradicts the term prevention. However, such criteria are still used due to the huge dimensions of the country.

3.3.2 Flood warning system of Itajaí

The flood early warning system of Itajaí is described in this section, taking into account an interview carried out with the current coordinator of the Civil Defence of Itajaí, Mr Everlei Pereira. In summary, river level and precipitation data are transmitted via radio to the Civil Defence of Itajaí, to whom the stations belong. The Civil Defence does not run flood forecast models, but they have received the support from the University of the Valley of Itajaí (UNIVALI) to estimate a potential flood during critical situations. The Civil Defence of Itajaí will further disseminate the warning to the population through the radio and television every hour. Also, they provide warning bulletins on their

website and they receive calls from the population through the number 199. A scheme of the flood warning system of Itajaí is presented in Figure 37.

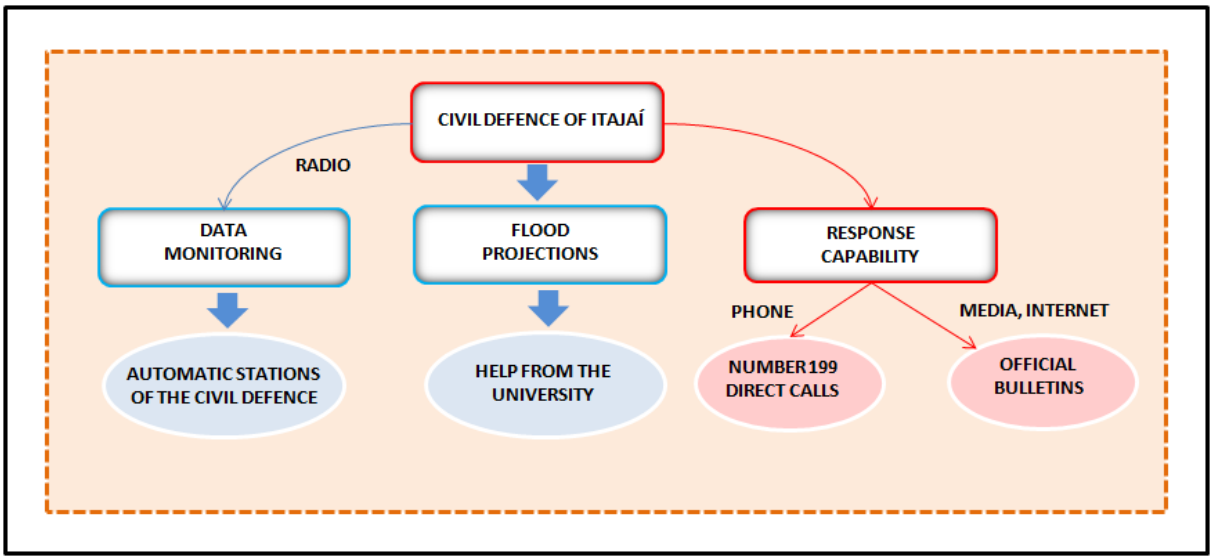

Figure 37– Scheme of the Flood Early Warning System of Itajaí.

Risk Knowledge

The Civil Defence of Itajaí counts the support of a geologist and an environmental engineer as part of their team. They are currently developing mappings of flood prone and hillside risk areas. These maps are undoubtedly useful for the identification of the most vulnerable communities and prioritize the activities of the Civil Defence in these areas.

Monitoring

The data monitoring in Itajaí consists of eight stations for the measurement of rivers' levels and nine stations for the rain's monitoring. As shown in Figure 38, these automatic stations are distributed throughout the rivers and streams that pass by the city: Itajaí-Açu River (2 stations), the rectified channel of the Itajaí Mirim River (2 stations); the old course of the Itajaí Mirim River (2 stations), Murta's stream (1 station) and Canhanduba's stream (1 station). They were installed in February 2011 by using financial resources from the municipality, so that the stations belong to the Civil Defence of Itajaí. An outsourced company was hired to install the pressure sensors. The same company is responsible for the maintenance of the stations. The maintenance contract establishes that the outsourced company has up to 6 hours to fix a potential problem. According to the COMDEC's coordinator, the stations have been working satisfactorily since the beginning of their operation. For instance, during the event of 2011, there was no loss of data or fall of sensors.

The data registered by the stations are transmitted to the Civil Defence of Itajaí every 10 minutes via radio. The radios are equipped with batteries and solar panels, so that the system does not rely on energy supply.

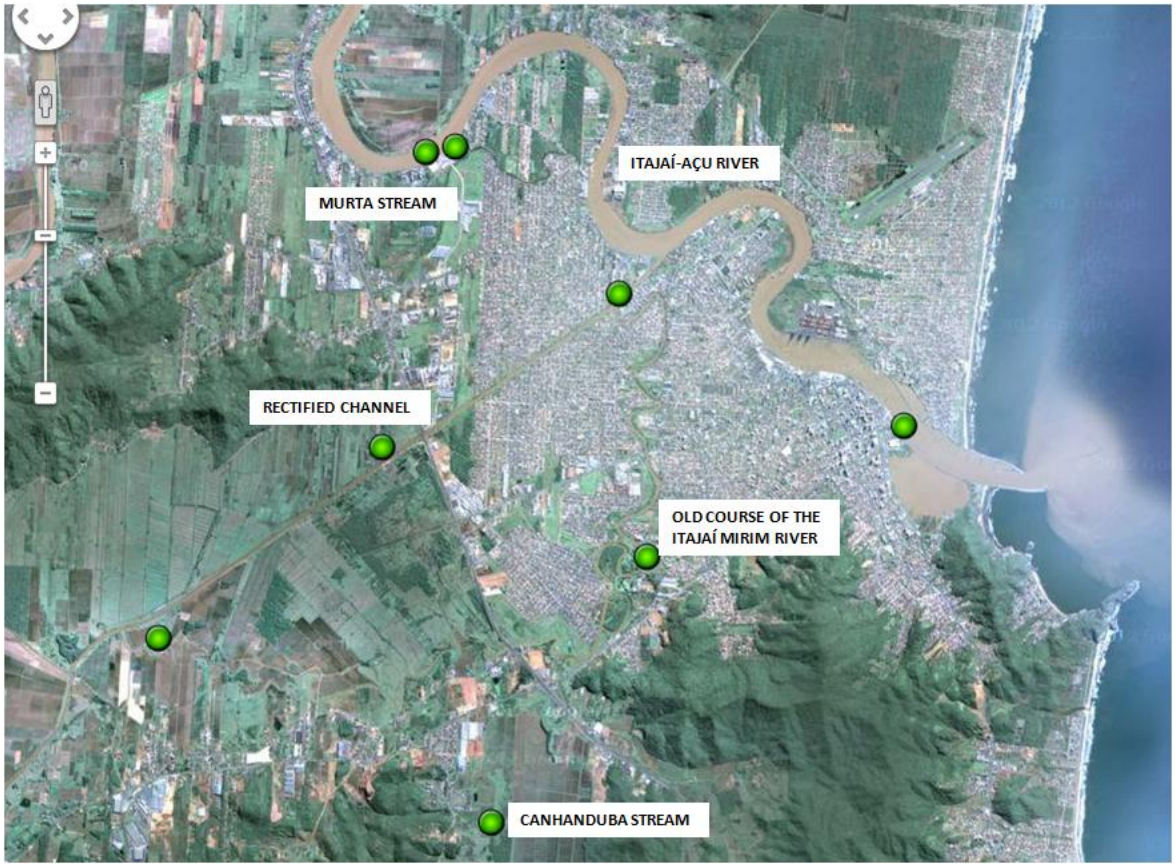

Figure 38 – Points of river's level monitoring in the city of Itajaí. Source: DC Itajaí, 2012.

Warning

As regards to data interpretation, the Civil Defence of Itajaí does not run models for forecasting floods or have the background to estimate the river's level. The COMDEC's coordinator clarifies that at the moment they have a flood monitoring system rather than a flood warning system. During the flood event of 2011, which lasted 2 days, the Civil Defence of Itajaí had a great support from the University of the Valley of Itajaí (UNIVALI). A Professor from the UNIVALI made some projections by interpreting weather forecasts and the data registered by the Civil Defence's stations. At some points, they were able to warn the population 36 hours in advance. They showed through the media graphs of the growth of the flood wave. According to members of the COMDEC, the fact that the flood event in the city was being monitored eased the work of the Civil Defence, as they had enough arguments to show to the population that their decision to evacuate the population was correct.

Dissemination

The Civil Defence of Itajaí updates their website regularly with meteorological bulletins, including information on weather forecasts and astronomic tide projections. This is very important because the city of Itajaí is not only affected by river and flash floods, but also by the tide increase of the water from the Atlantic Ocean. In critical situations, official bulletins are released every hour through the radio and television. Journalists take the information with the Civil Defence of Itajaí and disseminate it to the population. The Civil Defence recognized the great role of the media during the flood of 2011, as they delivered the information to the community in an organized manner. Furthermore, the Secretariat of Social Communication was very important as they not only

organized the information, but also established a Press Consultancy to the communication vehicles (DC Itajaí, 2012).

The Civil Defence of Itajaí is currently writing a new document titled "*Alert Protocol*", in order to discipline the communication between the Civil Defence and the communication media, as well as to establish what the media would inform during disaster events. The idea is to standardize the warning dissemination by delivering protocols with a standard voice to the media. An example of a warning message which would be released during an *Alert Stage* is shown below.

"The Civil Defence informs all that we have entered into the Alert Stage. Residents of areas of risk should seek safe places until the stage is lowered. In case there is not a safe place to stay in, inhabitants should head towards the official shelters. The Civil Defence, through the telephone 199 or website, informs you of the shelters in operation and reminds you that interdicted properties should not be occupied until a new inspection and liberation is executed by a specialized team. Follow the schedule of this broadcaster for further information."

Response Capability

The Civil Defence of Itajaí is concluding the production of its Contingency Plan, which is similar to the ones developed by the Civil Defence of Blumenau and Rio do Sul. The city of Itajaí was divided into 10 Areas of Civil Defence (ARDEC's), delimitated by administrative zones (Figure 39). Each zone contains a list of shelters for the evacuation of the population. However, these shelters can only be activated by the Civil Defence and be used by the population of the same administrative zone, in cases of adverse events (DC Itajaí, 2012). The shelters were selected by a Commission, which comprised of several institutions such as the Civil Defence, the Sanitary Surveillance and the Social Assistance.

At the moment, agents of the Civil Defence are updating, through the application of questionnaires, the information concerned with the capacity of the shelters. For example, information on whether the shelter has been affected by floods or whether there is stored food or other supplies such as mattresses, drinking water, etc. Furthermore, the shelters will be activated according to the dimension of the event, taking into account the flash floods of 2008 as a major event and the river floods of 2011 as an intermediate event, which affected 95% and 65% of the territorial area of Itajaí, respectively (DC Itajaí, 2012).

As regards to the response to disasters, the Civil Defence work together with various entities (Policy, Fire Fighting, etc), which form the GRAC. Each entity will develop activities according to its legal competence. A command post will be organized within the structure of the Civil Defence of Itajaí. Several activities have to be developed by the GRAC during the response stage: mobilization of communication systems, convening of volunteers, formation of brigades, rescue of victims, first aid, registers of affected people, sanitary surveillance, epidemiological diseases, etc (DC Itajaí, 2012).

With reference to educational works within the community, the COMDEC has started a project called "*Safer Community*", which encompasses from talks in schools and companies to the placement of placards in target communities. Moreover, they aim to execute evacuation plans for all establishments of the city, such as schools and shopping malls, so that the population is also trained to tackle eventual problems. It is important to remark that the Civil Defence should act in any situation in which the population is put in risk, and not only during flood events. For instance, the Civil Defence has to act in cases of fires, explosions, chemical accidents, falls of rocks, etc.

At present, there are no Community Nuclei of Civil Defence (NUDECs) in Itajaí, but the Civil Defence intends to implement the NUDECs by seizing an ongoing work of the Municipal Fire Station. This work named "*Community Brigade*" consists in training some people in the community to give the first attendance during a fire event. The fact that these people have already some training; they could be engaged in the implementation of community groups for acting as well as in the activities of the Civil Defence. The coordinator of the COMDEC makes an important point, mentioning that the visit of the Civil Defence generates some natural expectations in the community, so that they have to be prepared with trained and qualified people to fulfil this role within the community. Otherwise, the community might lose trustworthiness in the work of the Civil Defence, and this might hinder a future approach.

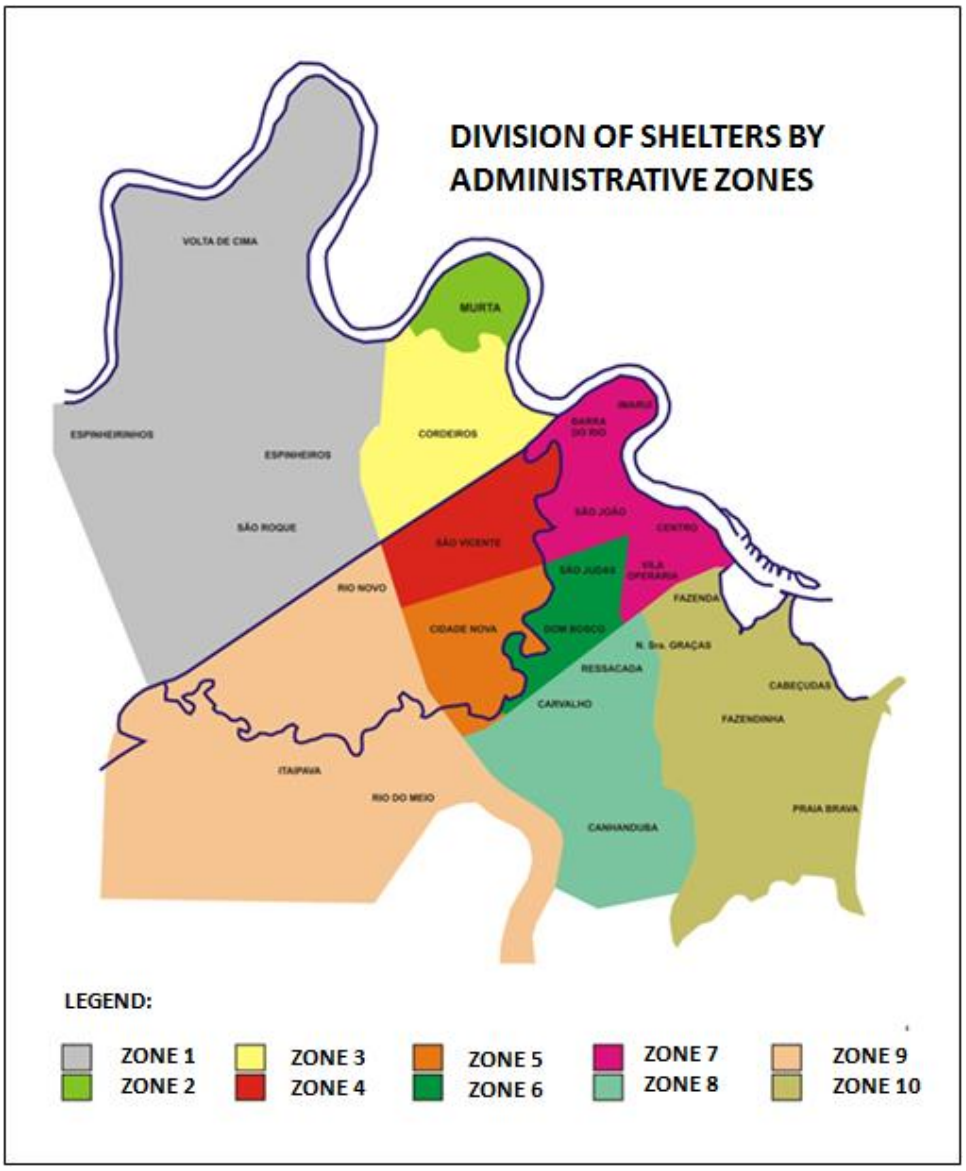

Figure 39 – Delimitation of Areas of Civil Defence in the city of Itajaí. Source: DC Itajaí, 2012.

3.4 Suggestions for the improvement of Civil Defence Centres

An important aspect to be discussed here refers to the dissemination strategies used by Civil Defence Centres to warn the population about an impending flood. As mentioned before, the Civil Defence of Blumenau, Rio do Sul and Itajaí usually emit official bulletins through the radio and television. Key factors in effective dissemination embrace the speed at which the information is released and the content of information which should be understandable by the population. In this context, both radio and television still appear to be effective, as they are able to communicate detailed information to a broad population (Wattegama, 2007). However, its effectiveness can be compromised at night when this media is usually switched off or when the power is disrupted (Attorney-General's Department, 2009). On the other hand, battery operated radios can continue to function after power cuts, but again they must be switched on. As stated in QFCI (2011), radios are an effective technique for disseminating warnings to isolated communities where internet and mobile telephones are not available. In general, radio broadcasts should include information on road closures, evacuation centres and what to do in a certain location. The *Protocol Alert* which has been developed by the Civil Defence of Itajaí is a good example of an effective warning message.

Some dissemination strategies could complement the ones being used by the Civil Defence Centres. The use of several methods assures that warnings reach all members of communities and as a result people are more likely to act in response (Sene, 2008; QFCI, 2011). Sirens and alarms might work well to alert communities in risk zones, when preceded by an intensive program of public education, so that people understand the meaning of the sound and are instructed on what to do (QFCI, 2011). Although sirens are able to reach outdoor populations at fast speed, the sound is barely propagated inside buildings (Attorney-General's Department, 2009). To rectify this, sirens or alarms can be transmitted to residents while indoors using another method, such as telephone ringing (Wattegama, 2007). In general, sirens are recommended in smaller towns or rural communities vulnerable to flash flooding (QFCI, 2011).

Telecommunication systems, such as telephones and mobiles, also play a significant role in dissemination. For instance, some countries make use of mechanisms called "*telephone trees*" to warn communities about an incoming flood. In this mechanism, when individuals receive a warning message by phone, they are supposed to call a pre-determined number of people (e.g. four or five), following a pre-prepared list until all intended persons are warned (Wattegama, 2007). Another technique refers to *dial out systems*, which means that a computer database of telephone numbers can be activated to deliver warning messages for certain areas. Dial out systems allow messages to be sent simultaneously to large numbers of individuals and can leave voice messages (Attorney-General's Department, 2009).

Another interesting flood warning service is used in England and Wales, where over 5.5 million properties are at risk of flooding (Environment Agency, 2011). Flood warnings are issued by the UK Environment Agency through an automated dissemination system called *Floodline Warning Direct*. This free service allows warnings to be sent by telephone, mobile, email, SMS text message or fax. Messages can be received in several languages, according to the subscriber's preferences when registering for the service. The advice message by phone or SMS is also complemented with several community-based methods, such as flood sirens, flood wardens, loud hailers and doorknocking. Moreover, warnings are broadcast on local radio and television and information on the Environment Agency's website is updated every 15 minutes (Environment Agency, 2011). As stated in Handmer

(2001) and Sene (2008), successful flood warnings should include both informal and formal sources of warning information, a true understanding between the public and the Civil Defence regarding the warning message and the functioning of the whole system, cooperation between the involved institutions, and identification of the local needs.

Several activities undertaken by the Civil Defence Centres of the Itajaí River Basin today seems to be promising. For instance, coordinators are aware of the need to have a multidisciplinary team, given that the Civil Defence performs numerous activities, from the mapping of risk areas to awareness-raising programs within the community. Both the Civil Defence of Blumenau and Itajaí are formed by professionals from different areas (e.g. Geology, Engineering), but the Civil Defence of Rio do Sul definitely lacks human resources. They not only need to employ more permanent staff, but also to provide a 24 hours service. Nevertheless, the smaller the municipality, the harder it is for them to attain financial resources for disaster management issues. Moreover, all Civil Defence Centres do not have hydrologists within their team, so that flood forecasts depend whether on other institutions like the CEOPS or on their own expertise and willingness to develop their own flood forecast systems.

As regards to the emergency response, the three Civil Defence Centres being studied have similar Contingency Plans, which would be put into action during the occurrence of a disaster. However, Civil Defence Centres have to make sure that the Plan is well updated and available to all entities of the GRAC. Furthermore, training programs should be executed not only with the GRAC's entities, but also with the population. As stated in Sene (2008), information technology can help in executing more realistic training exercises though the combination of multimedia simulations and animation of flooded areas in computer models of cities. Furthermore, Geographical Information Systems can assist during the planning phase to execute flood risk maps, and to analyse access routes, infrastructure and key services that might be affected by certain flooding (Sene, 2008). Some Civil Defence Centres of the basin, such as the Civil Defence of Rio do Sul, have already executed flood risk maps for different flood heights. However, in Brazil there is no standard to be followed in the creation of flood risk maps, so that each Civil Defence Centre executes them according to its knowledge and conditions, taking into account the existing cartography.

A good example in such context is the new European Floods Directive (Directive 2007/60/EC), which entered into force in November of 2007, specifically to standardize flood risk management among all European countries. The referred directive is based on three main pillars and countries have deadlines to implement each one of them: 1) preliminary flood risk assessment of European river basins and associated coastal zones, 2) development of flood hazard maps and flood risk maps for such areas, and 3) development of integrated flood risk management plans (Floods Directive, 2007).

The Floods Directive acts as a guide to the creation of flood maps and flood risk management plans. For instance, the directive states that flood hazard maps should be produced for three different scenarios (flood of low probability, medium probability or return period higher than 100 years, and high probability), and that some elements should be covered in these maps, such as the flood extent, the water level, and the flow velocity or the relevant water flow (Floods Directive, 2007). With reference to flood risk maps, they should present the number of inhabitants potentially affected, the type of economic activity potentially affected, the installations that can cause accidental pollution in case of flooding, and other useful aspects like the indication of areas where floods with a large amount of sediments can take place (Floods Directive, 2007). Lastly, as regards to

flood risk management plans, several elements should be included (preliminary flood risk assessment, flood risk maps, description of appropriate objectives for flood risk management, measures to accomplish the proposed objectives, and the methodology), as well as a description of the plan's execution. These plans should comprise all aspects of flood risk management, including flood forecasts and early warning systems (Floods Directive, 2007).

A deep review of the referred Floods Directive could support the activities that have been developed by Civil Defence Centres and by other institutions involved in flood risk management in the Itajaí River Basin. Also, a review of the recommendations of the World Meteorological Organization (WMO) could be useful for deciding whether to increase or not the number of monitoring stations in the basin. For instance, the WMO suggests as minimum network density 1 precipitation station for every 10-20 km^2 in urban areas and 1 station for every 250 km^2 in mountains (WMO, 2008).

Apart from the flood early warning system, several other measures can assist the work of the Civil Defence, such as temporary flood barriers, sandbags and pumping stations. These measures have been used in the city of Cologne, in Germany, which is the most flood affected city in Europe (STeB, 2012). For instance, high volume pumps are used to reduce water levels, and sandbags are provided to fill gaps in defences and to protect properties (Sene, 2008). Also, a lot of money was invested in the construction of flood walls, flood retention plains, measures underground, and in flood management. Although all these measures require time and financial resources, the "flood mobile walls" are worth analysing. These temporary and demountable barriers are placed at sites where flooding is expected, considering that a flood warning is received in advance (Sene, 2008). In the case of Cologne, the mobile walls are mounted for three different flood heights, taking into account the floods with return periods of 50, 100 and 200 years. As stated in Jha *et al* (2012), the walls are set up in less than 10 hours along a total extent of 9.5 kilometres of riverbank. Roughly 350 people are required for the loading, transportation and erection of the complete protection walls (Jha, Bloch, & Lamond, 2012). Yet, Cologne is only affected by river floods and not by flash floods, so that emergency managers have time to set such walls (Figure 40). In the case of the Itajaí River Basin, this would only be possible if the flood warning was issued at a certain time in advance.

Another interesting idea that could be used in emergency response is the concept of an event timeline. As mentioned in Sene (2008), the timeline relates the sequence of incidents, emergency calls, response actions and other facts that occur during an event like flooding. Timelines can assist other emergency responders through the access of real time information over secure websites (Sene, 2008). Also, computerized systems allow the register of occurrences from a wide range of institutions (e.g. Fire fighting, Military Police). The Civil Defence could further use the timeline to review the emergency actions taken and identify aspects to be improved. An example of the flood event timeline in the city of Cologne, Germany, is shown in Figure 41.

Figure 40 – Temporary flood walls being installed next to the Rhein River. Source: SteB, 2012.

8.30 m	**Flood mark II, closing of shipping**
8.20 m	construction of a protection wall of 265m in Porz-Zündorf, WDR terrain of "Anrheiner" are flooded
8.10 m	the promenade of the old city of Cologne starts getting flooded.
8.00 m	several gates in the channel are going to be activated; 22 flood pumps are in operation
7.00 m	The Big Flood Protection Centre Cologne will is going to institute depending on the water's increase (round-the-clock, in the headquarter: German Life Guard Association, police, German Federal Agency for Technical Relief and other authorities)
7.00 m	big gate programme in the channel; more than 250 measures have been taken including the installation of flood water cover lids, 12 flood water pumping works are in use, the big pumping works (e.g. near the exhibition centre) can deliver up to 15,000 m^3/h. First mobile walls are installed in the Rodenkirchener Auenviertel In Porz Zündorf they are flooding the Groove
7.00	**Flood stages IV: > 7.00 m > 10.70 m C. G.**
6.80 m	the vertical lift gate in Rodenkirchen (18 m long, 3.50 m high) has to be pulled up
6.70 m	the camp-sites in Rodenkirchen and Poll are affected and have to be cleared
6.50	**Flood stages III: >6.50 m - < 7.00 m C. G.**
6.30 m	the parking place near the Bastei is flooded
6.20 m	**Flood mark I, confinement for shipping (driving only in the middle, reduced speed)**
6.00 m	already 5 pumping works are in operation
5.75 m	the parking place near the Bastei starts getting flooded
5.50 m	Leinpfad which is flooded partially, has to be closed off
5.50	**Flood stages II: > 5.50 m - < 6.50 m C. G.**
4.50 m	Small Flood Protection Centre is going to institute and the first flood control measures in the channel are going to be realized, too
4.50	**Flood stages I: > 4.50 m - < 5.50 m C. G.**
3.21 m	**Mean water (10 years average of all water marks evaluated statistically)**

Figure 41– Example of the flood event timeline in Cologne. Source: SteB, 2012.

4 STAKEHOLDER'S PERSPECTIVES ON THE FLOOD EARLY WARNING SYSTEM IN THE ITAJAI RIVER BASIN

The Flood Early Warning System (FEWS) found in the Itajaí River Basin involves the performance of several institutions as discussed in Chapter 2. In brief, there are currently two telemetric networks functioning at the basin level: the SDS's network which is monitored by the CEOPS, and the ANA's network which receives maintenance from the EPAGRI. The DEINFRA monitors the three flood contention dams in the basin. The Itajaí River Basin Committee has defended the institutional structure of the FEWS for years. In addition, the Civil Defence of Santa Catarina (SDC) has recently put effort into a project which aims to amplify and strengthen the current FEWS in the basin.

Hence, the key stakeholders in the functioning of the FEWS of the basin are the following: SDS, CEOPS, ANA, EPAGRI-CIRAM, DEINFRA, Itajaí River Basin Committee, SDC, and Civil Defence Centres at Municipal Level (Blumenau, Rio do Sul and Itajaí). After identifying these key stakeholders, interviews were carried out with representatives of each one of these institutions during the months of April and May of 2012. The mode of survey used was face-to-face interviewing, except with the ANA's representative, who answered the questions through email. The identity of the interviewees is not revealed in this section, given that the opinion of a representative might be something personal and not necessarily indicative of the belief of the whole institution. In some cases, such as the interviews with the CEOPS and the EPAGRI, a few representatives answered the questions collectively. Furthermore, interviewees signed a document declaring they agreed the use of the interview for academic purposes (Annex 7.6). Also, it was made clear to interviewees that they were free to abstain from answering a question.

The interview questions were chosen to meet the four central aspects of the SWOT Analysis, which stands for the identification of Strengths, Weaknesses, Opportunities and Threats of a certain subject, through the holistic perspective of various stakeholders. The SWOT is a technique usually developed for the analysis of problems in the context of planning and strategies in institutions. According to Kauffman Gonzalez (n.d.), the SWOT analysis facilitates the assembly of a framework of the current situation regarding institutions, so that it is possible to execute a precise diagnostic, which can be used in decision making processes.

The recognition of strengths, weaknesses, opportunities and threats allows planners to take the required precautions to increment the strengths, diminish or eliminate the weaknesses, take advantage of opportunities, and to reduce the negative impacts coming from these threats (Kauffman Gonzalez, n.d.). Moreover, as stated in Huu Ti (2004), Terrado *et al* (2007), and Hashemi *et al* (2011), the SWOT Analysis is a useful tool for identifying problems and creating information for the formulation of future strategies. In this context, interviews based on the SWOT Analysis were used as a guide for the assessment of the current state of the flood early warning system in the Itajaí River Basin, and to outline future actions to develop an effective system. The results of such interviews are further discussed.

4.1 Strengths of the Flood Early Warning System in the Itajaí River Basin

With reference to the strengths of the flood early warning system, interviewees from several institutions (CEOPS, SDS, SDC, Itajaí River Basin Committee, and COMDEC of Blumenau) recognized the importance of the current system and the commitment of the CEOPS in executing flood forecasts. According to the CEOPS interviewees, the background of the CEOPS members (Meteorology and Hydrology), as well as the experience of more than twenty years in data monitoring and issue of warnings are indeed positive points in the existing system. As highlighted by the interviewee of the Itajaí River Basin Committee, it is remarkable that the operation of the flood early warning system takes place in the university (FURB), and is monitored by professors. The commitment of the FURB with the regional community, and the experience associated to flood management by regional entities, are definitely advantages. Also, according to the interviewee's point of view, the fact that such a system exists and that regional entities know each other and can work together is already an advance.

The SDC's representative gives merit to both the Itajaí River Basin Committee and the CEOPS for having structured the existing flood early warning system. The interviewee mentioned that, due to the large occurrence of flooding in the past, regional institutions have continued to monitor river level and to develop flood forecast models throughout the decades. Furthermore, the SDS's interviewee complements the CEOPS on the role it has played in communicating flood forecasts to the Civil Defence and providing useful information on the operation of the flood contention dams in the basin. However, both interviewees of the SDS and the SDC believe that the current system requires more investment and that much can be improved with the evolution of new technology.

Interviewees of Civil Defence Centres (COMDECs) also pointed out some strengths of the flood early warning system. Firstly, the representative of the Civil Defence of Itajaí raised the fact that the basin is relatively small and is located only within the boundaries of the state of Santa Catarina. According to the interviewee, flood risk management should be simpler if other federation's entities are not involved, but still depends on the unification of all COMDECs of the basin to strengthen the flood early warning system. Secondly, the representative of the Civil Defence of Rio do Sul mentioned that the communication via radio between the municipalities and the DEINFRA's dams has worked well during flood events. Lastly, the representative of the Civil Defence of Blumenau declared that the flood forecasts executed by the CEOPS are very reliable. The interviewee also praised the work of the CEOPS' members, who truly commit themselves during emergency situations and give the required information on river's level to the Civil Defence of Blumenau. Moreover, the interviewee comments on the current concern of the Civil Defence over executing accurate forecasts not only for river floods, but also for landslides and flash floods.

Both the interviewees of the DEINFRA and the CIRAM argued that for the first time there is a stronger cooperation between the institutions at state level, and that integrated models have been proposed as regards to flood risk management. Also, the CIRAM's interviewee highlighted the governmental support as a positive aspect of the current FEWS, since the government recently created the State Secretariat of Civil Defence (SDC) that is promoting a project for the enlargement of the hydrological network. In addition, CIRAM's representatives commented that several mayors want to buy monitoring stations and to participate in the FEWS, so that the demand for information on flood issues is presently large. Other CIRAM interviewees stated that many City Halls are hiring specialists on the subject to work in their Civil Defence Centres. According to the interviewee, the

recent personnel training in the Civil Defence is certainly a positive aspect. The interviewee explains that, in former times, employees of the Civil Defence changed every four years according to the governmental mandate and were therefore very vulnerable to Politics. Consequently there was no continuity in actions between the mandates and a lot of information was lost.

Finally, the ANA's interviewee listed several strengths of the flood early warning system in the basin, in terms of their hydrological network and not the one monitored by the CEOPS. For instance, the interviewee mentioned the modernization of monitoring, resources for the network's maintenance and the recent restructuring of the Civil Defence at national level as positive points. As regards to the modernization of monitoring, automatic stations were recently installed in the basin to monitor the flood conditions satisfactorily, through data transmission via satellite (GOES). The ANA's interviewee declared that 12 more automatic stations will soon be installed in the basin to meet the objective of modernizing the existing network. Another positive aspect is the guarantee of resources for the operation and maintenance of field equipment through a contract between the ANA and the EPAGRI-CIRAM. Furthermore, the ANA has put effort into assuring the continuous investments in equipments of monitoring, such as telemetric systems and sensors. Lastly, the interviewee points out the creation of the CENAD as a good aspect for flood early warning systems, since there is a better cooperation among the Civil Defence of the Union, State and Municipalities.

Some quotes extracted from the interview's transcriptions illustrate the standpoints of the institutions as mentioned above are presented in Table 10.

Table 10 – Quotes referred to the strengths of the flood warning system in the Itajaí River Basin.

INTERVIEWEES	STRENGTHS OF THE FLOOD EARLY WARNING SYSTEM
CEOPS	*"The quality of staff training and the experience of more than 20 years in the activity of monitoring and warning."*
Itajaí River Basin Committee	*"The fact that there is a lot of experience already associated with this; the fact that the FURB has this regional commitment."*
SDC	*"We do not start from scratch, because there is this track record of the FURB, the Itajaí River Basin Committee, as well as the SDS."*
COMDEC Blumenau	*"I see firstly the availability of the CEOPS' scientists, their commitment in emergency situations to give this information. It is a reliable system."*
COMDEC Rio do Sul	*"The Amateur Radio was the key point, which saved us in the lack of a better communication during the flooding of 2011."*
COMDEC Itajaí	*"Our basin is relatively small and it is a basin only at state level."*
SDS-DIRH	*"We cannot deny the importance of the current system, but it requires larger investments."*
DEINFRA	*"The positive point is that, due to the need, there is a strengthened cooperation."*

EPAGRI-CIRAM	*"The governmental support to have a monitoring network at state level, the integration of institutions working together, and the centralization of the information in only one place."*
ANA	*"Modernization of monitoring, resources for the network's maintenance and the recent restructuring of the Civil Defence."*

4.2 Weaknesses of the flood early warning system in the Itajaí River Basin

In regard to the weaknesses of the flood early warning system in the Itajaí River Basin, interviewees of four institutions (CEOPS, ANA, SDC and Itajaí River Basin Committee) highlighted the lack of institutional integration and coordination as a deficiency of the system. From the point of view of the ANA's interviewee, there is an evident need to improve the coordination of the institutions involved in data monitoring and actions of flood prevention. This is clearly shown by the fact that some municipalities of Santa Catarina began to install their own flood early warning systems, without much liaison with state and federal bodies. The interviewee of the Itajaí River Basin Committee stated that the flood early warning system does not have institutional support, the CEOPS monitors one hydrological network of the basin, but this is in fact a function of the State.

Interviewees of the SDS and the SDC said that another fragility of the system is the lack of an effective maintenance of the stations. The CEOPS' interviewees stated that there is no defined budget for this sector. For instance, at the moment the CEOPS does not receive any financial resources for the network's maintenance. However, the CEOPS' members strive to obtain such resources through other projects. Apart from that, three institutions (SDS, COMDEC of Rio do Sul, SDC) believe that more monitoring stations should be installed to improve the FEWS in the basin. The DEINFRA's interviewee pointed out that there is a lack of information regarding both the real-time situation and forecasts.

Moreover, both the representatives of the SDC and the COMDEC of Rio do Sul commented that the radar coverage in the basin is currently deficient. Radars can detect localized precipitations at a certain time in advance, so that they can help in forecasting flash floods. Also, the SDS's interviewee claimed that there is a need to invest more in the development of hydrological models for the basin. As stated by the representative of the Itajaí River Basin Committee, the great weakness of the current FEWS is that flood forecasts are executed only for the city of Blumenau. As explained in Chapter 3, the city of Gaspar can benefit from the flood forecasts for Blumenau, and the Civil Defence of Rio do Sul acts on its own with the development of forecast models for the city. Yet, most of the municipalities of the basin do not rely on flood forecasts.

Moreover, according to the interviewee from the COMDEC of Blumenau, the CEOPS is a centre for studies and research, and not really a flood forecast centre itself. Although the CEOPS develops such forecasts, there is a need to have a constant 24 hour service. The ANA's interviewee adds that the university, through the CEOPS, can contribute enormously with modelling, calibration of models or testing sensors and equipments, but that their potential should not be spent on the permanent monitoring of extreme events.

The interviewee from the COMDEC of Blumenau remarked on other deficiencies of the current FEWS. From the interviewee's standpoint, sub-basins of municipalities like Blumenau should be monitored through sensors or limnimetric scales, especially for the case of torrential events. As stated by the interviewee, it is not enough to work only with the Itajaí-Açu River to define the flood conditions in Blumenau. Lastly, the interviewee stated that there are sensors of several institutions (ANA, CIRAM-EPAGRI, CEOPS and CELESC) placed at the Itajaí-Açu River. However, this monitoring occurs in an uncoordinated manner, in which sensors are placed to meet exclusively the needs of the institutions to which they belong. For instance, the CELESC is interested to know about the water quantity for energy power, whereas the ANA registers the river's level and the river's flow. From the interviewee's point of view, it would be easier to have coordination and share such information, so that fewer sensors would be required at the same point in the river.

Furthermore, interviewees of three institutions (CIRAM-EPAGRI, SDC and COMDEC of Itajaí) criticized the vulnerability of the current transmission system (mobile phone via GPRS) used in the monitoring network of the SDS. The interviewees commented that the telemetric system did not work during the floods of 2011. Also, the CIRAM's interviewees stated that the transmission through GPRS is compromised in peripheries and cities further away where the signal from the antenna is weak. In addition to this, during flood events, the system is usually overloaded due to the excess of people using the signal through mobile phones and due to the heavy clouds. They believe that the data transmission is certainly a fragile aspect of the current system, which might also derive from the lack of specific resources for maintenance.

Another weakness pointed out by some interviewees (SDS, COMDEC of Itajaí and SDC) refers to the communication mechanism between the involved institutions in monitoring and forecasts, and the Civil Defence. The representative of the COMDEC of Itajaí argues that Civil Defence Centres cannot dispute information (river levels, precipitation, etc) through websites with ordinary citizens. The information has to be firstly delivered to the COMDECs, so that they can release official bulletins and instructions to the population. This is also important to avoid speculations from the media and divulgence of non-official information. In this context, the interviewee believes that the possibility of having two parallel communication networks should be considered, one for the population and another restricted to the Civil Defence.

The SDC's interviewee pointed out other deficiencies of the flood early warning system: the poor monitoring and operation of the dams, and the lack of maps of risk areas regarding most municipalities of the basin. Besides the interviewee mentioned that just a few municipalities have Contingency Plans, such as the ones shown in Chapter 3, so that the lack of implementation of these plans is certainly a deficiency. Furthermore, the CIRAM's interviewees mentioned the need to have integrated actions in the basin. The interviewees brought attention to the case of the channel built in the 1960s in the Itajaí-Mirim River. The channel solved at the time the problem of flooding in the city of Brusque, but consequently the rapid runoff became a problem for the downstream cities like Itajaí.

Table 11 illustrates some quotes demonstrating the points of view of the interviewees, as regards to the weaknesses of the current flood early warning system.

Table 11 –Quotes regarding the weaknesses of the flood warning system in the Itajaí River Basin.

INTERVIEWEES	WEAKNESSES OF THE FLOOD EARLY WARNING SYSTEM
CEOPS	*"The lack of a defined budget for the sector."*
Itajaí River Basin Committee	*"It is a flood early warning system only for Blumenau, but the system should be for the entire basin."*
SDC	*"Lack of institutional integration, stations without effective maintenance, uncoordinated monitoring networks, vulnerable system of data transmission, deficient radar coverage, etc."*
COMDEC Blumenau	*"The CEOPS is a centre for studies and research, and not really a flood forecast centre itself. For example, the professor is in the classroom, so it is a weakness of the system"*
COMDEC Rio do Sul	*"Few monitoring points and a lack of radar. I believe that in terms of investment and return, radars and monitoring stations are the best cost-benefit option, better than large works and dams."*
COMDEC Itajaí	*"The matter of data transmission and the communication mechanism between the institutions."*
SDS-DIRH	*"It is necessary to increase the number of monitoring stations and to invest in the development of hydrological models."*
DEINFRA	*"The lack of information regarding the real-time situation and forecast"*
EPAGRI-CIRAM	*"The data transmission is a considerable weakness, maybe this is due to the lack of specific resources for this matter."*
ANA	*"The lack of integration (procedures and systems) among the involved institutions."*

4.3 Opportunities of the flood warning system in the Itajaí River Basin

Interviewees of three institutions (SDS, COMDEC of Blumenau and COMDEC of Itajaí) indicated that the recent governmental support is a great opportunity for improving the flood early warning system in the Itajaí River Basin. According to the SDS's representative, governments at both state and federal levels are dealing more responsibly with the matter of natural disasters, maybe due to the pressure placed on them by the population. The spokesperson of the Civil Defence of Blumenau believes that the government's concern refers to the importance of the basin in the state of Santa Catarina. Twenty percent of the state's population live in the Itajaí River Basin and 25% of the state's revenues come from there. The interviewee adds that if there is governmental support to invest in flood prevention, municipalities should profit from this to improve their flood early warning systems. As mentioned by the representative of the Civil Defence of Itajaí, governors are worried by the fact that natural disasters have occurred very often, and therefore the financial resources and political

will should finally be put together to invest and maintain the FEWS. Apart from that, the interviewee highlights as an opportunity, the evolution of the Civil Defence within the entities of the Federation.

The CIRAM's interviewees believe that there are several opportunities to improve the FEWS at the moment. For instance, the latest increase of extreme events due to climate change can be a threat and an opportunity at the same time. It is an opportunity in the sense that there is a strong motivation, including political, to the extent that resources are released to this area (e.g. densification of stations, development of hydrological models connected to the meteorological ones). Furthermore, the interviewee mentioned as an opportunity the fact that physical works are being set as a priority in the list of governments at local, state and federal levels. Also, at the moment mayors feel more pressed to implement Master Plans and to define areas for specific land uses. According to the CIRAM interviewee, such plans used to exist only on paper, but now mayors are putting in an effort to implement Master Plans. Moreover, from the viewpoint of the CIRAM interviewees, the definition of public policies plays an important role in this issue. As mentioned before, the federal government provides funds to the municipalities for the construction of dwellings only in areas that are not at risk. This obliges municipalities to do the survey of risk areas and to control the occupation of irregular areas.

The interviewee of the Civil Defence of Rio do Sul claimed that the purchase of radars and monitoring stations should improve significantly the flood early warning system in the basin. For the representative of the Committe of Itajaí, the latest interesting action was the installation of the 10 monitoring stations by the National Water Agency (ANA), as the state government has not assumed the responsibility so far. Another opportunity mentioned by the interviewee was the Regional Forum of Disasters Prevention, which took place in May of 2012 in the Regional University of Blumenau (FURB). The first meeting of the forum aimed to discuss the existing flood early warning systems in the basin and the ones being installed by municipalities. The idea is to join the municipalities of the basin, in order to share information (e.g. networks, flood risk maps) and to understand their local needs and expectations. Unfortunately, however, only 10 out of 53 municipalities attended this first meeting.

An interesting opportunity highlighted by the ANA's interviewee is the implementation of a Situation Room for the state of Santa Catarina with the support of the National Water Agency. Situation rooms refers to centres where the main stakeholders come together to make decisions when a disaster strikes. According to the interviewee, the state will this year receive the equipment required for mounting such a structure. Also, the Situation Room of Santa Catarina will be connected to the situation rooms of the ANA, CEMADEN and CENAD. In this context, the ANA is working on the improvement of the computational systems for the collection, treatment and diffusion of real-time data, in order to have a friendlier and more efficient system embedded in the Situation Rooms.

The DEINFRA's interviewee focused on the report titled "Prevention and Mitigation of Disasters in the Itajaí River Basin" as an opportunity, developed in 2010 by the Japanese International Corporation Agency (JICA). The JICA's report proposes several flood prevention measures for the Itajaí River Basin, such as heightening of dams, widening of rivers, dykes, flood gates, etc. All proposed measures are budgeted at R$ 2 billion. However, the Brazilian government itself should provide the required financial resources in case of implementing such measures.

Interviewees of the CEOPS and the SDC indicated as an opportunity the project being promoted by the Civil Defence of Santa Catarina (SDC) for the amplification and strengthening of the flood early

warning system in the Itajaí River Basin. This project was initially based on the JICA's report, which proposed as a non-structural measure for flood prevention the restructuring of the warning system for river floods and the implantation of a warning system for landslides and flash floods. The SDC reformulated the JICA's proposal and enlarged the budget (from R$ 8 to 25 millions) designated to the flood early warning system. According to the SDC's interviewee, several actions were added to the JICA's proposal, such as the mapping of risk areas and the acquisition of a meteorological radar. Also, in contrast to the JICA's proposal, the SDC's project will not deal separately with the warning system for landslides and those for floods. This project involves the work of several institutions at the state level (SDC, SDS, CIRAM, DEINFRA and CIASC) and the participation of universities (FURB and UFSC). In the future the City Halls and the Itajaí River Basin Committee will also be involved.

The main objective of this project is to restructure the flood early warning system of the Itajaí River Basin for flash and river floods, and landslides, by providing an integrated and reliable system which is operated 24 hours a day. To meet this goal, the project has eight main targets (SDC, 2012):

1) The Creation of the Operational Plan of the Flood Early Warning System in the Itajaí River Basin, which aims to define clearly the responsibilities of the institutions involved in the system.

2) To draw up the Contingency Plans for the 53 municipalities of the basin. Each municipality should be in charge of its own contingency plan, but the SDC will provide training and workshops to help the creation.

3) The Mapping of Risk Areas (flash and river floods, and landslides) of the 53 municipalities. The cartographic basis of the SDS will be used for the production of risk maps.

4) The Consolidation of the Hydrometeorological network by integrating all existing networks (SDS, EPAGRI-CIRAM, ANA, DEINFRA and municipalities). Furthermore, 53 hydrological stations are likely to be installed in the basin. At some places in the basin, the system will also have redundant measurement through radar sensors, pressure sensors and transmission via satellite to assure the back-up of information.

5) The Purchase and Operation of the Meteorological Radar, which will provide very short-term weather forecasts. Although short-term weather forecasts are more important for landslides and flash floods, these data will also be put into hydrological models for river floods.

6) The Development and Implementation of Operational Models for meteorological forecasts, river and flash flood forecasts, landslide forecasts, and the operation of dams. For this target, the SDS aims to employ consultants in hydrology and information technology and the EPAGRI might promote a public tender to hire more hydrologists. Also, the SDC might hire an outsourced company to develop the models and insert them in the structure of the EPAGRI, as explained by the SDC's interviewee.

7) The Structuring of a Centre for Monitoring and Forecasts, which will be located at the EPAGRI-CIRAM.

8) The Structuring of a Centre for Warning and Disaster Management, which will be placed at the SDC.

The Figure 42 shows the structure of the proposed flood early warning system. The idea is to follow the same scheme of the CENAD and the CEMADEN at federal level, so that the CIRAM would execute the forecasts and the SDC would issue the warnings. The CIASC would provide the systems of information, software, radios. A Situation Room will integrate the DEINFRA and the SDS too, and at the same time the SDC will have a 24h room with a redundant system of transmission and energy to assure the robustness of the system. As explained by the SDC's interviewee, the same structure will be provided for three Regional Centres of the Basin (Rio do Sul, Blumenau and Itajaí), which will be connected to all COMDECs and the population through the internet. As stated in the project, the implementation of the actions mentioned here should be accomplished within 18 months and with a total cost of roughly R$ 25 million (SDC, 2012).

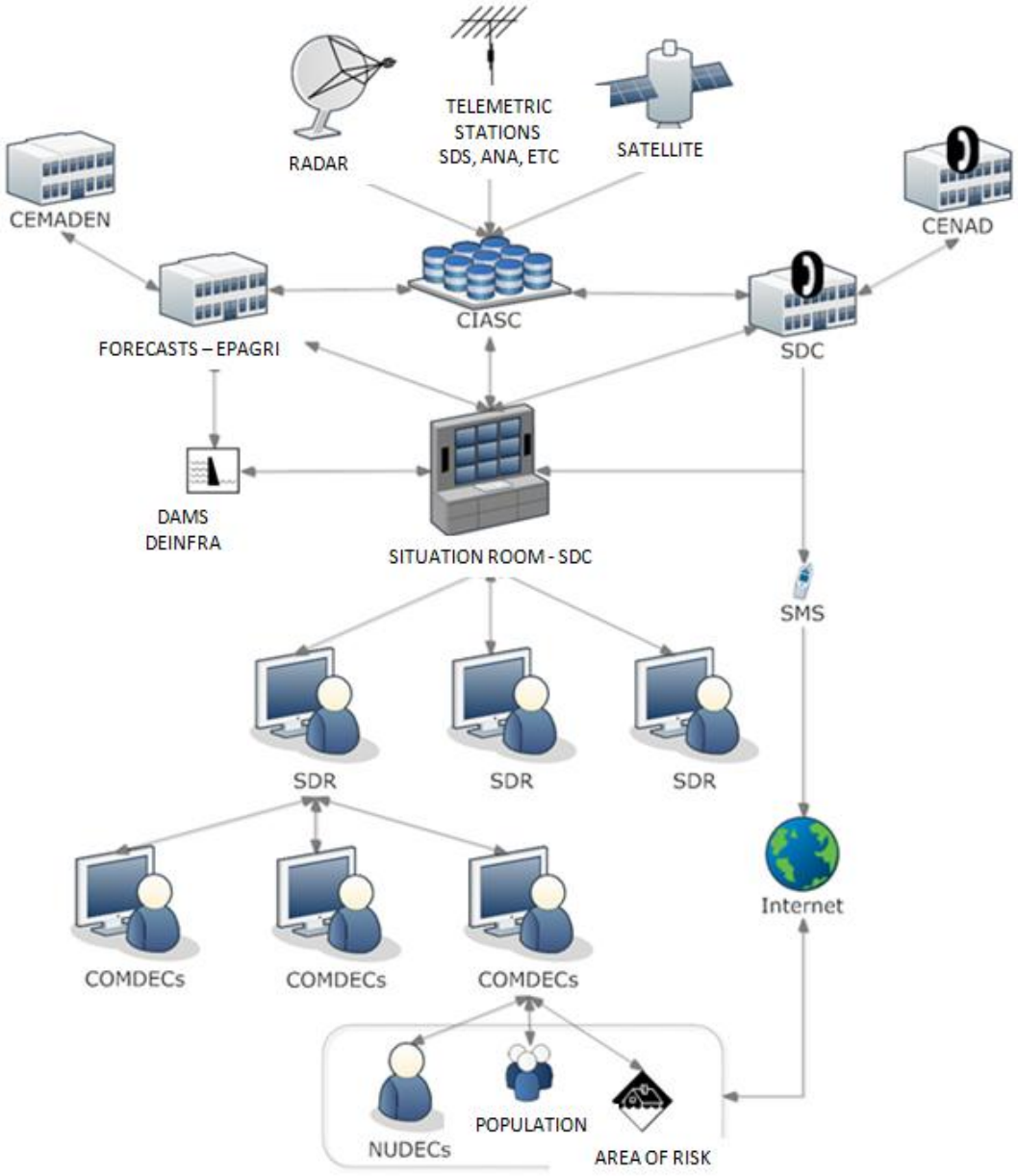

Figure 42 – Structure for the FEWS proposed in the SDC's project. Source: SDC, 2012.

Quotes extracted from the interview's transcriptions show the points of view of the institutions involved in the current flood early warning system, as presented in Table 12.

Table 12 –Quotes about the opportunities of the flood warning system in the Itajaí River Basin.

INTERVIEWEES	OPPORTUNITIES FOR THE FLOOD EARLY WARNING SYSTEM
CEOPS	*"The state's project for the monitoring of the Itajaí River Basin, which has been implemented by the SDC, is a good opportunity."*
Itajaí River Basin Committee	*"The idea of this Regional Forum is to have a request from the bottom, with all municipalities together"*
SDC	*"I believe that the great opportunity is this project for the development and strengthening of the flood early warning system of the Basin."*
COMDEC Blumenau	*"Municipalities should ride on the back of this State's governmental support and improve their flood early warning systems as well."*
COMDEC Rio do Sul	*"The affair of radars and monitoring stations improves the flood early warning system a lot."*
COMDEC Itajaí	*"I think that now financial resources and political will are finally together in this regard."*
SDS-DIRH	*"Governments at state and federal levels have finally wised up to the matter of natural disasters"*
DEINFRA	*"The JICA that has studied the basin since the flooding of 1983 and has proposed several measures to solve the problems."*
EPAGRI-CIRAM	*"Today mayors feel under pressure to occupy proper areas of occupation, which gives rise to the implementation of Master Plans."*
ANA	*"Implementation of the Situation Room in the state of Santa Catarina, in the same mould of the ANA."*

4.4 Threats to the flood early warning system in the Itajaí River Basin

Interviewees mentioned many threats to the proper functioning of the flood early warning system (FEWS) in the Itajaí River Basin. For instance, the SDC's interviewee believes that although there is this great opportunity to improve the FEWS through their project, the SDC depends on several institutions to actually make the system work. The interviewee described that a threat is the fact that without the required financial resources and the employment of specialists, such a project could be compromised. From the standpoint of the SDS's interviewee, one threat could be the issue of maintenance and continuity of the system. The interviewee explains that institutions have put a lot of effort into developing the new project, as well as to organize the biddings and purchase of a new

radar. However, future governments have to be aware of the costs related to the system's maintenance to provide a long-term functioning of the system.

Likewise, the CIRAM's interviewees mentioned political interference as a threat, because this might hinder the continuity of projects that have been developed. They say that with every change of mandate, the government creates new institutions and changes secretaries, without analysing deeply the segments of the State. Consequently there is an overlap of duties and therefore financial resources are diluted among institutions. The interviewees believe that these resources should be instead concentrated on only one institution which they feel would provide a more detailed, long-term work. The interviewees also indicated the governmental bureaucracy as a great threat for the functioning of the flood early warning system, since the process for the release and application of financial resources through biddings is very slow.

The ANA's interviewee believes that a threat to the FEWS is the lack of focus from the government to clarify the attributions among the SDS, FURB and the CIRAM. Furthermore, the interviewee stated that the Itajaí River Basin Committee should promote more integration within the society and not divergence among the institutions. On the other hand, the interviewee of the Committee of Itajaí declared that the SDC is the greatest threat today, since they are executing a new project independently from what has already been accomplished in the basin. As for the DEINFRA's interviewee, he believes there are currently no threats to the correct functioning of the FEWS in the basin.

The interviewee of the COMDEC of Rio do Sul criticized that some institutions like the DEINFRA keep investing in data transmission through mobile phones, even though this technology has failed during previous flood events. The interviewee believes that the choice of technology should definitely be rethought, as the radio system appears to be more efficient than mobile phones. The representative of the COMDEC of Itajaí highlighted the lack of equal treatment between the municipalities as a threat and stated that the basin should be understood as a whole and not as individual parts. Also, the interviewee of the COMDEC of Blumenau stated that the population's lack of concern is definitely a problem, at least in Blumenau. Even if inhabitants are aware of the risks of floods or landslides in certain areas, some of them still occupy these areas. Although the Civil Defence has a team for the inspection of occupation in irregular areas, it is not yet enough to cover the entire city.

Another potential threat according to the interviewee of the COMDEC of Blumenau is the lack of investment. The interviewee gave the example of the ALERTABLU, which is a project budget at R$ 12million to execute a warning system for flash floods and landslides only for the city of Blumenau. However, the project was not approved by the CENAD at federal level, so that the City Hall is trying to finance the project with municipal resources. The ALERTABLU foresees the installation of 25 pluviometric stations in the city of Blumenau. The data would be transmitted every 15 minutes via radio and via GPRS as a redundant system. They would also use the information from the meteorological radar which is being purchased by the SDC. With these data, nowcasting weather forecasts in high resolution would be executed in an Operation Centre, which would be located in the Civil Defence of Blumenau and would provide a 24 hours service. The CEOPS' interviewees mentioned as a threat exactly the fact that the ALERTABLU's project and the SDC's project might not include the participation of the CEOPS/ FURB in the planned activities.

Quotes from the transcriptions are shown in Table 13, in order to illustrate the different standpoints of the interviewees regarding the threats to the flood early warning system in the Itajaí River Basin.

Table 13 –Quotes regarding the threats for the flood warning system in the Itajaí River Basin.

INTERVIEWEES	THREATS FOR THE FLOOD EARLY WARNING SYSTEM
CEOPS	*"The SDC's project and the ALERTABLU might not accept the participation of the CEOPS/FURB in their programming."*
Itajaí River Basin Committee	*"The great threat today is the State Secretariat of Civil Defence that is executing a new project regardless of what has already been done."*
SDC	*"We really depend on many institutions to make the system work, thus the threats surely increase."*
COMDEC Blumenau	*"The lack of investment. The lack of concern of the population, even if they know about the risk, they occupy these areas."*
COMDEC Rio do Sul	*"Investments in mobile phone, I think that everything should be changed to radio to assure that the system will work."*
COMDEC Itajaí	*"There are still great restrictions in giving an equal treatment to the municipalities and considering the basin as a whole."*
SDS-DIRH	*"We hope that future governors provide resources for the system's maintenance, otherwise the system will end scrapped and we will go back to square one."*
DEINFRA	*"There are no threats; sometimes there are some personal interests in the path, but nothing that is not manageable".*
EPAGRI-CIRAM	*"The governmental bureaucracy, the laws that hinder the application of financial resources."*
ANA	*"The lack of focus from the political part as regards to the clarification of roles among the SDS, FURB-CEOPS and EPAGRI-CIRAM."*

4.5 Evaluation of the flood early warning system in the Itajaí River Basin

The evaluation of the existing flood early warning system in the Itajaí River Basin is presented in Figure 43, taking into account the perspectives of all interviewees. Although all aspects documented in Figure 43 have already been commented on, it is worth analysing some of them further. For instance, some interviewees complained about the transmission of data via GPRS as it did not work during the flood event of 2011. However, members of the CEOPS explained that the transmission failed due to a problem in the software used in the telemetry and not due to the cellular's technology itself. The SDC's interviewee mentioned that they should have had a back-up system to assure the data transmission in extreme events. Yet, the CEOPS depend on financial resources from other institutions for the installation and maintenance of monitoring networks. Furthermore, at the

moment there is not a specific budget for the maintenance of the SDS's network, which might compromise the functioning of the referred network.

As regards to the ANA's network, the ANA has an agreement with the EPAGRI-CIRAM for the maintenance of the hydrological stations. However, as described in Chapter 2, at the time of these interviews, the CIRAM had only one employee executing the maintenance of conventional stations in the entire state and no one for the automatic stations. Nevertheless, they were putting effort into hiring more employees through a public tender or through a contract with an outsourced company. Apart from that, interviewees of some institutions commented that today it is not very expensive to buy monitoring stations, but the challenge is to obtain financial resources to provide a long-term maintenance of the system.

Another weakness mentioned by several interviewees is the fact that flood forecasts are executed only for Blumenau. However, a member of the CEOPS explained that other City Halls have not so far proposed partnerships with them. As a result, their work is indeed focused on the city of Blumenau. Also, the interviewee highlights that forecasting floods is a difficult task. Models can give errors of 1-2 meters, so that one needs to evaluate the results and have sensitivity in the model. In this context, flood forecasts require not only time and data, but also experience from the ones who run the models. Apart from that, the recent Forum for Disaster Prevention promoted by both the FURB and the Itajaí River Basin Committee was an attempt to bring together the municipalities of the basin and share the information concerned with flood early warning systems. Yet, only a few municipalities participated in the forum, which also shows the lack of involvement on behalf of the City Halls in activities at the basin level.

All interviewees believe that there is a good communication between the involved institutions in the flood early warning system, or at least with some of them. For instance, the interviewee of the COMDEC of Rio do Sul commented that the CIRAM and the SDC usually call directly to their mobiles in cases of warnings of extreme events. The SDC's interviewee highlighted that the communication channel has improved a lot, but that the base is not yet integrated. For example, the CEOPS's data are not yet shared with the EPAGRI-CIRAM. The ANA's interviewee mentioned that the data from the ANA's stations can be accessed on the internet by the involved institutions (EPAGRI, SDS, FURB, DEINFRA and Civil Defence).

With reference to the efficiency of the flood early warning system in the Itajaí River Basin, 40% of the interviewees categorized the system as efficient. Some of the interviewees believe that the FEWS is efficient as it is often used as a benchmark by other cities in Brazil. Others point out the reliability of the system since its implementation in 1984. 10% of the interviewees classified the FEWS as regular, given that flood forecasts are executed only in large centres like Blumenau. Furthermore, 40% of the interviewees stated that the FEWS is unsatisfactory due to several reasons, such as the lack of monitoring stations, hydrological models and maps of areas at risk. Also, they commented that the population is not trained to act during extreme events, so that contingency plans still need to be effectively implemented. Lastly, 10% of the interviewees mentioned that the system's functioning ranges from regular to efficient according to the features of the occurring hydrological event. They also commented on the need to have a continuous coordination among the areas of Meteorology, Hydrology, Operation of Dams and the Civil Defence in the Itajaí River Basin. However, they pointed out the work of the SDC as a promising action to achieve the integration and communication among the institutions involved.

Strengths

- Commitment of the CEOPS-FURB;
- More than 20 years of experience;
- Previous work of the FURB, Committee and SDS;
- Reliable system for Blumenau;
- Relatively small basin;
- Communication via radio;
- Strengthened cooperation at state level;
- Creation of the State Secretariat of Civil Defence (SDC);
- Specialists in Civil Defence Centres;
- Involvement of Mayors;
- Modernization of the ANA's network;
- Resources for the maintenance of the ANA's network;
- Creation of the CENAD at federal level.

Opportunities

- Governmental support;
- Financial resources for flood issues;
- Media focus to Climate Change;
- Evolution of the Civil Defence;
- Implementation of Master Plans;
- Definition of Public Policies;
- Purchase of the meteorological radar and monitoring stations;
- Implementation of the ANA's stations;
- Regional Forum of Disaster Prevention;
- Situation Room for Santa Catarina;
- Improvement of computation systems of the ANA;
- JICA's proposals;
- SDC's project for the amplification and strengthened of the warning system.

Weaknesses

- A lack of institutional integration;
- Uncoordinated networks;
- A lack of an effective maintenance;
- The need to install more stations;
- Deficient radar coverage;
- The need to invest in hydrological models;
- Flood forecasts only for Blumenau;
- The need to have a 24 hours service;
- Lack of information-sharing;
- Data transmission via GPRS;
- Communication mechanism between institutions;
- Poor monitoring and operation of dams;
- A lack of maps of areas at risk;
- Few contingency plans in the basin;
- Disintegrated actions in the basin.

Threats

- Several institutions involved;
- Financial resources;
- Continuity of the system through changes of governmental mandates;
- Political interference;
- Governmental bureaucracy (biddings);
- A lack of focus in the attributions among the SDS, FURB and CIRAM;
- Misguided investments in mobile phones;
- State Secretariat of Civil Defence (SDC);
- A lack of equal treatment to the municipalities of the basin;
- The population's lack of concern about the flood and landslide risks;
- Exclusion of the CEOPS from the ALERTABLU and SDC projects.

Figure 43 – SWOT analysis according to the interviews with the involved stakeholders.

5 CONCLUSIONS

Although the flood early warning system in the Itajaí River Basin is often used as a benchmark by other Brazilian cities, there are important issues that remain to be solved in order to assure its optimal functioning. At the moment there is not an effective and integrated flood early warning system at the basin level. Instead, there are only a limited number of actions carried out independently in the largest cities of the basin. Proof of this is that the three Civil Defence Centres (Blumenau, Rio do Sul and Itajaí), which were analysed at local level during this work, use data from distinct monitoring networks and have different methods for forecasting an oncoming flood. Moreover, the flood conditions of most municipalities of the basin are not being monitored and even less forecasted.

Considering the key components established by the UN/ISDR (2006), the existing flood early warning system for the Itajaí River Basin fails in all aspects. As regards to Risk Knowledge, most municipalities do not have maps of flood risk (SDC, 2012). The state government, or municipalities, should propose partnerships with universities or hire private companies to produce these maps. Another option would be to employ geologists within the team of Civil Defence Centres, as appears to be working well in Blumenau and Itajaí. However, administrators of City Halls do not often have this culture of disaster prevention and consequently they do not feel that money should be invested in the execution of flood risk maps by outsourced companies or by hiring specialists to work in the City Hall. Furthermore, the Municipal Civil Defence Centres alleged that resources from the federal government are usually meant for the response to disasters and rarely for the prevention stage.

As regards to Monitoring and Warning, there is clearly a need to increase the network coverage, especially for the monitoring of flash floods. The SDS's network counts with only 16 points of monitoring for the entire area of the Itajaí River Basin (roughly 15,100 km^2). However, several monitoring stations are being purchased by institutions like the DEINFRA, ANA, SDS and EPAGRI. Even so, one of greatest fragilities of the current system is the lack of financial resources for the maintenance of stations. Thus, it is crucial that institutions have in mind the costs associated to maintain these stations in the long-term and avoid the occurrence of abandoned stations.

With reference to Dissemination, Civil Defence Centres in the Itajaí River Basin warn the population mainly through the radio and television. They also have telephone lines to provide information to the population. In addition, the Civil Defence of Santa Catarina has successfully used social media (e.g.Twitter) to disseminate flood warnings and information about local conditions. These methods clearly have the potential to warn a broad population in a rapid fashion. Yet, they can be disrupted by power cuts or network failures during flood events. Also, the effectiveness of some methods (e.g. television, radio) might be compromised at night when the media are switched off. Hence, it is important to combine several methods to assure that all individuals receive the warning. For instance, sirens and loud hailers in communities at risk should complement warning messages delivered by mass communication systems. In addition, the creation of standard messages, such as the Protocol Alert being developed by the Civil Defence of Itajaí, is an important strategy to assure that accurate information is published by the media.

Regarding Response Capability, most of the municipalities of the basin do not have Contingency Plans and consequently are usually unprepared when a disaster strikes. These Plans are essential for the definition of activities that should be executed by emergency responders. Contingency Plans also define official shelters for the evacuation of the population. The Civil Defence of Blumenau and Rio do Sul have similar Contingency Plans which appear to be effective according to the size of the event. There is not a standard for the production of such plans, but the idea of the Civil Defence of Rio do Sul to include an Annex entirely designated to the Flood Early Warning System could be suggested in other municipalities.

In the author's opinion, the project being proposed by the SDC, together with other state institutions (DEINFRA, CIRAM, SDS and CIASC) seems to be indeed a good opportunity for the improvement of the current FEWS. In this project interesting ideas will be implemented, such as the placement of a situation room in the SDC. Situation rooms have also been previously proposed in meetings of the Itajaí River Basin Committee. These situation rooms are essential in decision making processes, since it functions as a centre for disaster risk management by putting together the main stakeholders during critical events.

The SDC's project would meet most of the needs of the current system. The project includes the purchase of a meteorological radar and at least another 53 monitoring stations in the basin (one in each municipality). This would help in the monitoring of flash floods and landslides, which is currently very deficient in the Itajaí River Basin. In addition, they plan to create a common database among the partner institutions, so that the information concerned with the hydrometeorological network would be shared. It is very important that they include aspects like "last maintenance" and "responsible agency" in the database, in order to control the maintenance of the stations throughout the years and to avoid the abandonment of stations in the basin.

A great weakness of the current flood early warning system for the basin is the fact that flood forecasts are executed only for Blumenau and Rio do Sul. In this context, the SDC's project envisages the development of new models for flash and river flood forecasts for several cities of the basin. They aim to develop warnings 6 hours in advance for flash floods and 8 to 12 hours in advance for river floods (SDC, 2012). It is essential that they hire an outsourced company for the execution of these models to speed-up the process. Moreover, models can give significant errors, so it is extremely important to have experienced professionals to add their knowledge when executing flood forecasts. They should propose a long-term partnership with the CEOPS for advisory services and perhaps the training of hydrologists expected to be employed by the EPAGRI-CIRAM.

The Civil Defence Centres of Rio do Sul and Itajaí emphasized that the telemetry via radio has been working more satisfactorily than mobile phone via GPRS. The SDC's project plans to use data transmission via radio and via satellite GOES (ANA's network). Also, the telemetry via GPRS will be considered at sites near large cities to reduce costs with data transmission (SDC, 2012). It is essential to transfer warning information through more than one telemetry system to assure there is a back-up for the correct functioning of the FEWS.

The SDC's project is indeed very ambitious as they expect to implement all the eight targets mentioned in Chapter 4 in only 18 months, but if put into practice, it would be the most promising action for the improvement of the current FEWS. Also, this project involves the joint work of several institutions at state level (DEINFRA, SDC, SDS, EPAGRI-CIRAM), which might be evidence of an improving understanding and communication among the institutions. However, the Itajaí River Basin

Committee should also participate in this new project. According to the legislation (Decree n.3426 of 1998) from which the Committee was created, they should promote the joint work of the intervening entities related to water resources in the basin, and follow the activities of operation, maintenance and warning of the flood contention system of the basin (Santa Catarina, 1998).

Furthermore, most of the institutions involved in the flood risk management of the Itajaí River Basin are public institutions, and therefore are very vulnerable to governmental changes. The government often creates new Secretariats or Departments and attributes similar competences to institutions, which hinders not only the clear understanding of the role of each institution, but also the continuity of actions throughout the years. For instance, although the current state government is giving support for the execution of projects for disaster risk management, future governors have to be aware of the costs of maintaining such systems in the long-term. Moreover, it would be interesting to have a law specifically for flood risk management in the state of Santa Catarina, where the competences of all stakeholders would be found in the same document. Clearly the document would have to be regularly updated and should contain the detailed responsibilities of every institution. Also, all criteria and recommendations for the execution of flood risk management plans and flood risk maps could be included in the law, as it occurs in the European Floods Directive (2007). However, Brazil has many laws which would be beneficial, but have no effect due to the lack of legislation enforcement in the country.

Another challenge for the current FEWS is governmental bureaucracy. In Brazil public institutions have to execute bids to hire services or to purchase products. This process could be sped-up by employing private companies for certain activities and therefore avoiding problems such as the lack of maintenance of the stations, which can compromise the functioning of the FEWS during flood events.

Moreover, some of the laws studied in this work, such as the Decree n.5376/05 of 17.02.2005, do not seem wholly realistic. Many competences are designated to the COMDECs at municipal level, but most of these institutions are formed by only one person. It is unfeasible to expect this one person to execute all competences stated in the law. For instance, the COMDECs should inspect buildings in areas at risk, create and implement contingency plans, vulnerability and risk maps, as well as increment activities of monitoring and warning to optimize forecasts. Also, they should promote the participation of communities and organize shelters for the evacuation of the population. The responsibilities of the COMDECs involve all stages of disaster risk management, but to actually achieve this, they certainly need a multidisciplinary team with a sufficient number of qualified employees.

In addition, the work developed by the COMDECs depends significantly on the dedication of their coordinators and the financial resources available in the cities. For instance, the COMDEC of Itajaí has evolved notably in only a few years. They have recently implemented their own flood early warning system with municipal resources. They hired ten employees to increase their team and have executed maps of flood and landslide risk. As regards to the COMDEC of Rio do Sul, although they lack human resources, the coordinator has managed to develop a method for forecasting floods alone and has also created a Decree with the delimitation of areas at risk in the municipality. However, during disasters, the COMDEC of Rio do Sul is not able to run models for flood forecasts, at the same time as executing response activities (e.g. mobilization of shelters for evacuation, distribution of donations) because they have only three employees.

The Civil Defence of Blumenau has a well structured team that includes support from the CEOPS for monitoring and flood forecasting, as well as from the Geology Secretariat for the identification of areas at risk. Also, they are currently assembling financial resources for the development of the ALERTABLU, which would provide better monitoring and forecasting of flash floods and landslides for the city of Blumenau. However, municipalities like Blumenau and Itajaí have large populations and play an important role in the economy of the state, so that financial resources and the development of activities might be enabled with the support from the City Hall. On the other hand, the smaller the municipality, the more difficult the attainment of financial resources for disaster management issues is.

The involvement of the population is a key aspect for the optimal functioning of flood early warning systems. The population should know how to act during disasters and should adopt behaviour that reduces risk. Unfortunately many inhabitants occupy hillsides or vulnerable areas, even if they are aware of the risks. The Decree n.5376/05 of 17.02.2005 brings the interesting concept of NUDECs, which work as centres that host reunions and debates between the COMDECs and local communities to promote and coordinate the activities of the Civil Defence at local level. Although some initiatives have been taken to implement NUDECs in the cities of Blumenau, Rio do Sul and Itajaí, at the moment there are no NUDECs in these cities.

Another option is to promote the involvement of the population through the CONSEGs (Community Councils of Security), which have already been founded in several cities. The CONSEGs are community groups who voluntarily work within the activities of institutions regarding public safety and social defence, such as the Military Police and the Fire Brigade (Duarte, 2008). A partnership between the Civil Defence and CONSEGs would contribute to the empowerment of inhabitants in activities of disaster risk management. Furthermore, the recent Law n.12608/12 of 10.04.2012 recommends the inclusion of principles of Civil Defence in mandatory courses in schools, which seems to be a promising strategy to improve the risk perception of the population in general.

To conclude, this work has discovered that flood early warning systems seem to be an effective measure in flood risk management and usually imply fewer costs than structural preventative measures. Also, they have the potential to be improved greatly by today's advances in communication and information technology. However, the effective functioning of the flood early warning system in the Itajaí River Basin can be hampered by an overly complex network of different administrative bodies and too many bureaucratic barriers. Other potential flaws are a lack of manpower to maintain the monitoring stations, and a difficulty to enforce planning laws aimed at reducing risk. This work has hopefully clarified the overall picture of how the system functions and allows stakeholders to understand each other's views. This should enable them to work more closely together in the future and observe where improvements can be made, in order to reach the ultimate objective, which is to avoid human and economic losses.

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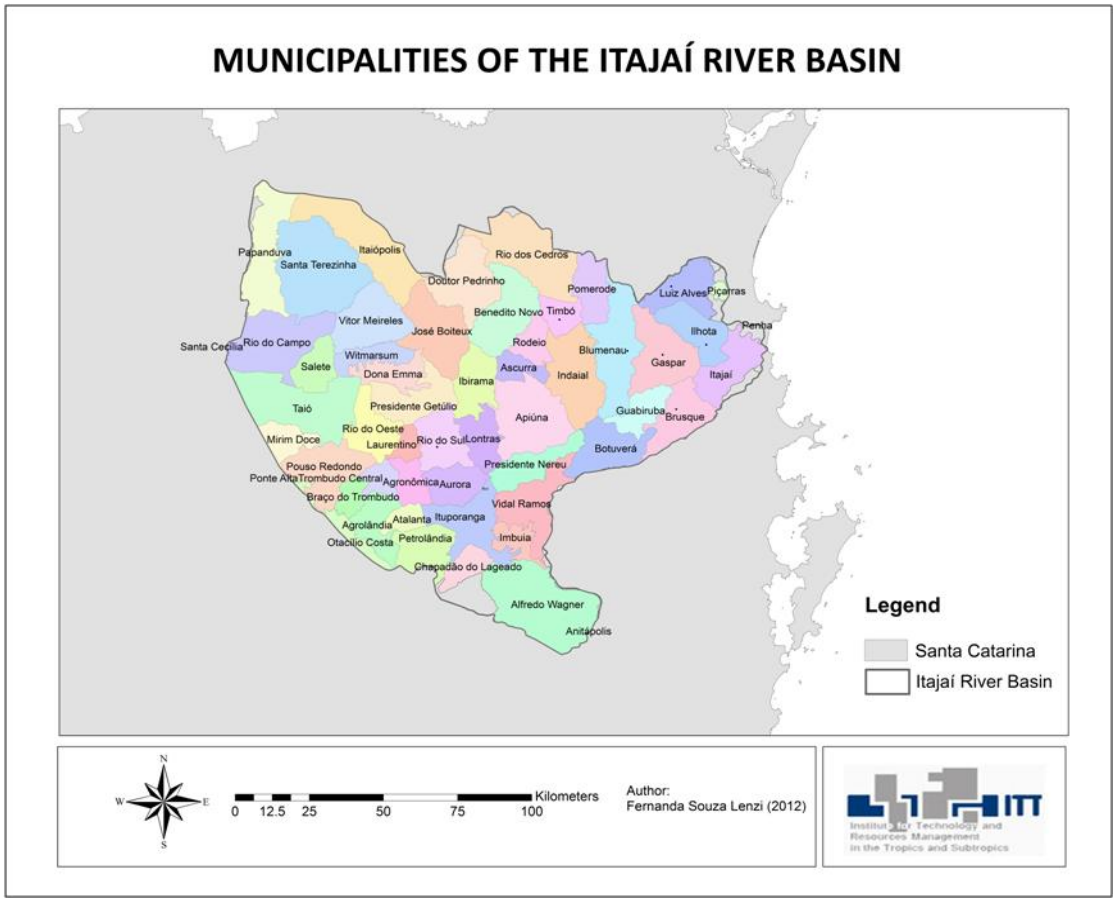
7 APPENDICES

7.1 Population of the municipalities of the Itajaí River Basin

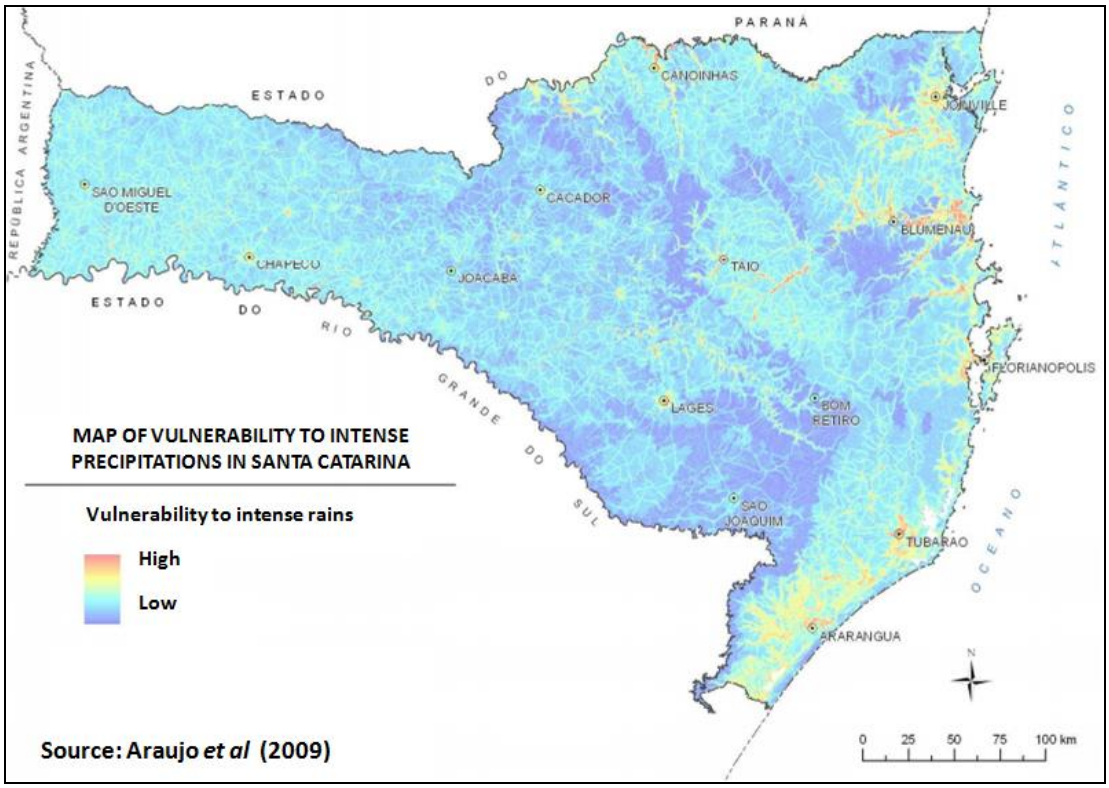
Municipality	Population	Municipality	Population	Municipality	Population
Agrolândia	9,323	Guabiruba	18,430	Pouso Redondo	14,810
Agronômica	4,904	Ibirama	17,330	Presidente Getúlio Vargas	14,887
Alfredo Wagner	9,410	Ilhota	12,335	Presidente Nereu	2,284
Apiúna	9,600	Imbuia	5,707	Rio do Campo	6,192
Ascurra	7,412	Indaial	54,854	Rio dos Cedros	10,284
Atalanta	3,300	Itaiópolis	20,301	Rio do Oeste	7,090
Aurora	5,549	Itajaí	183,373	Rio do Sul	61,198
Balneário Piçarras	17,078	Ituporanga	22,250	Rodeio	10,922
Benedito Novo	10,336	José Boiteux	4,721	Salete	7,370
Blumenau	309,011	Laurentino	6,004	Santa Terezinha	8,767
Botuverá	4,468	Lontras	10,244	Taió	8,674
Braço do Trombudo	3,457	Luis Alves	10,438	Timbó	36,774
Brusque	105,503	Mirim Doce	2,513	Trombudo Central	6,553
Chapadão do Lageado	2,762	Navegantes	60,556	Vidal Ramos	6,290
Dona Emma	3,721	Penha	25,141	Vitor Meireles	5,207
Doutor Pedrinho	3,604	Petrolândia	6,131	Witmarsum	3,600
Gaspar	57,981	Pomerode	27,759		

Source: Data extracted from SPG (2012).

7.2 Municipalities of the Itajaí River Basin



7.3 Vulnerability map of the State of Santa Catarina



7.4 Interviews with the stakeholders of the FEWS in the Itajaí River Basin

1) Name of the Institution: _____

2) Characteristic of the institution: ( ) Private Institution ( ) Public Institution

3) What are the objectives of the institution today as regards to flood risk management?

_____

_____

4) Which activities have been developed by your institution regarding the flood early warning system in the Itajaí River Basin?

_____

_____

5) What are the largest difficulties in executing the activities developed by your institution (lack of resources, lack of integration among institutions, lack of training, etc)?

_____

_____

6) Are there good communication and information exchange between your institution and the others involved with flood risk management?

( ) Yes ( ) No

Because:_____

7) From your point of view, how do you classify the efficiency of the flood early warning system in the Itajaí River Basin?

( ) Very efficient

( ) Efficient

( ) Regular

( ) Unsatisfactory

Because:_____

8) In your personal opinion, what are the strengths of flood early warning system in the Itajaí River Basin?

_____
_____
_____

9) According to your viewpoint, what are the largest debilities of the flood early warning system in the Itajaí River?

_____
_____
_____

10) Could you identify current opportunities for the improvement of the flood early warning system in the Itajaí River Basin?

_____
_____
_____

11) Could identify threats to the well functioning of the flood early warning system in the Itajaí River Basin?

_____
_____
_____

12) What has been improved regarding the flood early warning system after the flood events of 2008 and 2011 that took place in the Itajaí River Basin?

_____
_____
_____

7.5 Interviews with the coordinators of the Civil Defence Centres

1) Risk Knowledge

-Is there mapping of areas at risk?

-If yes, when and which institution executed these maps?

2) Data Monitoring

-Location of the pluviometric and fluviometric stations.

- Data monitoring through sensors or conventional measures (conventional rules and standard rain gauges)?

-Which institution installed the stations?

-Who is in charge for the maintenance of the stations? Any outsourced company?

- How long have the stations worked?

-Are there many problems in the functioning of the stations?

3) Data transmission (from sensors to the responsible agency)

- Which institutions are expected to receive these data?

- With which frequency the data are transmitted to the responsible agency?

- What is the dissemination technique used for data transmission (e.g. radio, internet, mobile, telephone)?

-Any problems were detected in the data transmission?

4) Data interpretation and models for flood forecasting

-What is the model used for forecasting floods?

-Type of data used in the model.

-What are the limits regarding the river's level for issuing a warning?

-Which institutions are contacted in the case of a critical situation?

-Largest difficulties faced until today (e.g. lack of financial resources, lack of training, lack of monitoring stations, maintenance).

5) Dissemination of warning messages to stakeholders

-With which frequency the warning message is disseminated?

-Example of the warning message.

-Who is warned by the Civil Defence (only the population or some other institutions?)?

-Which dissemination techniques are used for warning the stakeholders?

-Problems presented during the last flood events (e.g. electricity shortages).

6) Response Capability

-How many employees work in the Civil Defence Centre?

-Is there any Contingency Plan, including the number and location of evacuation centres?

-Who is the institution in charge for executing this plan?

-When was the plan last updated?

- How has the awareness among the population been worked (educational campaigns, handouts, etc)? Does the population know how to act during flood events?

-Are there investments to improve the flood early warning system?

- Are most of the financial resources designated to flood prevention or response?

-How many NUDECs (Community Groups of Civil Defence) exist in the municipality?

7.6 Revised Informed Consent Form delivered to the stakeholders.

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Estou sendo convidado(a) a participar da pesquisa cujo objetivo geral é identificar as instituições envolvidas no funcionamento do sistema de alerta à inundações na Bacia Hidrográfica de Itajaí e propor melhorias para fortalecer a estrutura institucional do sistema. Como parte dessa pesquisa, será estudado também as atividades desenvolvidas pela Defesa Civil a nível municipal, levando em conta os aspectos de monitoramento, telemetria, interpretação dos dados e disseminação da mensagem de alerta aos atores envolvidos.

A presente pesquisa será realizada pela estudante Fernanda Souza Lenzi, que faz parte de um programa de mestrado de duplo diploma entre a "Universidad Autonoma de San Luis Potosi", no México, e o "Institute for Technology and Resources Management in the Tropics and Subtropics", na Alemanha. Este programa de mestrado intitulado "Environment and Resources Management" tem como objetivo estimular a cooperação entre a Alemanha e a América Latina.

Minha participação no projeto consistirá em participar de uma entrevista, que durará aproximadamente 60 minutos e será gravada, para ser transcrita posteriormente. Nessa entrevista serão abordados aspectos referentes ao sistema de alerta a inundações, os problemas do sistema e o que está sendo feito para sua melhoria. A pesquisadora prestará quaisquer esclarecimentos que eu julgar necessário antes, durante ou depois da entrevista.

Por ser uma pesquisa de interesse exclusivamente científico, aceito participar da mesma espontaneamente. Concordo com as informações acima e assino duas vias, nas quais uma ficará em minha posse e a outra na posse da pesquisadora.

Eu, _____, telefone n◦_____, consinto em participar voluntariamente da pesquisa realizada pela pesquisadora Fernanda Souza Lenzi.

_____ _____

Assinatura do entrevistado Assinatura da pesquisadora